Food Supply of Juvenile Pink Salmon in the Subarctic Frontal Zone of the Western North Pacific Ocean in the Winter and Spring

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The offshore waters of the North Pacific Ocean are the main areas inhabited by pink and other Pacific salmon in winter and spring. The winter period of marine life of Pacific salmon has been studied insufficiently. Ecosystem studies and research began in 1986-1992 and significantly increased the available information on salmonid ecology during the winter and spring in the open ocean. In 2009-2011 the Pacific Research Fisheries Center (TINRO, Russia) conducted another series of complex research surveys of winter-spring salmon habitat conditions in the Subarctic frontal zone of the western North Pacific Ocean.

Asian pink salmon in the winter-spring period are mainly distributed in the Subarctic frontal zone and in neighboring waters to the north in habitats exhibiting a wide range of temperature, 0.5°-12°C, and salinity, 32.7‰ to 34.9‰. Analysis of 1986-1992 and 2009-2011 data has provided for the determination that spatial distribution of pink salmon depends on the western Subarctic cyclonic macrocirculation state and on the position of the frontal zone of the East Kamchatka Current ocean branch. The state of the western Subarctic cyclonic macrocirculation pattern can be described as "stretched", "compressed", or "normal". These states are distinguished by heightened intensity of the Subarctic Current and intensity of the progression of the Aleutian and ocean branch of the East Kamchatka currents.

When the western Subarctic circulation was in a "stretched" state, pink salmon were distributed more evenly and over a wider area, including in areas to the southeast and eastwards where pink salmon catches were reported between 38°N and 45°N. When the western Subarctic circulation was in a "compressed" state, pink salmon were located in areas further northwards, and the main pink salmon catches were located between 41°N and 45–46°N, closer to the Kuril Ridge (Naydenko in press).

As the epipelagic zone of the northwestern Pacific Ocean is a biotope with clearly expressed dynamics of water circulation and a wide range of temperature and salinity values, salmon habitat conditions differ with regard to these conditions through the season and on an interannual basis.

One index of food supply for salmon is the total biomass of consumers of fodder zooplankton in areas inhabited by salmon. In 2009-2011 it was established that the main biomass of these consumers in the upper epipelagic zone consisted of Pacific salmon, mezopelagic fish, and squids. These nekton groups were the main consumers of fodder resources in the central and western parts of Subarctic frontal zone in winter-spring. The survey in 2010 was unusual because there was a high biomass of Japanese anchovy (*Engraulis japonicus*) caught. But anchovy were present in trawl catches conducted only in transitional subtropical waters. Pink salmon catches were low in transitional subtropical water masses. The nekton density in the research area ranged from 0.37 to 0.65 ton/km^2 in different years, which were very low values for such a huge area.

The basic trophic relationships among juvenile pink salmon (and other fish and squid) and major zooplankton groups were investigated and daily consumption of forage resources by nekton in the upper epipelagic zone was estimated. Our results showed that the trophic linkages of juvenile pink salmon in winter were directed upon consuming copepods, euphausiids, chaetognaths, hyperiid amphipods, and pteropods (other prey groups had smaller values). The daily consumption of these zooplankton groups by juvenile pink salmon varied depending on salmon abundance and did not exceed 2-14 thousand tons. The daily consumption of zooplankton by all nekton in the upper epipelagic zone was not high either—5 to 20 thousand tons. Our estimates for the total biomass of zooplankton in the western Subarctic frontal zone in these years were 84-158 million tons, significantly higher than consumption estimates. The ratio of the biomass of fodder plankton and nekton varied from 134 to 315 thousand tons in 2009-2011. The ratio was lower in 2009 when abundance of pink salmon, squids, and mezopelagic fish was high. But this index was high in comparison with other areas and seasons. These estimates show that winter is not a period of fasting when food resources are scarce.

The feeding activity of juvenile pink salmon in 2009-2011 was not low; the index of stomach filling (ISF) changed from $5^o/_{ooo}$ to $460^o/_{ooo}$ (averaging 54-140$^o/_{ooo}$ in different years), but the ISF in winter was lower than ISF in fall. Pink salmon lipid content was depleted in the winter compared to the level in the fall.

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Data on abundance and availability of zooplankton, abundance of nekton, the ratio of the biomass of fodder plankton and nekton, and daily consumption estimates by all nekton on zooplankton prey testify there is sufficient fodder zooplankton for juvenile pink salmon and other nekton in the northwestern Pacific Ocean in the winter and spring. However, there is a marked decrease in feeding activity and lipid content of pink salmon in winter. We do not consider the decrease of these parameters from fall to winter as evidence of unfavorable ambient winter conditions. It can be an expression of an internal rhythm related to pink salmon physiological cycles, adaptation to dwelling in cooler waters, and winter residence in waters with feeding conditions less favorable than summer conditions.