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STUDIES ON *COPEPODA* IN BAY OF KOTOR - COASTAL WATERS OF SOUTHERN ADRIATIC

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SYNOPSIS

The species composition and horizontal distribution of Copepoda were studied from January to December 2004 in the closed coastal waters of Bay of Kotor (southern Adriatic). The research was done at 3 stations, three along the very shore, in the immediate vicinity of shellfish farms, and four in deeper water. 42 species of Copepoda were identified, and in the same time the main hydrographic parameters (T°C, ‰, pH, O_2mL/L, O_2%, 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.

INTRODUCTION

Geographic position and specific ecological conditions make Boka Kotorska Bay a distinct biotope (Fig.1). 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 Kotor in 2004. 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. First all-including studies of plankton copepods in this biotope were performed by Vukanić, D. (1971, 1979). 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, 42 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. The overall complexity also explains why, despite the establishment of a small set of paradigms, no simple and wide-ranging rules have been agreed upon for the annual cycle of plankton and for the functioning of the pelagic ecosystem in coastal waters (Ribera d' Alcala et al., 2004). Benović & Onofri (1983) cite data on zooplankton for one station in Bay of Kotor for the period January-May. They recorded presence of eighteen species of Copepoda. When they compared the ratio of various zooplankton groups, they concluded that Copepoda do not represent more than 50% of the total number of individuals. 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. & Vukanic, D. (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 2003.

MATERIALS AND METHOD

STUDY AREA - Boka Kotorska Bay is situated in the southeastern part of Adriatic. Its geographical position is determined by key points: 42º31'N, 42º23'32''S, 18º46'32''E i 18º30'29W. It penetrates into the mainland for 28 km and is composed of four bays that are interconnected: Bay of Hercegnovi (which directly communicates with the open sea), Bay of Tivat, as well as the inner bays, Risan and Kotor Bays (Tab.1).

SAMPLING - Zooplankton was sampled in 2004, on 25th each month, at seven stations. The plankton nets used were of Nansen type, either surface area of the opening 1/4m^2 - length 2.5m, or surface area of the opening 1m^2 - length 3.5m. The density of the mesh was 150µm and 200µm. Vertical samples were taken from 10m

to 0m at the shallow stations and 30m to 0m at the deep stations of each 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.

Table 1: Morphometric data of Bay of Kotor.

	Bay of Kotor
Surface	16.262km^2
Volume	439.106.000m^3
Max. depth	52m
The bay lenght	9.55km
The coast length	25.0km
Average width	1.605km
Max. width	3.525km

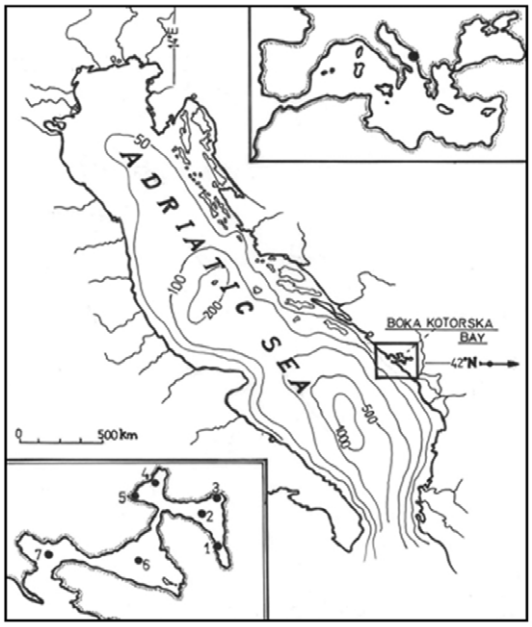

Figure 1: Map of sampling area in southern Adriatic [1: (P-IBM); 2: (P_1-K); 3: (P-O)] (Vukanić, V., 2005).

RESULTS

ENVIRONMENTAL CONDITIONS - The maximal temperature (27.7ºC) was recorded in July, while the medium maximal temperature of all layers was 25.3ºC. The minimal temperature (10ºC) was recorded in Bay of Risan (P_2-R) in February. The salinity of the sea varied within the values 7.9‰ - 38.71‰, and the lowest value ever recorded in the Bay was registered at the shallow station P-IBM in the surface layer 0-5m, 2.30‰ in September. The percent of oxygen saturation was over 100%, and the greatest value was recorded at the shallow station P-O in June (220%), while at the surface at the middle of Bay of Kotor (P_1-K) it was 117%. 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 (Tab.2).

Table 2: Average values of hydrografic parametars in coastal waters of southern Adriatic Sea (Boka Kotorska Bay), January – Decembre 2002.

	P-IBM	P-O	P_1-K
Layer 0m			
Temperature (ºC)	10.3±25.6	10.6±25.6	12.8±22.6
Salinity (‰)	2.3±20.6	8.1±33.7	24.2±26.9
Oxygen (mL/L)	7.1±16.5	7.1±16.5	5.9±8.8
Layer 0-2m			
Temperature (ºC)	12.8±26.6	12.8±25.6	
Salinity (‰)	14.3±34.3	26.9±34.8	
Oxygen (mL/L)	6.5±12.7	6.6±9.2	
Layer 2-5m			
Temperature (ºC)	13.05±22.6	13.05±22.6	14.2±23.06
Salinity (‰)	29.05±37.2	30.6±37.0	30.6±36.09
Oxygen (mL/L)	6.4±11.3	6.6±12.3	5.3±8.4
Layer 5-10m			
Temperature (ºC)	13.1±22.0	13.1±22.0	14.4±21.2
Salinity (‰)	35.6±37.7	35.7±37.1	30.6±37.5
Oxygen (mL/L)	6.3±14.05	6.3±16.4	5.2±8.6
Layer 10-30m			
Temperature (ºC)			14.3±20.4
Salinity (‰)			35.4±38.0
Oxygen (mL/L)			5.2±8.8

COPEPODA GENERAL DISTRIBUTION - During the yearly cycle of study we recorded 42 species of copepods. Quantitatively important are 8 species on the shallow habitats, which comprise 39.6% 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 (Tab. 3).

Calanus helgolandicus Claus – It is distributed almost equally at all the stations within Boka Kotorska Bay. It appears in a relatively small number of specimens throughout the study year, and somewhat greater abundance was recorded in late winter and early spring. During the summer it is either rare or completely missing. The maximum of abundance is in April. The percentage of qualitative representation when compared with other Copepoda is very low – 0.04% to 0.08%.

Paracalanus parvus (Claus) – Typical neritic surface species of warm waters in subtropical region, it is almost equally distributed through the Bay of Kotor. It has a long period of occurrence and two yearly maximums of abundance: winter and summer. It belongs to dominant copepods of 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 (P-IBM) to 8.65% in Bay of Kotor (P-K). The medium value of percent participation for the whole Bay, when compared to other Copepoda was 4.02%.

Clausocalanus arcuicornis (Dana) – This sub-surface ocean warm-water species is relatively common in Boka Kotorska Bay. It is most abundant in the winter period and early spring. The abundance and density increase as we move toward the open sea. The percent participation in the Bay of Kotor is 0.02% (P_1-K).

Temora stylifera (Dana) – Surface tropical species, continuously present in the plankton of Boka Kotorska Bay. It si almost completely lacking in the inner waters from late winter to late spring, and does not have any quantitative significance. Medium yearly value of percent participation for the whole Bay is 0.29%.

Oithona helgolandica (Claus) – It is distributed throughout the studied area. It becomes more common and abundant from the inner toward the outer stations, closer to the open sea. The maximum of appearance is in the warmer period. At the

shallow stations at the very coast of the Bay, the percent participation 0.32% near the Institute (P-IBM) to 1.78% Bay of Kotor (P-K).

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 from 37.8% in the shallow part of Kotor to 23,8% near Orahovac (P-O).

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 11.5% near the Institute (P-IBM), 2.8% near Orahovac (P-O) and 3.98% Bay of Kotor (P-K).

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 2.6% in Kotor (P_1-K).

Table 3: Species list of Copepoda found in Boka Kotorska Bay (southern Adriatic) during 2002.

Species	P-IBM	P-O	P_1-K
Calanus helgolandicus Claus		+	+
Calanus tenuicornus Dana	+	+	+
Nanocalanus minor Claus	+		+
Neocalanus gracilis (Dana)		+	
Pracalanus parvus (Claus)	+	+	+
Calocalanus pavo (Dana)	+	+	+
Calocalanus styliremis Giesbrecht	+	+	+
Ischnocalanus plumulosus (Claus)	+	+	+
Mecynocera clausi Tompson		+	+
Clausocalanus arcuicornis (Dana)		+	+
Clausocalanus jobei Frost&Fleminger	+	+	+
Clausocalanus paululus Farran	+	+	+
Clausocalanus furcatus (Brady)	+	+	+

Ctenocalanus vanus Giesbrecht	+	+	+
Diaixis pygmaea G.O.Sars	+	+	+
Centropages typicus Kröyer		+	+
Centropages kröyeri Giesbrecht	+	+	+
Temora stylifera (Dana)	+	+	+
Lucicutia flavicornis (Claus)			+
Candacia armata (Boeck)			+
Candacia longimana (Claus)			+
Acartia clausi Giesbrecht	+	+	+
Oithona helgolandica (Claus)	+	+	+
Oithona nana (Giesbrecht)	+	+	+
Oithona plumifera Baird	+	+	+
Microsetella norvegica (Boeck)	+	+	+
Macrosetella gracilis Dana	+		+
Euterpina acutifrons (Dana)	+	+	+
Clytemnestra rostrata (Brady)	+	+	+
Labidocera wollastoni Lubbock		+	+
Oncea dentipes Giesbrecht		+	+
Oncaea media Giesbrecht	+	+	+
Oncaea mediterranea (Claus)			+
Oncaea subtilis Giesbrecht	+	+	+
Sapphirina lactens Giesbrecht			+
Corycaeus clausi Dahl		+	+
Corycaeus typicus Kröyer	+		+
Corycaeus ovalis Claus		+	+
Corycaeus brehmi Steuer	+	+	+
Corycaeus rostratus Claus		+	+
Aetideus armatus Boeck		+	
Pontella mediterranea (Claus)		+	
Euchaeta hebes Giesbrecht		+	+
Euchaeta marina (Prestandrea)			+
Copepoditi♀♂	+	+	+
Total number of species	25	37	42

The number of species represented in catch gradually decreases from the open sea toward the inner waters of the Bay, so at the final station in Kotor Bay (P-

K) following species were absent: *Neocalanus gracilis* (Dana), *Calocalanus contractus* Farran, *Clausocalanus lividus* Frost&Fleminger, *Eucalanus elongatus* (Dana), *Temora longicornis* (Muüler), *Hetrprhabdus papilliger* (Claus), *Haloptilus longicornis* (Claus), *Microsetella rosea* Dana, *Oncaea ornata* Giesbrecht, *Copilia quadrata* Dana, *Sapphirina nigromaculata* Claus, *Sapphirina opalina* Dana, *Corycaeus furcifer* Claus, *Corycaeus giesbrechti* Dahl, *Aetideus armatus* Boeck, *Pontella mediterranea* (Claus), *Paracandacia simplex* (Giesbrecht), *Candacia tenuimana* (Giesbrecht), *Calocalanus styliremis* Giesbrecht, *Scolecithrix bradyi* Giesbrecht, *Lubbockia squilimana* Claus and *Phaenna spinifera* Claus (Tab. 3).

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 Kotor is 61.49% (Tab. 3).

DISCUSSION

The copepod fauna of Bay of Kotor is characterized by a relatively big number of species (Tab. 3). 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) and Mali Ston Bay (Hure & Scotto di Carlo, 1974; Vukanić, D. 1979; Onofri, 1984). These bays have significant hydrographic and morphometric differences from Boka Kotorska Bay, which deeply penetrates into the mainland and 300 communicates with the open sea of the deep southern Adriatic. 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, 42 species of copepod crustaceans have been recorded in Boka Kotorska Bay (Tab. 3).

Data from previous studies (Gamulin, 1938; Vukanić D., 1971, 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. Out of the quantitatively more important copepods, at the shallow station P-O most important are: *Paracalanus parvus* (Claus) *6.2%, Euterpina acutifrons* (Dana) 6.5%, *Oithona nana* (Giesbrecht) 37.8%, while within the total number of copepods they are relatively well distributed throughout the Bay. 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 shallower part of Bay of Kotor (P-IBM, P-O).

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 & Scotto di Carlo, 1974; Vukanić, D., 1979; 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%. Some autors cites the percent participation of 48.23% for the inner waters of Bay of Kotor in summer season.

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 raning from hours to seasons (Walsh, 1988). This variability may be reflected in the dinamic 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 (Fig. 2). The spring maximum had greater oscillations in quantity of Copepoda. Mazzocchi and D'alcala (1995) present data on Gulf of Naples in the shore station (0-50m layer) at beweekly intervals from 1984-1990, two peaks in zooplankton abundance were revealed. The first small peak was apparent from average values for April for the whole investigated period, the second peak was observed in August. The minimum zooplankton abundance can be defined mainly by the seasonal cycle of copepods. Zooplankters forming the summer peak are mainly composed of cladocerans. Similar seasonal changes in in zooplankton abundance and biomass were observed in other inshore regions of the eastern Mediterranean Sea (Kovalev et al., 2003).

This is aligned with the ecological situation in Bay of Kotor, 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 et al., 2003).

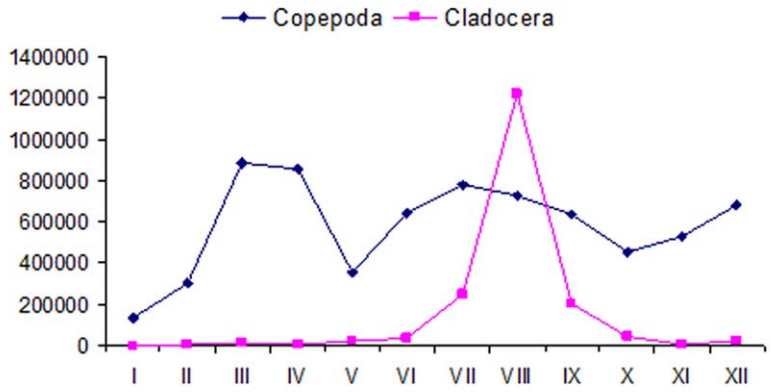

Figure 2: Fluctuations in abundance of Copepoda and Cladocera during the studied year in Boka Kotorska Bay (southern Adriatic).

CONCLUSION

The waters of Bay of Kotor show some very prominent oscillations in hydrographic conditions. In thermal sense, Bay 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.

The fauna of Copepoda is characterized by decrease in abundance of typical estuary-neritic species. The taxonomic structure of fauna of Copepoda is monotonous. In Bay there are two maximums of abundance, one in spring and one in late summer. 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 (Fig. 2). This data of the summer maximum have supported the hypothesis that Boka Kotorska Bay is a eutrophic area.

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