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Traumatization and infestation of the Pacific salmon in the western Bering Sea and adjacent Pacific waters during summer-autumn period of 2003

by

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Abstract

Traumatization and infestation of the Pacific salmon in the western Bering Sea and adjacent Pacific waters during summer-autumn period of 2003 are analysed based on data from two complex epipelagic surveys. The rates of different types of traumatization and infestation occurrence are species- and age-specific and are subject to significant spatio-temporal variability. The highest rate of sea lice infestation was observed in juvenile chinook, pink and coho salmon. Rate of North Pacific daggertooth injuries was significantly lower than rate of sea lice infestation. On the other hand, rate of North Pacific daggertooth (Anotopterus nikparini) injuries was significantly higher than rate of lampreys (most likely by Pacific lamprey (Lampetra tridentata)) and longnose lancetfish (Alepisaurus ferox) injuries. The highest rate of North Pacific daggertooth injuries was observed in immature and mature chum salmon. Rate of lamprey injuries was extremely low in all salmon species. The highest rates of lamprey injuries were observed in mature pink, coho and chum salmon. The spatial distribution of traumatized and infected salmon was non-uniform and aggregated in its character. Average length of juvenile, immature and mature salmon specimens infected with sea lice was higher compared to healthy fish. Clark condition factor seemed not to be influenced by sea lice infestation. Average length of immature chum and sockeye salmon with North Pacific daggertooth injuries was significantly higher as compared with not traumatized fish. In addition, a significant decrease in Clark condition factor was noted for chum and sockeye salmon, which were injured by North Pacific daggertooth.

Introduction

Research on spatio-temporal variability of injures and infections of the Pacific salmon in the Bering Sea waters is very important for studying the influence of natural mortality factors on natural and artificially produced salmon during their mass joint summer-autumn foraging migrations throughout this region. The urgency of such work arises from a small number of published data on this problem. In the majority of such articles the influence of only one predator or parasite is considered, which does not afford to judge about the comparative contribution of various factors to the total natural mortality.

Materials and methods

The data of two complex epipelagic trawl surveys in the western Bering Sea and adjacent Pacific waters (summer survey from July 15 to August 24, 2003 and autumn survey from

September 14 to October 25, 2003), performed by TINRO-Center, served as the material for this study. During the biological analysis, we recorded sea lice and various kinds of injuries on Pacific salmon bodies. A type of injury was determined based on its external appearance (Welch et al., 1991; Shuntov et al., 1993; Radchenko, Semenchenko, 1996; Melnikov, 1997; Balanov, Radchenko, 1998). A share of infected and injured individuals in a catch was calculated. The obtained data were averaged for 12 biostatistical areas of the Bering Sea (Fig. 1) (Shuntov, 1989).

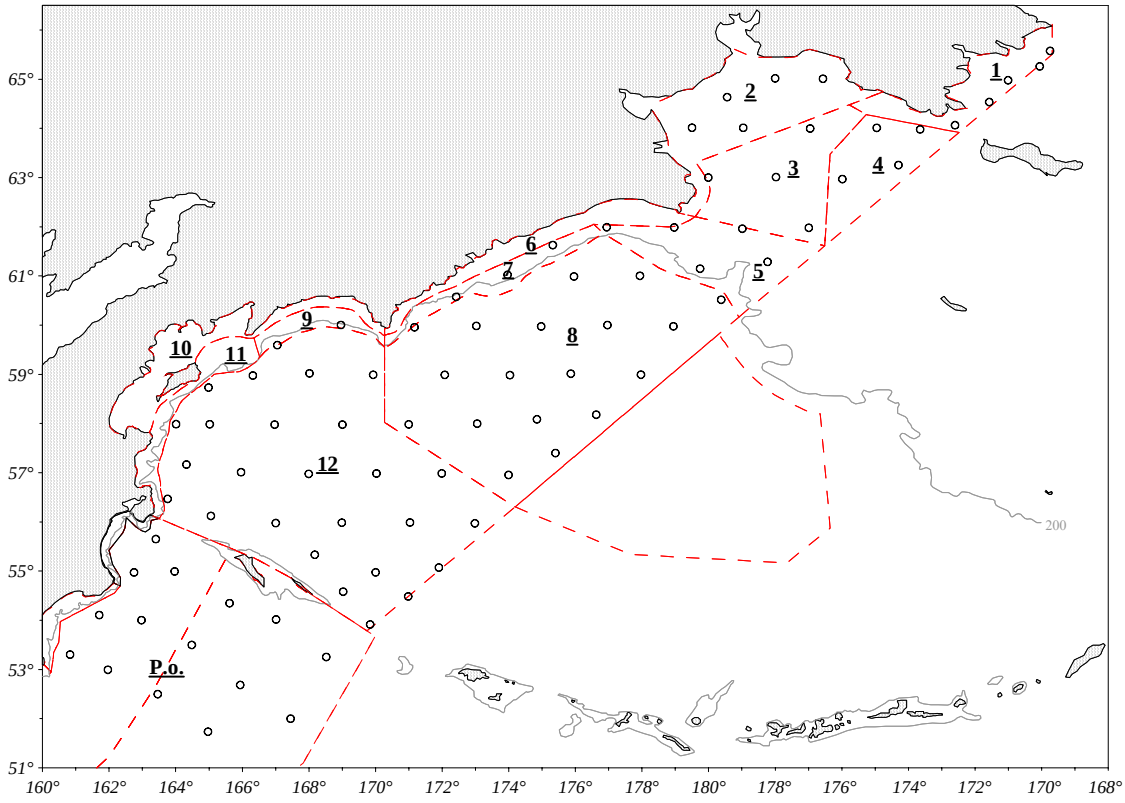

Fig. 1. Stations locations in epipelagic layers of the western Bering Sea and adjacent Pacific waters during two surveys. Underlined numbers are the numbers of biostatistical areas (Shuntov, 1989). "P.o."- biostatistical areas 5 and 6 of the Pacific Ocean.

Results and Discussion

A considerable share of the Pacific salmon in the catches was injured and infested. It was obvious that the most wounds were made by North Pacific daggertooth (Anotopterus nikparini) (Fig. 2). As to parasitic infection, high number of individuals, infected by sea lice, was evident. Sea lice infection was the most frequent during both summer and autumn surveys. Juvenile chinook, pink and coho salmon were infected by these parasites to the greatest extent (36.0, 29.7, 24.0%, respectively). The share of immature chum salmon infected by sea lice was considerably smaller (4.8-8.1%). Immature sockeye salmon, which was the second species by its abundance in the studied area, was even less infected (1.1-1.7%). The share of infested individuals of mature chum and pink salmon was rather high (12.7-12.9 and 13.9%, respectively).

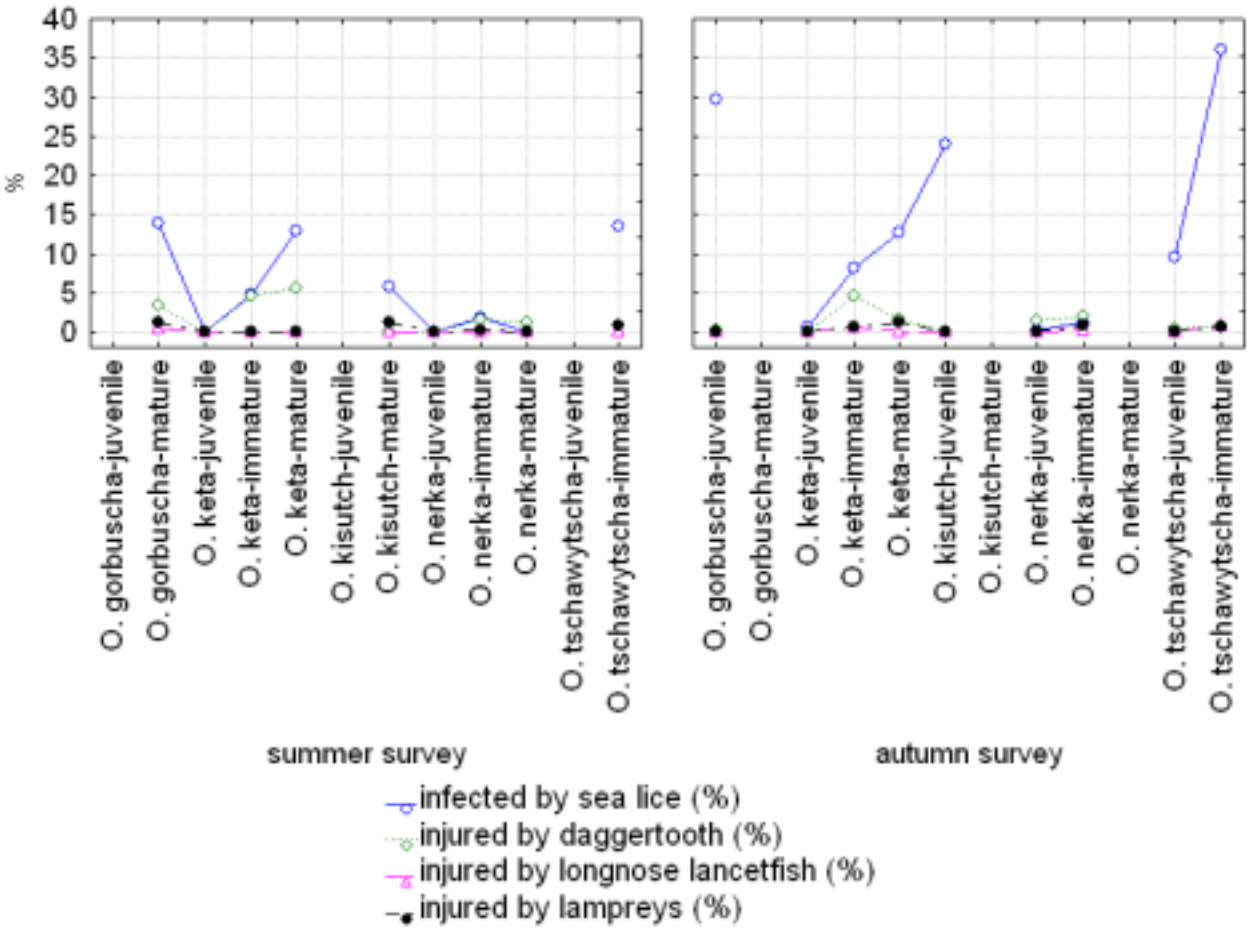

Fig. 2. The share (in % of the total catch along vertical axis) of injured and infested individuals for different Pacific salmon species caught during two surveys (summer survey - July 15 - August 24, 2003, autumn survey - September 14 - October 25, 2003) in the western Bering Sea and adjacent Pacific waters.

Sea lice include a number of species of several genera. Pacific salmon in the Bering Sea are most usually infested by Lepeophtheirus salmonis species (Nagasawa, Ishida, Todakoro, 1995; Johnson et al., 1996). According to published data (Nagasawa, Ishida, Todakoro, 1995) in summer of 1991 in the Bering Sea and adjacent Pacific waters about 90% of pink salmon and 45% of chum salmon were infected by Lepeophtheirus salmonis. This is much greater than the values obtained by us for these Pacific salmon species.

Percentage of pink, chum and chinook salmon injured by North Pacific daggertooth was essentially lower than that of fish infected by sea lice, but much higher than that of fish injured by lampreys (most likely by Lampetra tridentata, which was the most abundant lamprey species during both surveys) and longnose lancetfish (Alepisaurus ferox). During the summer survey, the greatest percentage of individuals injured by North Pacific daggertooth was observed for immature and mature chum salmon, which was the most abundant salmon species in the area studied (4.5 and

5.6%, respectively). During the autumn survey, percentage of immature chum salmon with such type of injures was still high (4.5%). Immature sockeye salmon was the second by occurrence (1.9%) of such injuries after immature chum salmon. It does not agree with the data of Radchenko (1994) according to which sockeye salmon was more frequently injured by North Pacific daggertooth and longnose lancetfish. According to our data, chinook and coho salmon in the Bering Sea were less frequently injured by North Pacific daggertooth in comparison with the published data for the Pacific waters off the Kuril Islands (Savinykh, Glebov, 2003). According to the observation of these authors, Pacific salmon are injured by North Pacific daggertooth more frequently in the Pacific waters off the Kuril Islands than in the Bering Sea. Pink salmon in the Bering Sea is also less injured by North Pacific daggertooth than in the Pacific waters off the Kuril Islands (Melnikov, 1997).

During the autumn survey, some of juvenile salmon from our catches were undoubtedly injured by North Pacific daggertooth. However, the average percentage of such individuals in a catch was relatively low: pink salmon – 0.1, sockeye salmon – 1.5, and chinook salmon – 0.5%. Apparently the share of individuals with such injures, due to their low survival, is much lower than the initial share of juvenile salmon injured by North Pacific daggertooth. Not taking into account juvenile individuals, immature chinook salmon is the least injured by North Pacific daggertooth among all salmon species (summer survey – 0.7, autumn survey – 0.8%).

The share of fishes with lamprey bites was very small for all salmon species (less than 1.2%), and the largest values of this characteristic were observed in mature pink, coho and chum salmon (Fig. 2). Similar values of this characteristic were observed for immature chum, sockeye and chinook salmon (0.5-0.8%).

Occurrence of injures by longnose lancetfish was very low for all salmon species studied. In both surveys mean percentage of such injures did not exceed 1% for any of salmon species studied. During the summer survey this type of injures was observed only for immature chum, sockeye and chinook salmon, and during the autumn survey – for mature chum salmon as well.

Now we will consider spatial variability of injures and infections of the Pacific salmon. Geographical variation in sea lice infestation level was rather high (Fig. 3). Clinal variation in sea lice infestation level was not expressed and for some species the obtained data strongly differed between summer and autumn surveys. Similarity in sea lice infestation levels was more often observed in the neighboring biostatistical areas. Aggregated pattern of sea lice infestation levels can be also seen on the maps of geographic distribution of this characteristic (see, for example, Fig. 4).

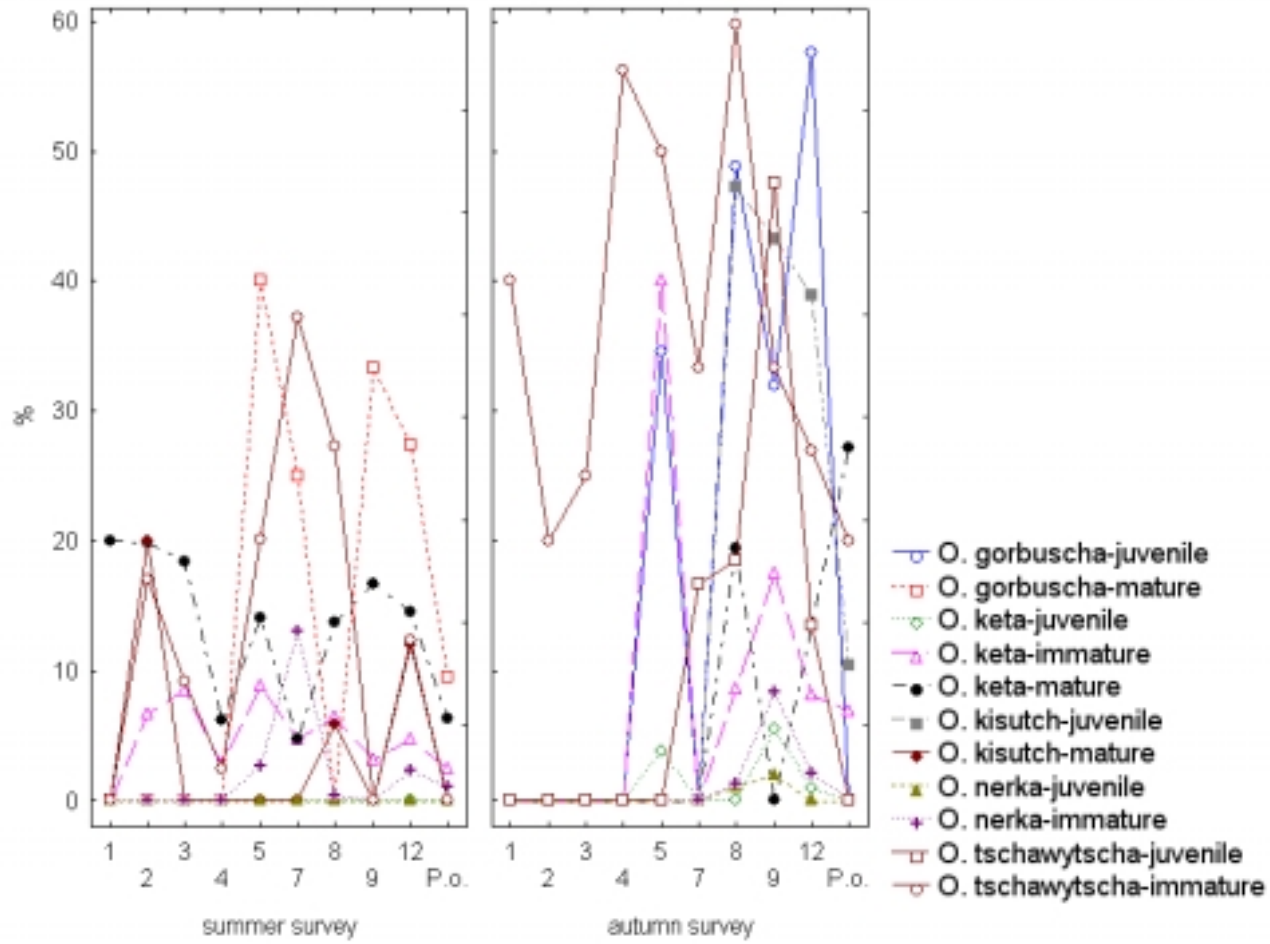

Fig. 3. Frequency distribution of the share of individuals (in % of the total catch) infected by sea lice in different biostatistical areas during two surveys. Biostatistical areas are shown along horizontal axis. Location of biostatistical areas is shown in Fig. 1.

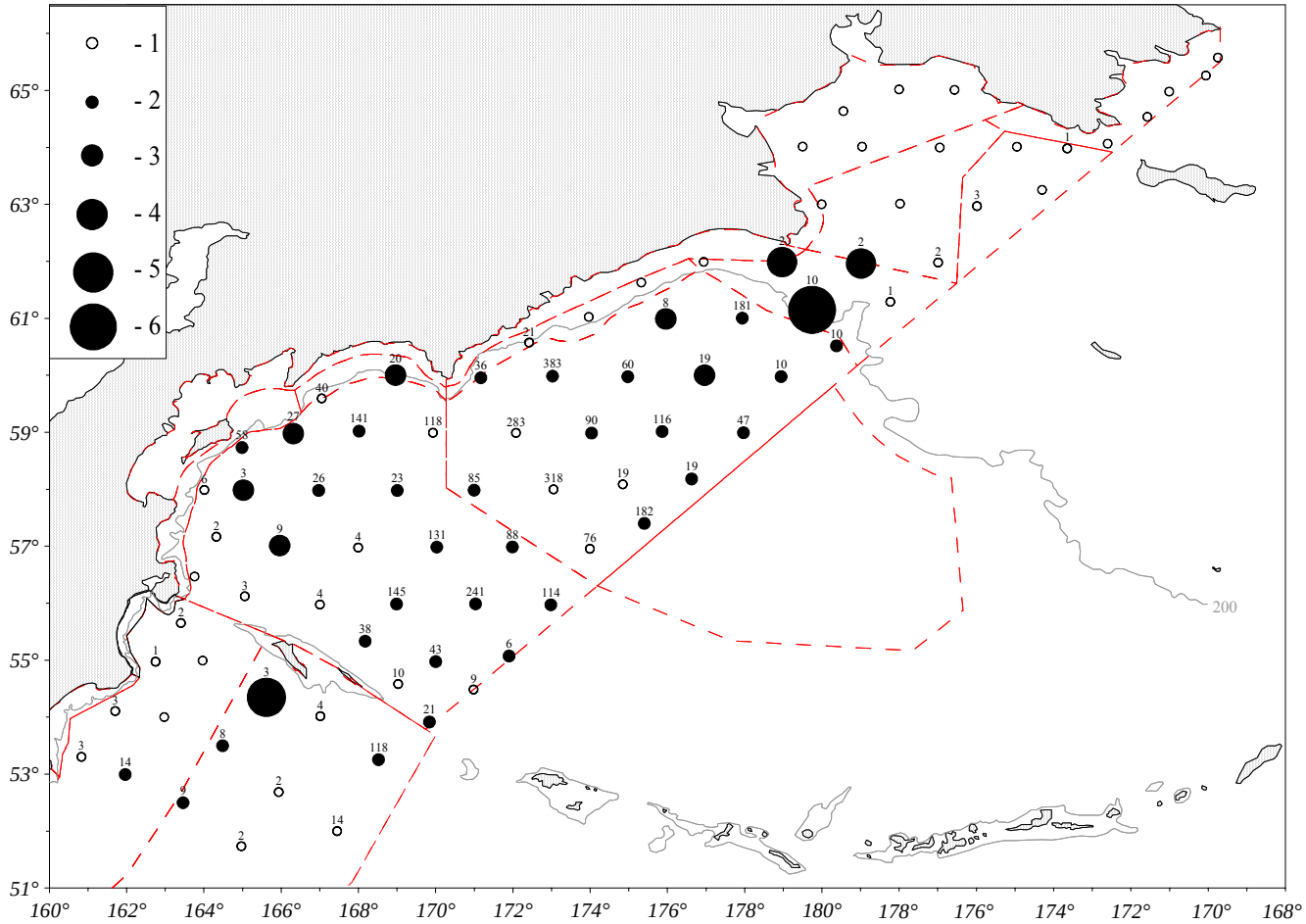

Fig. 4. Spatial distribution of the share of immature chum salmon (in % of the total catch) infected by sea lice in the western Bering Sea and adjacent Pacific waters during the autumn survey (September 14 - October 25, 2003). Designations: 1 – 0; 2 - <20; 3 – 20.1-40; 4 – 40.1-60; 5 – 60.1-80; 6 – 80.1-100%. Numbers designate CPUEs (individuals per hour) for non-zero catches.

It should be noted that frequency distributions of sea lice infestation levels differed significantly from normal distribution (Fig. 5). For different types of injures we observed similar situation in frequency distributions. The obtained bar charts were characterized by a considerable skewness and kurtosis, which implies aggregation and irregularity in spatial distribution of levels of injuries and infestation.

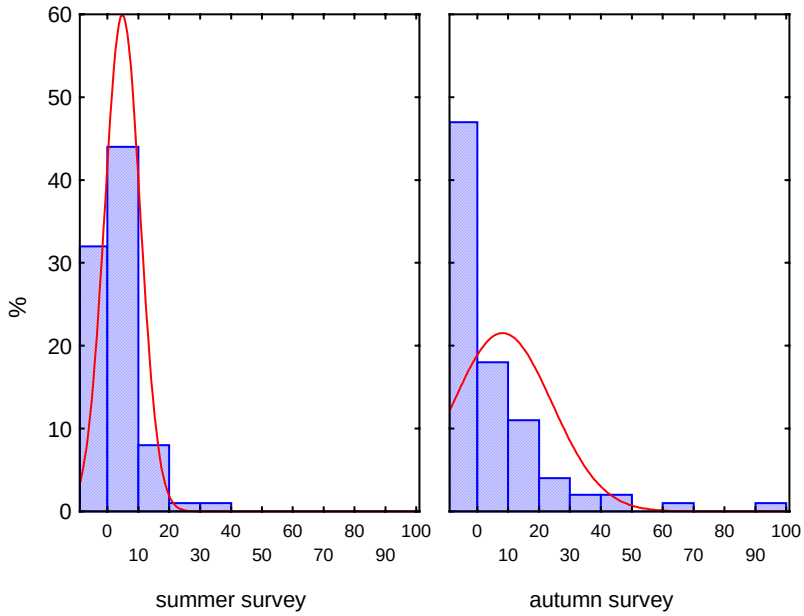

Fig. 5. Frequency distribution of the share of immature chum salmon (in % of the total catch – horizontal axis) infected by sea lice. Vertical axis shows the share of trawlings (in % of the total number of trawlings) with a specified share of infected individuals. A solid line here and below - normal distribution.

Our data showed significant spatial aggregation in levels of injuries occurrence. To be more specific, for the most studied salmon species during the both surveys the number of individuals injured by North Pacific daggertooth was greater in the southern deep water areas than in the northern shallow waters (Fig. 6). This fact agrees both with our data on aggregation of North Pacific daggertooth in the Pacific waters off the Commander Islands and southwestern regions of the Bering Sea and with the results of previous studies (Melnikov, 1997; Savinykh, Glebov, 2003).

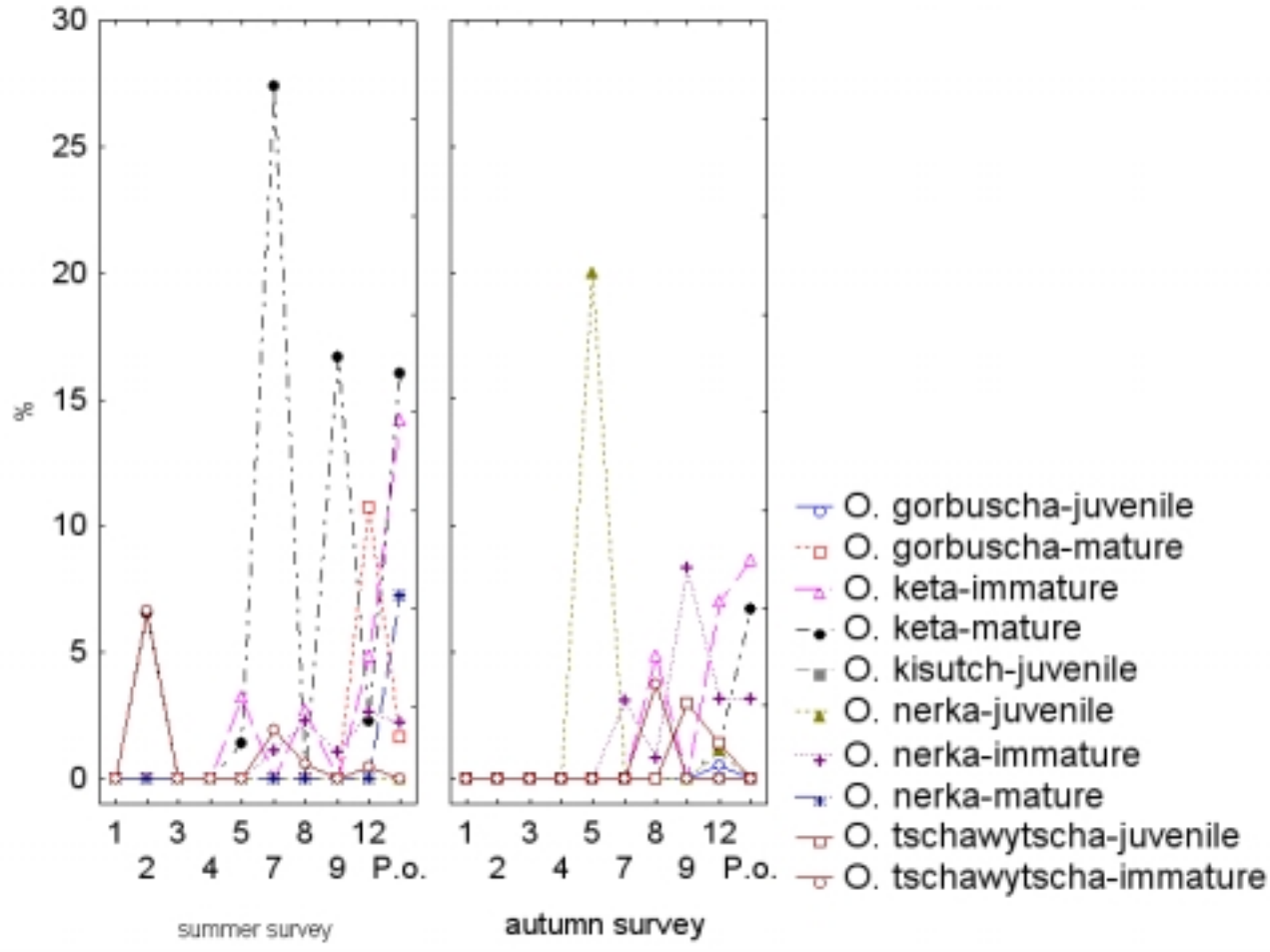

Fig. 6. Frequency distribution of the share of individuals (in % of the total catch) injured by North Pacific daggertooth in various biostatistical areas during two surveys.

Clinal variation in occurrence of individuals injured by North Pacific daggertooth manifested itself in statistically significant ($P<0.05$) negative correlation between the latitude of trawling location and the share of fishes injured by North Pacific daggertooth, which was observed for immature chum and sockeye salmon during both surveys (Fig. 7). During summer, North Pacific daggertooth migrates northwards to the central part of the Bering Sea, but its main concentrations within the area surveyed are located on the Pacific waters off the Commander Islands. The northward decrease in share of individuals injured by North Pacific daggertooth, which has been observed earlier for chinook and coho salmon in the waters off the Kuril Islands, can also be explained in the context of predator and prey migrations (Savinykh, Glebov, 2003).

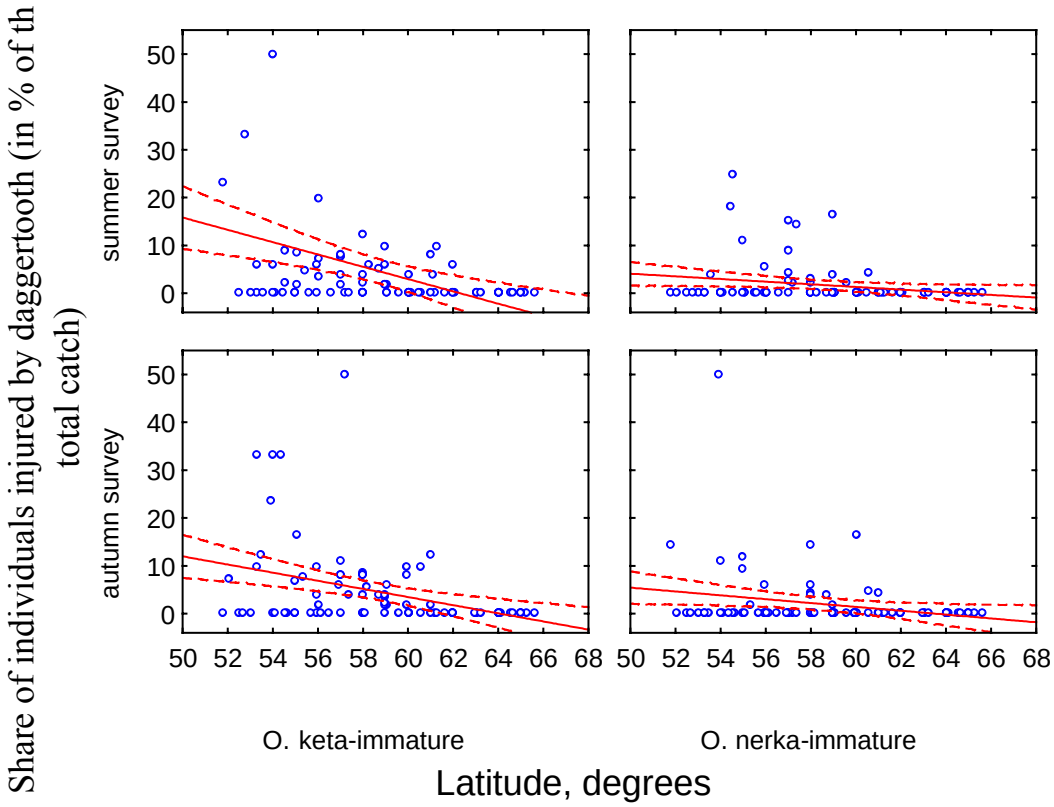

Fig. 7. Relationship between latitude of trawling location and share of individuals injured by North Pacific daggertooth (in % of the total catch). Solid lines - trends, dotted lines – 95% confidence interval of the trend lines.

Just like for the other types of injures and infections of Pacific salmon, the obtained frequency distributions differed significantly from normal the normal one, which suggests about irregular spatial allocation of individuals injured by North Pacific daggertooth (see, for example, Fig. 8). It is interesting that pink salmon injured by North Pacific daggertooth were distributed relatively evenly in waters off the Kuril Islands (Melnikov, 1997).

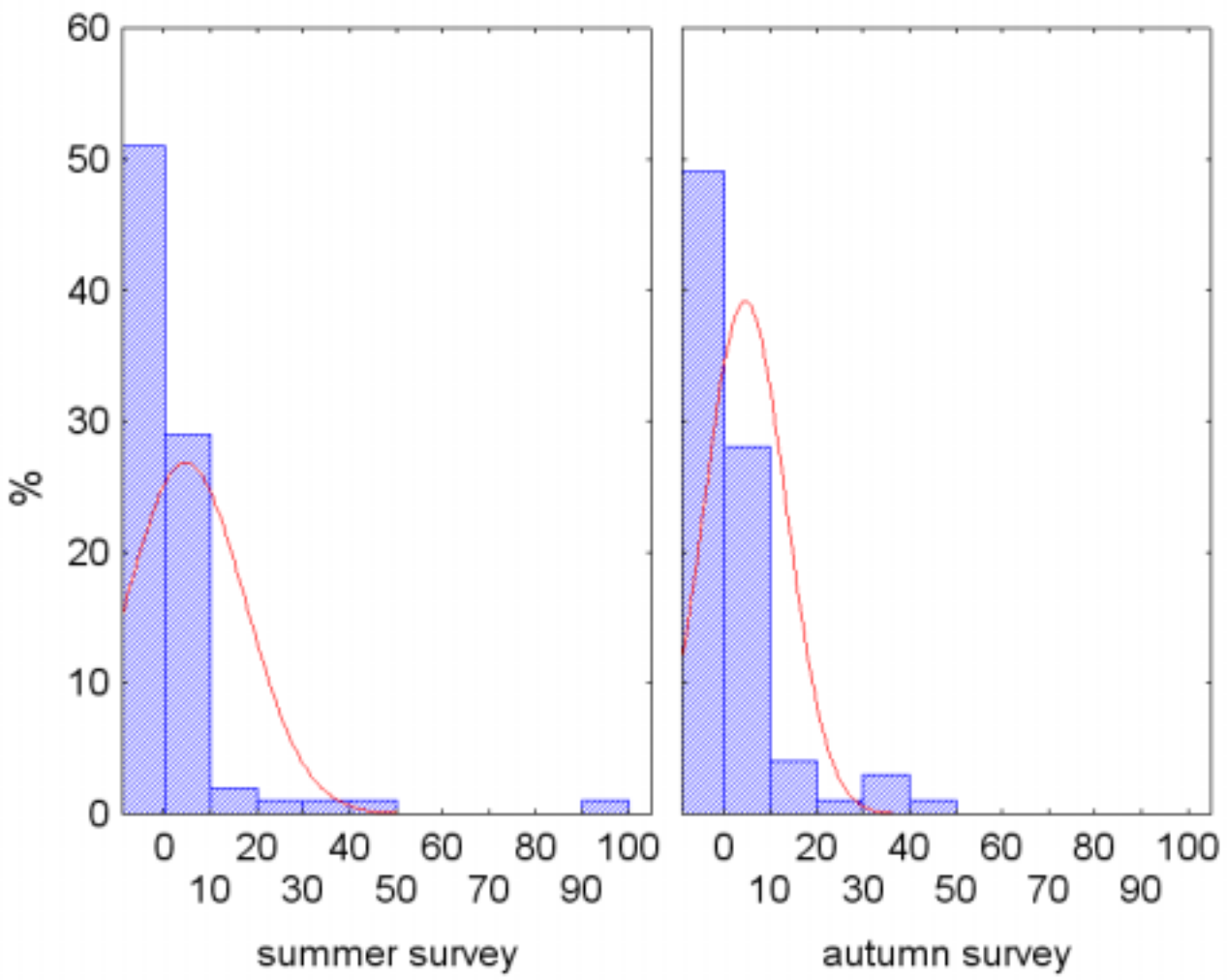

Fig. 8. Frequency distribution of the share of immature chum salmon (in % of the total catch) injured by North Pacific daggertooth. Designations follow those in Fig. 5.

As for the other two types of injures (by longnose lancetfish and lampreys), spatial aggregation of individuals with such injures was observed. This implies uneven spatial distribution of longnose lancetfish and lampreys themselves. Individuals injured by longnose lancetfish were even stronger concentrated to the southern deep water areas of surveys (Fig. 9), as compared with fishes injured by North Pacific daggertooth. This fact is well explained by lesser migration of longnose lancetfish to the Bering Sea as compared with North Pacific daggertooth. The percentage of individuals dying quite soon after longnose lancetfish attacks is considered to be greater than that after North Pacific daggertooth attacks (Melnikov, 1997; Savinykh, Glebov, 2003).

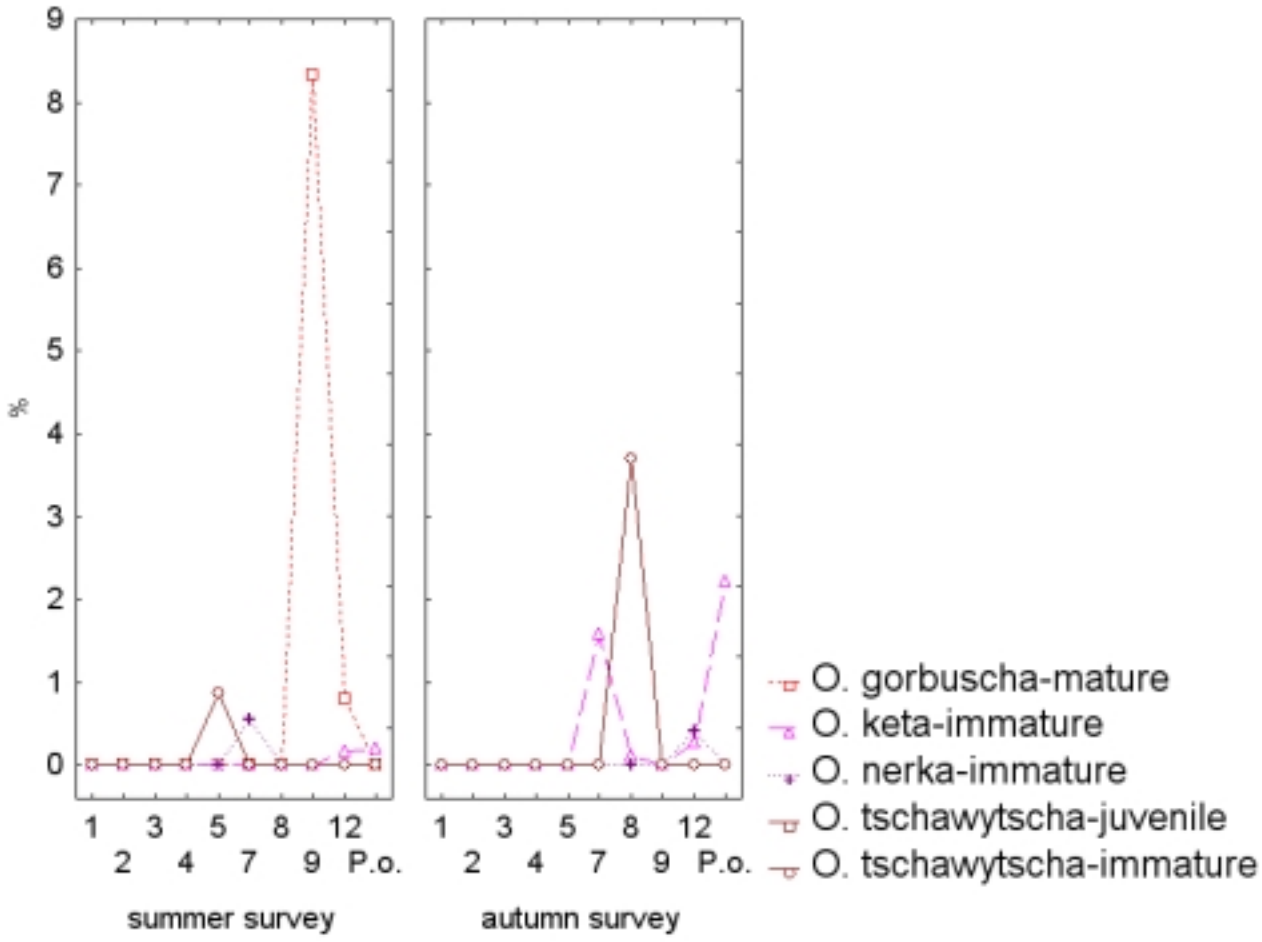

Fig. 9. Frequency distribution of the share of individuals (in % of the total catch) injured by longnose lancetfish in different biostatistical areas during two surveys.

During the summer survey Pacific salmon injured by lampreys were approximately equally distributed in various biostatistical areas (Fig. 10). However, in all Pacific salmon species during the autumn survey the largest percentage of individuals injured by lampreys was observed in the coastal 7th biostatistical area and, partially, in the north-western part of the 8th area. This fact is well explained by location of highest Pacific lamprey catches in the coastal zone during both surveys.

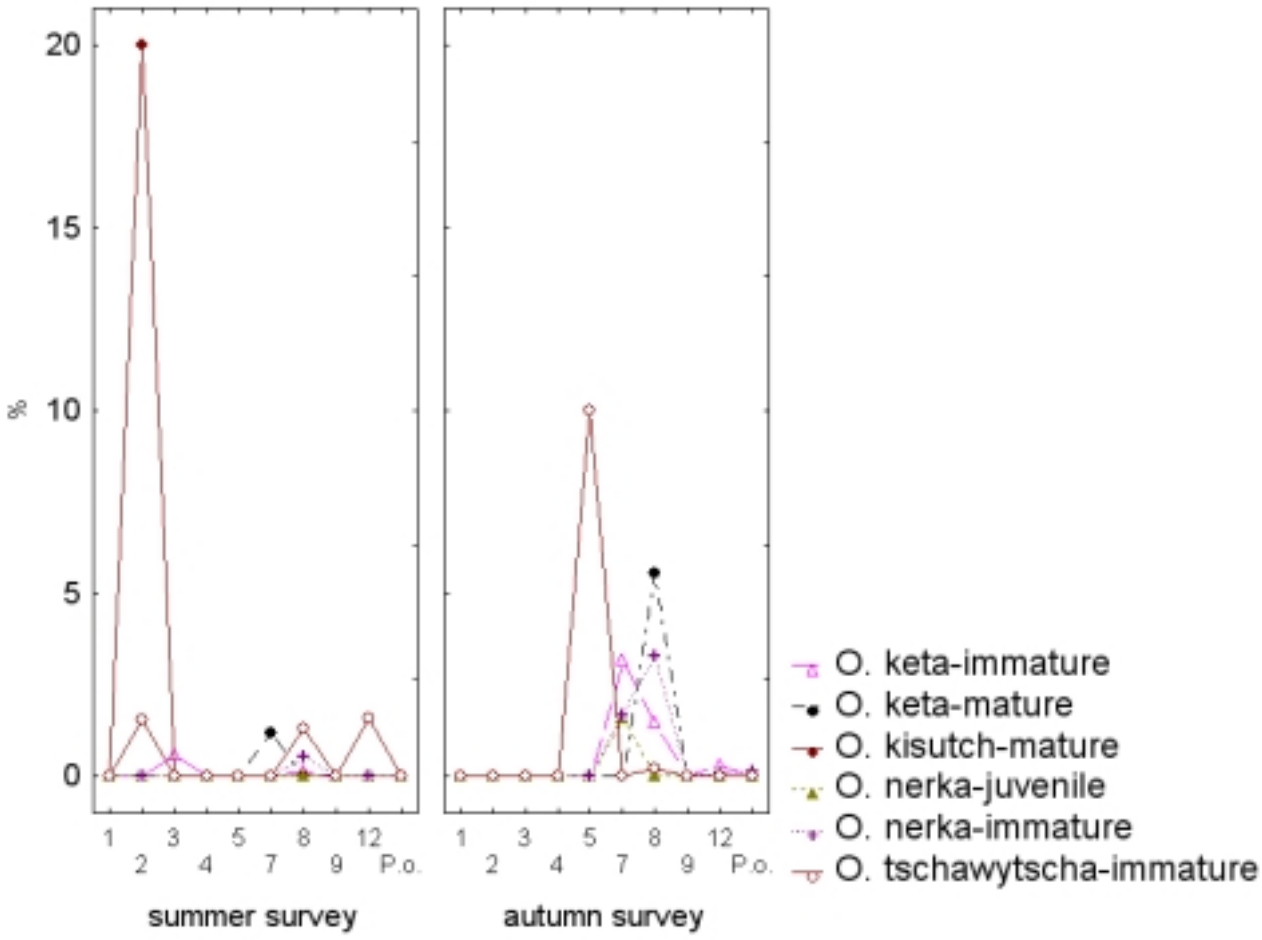

Fig. 10. Frequency distribution of the share of individuals (in % of the total catch) injured by lampreys in different biostatistical areas during two surveys.

Average length of juvenile, immature and mature salmon specimens infected with sea lice was higher compared to healthy fish (Table). Clark condition factor seemed not to be influenced by sea lice infestation. Average length of immature chum and sockeye salmon with daggertooth injuries was significantly higher as compared with not traumatized fish. In addition, a significant decrease in Clark condition factor was noted for chum and sockeye salmon, which were injured by daggertooth (Table).

Table.

Average values of biological characteristics of healthy and infected or traumatized individuals

Species and fertility stage	Type of infection or injury	Fork length, cm		Clark condition factor, %		Number of salmon analysed	
		no infection or injury	presence of infection or injury	no infection or injury	presence of infection or injury	no infection or injury	presence of infection or injury
O. gorbuscha-mature	sea lice	46.3	47.1	1.24	1.26	124	87
O. gorbuscha-juvenile		21.9	22.2	1.03	1.03	284	578
O. keta-immature		42.7	46.4	1.21	1.22	3776	270
O. keta-mature		62.7	64.0	1.34	1.34	541	116
O. kisutch-juvenile		29.2	29.4	1.45	1.46	30	144
O. nerka-immature		40.7	43.0	1.30	1.31	2060	37
O. tschawytscha-immature		42.8	49.8	1.42	1.46	361	238
O. tschawytscha-juvenile		23.4	24.9	1.40	1.39	124	50
O. keta-immature	North Pacific daggertooth	42.8	45.1	1.21	1.19	3890	156
O. keta-mature		63.1	61.0	1.35	1.31	622	35
O. nerka-immature		40.7	44.4	1.30	1.25	2044	53

In conclusion, it should be noted that injuries by sea mammals were extremely rarely observed during both surveys. It is known that sea mammals attacks, as well as attacks of salmon shark (Lamna ditropis) and spiny dogfish (Squalus acanthias), are more lethal to salmon than that of North Pacific daggertooth (Melnikov, 1997; Savinykh, Glebov, 2003). This fact explains almost complete absence of individuals with injuries by sea mammals in our samples. In addition, sea mammals attack Pacific salmon mainly in the coastal zone, which was not investigated during the surveys described. It can be concluded that occurrence of the studied injures and infestations is species- and age-specific, and is subjected to a substantial spatio-temporal variability.

Acknowledgements

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