Hydrobiological Investigations by the TINRO-Centre under the BASIS-2003 Program: Zooplankton and Pacific Salmon Feeding

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In September and October of 2003, the researchers of TINRO Centre undertook three complex expeditions to the Bering Sea (Fig. 1) during which they collected plankton using a Juday net. These samples were later processed according to the standard methods developed and practiced at TINRO (Volkov et al. in press).

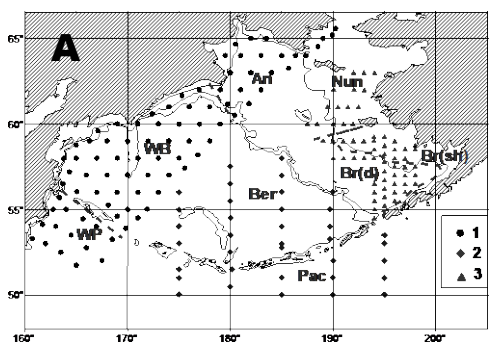
Small-fraction zooplankton (< 1.2 mm) were the most abundant in number and biomass in the shallow waters of the North-East Bering Sea (Table 1). The middle-size zooplankton fraction (1.2–3.3 mm) had the least biomass of the three fractions. As such, the middle size zooplankton biomass was within 15–95 mg/m^3 (4.5%–20% of the total). Only in the Bristol Bay shallow waters was this fraction found higher than the large fraction. The large-fraction zooplankton dominated throughout the year in most of the Far Eastern seas and in the adjacent Pacific oceanic waters which serve as feeding areas for numerous commercial species. As the abundance of this large fraction mainly determines the feeding base for commercial fishes, special attention has been given to the analysis of this part of the plankton.

During the period of the research, the highest biomass of large-size zooplankton occurred in the areas where the volumes of small-size fractions were lowest, and vice versa, i.e. (Fig. 2). The small-size zooplankton dominated in the total volumes caught in all the three eastern zones of the Bering Sea. Large-size zooplankton fraction biomass was the lowest especially in the Bristol Bay shallow waters where it was represented by only 9% of zooplankton total biomass. As for the other areas, with the exception of the Anadyr Bay, large-size zooplankton fraction biomass was considerably higher and its share was as much as 78%–85%.

As for the large-fraction zooplankton biomass parameters, copepods and chaetognaths dominated over the major part of the Bering Sea, while in the Okhotsk Sea, euphausiids dominated followed by chaetognaths and copepods, both represented in equal amounts. The leading 10 species caught in all areas made up over 90%, and the first three species represented 55% (from 55% to 79%). As for the shallow eastern areas, small-fraction species dominated, while in the rest areas, there outnumbered large-fraction zooplankton.

Data on salmon feeding (mainly chum and sockeye) and their food abundance were collected during the expedition of the fall season of 2003, which was undertaken on three research ships and covered the major part of the Bering Sea (Efimkin et al. in press). In deep waters of the Bering Sea (Western and Central parts), the large-fraction zooplankton was the major food for salmon (70%–100%), while nekton represents only 0%–30%. It is important to note that chum salmon had a preference in pteropods and hyperiids, while sockeye ate mostly hyperiids and pteropods, the share of which was much lower in zooplankton than in stomachs. In autumn, the feeding of chum salmon declined considerably, though the composition remained approximately the same. The share of chaetognaths in their food was much lower than in zooplankton.

Fig. 1. A: Planktonic stations (BASIS), summer–autumn 2003 (Isobat 50, 200, 1000 m; 1 - "TINRO", Juday (BSD) Net, 14.09–25.10; 2 - "Kaiyo Maru", BSD and Norpac Nets, 30.08–19.09; 3 - "Sea Storm", BSD Net 150–0 m, 31.08–08.10). Areas: An - Anadyr bay, WB - western Bering Sea, WP - western Pacific, Ber - central Bering, Pac - central North Pacific, Br(sh) - Bristol shallow part, Br(d) - Bristol depth part, Nun - Nunivak area. **B**: The generalized map of surface currents in Bering Sea in warm half-year (Khen, 1988). Currents: 1-Attu, 2 - Central-Bering, 3 - West-Alaska, 4 - Navarin, 5 – Kamchatka.



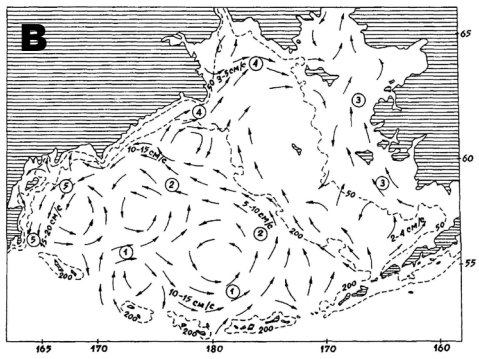


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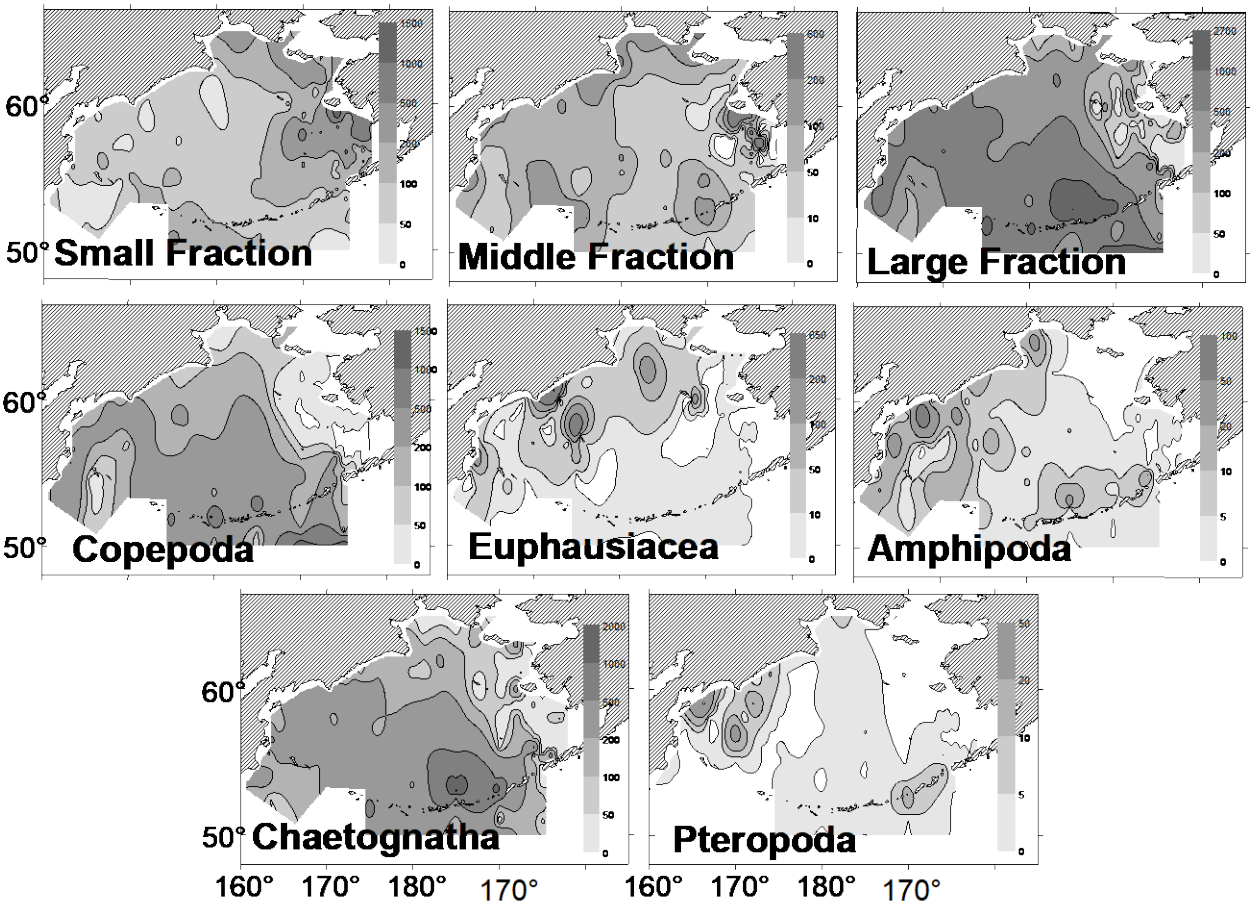
Table 1. Composition of zooplankton of Bering Sea in autumn 2003 (with coefficients of catch). Areas: An - Anadyr bay, WB - western Bering Sea, WP - western Pacific, CB - central Bering, AT - Aleut-Pacific, Nun - Nunivak area, Br(d) - Bristol depth part, Br(sh) - Bristol shallow part.

Composition of Zooplankton	"Sea Storm			"Kaiyo-Maru		"TINRO" (day)			"ТИНРО" (night)		
	Br(sh)	Br(d)	Nun	CB	AT	An	WB	WP	An	WB	WP
Total Biomass	**661.7**	**349.8**	**339.2**	**1,004.4**	**713.9**	**471.9**	**718.1**	**498.2**	**892.3**	**716.4**	**684.5**
Small Fraction	514.7	217.4	187.4	88.3	95.7	144.1	64.8	49.2	147.7	64.5	60.5
Middle Fraction	89.9	15.6	47.6	58.9	37.0	94.6	77.4	61.9	83.0	75.3	55.2
Large Fraction:	***57.1***	***116.8***	***104.3***	***857.2***	***581.2***	***233.2***	***575.9***	***387.1***	***661.6***	***576.6***	***568.8***
Copepoda	*1.6*	*41.6*	*5.1*	*316.5*	*356.1*	*93.6*	*188.3*	*202.3*	*97.0*	*217.9*	*301.5*
Euphausiacea	*0.1*	*1.1*	*12.3*	*6.2*	*3.4*	*34.3*	*40.7*	*20.9*	*284.1*	*65.9*	*90.9*
Hyperiidea	*0.5*	*1.3*	*0.2*	*9.0*	*4.1*	*7.3*	*14.9*	*8.9*	*8.8*	*16.4*	*8.8*
Chaetognatha	*29.7*	*69.4*	*51.9*	*508.7*	*206.9*	*92.0*	*296.0*	*143.2*	*131.4*	*247.5*	*156.2*
Coelenterata	*10.6*	*2.3*	*31.2*	*15.2*	*8.5*	*2.4*	*29.1*	*10.6*	*13.9*	*20.2*	*8.6*
Other	*14.5*	*1.0*	*3.6*	*1.6*	*2.2*	*3.6*	*6.9*	*1.2*	*126.4*	*8.7*	*2.8*

Fig. 2. Distribution of the three biomass fractions of zooplankton and groups of the large fraction at 200 (bottom) – 0 m, day-time, mg/m^3.



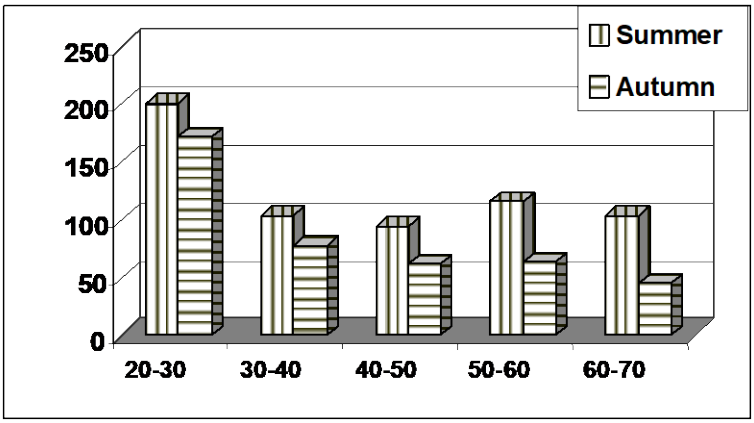
In the eastern part of the Sea, chum salmon, almost exclusively ate fish (pollock fingerlings and *Leuroglossus schmidti*), sockeye salmon preferred pollock fingerlings and crab larva. It was determined that only in sockeye salmon's food (the fish 15–20 cm long), zooplankton represented 30% (euphausiids), and this was similar to generally the typical composition of the plankton population, in which small-size sooplanktonic animals prevail.

Large fraction zooplankton was the food basis for chum and sockeye salmon (70–100%), while nekton represents only 0–30%. In the western part of the Bering Sea, there was a noticeable preference in food of chum salmon for pteropods and hyperiids, but for sockeye salmon there was an evident preference for hyperiids, the percentage for of which was always much lower in the plankton, than that observed in stomachs. The number of euphausiids in their food was also large especially for chum salmon. In some regions during some years, the percentage was as high as 50–60%.

In the autumn, the stomach contents of chum salmon (the size above 40 cm) decreased (Fig. 3). The share of squids rose considerably, while jellyfishes decreased with the amount of young fishes remained unchanged. The daily rhythmics of feeding in both species was similar. The least activity was observed at night while, the greatest occurred in the afternoon and in the evening. Almost all food was digested by dawn. In the central part of the Sea, coelenterates, pteropods, hyperiids and euphausiids were the major diet of chum salmon and euphausiids and hyperiids dominated for sockeye salmon. Small squids prevailed in the food of sockeye, and chum salmon. In the eastern part, chum salmon ate almost exclusively fish (juvenile pollock and sand lances), while sockeye salmon preferred juvenile pollock and crab megalops.

During the last 3 years, there has been a trend to decreased biomass of the preferred zooplankton. Such fluctuations are specific to the Far Eastern seas and take place regularly within the period of 5–7 years. Collecting of data for plankton and feeding of Pacific salmon only during the daytime is not sufficient to give an opportunity to study the daily rhythmics, and consequently, to calculate daily and monthly nutrition as the results underestimate the role of many other species (euphausiids, mysids and some species of copepod) in the feeding of nekton.

Fig. 3. Intensity of food of Chum salmon in western Bering Sea ($^0/_{000}$).



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