Interannual Dynamics of Abundance of Pink and Chum Salmon Juveniles and their Average Body Size in the Sea of Okhotsk in 1998–2017

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In the early 2000s, there were notable changes in the climate and oceanography in the Far Eastern seas, which were reflected in biotic changes (Shuntov 2016). A gradual decrease in the ice cover was observed in the Sea of Okhotsk (Ustinova and Sorokin 2013). From 2006–2017, the ice cover of the Sea of Okhotsk was minimal for the last 60 years (Fig.1).

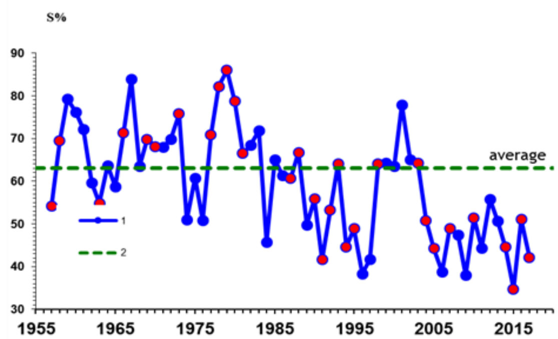

Fig. 1. Average winter ice cover of the Sea of Okhotsk (Ustinova and Sorokin 2013 (with addition)).

A progressive decrease in plankton biomass was observed after 1980 in the Sea of Okhotsk, and it increased in the Bering Sea and adjacent Pacific waters during the same period (Shuntov and Temnykh 2011; Shuntov and Volvenko 2017) (Fig.2). In the nektonic communities, an increase of subtropical fish abundance has been observed in the Sea of Okhotsk since the second decade of the 2000s (Shuntov 2016). Along with changes in plankton and nekton communities in the Far Eastern seas, certain changes in the dynamics of salmon regional stock abundance have been noted. A negative trend of abundance dynamics was present in some southern salmon stocks in the second decade of the 2000s (Shuntov and Temnykh 2017). At the same time, the abundance of pink and chum has increased in the northern coastal areas, which was partly associated with favorable conditions for reproduction beginning from the first decade of the 2000s.

Research objectives of this investigation are to consider the features of the dynamics of abundance and average body weight of pink and chum salmon in the southern part of the Sea of Okhotsk during relatively “cold” (1998–2006) and "warm" (2007–2017) periods and to assess the impact of a decrease in plankton biomass in the Sea of Okhotsk on the abundance, size and mortality of juveniles.

This study is based on findings of 20 complex epipelagic surveys conducted in the Sea of Okhotsk by TINRO-Center in September–November 1998–2017. The surveys included abundance estimation of salmon, ecologically-related plankton and nekton species, and fish diet analysis. Fish were sampled with pelagic trawls (vertical opening 25–45 m, horizontal opening 35–50 m) equipped with a small-size mesh (1 cm) lining the cod end. Zooplankton samples were obtained using a Jedy net (0.1 m^2 mouth opening and 0.168-mm mesh). For more details see Shuntov (2001).

The abundance of pink salmon juveniles in the Sea of Okhotsk in 1998–2017 varied within the range of 442 million–1.833 billion fish for odd generations, and 569 million–1.507 billion fish—for even generations. In autumn 2017, the highest level of juvenile pink salmon abundance (2.752 billion fish) was recorded in the Sea of Okhotsk (Fig. 3). Pink salmon have absolutely dominated among salmon juveniles, ranging from 53 to 89% of their total abundance. Chum salmon juveniles’ abundance varied from 164 to 926 million individuals during the study period, an average of 32% of the total abundance of these two salmon species.

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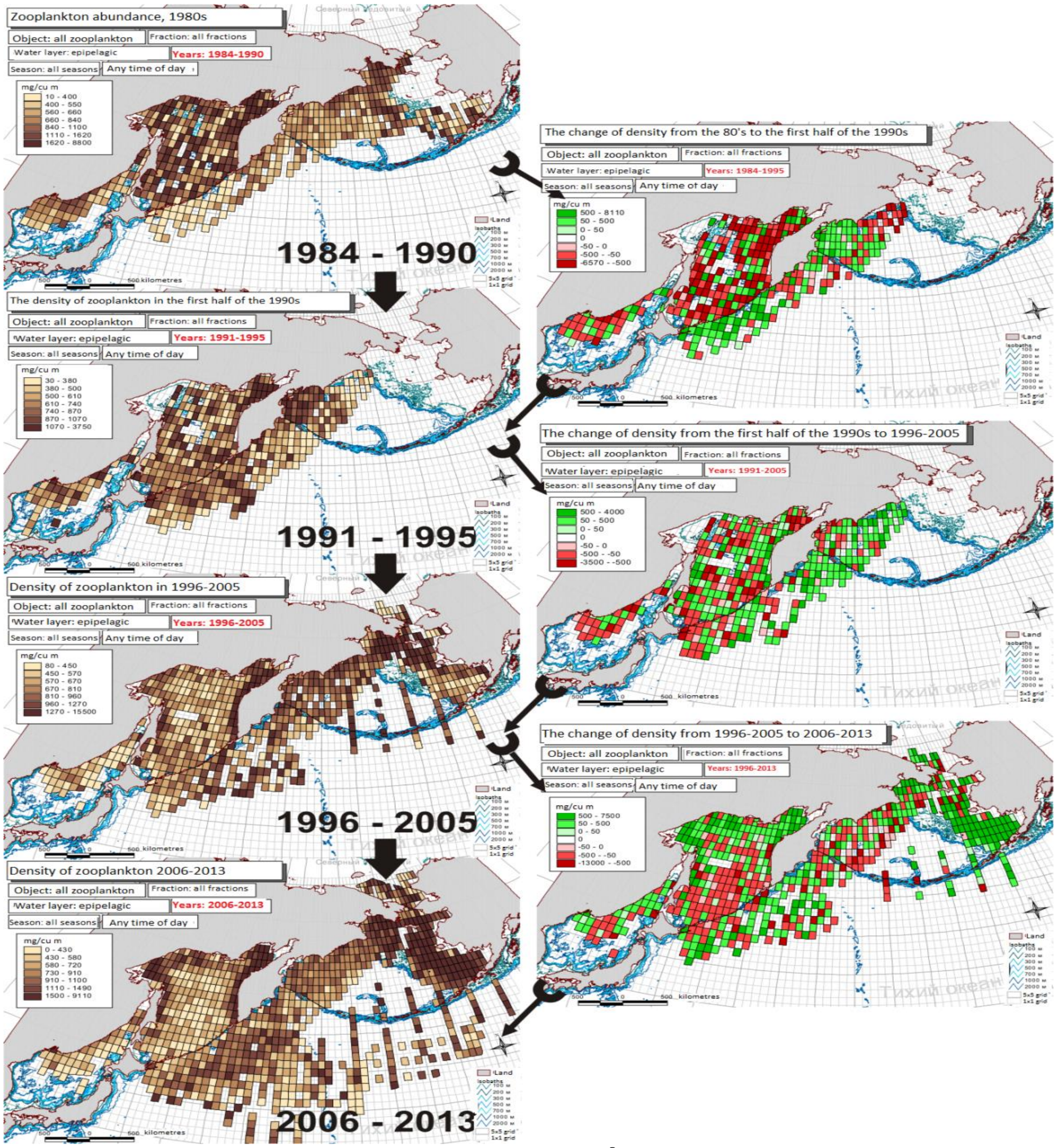

Fig. 2. Long-term dynamics of total zooplankton biomass (mg/m^3) in the epipelagic layer of the North Pacific (Shuntov and Volvenko 2017). Right inserts show interdecadal change of the biomass: red—decrease, green—increase.

The annual average body weight of the pink salmon juveniles was 154.2 g, varying within 107–198 g. The annual average body weight of the chum salmon juveniles was 145.1 g varying within 115–176 g (Fig. 3).

As shown in Fig. 3, the dynamics of both pink salmon and chum salmon abundance and their average sizes is synchronous. Statistically significant Spearman correlation coefficients between pink and chum juvenile salmon abundance and between average body weight of these species are very high (respectively r = + 0.84 and r = + 0.83 (p<0.05)) (Table 1). As it was noted earlier, (Shuntov and Temnykh 2008; Radchenko at al. 2013; Temnykh at al. 2017), these features of dynamics of the pink/chum abundance and their body size, as well as the features of spatial distribution (cohabitation during the autumn feeding migrations) indicate the complementarity of these species. Furthermore, the changes in abundance and average body size of pink and chum salmon juveniles in the western Bering Sea are similar (Fig.4), despite the fact that the East Kamchatka juvenile pink salmon are many times more abundant compared to the chum salmon. Statistically significant Spearman correlation coefficients between pink/chum juvenile salmon abundance and between average body weight sizes of these species are very high (respectively r = + 0.85 and r = + 0.79 (p<0.05)).

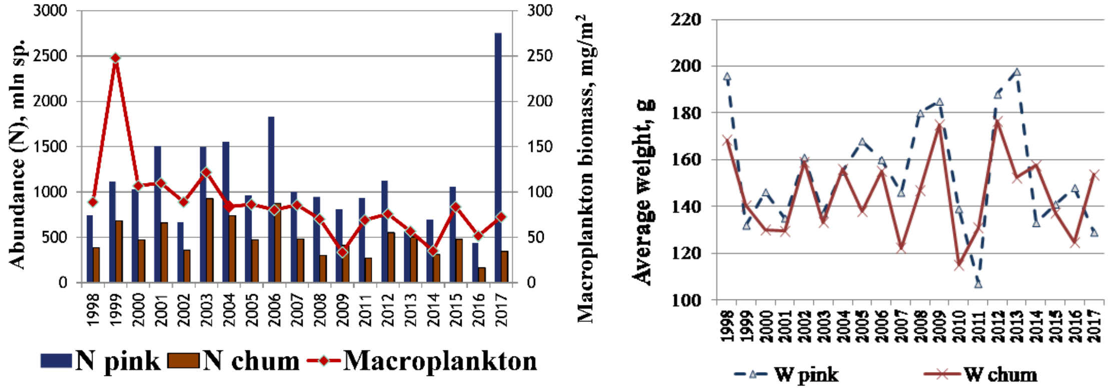

Fig. 3. Dynamics of abundance and average body size of pink and chum salmon juveniles in the Sea of Okhotsk in fall 1998–2017.

Table 1. Spearman Rank Order Correlations Coefficients between abundance and average body weight pink and chum salmon juveniles of Okhotsk sea stocks.

	Marked correlations are significant at *p* <0.5000			
	Juvenile pink salmon abundance	Average weight of juvenile pink salmon	Juvenile chum salmon abundance	Average weight of juvenile chum salmon
Juvenile pink salmon abundance	1.000000	-0.142857	0.840659	0.043956
Average weight of pink salmon juveniles	-0.142857	1.000000	-0.181319	0.835165
Juvenile chum salmon abundance	0.840659	-0.181319	1.000000	0.087912
Average weight of chum salmon juveniles	0.043956	0.835165	0.087912	1.000000

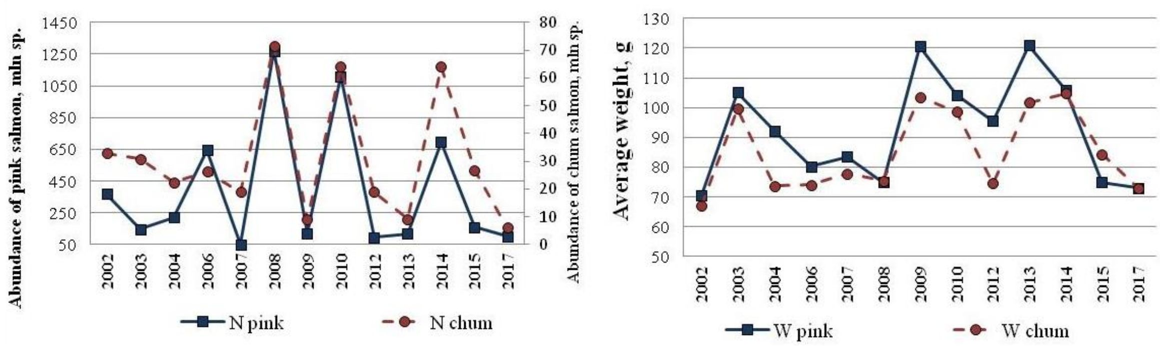

Fig. 4. Dynamics of abundance and average body size of pink and chum salmon juveniles in the western Bering Sea in fall 2002–2017.

The higher abundance of both pink salmon and chum salmon was observed in the Sea of Okhotsk during the relatively colder period (1998–2006). This period was characterized by relatively higher concentrations of macroplankton in the southern part of the sea (in average 110 g/m^2). In the subsequent warmer period of 2007–2016 (the period of minimum ice cover of the Sea of Okhotsk), a decrease in the macroplankton biomass was noted in the southern part of the sea (to an average of 64 g/m^2). The number of salmon yearlings has also decreased (Fig. 3). Formally, a statistically significant positive correlation is observed between the concentrations of plankton and the number of salmon juveniles in the deep-water part of the Sea of Okhotsk. Spearman correlation coefficients between average macroplankton biomass and abundance of each species were +0.51 (p <0.05). However, the food supply of salmon juveniles is not a factor limiting salmon abundance in the southern part of the Sea of Okhotsk in the autumn of the 2000s.

- Despite the decrease in plankton concentrations in 2006–2016, their reserves in the deep-waters of the sea are very large. In the "warm" period, the plankton biomass per 1,000 juveniles has increased from 28.6 to 37.6 metric tons.
- More stringent food relationships among salmon yearlings due to density-dependent factor were characteristic for the cold years of 2000–2006. In the warm years of 2007–2011, conditions with high food supply for juveniles were observed (Zavolokin 2013; 2014).
- The plankton biomass decrease did not affect the change in the average size of the juveniles, as evidenced by the absence of statistically significant correlation between the average size of chum and pink juveniles and macroplankton biomass in the southern Okhotsk Sea. A significant decrease in the average size of pink salmon juveniles in even generations (an average of 20 g) is due to an increased abundance of Kamchatka stocks in the Sea of Okhotsk in the period 2007–2016. Kamchatka pink salmon juveniles are smaller in comparison with the pink salmon juveniles of the southern stocks. When Sakhalin-Kuril pink salmon stocks dominated in the Sea of Okhotsk, the average size of juveniles did not change and amounted to an average of 161 and 165 g, respectively for the periods of 1998–2006 and 2007–2016. In general, the average sizes of juvenile pink salmon depend on the proportion of "south" stocks in the sea of Okhotsk ($R = + 0.72$ ($p>0.05$)).

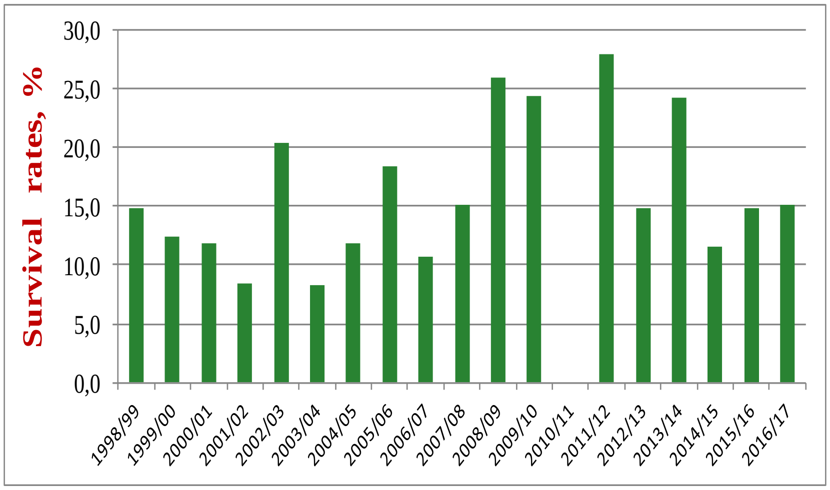

Fig. 5. Survival rates of pink salmon belonging to the Sea of Okhotsk stocks during period from fall surveys until spawning approaches to coasts, 1998–2017.

Despite the lower abundance of pink salmon juveniles in the sea of Okhotsk during the last 10 years, their survival increased in the following marine life stages (Fig. 5). So, the survival rate of pink salmon for odd generations increased on average from 14 to 17% in comparison with the period of 1998–2006, for even generations almost twice as much (from 12 to 21%). An increase in survival rates of the juvenile pink salmon by half during winter and spring in 2008–2011 indicated the presence of favorable forage conditions in "warm" period. A noticeable increase in the survival rate of pink salmon in the last 10 years is due, first of all, to the lower death rates of the pink salmon from the "northern" stocks (Kamchatka and the continental coast of the Sea of Okhotsk).

REFERENCES

Radchenko, V.I., O. S. Temnykh, and A.V. Zavolokin. 2013. Review of Studies on Asian Juvenile Pacific Salmon Stocks, 2006–2012. NPAFC Technical Report 9: 1–10. N. Pac. Anadr. Fish. Comm. Tech. Rep. 9: 1–10. (Available at http://www.npafc.org)

Shuntov, V.P. 2001. Biology of the Far Eastern Seas of Russia. Vol. 1. TINRO-Center, Vladivostok. 580 p. (In Russian)

Shuntov, V.P. 2016. Biology of the Far Eastern Seas of Russia. Vol. 2. TINRO-Center, Vladivostok. 604 p. (In Russian)

Shuntov, V.P., and I.V. Volvenko. 2017. Supplements to quantitative assessments of zooplankton in the Far Eastern Seas and adjacent waters of the North Pacific. Izv. TINRO. 191: 130–146. (In Russian).

Shuntov, V.P., and O.S. Temnykh. 2008. Pacific salmon in marine and oceanic ecosystems. Vol. 1. TINRO-Center, Vladivostok. 481 p. (In Russian)

Shuntov, V.P., and O.S. Temnykh. 2011. Pacific salmon in marine and oceanic ecosystems. Vol. 2. TINRO-Center, Vladivostok. 473 p. (In Russian)

Shuntov, V.P., and O.S. Temnykh. 2017. The Far Eastern salmon fishing season-2017 through the prism conformity of theory and practice. Bulletin of Pacific Salmon Studies on the Far East 12: 3–14. (In Russian)

Temnykh, O.S., A.N. Kanzeparova and P.O. Emelin. 2017. Interannual dynamics of the abundance and average sizes of juveniles pink salmon and chum salmon in the Sea of Okhotsk in the 2000s. Bulletin of Pacific salmon studies in Far East 12: 159–168. (In Russian).

Ustinova E.I. and Yu.D. Sorokin. 2013. Recent state and variability of climate and oceanographic conditions in the Far-Eastern Seas. Ecology of the marginal seas and their basins. Materials of the International Scientific conference. Vladivostok. pp. 343–352.

Zavolokin A.V. 2013. Feeding habits, consumption rates, and growth of juvenile Pacific salmon in relation to fluctuations of the forage base and salmon abundance. N. Pac. Anadr. Fish. Comm. Tech. Rep. 9: 97–100. (Available at http://www.npafc.org)

Zavolokin, A.V. 2014. Food supply of Pacific salmon in marine and ocean life period. Ph.D. thesis. TINRO-Center. Vladivostok. 47 p. (In Russian).