



SEASON ASPECT OF ABUNDANCY OF COPEPODA IN THE BAY OF RISAN (BOKA KOTORSKA BAY)

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Key words:

Copepoda,
Adriatic,
Bay of Risan,
abundance,
coastal waters

Ključne riječi:

Copepoda,
Jadran,
Risanski zaliv,
abundance,
priobalne vode

SYNOPSIS

The species composition and horizontal distribution of Copepoda were studied from January to December 2002. in the closed coastal waters of southern Adriatic (Bay of Risan). The research was done at 2 stations, one along the very shore, in the immediate vicinity of shellfish farms, and one in deeper water. 44 species of Copepoda were identified, and in the same time the main hydrographic parameters (T°C, ‰, pH, O₂mL/L, O₂%, transparency according to Secchi, color of the sea according to Forell) were measured and analyzed. The dominant species: *Paracalanus parvus* (Claus), *Centropages kröyeri* Giesbrecht, *Acartia clausi* Giesbrecht, *Oithona nana* (Giesbrecht), *Microsetella norvegica* (Boeck), *Euterpina acutifrons* (Dana), *Oncaea media* Giesbrecht and *Oncaea subtilis* Giesbrecht, participated with 39.6% in the total abundance of all Copepoda.

SEZONSKI ASPEKT ABUNDANCIJE COPEPODA U RISANSKOM ZALIVU (BOKA KOTORSKA)

SINOPSIS

Kompoziciju vrsta i horizontalnu distribuciju Copepoda smo istraživali u periodu od januara do decembra 202. godine u zatvorenim vodama južnog Jadrana (Risanski zaliv). Istraživanja su izvršena na 2 postaje, jedna u vrlo plitkom delu u blizini farme za uzgoj školjki, i druga dubokom delu zaliva. Registrovali smo 44 vrste Copepoda, i u isto vreme smo merili hidrografske parametar (T°C, ‰, pH, O₂mL/L, O₂%, prozirnost Secchi pločom, boja mora po Forell-u). Dominantne vrste Copepoda: *Paracalanus parvus* (Claus), *Centropages kröyeri* Giesbrecht, *Acartia clausi* Giesbrecht, *Oithona nana* (Giesbrecht), *Microsetella norvegica* (Boeck), *Euterpina acutifrons* (Dana), *Oncaea media* Giesbrecht i *Oncaea subtilis* Giesbrecht, su učestvovala sa 39,6% u ukupnoj abundanciji.

INTRODUCTION

Geographic position and specific ecological conditions make Bay of Risan a distinct biotope. The interactive relationships of its wildlife are influenced by influx of freshwater from the mainland as well as the currents from the open sea. Therefore we tried to use the data collected in one-year cycle of study in order to determine main regularities in oscillations of ecological parameters, important for fluctuations in diversity of whole copepod biocenosis. We presented a detailed list of Copepoda faunistic composition, position and role of dominant species in quantity of zooplankton, horizontal distribution and abundance, as well as data on diversity within the fauna of Copepoda in Bay of Risan in 2002. We presented the data on periodic penetration of autochthonous species from deeper open sea into the zone of coastal waters, that is, the length of their presence in eurihaline and eurithermic environmental conditions. The first data on the plankton copepods of Boka Kotorska Bay were by Car (1895-96) in the short overview of plankton of Boka Kotorska area. Gamulin (1938) after his short studies presented the data on distribution of species within the Bay, and he especially stressed the quantity data. These data pertain to November of 1936 and February and March of 1937. He cited that he rarely found adult *Calanoida* in Kotor and Risan Bay, and that there was a great abundance of juvenile stages of *Paracalanus*, *Centropages* and *Temora*. He recorded adult forms of species: *Oithona nana* (Giesbrecht), *Oncaea media* Giesbrecht, *Oncaea subtilis* Giesbrecht, *Microsetella norvegica* (Boeck) and *Euterpina acutifrons* (Dana). First all-including studies of plankton copepods in this biotope were performed by Vukanić, D. (1971, 1979, 1988). These data pertain to yearly cycles, broken into monthly data. Unusually high amplitudes were recorded for the main hydrographic factors of marine water within the Bay, and these were the most influential factors for the taxonomic structure and distribution of fauna of Copepoda. During this study, 44 species of Copepoda were recorded, as well as their distribution on the stations in the studied area. Especially in coastal and shelf waters, plankton abundance and species composition are characterised by a very high degree of spatial and temporal variability. This reflects the variety of terrestrial and offshore as well as atmospheric forcing and internal biological processes to which these boundary areas are subject. Kovalev A.V. *et al.* (2003) cite that dominant role in defining seasonal changes in total zooplankton abundance is played by the main group – copepods, which in some years from up to 90% of zooplankton numbers and biomass. During the warm period of a year, cladoceras may replace copepods. Vukanić, V. (2005) presents data on oscillations in number of copepod species in various bays in Boka Kotorska, comparing three study years within the thirty years period. Vukanić, V. & D. Vukanić (2005) present data on seasonal oscillations and horizontal distribution of species belonging to genus *Oithona* in Bokokotorski Bay, gathered during a one-year cycle of intensive studies of hydrography and zooplankton. The data presented in this paper are a part of research of complete zooplankton biocenosis in season 2002.

MATERIALS AND METHOD

Sampling - Zooplankton was sampled in 2002, on 25th each month, at seven stations. The plankton nets used were of Nansen type, either surface area of the opening 1/4m² - length 2.5m, or surface area of the opening 1m² - length 3.5m. The density of the mesh was 150µm and 200µm. Vertical samples were taken from 10m to 0m at the shallow stations in bay. The collected zooplankton material was fixated on the ship, in 2.5% formaldehyde-sea water. The qualitatively quantitative analyses were done in the laboratory from the representative sample of 1/25 of total catch, under the stereomicroscope and binocular lens. After that, the whole catch was carefully analyzed in order to record any rare species. The adult individuals of Copepoda were determined by species, while nauplii and juvenile Copepoda were represented together as copepodites. The quantity was presented as number of individuals under m⁻² below sea surface (ind.m⁻²). Temperature, salinity, pH, oxygen saturation and percent oxygen saturation were measured *in situ* with a probe Multiline P-4, at 0.5m, 2m, 5m and 10m in the shallow part of the Bay near the coast, and at 0.5 m, 10m, 15m, 20m and 30m of depth at central deep stations. The transparency of the sea was measured with Secchi disk, 30 cm in diameter, white in color. Color of the sea was measured according to Forell from I to XXI. Margalef's species richness index D was used to analyse diversity changes among layers:

$$D=S-1/\log N$$

where S is the number of species and N is the total number of individuals.

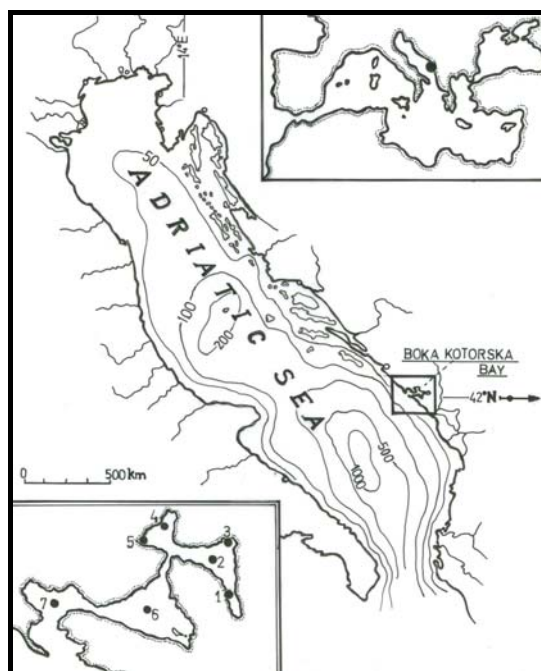


Fig.1. Map of sampling area in southern Adriatic [5: (P-M); 4: (P-R)] (Vukanić, V., 2005)

Tab.1. Morphometric data of individual bays within Bay of Risan

	Risan bay
Surface	8.005km ²
Volume	205.958.000m ³
Max. depth	36m
The bay lenght	4.55km
The coast length	12.6km
Average width	1.750km
Max. width	3.075km

RESULTS

Environmental conditions - The maximal temperature (27.7°C) was recorded in July, while the medium maximal temperature of all layers was 25.3°C. The minimal temperature (10°C) was recorded in Risan Bay (P₂-R) in February. The salinity of the sea varied within the values 9,7‰ - 38.71‰. Oxygen saturation varied from 4.68mL/L at the surface in June and July to 33.7mL/L at the 10 m depth at shallow station P-M in June. The percent of oxygen saturation was over 100%. The high values of oxygen saturation, which exceeded 100% throughout the year, show that the Bay is a biotope with a high degree of trophic activity. The whole Bay had relatively low values of transparency, from 4 m to 15 m in January. The color of the sea according to Forell ranged from II in June to VI in September.

Copepoda general distribution - During the yearly cycle of study we recorded 44 species of copepods. Quantitatively important are 8 species on the shallow habitats, which comprise 29.6% of copepod plankton: *Paracalanus parvus* (Claus), *Centropages kröyeri* Giesbrecht, *Acartia clausi* Giesbrecht, *Oithona nana* (Giesbrecht), *Microsetella norvegica* (Boeck), *Euterpina acutifrons* (Dana), *Oncaea media* Giesbrecht and *Oncaea subtilis* Giesbrecht. Also important are the rare copepods brought by currents into the zone of coastal waters: *Eucalanus elongatus* (Dana), *Calanus tenuicornis* Dana, *Neocalanus gracilis* (Dana), *Euchaeta hebes* Giesbrecht, *Euchaeta marina* (Prestandrea), *Lucicutia flavicornis* (Claus), *Labidocera wollastoni* Lubbock, *Oithona setigera* (Dana), *Sapphirina lactens* Giesbrecht, which are characteristic representatives of the open sea community.

***Paracalanus parvus* (Claus)** – Typical neritic surface species of warm waters in subtropical region, it is almost equally distributed through the Boka Kotorska Bay. It has a long period of occurrence and two yearly maximums of abundance: winter and summer. It belongs to dominant copepods of Boka Kotorska Bay. Within the Bay, it is more abundant during the winter and spring, especially in March, April and May, and the common and abundant status continues to summer-autumn period. The percent

participation when compared with other copepods in the plankton ranges from 2.2% at the shallow station to 4.65%. The medium value of percent participation for the whole Bay, when compared to other Copepoda was 4.02%.

Table 2. Average values of hydrographic parameters in coastal waters in Bay of Risan January – Decembre 2002.

	P-M	P ₂ -R
Layer 0m		
Temperature (°C)	11.1±23.3	11.6±21.8
Salinity (‰)	9.7±21.8	20.3±24.3
Oxygen (mL/L)	7.2±10.9	9.2±13.4
Layer 0-2m		
Temperature (°C)	12.8±24.6	
Salinity (‰)	26.93±34.8	
Oxygen (mL/L)	6.5±8.07	
Layer 2-5m		
Temperature (°C)	14.4±23.4	13.6±22.1
Salinity (‰)	29.4±37.03	35.05±36.3
Oxygen (mL/L)	6.4±8.7	8.5±11.9
Layer 5-10m		
Temperature (°C)	15.1±21.2	14.06±20.9
Salinity (‰)	32.5±37.4	36.2±37.6
Oxygen (mL/L)	6.3±10.6	9.5±11.3
Layer 10-30m		
Temperature (°C)		14.3±20.1
Salinity (‰)		37.4±38.1
Oxygen (mL/L)		9.4±11.7

***Centropages kröyeri* Giesbrecht** - This typical eurithermous and eurihaline species is abundant and common in semi-closed bays of the eastern coast of Adriatic, where it comprises a large part of plankton biomass. It is qualitatively important in Boka Kotorska Bay, and present at all the stations, with participation of 1.72% at the shallow station near Morinj (P-M) to 2.9% at the middle of Risan Bay (P₂-R). The maximal abundance was in July in inner waters of the Bay (30700 ind./m²). ***Acartia clausi* Giesbrecht** – This widely distributed and highly abundant species of Adriatic

Sea appears continuously in the plankton of Boka Kotorska Bay, with significant quantitative participation. It is more abundant and common in the spring-summer period, with a maximum value in late spring. The percent value ranges from 0.8% near Risan to 1.25%.

***Oithona nana* (Giesbrecht)** – This is a typical estuary-neritic species, in which the abundance and population density extremely increase when moving from the open sea toward the inner closed waters of Boka Kotorska Bay. It dominates in the plankton community of copepods, and according to population density and high levels of abundance it represents a typical summer form. Our data clearly show the increase in abundance from April to mid-summer, and the maximum abundance was in July and August. Percent participation when compared to other copepods in the plankton ranges was 26.7%.

***Microsetella norvegica* (Boeck)** – The abundance of this tiny neritic copepod is especially pronounced at the shallow stations near shellfish farms. The percent participation when compared to other copepods was 4,0% near Risan and 3.98% near Morinj. It was more abundant in winter and early spring. The maximum abundance was in the winter period – up to 44 000 ind./m² in Risan Bay (P₂-R) which is the smallest and with the greatest influx of freshwater.

***Euterpina acutifrons* (Dana)** – The only representative of this family is one of the dominant copepods in Boka Kotorska Bay. The population density and abundance decrease from the inner waters toward the open sea. There are two maximums during the year, one in winter and one in warm period. It is equally common and abundant throughout the Bay, while it was previously recorded at the open sea only as single individuals. The percent value ranges from 3.5% near Morinj to 12.7% in Risan Bay.

***Oncaea media* Giesbrecht** – It appears very commonly and in significant number of specimens in all bays of Boka Kotorska. It was most common and most abundant in Risanski Bay (P₂-R) - 56600 No.ind/m². This pattern was not previously noted for this species in the Bay. The maximum was recorded in autumn and winter. The greatest percent participation was in in Risan Bay 43.7%.

***Oncaea subtilis* Giesbrecht** – This species of pronounced surface habit was continuously present in the plankton in Boka Kotorska Bay. According to its population density and abundance, it is one of the dominant copepods. The maximum of abundance was recorded in winter, with another one in the warmer part of the year. The continuous yearly studies show that the abundance gradually increases from the warmer toward the colder period of the year. The greatest percent participation is 8.00% at Risan Bay.

Tab.3. Seasonal medium values of quantity (ind.m⁻²) and percent participation during the study.

Station	P-M	P ₂ -R	P-M	P ₂ -R
Season				
	<i>Paracalanus parvus</i> (Claus)		<i>Microsetela norvegica</i> (Boeck)	
Winter	4600	13500	1200	44000
Spring	6000	13400	20400	100
Summer	5100	47500	100	800
Autumn	3600	3600	200	100
%	3.51	6.03	4.0	3.5
	<i>Centropages krøyeri</i> Giesbrecht		<i>Euterpina acutifrons</i> (Dana)	
Winter	r	1600	1200	44000
Spring	2400	2400	20400	100
Summer	6500	32800	100	800
Autumn	600	700	200	100
%	1.72	2.9	4.0	3.5
	<i>Acartia clausi</i> Giesbrecht		<i>Oncaea media</i> Giesbrecht	
Winter	-	600	6200	19400
Spring	2000	4200	6600	6800
Summer	1100	5100	1100	3100
Autumn	200	300	4100	44900
%	0.6	0.8	12.3	43,7
	<i>Oithona nana</i> (Giesbrecht)		<i>Oncaea subtilis</i> Giesbrecht	
Winter	9600	51400	13900	46100
Spring	56600	155900	22600	14500
Summer	68100	101800	4500	10800
Autumn	29800	36700	7500	32200
%	29.9	26.7	8.8	8.0

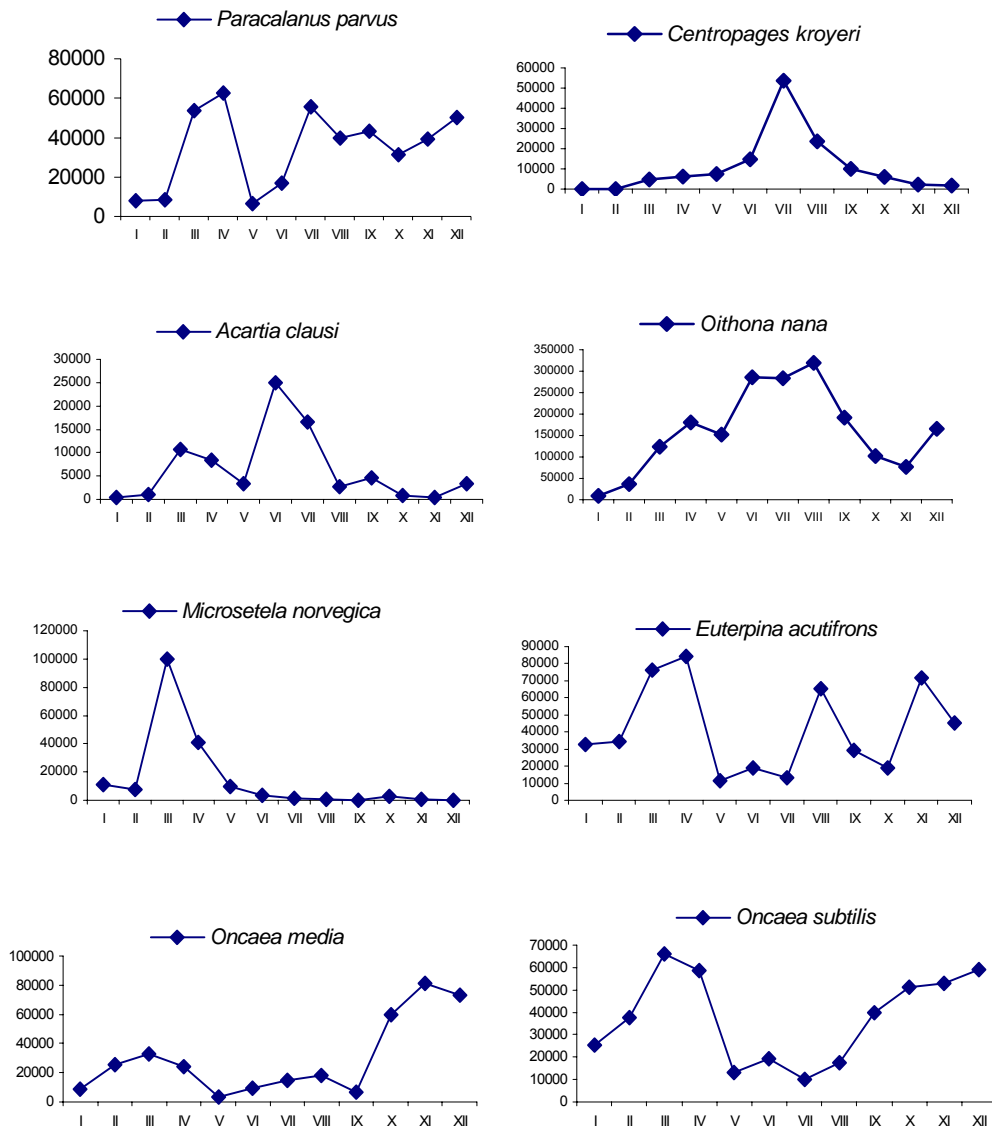


Fig. 2. Quantitative fluctuation of the dominant Copepoda during the study.

The largest part of quantitative structure in the copepod community of the Bay is comprised of juvenile forms in various stages of maturity, mostly eurithermous and eurihaline species characteristic for this biotope. The mean yearly value of percent participation of copepodites in Bay of Risan is 55.39%.

DISCUSSION

The copepod fauna of Bay of Risan is characterized by a relatively largest number of species. The long-term studies on copepods in the bays of the eastern

coast of Adriatic were only performed so far in Kaštelan Bay (Gamulin, 1939; Regner, D., 1979) and Mali Ston Bay (Hure *et al.* 1973; Vukanić, D. 1979, 1984; Onofri, 1984). Inner part of Boka Kotorska Bay (Risan and Kotor) does the plankton structure partially resemble the structure in Kaštelan and Mali Ston Bay. The specificity of copepod fauna is marked by some dominant eurithermous and eurihaline estuary-neritic species: *Paracalanus parvus* (Claus), *Oithona nana* (Giesbrecht), *Centropages kröyeri* Giesbrecht, *Euterpina acutifrons* (Dana), *Oncaea subtilis* Giesbrecht. During this research, 44 species of copepod crustaceans have been recorded in Bay of Risan. Their abundance and time-space distribution were analyzed.

Data from previous studies (Gamulin, 1938; Vukanić D., 1971, 1979, 1988, Regner D., 1979; Benović & Onofri, 1983), which correspond to our data, show that many surface species have a wide horizontal distribution and appear without more significant quantitative differences along the whole eastern coast of Adriatic, such as: *Paracalanus parvus* (Claus), *Temora stylifera* (Dana), *Centropages typicus* Kröyer, *Oithona plumifera* Baird, *Acartia clausi* Giesbrecht, throughout the year. Some of the open-sea species have a limited space and time appearance in the Bay, such as: *Neocalanus gracilis* (Dana), *Nannocalanus minor* Claus, *Euchaeta hebes* Giesbrecht, *Oithona plumifera* Baird, *Copilia quadrata* Dana. These copepods inhabit deeper parts of the sea in southern Adriatic, and are continuously present in the surface layers only in winter months, while in the other seasons appear in the surface layers only at night (Vukanić, D., 1988). The species *Centropages kröyeri* Giesbrecht 3.05%, *Microsetela norvegica* (Boeck) 3.5%, *Oncaea media* Giesbrecht 4.37% and *Oncaea subtilis* Giesbrecht 8.0% are dominant in the Bay of Risan. The pronouncedly neritic species *Oithona nana* (Giesbrecht) dominates among the copepods of the Bay, especially in the warmer period of the year, and is also recorded as a characteristic species in Mali Ston Bay (Hure *et al.* 1973; Vukanić, D., 1979; 1984; Onofri, 1984), which matches the data (Kršinić, 1995; Razouls, 1996) citing it as a dominant species in small bays in whole of Mediterranean. Richard & Jamet (2001), in the results of studies from Toulon Bay, cite that the percent participation of *Oithona nana* (Giesbrecht) in the population of adult copepods and holoplankton in the small bay was 46% and in the large bay 1.03%. Vukanić, D. (1983) cites the percent participation of 48.23% for the inner waters of Boka Kotorska Bay in summer season. *Temora longicornis* (Müller), characteristic for northern Adriatic and the western coastal belt to peninsula Gargano (Hure *et al.* 1980), was recorded during the winter period.

The category of species that separate this area from the northwestern areas of Adriatic includes the estuary-neritic forms: *Centropages kröyeri* Giesbrecht and *Oithona nana* (Giesbrecht). A small number of open-sea copepods was recorded in the Bay of Risan.

Penetration of open-sea copepod species into the zone of coastal water is better developed in winter and early spring. The surface forms, such as the species of *Calocalanus*, representatives of warmer seas, so called *feoplanktonts*, probably enter the Bay while carried with surface upward current.

Values of Margalef diversity index were: for the shallow stations near the shore: P-M (6.69); and for the deeper central stations P₂-R (7.06).

Coastal marine areas are of great ecological, economic and interest. They are highly variable systems, where changes in the water circulation patterns, and fluctuations of land influences (e.g. rivers, sewage flow) induce high temporal variability on scales ranging from hours to seasons (Walsh, 1988). This variability may be reflected in the dynamic of the populations, particularly planktonic ones, thriving in coastal systems. Such variability may hide the underlying seasonal patterns of organism abundance and biomass (Calabet, *et al.* 2001).

During this study, we recorded two yearly abundance maximums within the total zooplankton, a smaller one in spring and a larger one in summer, which was caused by appearance of extremely high-density population of Cladocera in August, especially the species *Penilia avirostris* Dana.

This is aligned with the ecological situation in Bay of Risan, which has very pronounced oscillations of hydrographic conditions. In thermal sense, this is not a homogenous area. The oscillations are most pronounced in the surface layers. The temperature maximum is mostly in July or August, while the minimum is in January or February. The data on temperature, salinity, oxygen saturation (which was always greater than 100%), pH, color of the sea and transparency, supported the hypothesis that this Bay is a pronounced eutrophic area. The spatial distribution of seasonal changes in coastal regions of the Mediterranean Sea corresponds to known concepts of latitude changes and local environmental differences. The role of antropogenic impact on seasonal changes is also important in this region (Kovalev A.V. *et al.*, 2003).

CONCLUSION

The waters of Bay of Risan show some very prominent oscillations in hydrographic conditions. In thermal sense, Bay of Risan is not a homogenous area, and the oscillations are most prominent in the surface layers. The temperature maximum is usually present in July or August, and minimum in January or February. Data on temperature, salinity, oxygen saturation (which was always above 100%), pH, color and transparency of the sea have supported the hypothesis that this Bay is a very eutrophic area.

The fauna of Copepoda is characterized by decrease in abundance of typical estuary-neritic species. The taxonomic structure of fauna of Copepoda is monotonous. The second one is usually somewhat smaller, however our data show a more pronounced summer maximum in total zooplankton, caused by an occurrence of enormous abundance of species *Penilia avirostris* Dana (Vukanić, V., 2006).

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