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HYDROGRAPHIC AND ZOOPLANKTON DATA IN THE BAY OF KOTOR COLLECTED DURING 2007/08

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Key words: zooplankton, Bay of Kotor, Copepoda, Cladocera, Copelata.

SYNOPSIS

Zooplankton was collected in the Bay of Kotor, coastal waters of southern Adriatic, from November 2007 to October 2008. At the same time we measured such hydrographic factors as temperature, salinity and transparency of sea water. The maximum temperature (28.2°C) was found in August and the minimum temperature (13.8°C) in February. Homothermia occurred in March. Maximum salinity was 39.00‰ at a depth of 25m in June. Minimum salinity was 15.08 in the surface layers during April. Transparency of the sea water was 18-36m in depth. We analysed zooplankton groups taking part in the total zooplankton collected from the study area. The following zooplankton groups were included in the analysis of species: Cladocera, Copepoda and Medusae. In the plankton samples of the study area we reported 5 species of Cladocera, 5 species of Copelata and 41 species of Copepoda. The order of abundancy and heterogeneity of zooplakters in the total sample were as follows: Copepoda 78%, Copelata 0,9%, Siphonophorae 0,88%, Chaetognatha 0,76%, Ostracoda 0,08%, Cladocera 15,7%, Pteropoda 1,2% and finally Medusae, Polychaeta, Desmomyaria and Cyclomyaria which consist less than 2%.

INTRODUCTION

The coastal zone has been highly variable systems that are exposed to a variety of land based pollution, especially by a man and intense fluctuations in the circulation of water masses. Synthesis of the data at a given time and space provides an opportunity to better understand the complex of dynamic processes in the marine life community. The quantity of plankton is affected by changes in the circulation of water masses, especially the climate. Changes in the species and groups composition of zooplankton during the year represent an integrated response of ecosystems to hydrometeorological conditions (Beaugrand et al., 2002). Boka Kotorska Bay consists 4 bays with their specific characteristics, such as the

pronounced influence of leaching from the surrounding mainland, influx of fresh water during the colder periods of the year and the impact of the open sea, which is mostly pronounced in Herceg Novi Bay. The Bay of Kotor is a relatively closed part of the sea, ecological specificity is reflected in taxonomic composition, distribution of both specific species and total zooplankton, and in this paper we will present only the Bay of Kotor. Specific environmental conditions and geographic location of the Bay of Kotor make it eutrophic biotope where biota reflects the impact of inflow of fresh water from the land and flow from the open sea. In this paper we present data on the zooplankton groups: Copepoda, Cladocera and Medusae, and only the Copepoda group been long-term studied. Parallely with the study of zooplankton, the physical and chemical parameters of the environment have been measured and analyzed. Spatio-temporal variations of hydrographic conditions in the Bay of Kotor are detailed presentated. Research program and research stations are set to provide a detailed review of hydrographic characteristics of the sea and the structure of zooplankton fauna. The research comprised the total zooplankton in the Bay in the annual cycle of intense research, and shallow habitats suitable for mariculture. Literature data for the Bay of Kotor are contained in the followed papers Car, 1895/96; Gamulin., 1938; Benović & Onofri, 1983; Vukanic, D. 1971, 1977, 1983, 1988, 1996, 2000, 2002; Vukanic, V. 2003a, 2003b, 2004, 2006, 2012. The results of these studies are of interest to the definition, assessment and conservation of biodiversity of zooplankton biocenosis in coastal waters of the southern Adriatic and a contribution to research in coastal waters in the Mediterranean and on the eventual design of biological monitoring programs: individual characteristic taxa, certain types of community groups and functional attributes of riparian ecosystems of the Adriatic, shortly, diversity of zooplankton communities.

MATERIALS AND METHODS

Our observations were based on the analysis of zooplankton samples collected monthly from November 2007 to October 2008 on three stations in Bay of Kotor: P1 is nearby the Institute, P2 is in the middle of the bay, P3 is nearby the Orahovac (Fig.1). Zooplankton was collected with Nansen net (100 and 150 microns). 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 (Tab.1). The transparency of the sea was measured with Seecchi disk, 30 cm in diameter, white in color. Color of the sea was measured according to Forell from I to XXI.

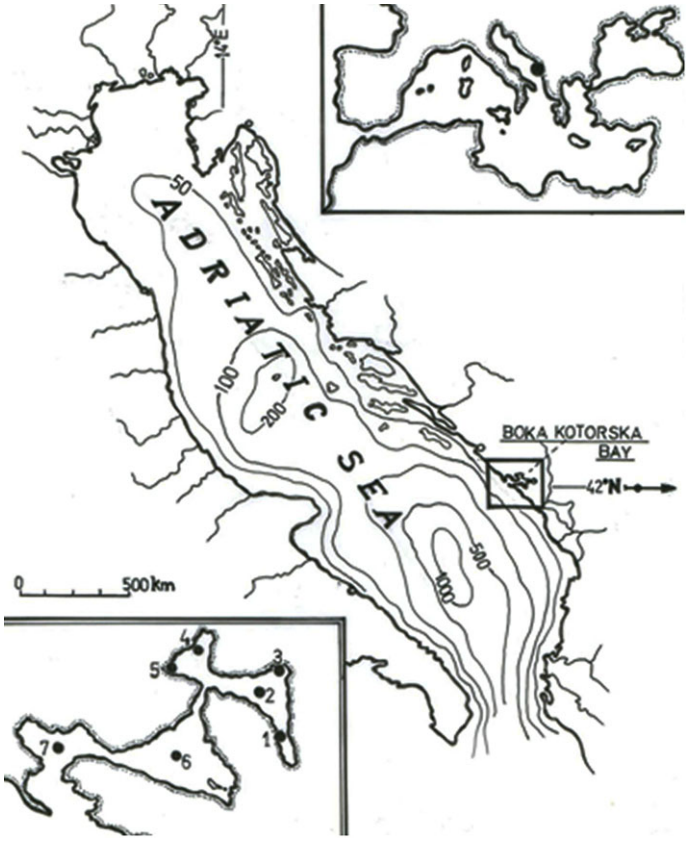

Figure 1: Map of sampling area in the Bay of Kotor (researched stations 1, 2 and 3).

RESULTS AND DISCUSSION

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 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-1 in the surface layer 0-5m, 2.30‰ in September. 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-3 in June. The percent of oxygen saturation was over 100%, and the greatest value was recorded at the shallow station P-3 in June (220%), while at the surface at the middle of Kotor Bay (P-1) 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. The whole Bay had relatively low values of transparency, from 4 m in Kotor Bay (P-1) in September. The color of the sea according to Forell ranged from II in June to VI in September.

Table 1: Average values of hydrografic parameters in coastal waters of southern Adriatic Sea (Boka Kotorska Bay), January – Decembre 2002.

	P-1	P-3	P-2
Layer 0 m			
Temperature (ºC)	9.3±25.6	11.6±25.6	12.0±23.0
Salinity (‰)	2.4±20.7	8.2±34.0	24.0±27.0
Oxygen (mL/L)	7.0±16.0	7.0±16.4	6.0±9.0
Layer 0-2 m			
Temperature (ºC)	13.0±27.0	13.0±26.0	
Salinity (‰)	14.0±34.0	27.0±35.0	
Oxygen (mL/L)	6.5±13.0	7.0±9.0	
Layer 2-5 m			
Temperature (ºC)	13.05±23.0	13.05±23.0	14.2±24.0
Salinity (‰)	30.0±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 5-10 m			
Temperature (ºC)	13.1±22.0	13.1±22.0	14.4±21.2
Salinity (‰)	36.0±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 10-30 m			
Temperature (ºC)			14.3±20.4
Salinity (‰)			35.4±38.0
Oxygen (mL/L)			5.2±8.8

Medusae - Typical species of coastal waters *Podocorine minima* and *Podocoryne minutes* were register at all station P1, P2 and P3 in Bay of Kotor (Fig. 2, Fig. 3, Fig. 4). Plankton and jellyfish *Laodicea undulata* and *Obelia* sp. defined as eurichaline and euritherme species (Babnik, 1948) were registered occasionaly at all stations in the Bay of Kotor. Maximum of abundance was recorded in March, August and October.

The number of species at research stations was quite uniform, as well as period of occurrence. From previous studies (Benovic & Onofri, 1983) the following species were well-known: *Podocorine minima, Podocoryne minuta, Obelia* sp. while for the other species, the first data were given by Vukanić, V. (2008).

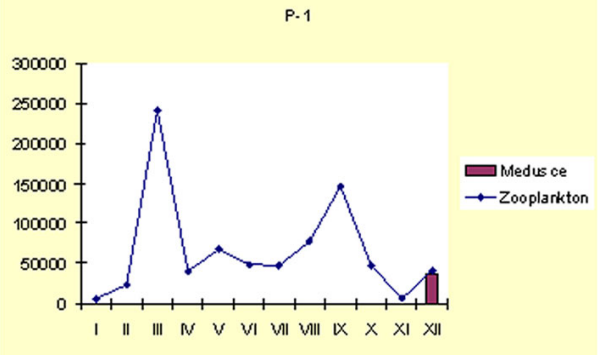

Figure 2:
Logarithmic diagram of the quantity flow of total zooplankton and Medusace near the Institute (P-1).

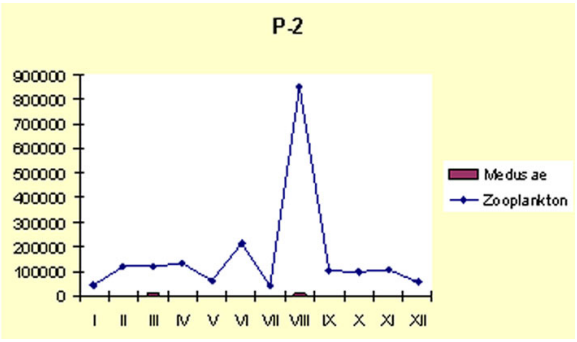

Figure 3:
Logarithmic diagram of the quantity flow of total zooplankton and Medusace in the Bay of Kotor (P-2).

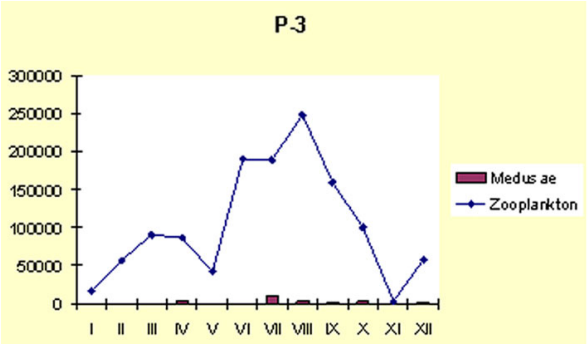

Figure 4:
Logarithmic diagram of the quantity flow of total zooplankton and Medusace near the shellfish farm in Orahovac (P-3).

Table 2: Qualitative distribution of jellyfish at the research stations in the Bay of Kotor.

Species \ Research stations	P-1	P-3	P-2
Podocoryne minima (Trinci)	+	+	+
Podocoryne minuta ((Mayer)		+	+
Obelia sp. Péron & Lesueur		+	+
Solmaris leucostylla (Will)		+	+
Laodicea undulata (Forbes & Goodsir)			+
Pelagia noctiluca Forsskál			+
Total	1	4	6

Cladocera –Most of them begin to appear in the plankton of the Bay of Kotor in February, while *Penilia avirostris* from April - May and to the end of October, and the extremely high occurance was recorded in July or August (Figs. 6-8, Tab. 2).

Penilia avirostris Dana, 1849 – Period of occurrence of this cladocerans in Bay of Kotor was from April to October (Vukanic, V. 2003a). Gamulin (1948) states that this species was recorded in the Adriatic and Mediterranean seas only for the last 40 years (95 years ago). In the middle Dalmacia island area this species is rare, but this is applicable for research in June when this species starts to occur in the plankton of the Adriatic sea (Steuer 1933).

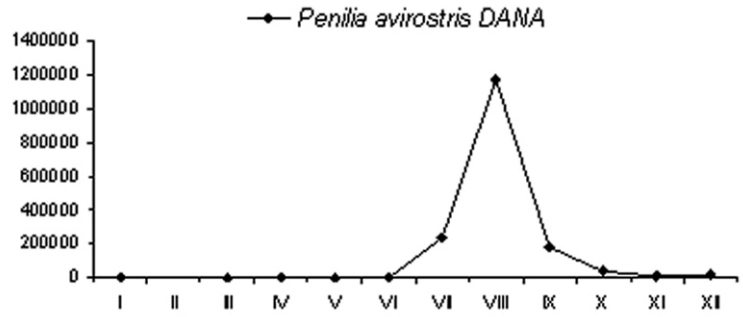

Figure 5: ***Penilia avirostris*** **DANA – annual quality flow (V u k a n i c, V., 2003a).**

The sea temperature at all research stations in the Bay of Kotor ranged from 23.6 º C to 23.9 º C, and at the seabed from 20.8 º C to 22.4 º C and salinity of 24.2 ‰ to 30.7 ‰ in August when the maximum abundance of this species in the whole Bay of Kotor was recorded. *Penilia avirostris* permanently inhabited littoral waters that are less saline than open sea. Many authors consider this species as indicator for brackish water in estuaries and bays of the Mediterranean. This fact has been confirmed in our research in Bay of Kotor, so we have noted it as an indicator of brakish and eutrophic waters in the Gulf during the summer (Vukanic V.,2003b) (Fig.5).

Evadne spinifera P.E. Müller, 1868 i *Evadne nordmanii* Loven – The first species was recorded at almost all research stations from February to September and the second species in small number of specimens or singularly during the cold period of the year. Vukanić D. (1975) says that it was the most abundant form in the pelagic zone at the entrance to the Bay of Kotor. When we've registered it in February and March the temperature was between 12.1 ° C at 0m to 14.5 ° C at 20 m and salinity of 10.6 ‰ to 37.3 ‰. Furnestin, M.L. (1957) classified species *Evadne spinifera* as warm-water plankton forms and *Evadne nordmanii* as cold water species, which is consistent with our observations, supported by detailed measurements of basic hydrographic parameters that we have performed beside with the zooplankton study. Both forms are usually more abundant in shallower waters closer to shore. *Evadne spinifera* is a coastal form, but not rare either to a

depth of 100m (Vukanić D., 1996). It occurs throughout the year with peak occurance in the spring, which is consistent with previous data for the Adriatic and the Mediterranean.

Evadne tergestina Claus, 1877. – It occurs in June, July, August and September, but in a much smaller number than *Evadne spinifera*. The majority of individuals in plankton was registered in August in entire Bay of Kotor. It lives almost exclusively at the surface layer of the sea from 0m to 20m. Gamulin (1948) and Vukanic, D. (1975) emphasize its abundance at the open sea and during the summer months.

Podon intermedius Liljeborg, 1853 – It is extremely neritic species. It is present in the plankton of Bay of Kotor throughout the year and significant abundance was recorded during the spring and summer. It is widespread in the Adriatic Sea, the Mediterranean, on the west coast of France, in front of the British Isles, ahead of Norway, in the North and Baltic Sea and in the eastern moderately warm Atlantic.

Podon leuckarti G.O.Sars, 1862 - are rarely found in individual specimens during the warmer periods of the year.

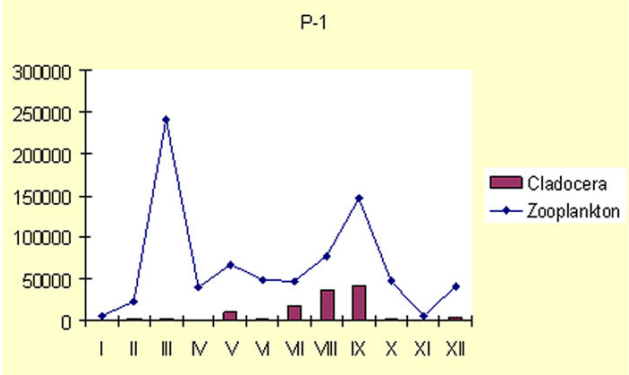

Figure 6:
Logarithmic diagram of the quantity flow of total zooplankton and Cladocera near the Institute (P-1).

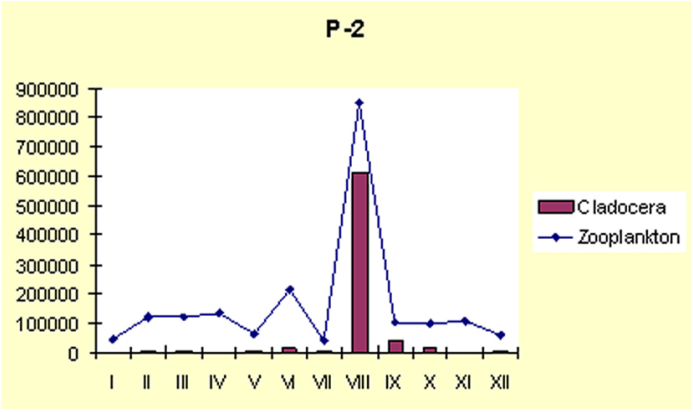

Figure 7:
Logarithmic diagram of the quantity flow of total zooplankton and Cladocera in the Bay of Kotor (P-2).

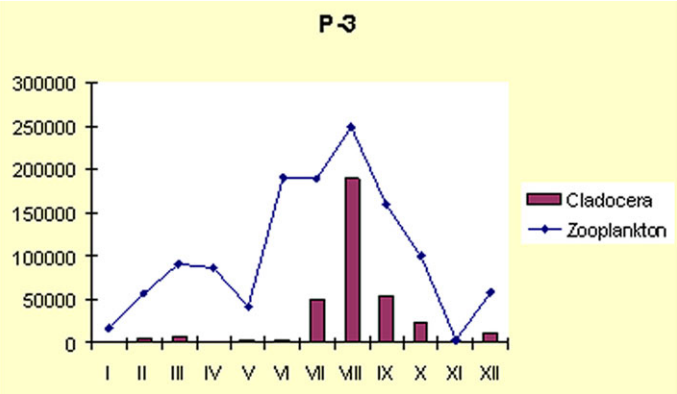

Figure 8:
Logarithmic diagram of the quantity flow of total zooplankton and Cladocera near the shellfish farm in Orahovac (P-3).

Table 3: Qualitative distribution of Cladocera in the research stations in the Bay of Boka.

Reseach Stations / Species	P-IBM	P-O	P_1-K
Penilia avirostris Dana	+	+	+
Podon intermedius Liljeborg.	+	+	+
Podon leucarti G.O.Sars		+	+
Podon juv			+
Evadne spinifera Müller	+	+	+
Evadne tergestina Claus.	+	+	+
Evadne nordmanni Loven		+	+
Total	4	6	7

Copepoda - Long-term research of Copepoda in the eastern Adriatic coast bays were carried out only in the Kastela Bay (Gamulin, 1939; Regner, D. 1979) and Malostonski Bay (Vukanic, D. 1979; Onofri, 1984). These bays are with different hydrographic and morphometry than Bay of Kotor that enters deeply into the land, and communicates with the open sea of the south coast. Only in the inner part of the Bay of Kotor (Kotor and Risan) plankton composition to some extent corresponds to the composition of the Kastela and Malistonski Bay.

Calanus helgolandicus (Claus, 1863) – in the the Bay of Kotor is a registered slightly more numerous in late winter and early spring. During the summer, it is rare or completely absent. Maximum number was recorded in April and in accordance to previous data (Vukanic, D. 1971, 1988) in March (Fig. 9). The percentage share in the Bay of Kotor was up to 0.08%.

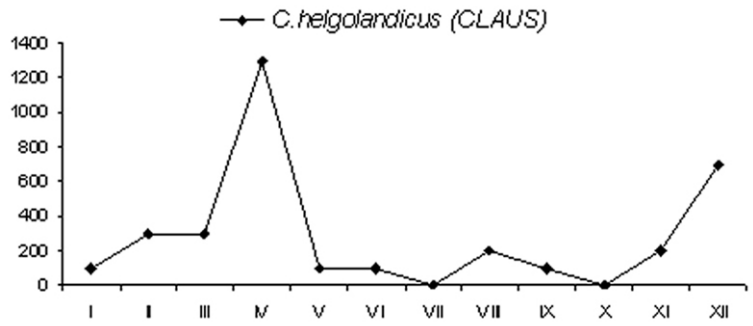

Figure 9: ***Calanus helgolandicus*** **(Claus). – annual quality flow during the year 2007/08.**

Mesocalanus tenuicornis Dana, 1849 – In Copepoda population is not of greater importance. It is present in deeper Bay station (P2) on shallow along the coast it's missing. It's slightly bigger occurrence was recorded in the early spring. In our material it is present at station P-2 at the deeper waters of the Bay of Kotor: Percentage share relative to other copepods ranges from 0.02% to 0.06%. Vukanic, D. (1971) records it as sporadic in individual specimens at all stations in the Bay of Kotor although quantitatively is of minor importance, which is in accordance with our data.

Paracalanus parvus (Claus, 1863) – This typically neritic species of warm surface water of subtropical areas is almost uniformly distributed throughout the Bay of Kotor. There is a long period of occurrence and two annual maximum abundance: winter and summer. It belongs to the dominant Copepoda of this Bay. It is more abundant in winter and spring, especially in March, April and May, and the frequency and abundance is prolonged during the summer. Similar data for eastern Adriatic coastal water have also been given by other authors (Graeffe, 1900; Grandori, 1913; Früchtl, 1920, 1924; Gamulin, 1938, 1939, 1948, 1979; Regner, D., 1973, 1979; Hure et al. 1980; Vukanić, D. 1971, 1988). According to the Vukanić, D. (1988), in the offshore waters of southern Adriatic number and frequency of this species declines, and grows in the waters of the Bay of Boka. Many data for the Mediterranean and the Adriatic sea indicate that this copepod are more numerous and more common in coastal areas and bays, and it belongs to the dominant copepods, which agrees with our data.

Calocalanus pavo (Dana, 1949) – This extremely superficial, zoogeographically tropical species occurs in the plankton of Bay of Boka mainly in late winter and early spring. This research registered *Calocalanus pavo* in the inland waters of the Bay of Kotor, although Vukanic, D. (1971, 1988) writes that he has not recorded it.

Mecynocera clausi I.C. Thompson, 1888. – Subsurface and warm-water species in the closed part of the Bay of Kotor is relatively rare in very few individuals.

Clausocalanus arcuicornis (Dana, 1849) – The subsurface oceanic warm-water species is relatively common in the Bay of Boka. The largest occurring is in

the winter and early spring. The frequency and the number is growing towards the open sea.

Clausocalanus jobei Frost & Fleminger, 1968 – in the Bay of Kotor it's massiveness grows from inland waters to the exit from the Bay, more numerous and more frequent is in the same direction during the summer and fall. This agrees with the data published by Hure & Scotto di Carlo (1970) and Vukanic, D. (1988).

Clausocalanus furcatus (Brady, 1883) – This typical surface species is relatively rare during the summer, and larger and more frequent appearance in plankton is recorded during winter and early spring. This coincided with the earlier data on the occurrence and frequency of the copepods in the Bay of Kotor (Gamulin, 1938; Vukanić,D. 1971, 1979, 1988).

Ctenocalanus vanus Giesbrecht, 1888 – This is one of the dominant copepod species. It is the one of the typical copepods of the Adriatic Sea in general. It was present at all stations, and the most common and most numerous was at the central part of the Bay of Kotor (P-2), where its largest percentage share of 0,43% was found.

Centropages kröyeri Giesbrecht, 1892 – neritic copepods, very numerous and common in semi-closed bays of the eastern coast of the Adriatic, where it makes much of phytoplankton biomass. It was quantitative significant in the Bay of Boka, present at all stations with percentage ranging from 1.80% to 3.1% in the middle of the Bay.

Temora stylifera (Dana, 1849) – surface tropical species that is constantly present in the plankton of the Bay of Boka. In the inland waters of the Bay it was almost completely absent from late winter to late spring and not of quantitative importance. Maximum of the abundance was recorded during the summer. Similar data had earlier authors for the coastal areas and bays of Eastern Adriatic (Car, 1895-1896; Graeffe, 1900; Grandori, 1910, 1913, 1914; Leder, 1917; Früchtl, 1920; Pesta, 1920; Vukanić,D. 1971, 1975, 1988).

Acartia clausi Glesbrecht, 1889 – This widespread copepods of the Adriatic Sea in the Bay of Kotor was continuously occurring in plankton with significant quantitative participation. It is more abundant in spring-summer period, with a maximum abundance in late spring. The percentage share was about 0.8% beside Kotor. The data for the Bay of Boka (Vukanić, D. 1988) states that the percentage share was from 0.5% to 1,05%, the same author states (1971) the percentage share from 4.1% to 10.4%.

Oithona similis Claus, 1866 – was widespread throughout the studied area. The frequency of occurrence and abundance increases from the inner to the outer stations closer to the open sea. Maximum occurrence was during the warmer periods of the year. At shallow stations along the coast of Bay of Kotor percentage ranges from 0.32% at the Institute (P1) to 1.78% in Orahovac (P-3) Vukanic, D. (1988) states the largest percentage share in the open sea in the amount of 1,55%.

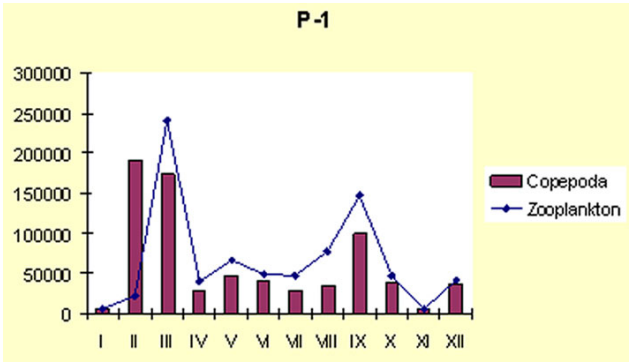

Figure 10:
Logarithmic diagram of the quantity flow of total zooplankton and Copepoda near the Institute (P-1).

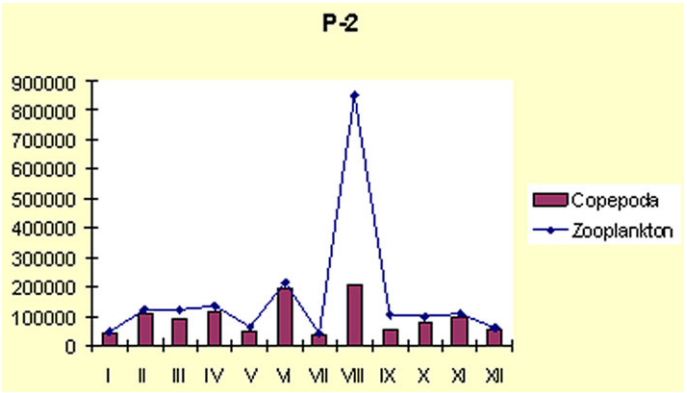

Figure 11:
Logarithmic diagram of the quantity flow of total zooplankton and Copepoda In the Bay of Kotor (P-2).

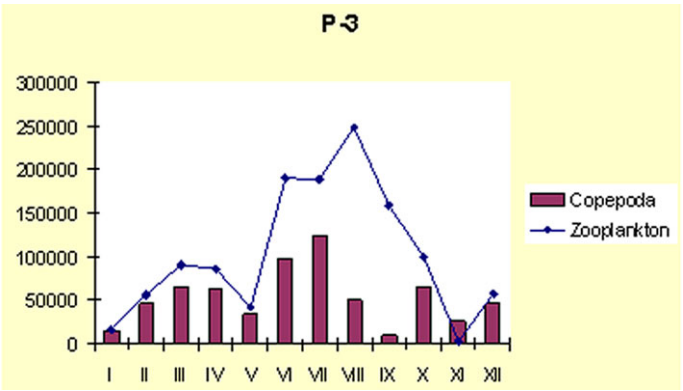

Figure 12:
Logarithmic diagram of the quantity flow of total zooplankton and Copepoda near the shellfish farm in Orahovac (P-3).

Oithona nana Giesbrecht, 1892 – the number and frequency of this typical estuarine neritics copepod increases from the open sea to the inland waters of the Bay. It dominates in plankton's copepod community and by its occurrence and abundance presents typical summer form, and this agrees with earlier data on the copepods in the eastern coastal areas of the Adriatic (Grandori, 1910, 1913, 1914; Gamulin, 1938, 1939; Regner,D., 1973; Vukanić,D. 1971, 1979, 1988).

Microsetella norvegica (Boeck, 1865) – this tiny neritic copepods had the frequency and abundance of plankton in the Bay of Boka particularly pronounced in the shallow stations near the farms of shellfish. Thus, the percentage of participation in relation to all other copepods accounted 11.5% at the Institute (P1) and at Orahovac (P3) 2.8%. This species has been marked as rare species by many authors in the Mediterranean with a wide horizontal distribution.

Euterpina acutifrons (Dana, 1847) – The only representative of Euterpinidae family belongs to a group of dominant copepods in the Bay of Boka. His frequency and abundance is declining from inland waters to the open sea. Maximum occurs twice a year, in winter and warm period. Has a uniform frequency and abundance, while at open sea earlier perceived only sporadically in individual specimens. Our observations are in accordance with earlier data, such as: Gamulin (1939) for the eastern coastal waters of the central Adriatic; Hure & Scotto di Carlo (1969) for the northern Adriatic Sea; Gamulin (1938) in the Bay of Kotor; Vukanic, D. (1979) and the Malistonski Bay (1971) and the Bay of Boka. It's percentage share ranges from 2.6% to 12.7% in the Bay of Boka.

Oncaea subtilis Glesbrecht, 1892 – This highly surface species was always present in the plankton of the Bay. By it's frequency and abundance, it is among the dominant copepods of the Bay. During flowering (red tide) of Dinoflagellata in Bay of Kotor in July 1975. percentage of *Oncaea subtilis* amounted to 46.13% (Vukanic, D. *et al.,* 1979). Maximum abundance was recorded during the winter and yet another one in the warmer period of the year. The continuous annual surveys per month showed that the number is steadily growing from warmer to the colder period of the year.

The main part in participation in the overall quantity of zooplankton belongs to planktonic copepods: 71.52% at the Institute (C-1) 61.02% at Orahovac (P-3), 75.09% in Bay of Kotor (P-2), 76.23%. Behind copepods, important place belongs to the cladocerans: 15.4% at the Institute (C-1), 30.1% at Orahovac (P-3), 13.95% and 35.15% in the Bay of Kotor (P-1). There are following other groups of plankton by the percentage of their participation. Medusae were present with minor percentage of the share in the zooplankton. After winter-spring maximum, the zooplankton biomass declines by the end of July, when starts to grow again towards the summer - autumn maximum. Very pronounced fluctuations of environmental factors in the Bay of Kotor caused by the strong influence of the surrounding land, in terms of the reduced influence of the open sea, created a specific environmental conditions for growth and development of the typical estuarine - neritic fauna. Natural eutrophication is increased where the plankton communities are one of the most important components of wildlife in the Bay.

Table 3: Qualitative distribution of copepods at the research stations in the Bay of Boka.

Species	P-IBM	P-O	P_1
Calanus helgolandicus Claus		+	+
Mesocalanus tenuicornus Dana	+	+	+
Nanocalanus minor Claus	+		+
Neocalanus gracilis (Dana)		+	
Pracalanus parvus (Claus)	+	+	+
Calocalanus pavo (Dana)	+	+	+
Calocalanus styliremis Giesbrecht	+	+	+
Calocalanus conctractus Farran			
Calocalanus plumulosus (Claus)	+	+	+
Mecynocera clausi Tompson		+	+
Clausocalanus arcuicornis (Dana)		+	+
Clausocalanus jobei Frost&Fleminger	+	+	+
Clausocalanus paululus Farran	+	+	+
Clausocalanus furcatus (Brady)	+	+	+
Ctenocalanus vanus Giesbrecht	+	+	+
Eucalanus elongatus (Dana)			
Diaixis pygmaea G.O.Sars	+	+	+
Centropages typicus Kröyer		+	+
Centropages kröyeri Giesbrecht	+	+	+
Temora stylifera (Dana)	+	+	+
Lucicutia flavicornis (Claus)			+
Candacia giesbrechti Grice&Lawson			+
Candacia longimana (Claus)			+
Acartia clausi Giesbrecht	+	+	+
Oithona similis (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)			+

Species	P-IBM	P-O	P_1
Oncaea subtilis Giesbrecht	+	+	+
Sapphirina lactens Giesbrecht			+
Corycaeus clausi Dahl		+	+
Corycaeus typicus Kröyer	+		+
Corycaeus ovalis Claus		+	+
Corycaeus brehmi Steuer	+	+	+
Farranula rostrata (Claus)		+	+
Aetideus armatus Boeck		+	
Pontella mediterranea (Claus)		+	
Euchaeta hebes Giesbrecht		+	+
Euchaeta marina (Prestandrea)			+
Copepoditi♀♂	+	+	+
Total	25	37	42

P1 was the most notable research stations of all deeper central stations in the Bay of Kotor and it is also the farthest from the open sea. Here is the most intense mixing and the impact of fresh water, as well as the summer heat, increased eutrophication that causes increased total biomass of zooplankton. We recorded the great abundance of a small number of species at this station, for example, high value of abundance of species *Penilia avirostris* that caused the peak total zooplankton in August (Vukanić, V. 2003a). In this research, it has been observed that there is no proper succession of the occurrence of peak abundance of zooplankton in the Bay of Boka. The whole area of research clearly manifested a summer minimum of all groups except Cladocera who are in annual maximum abundance at the time, especially summer form *Penilia avirostris*.

CONCLUSIONS

In this paper we define the part of zooplankton community of the Bay of Kotor and gave information about its components. We have identified the temporal and spatial patterns of zooplankton and register the occurrence of two maxima during the year, spring and autumn, and the emergence of the summer peak caused by the appearance of species *Penilia avirostris*. We concluded that the zooplankton biodiversity of Bay of Kotor was typical for coastal gulf's ecosystems in the eastern Adriatic. The waters of the bay have very extreme fluctuations of hydrographic characteristics. The most pronounced oscillations are in the surface layers. Maximum temperatures usually occur in July or August, and the minimum in January

or February. Data on temperature, salinity, oxygen saturation that is always accounted for more than 100%, pH, color and transparency has confirmed that the Bay of Kotor was highly eutrophic area. Extremely high values of salinity gradient was determined in the Bay (P-2), especially at the surface 0-5 meters. Euritherme and eurichaline neritic species were dominant in the zooplankton community, while in the warmer periods of the year when the value of environmental conditions approaching those of the open sea, there is a significant number of pelagic species. The presence and frequency of indicator species *Penilia avirostri* and *Oithona nana* indicate that the Bay of Boka is exposed to anthropogenic degradation and that this is the eutrophic area.

REFERENCES:

BABNIK,P. 1948. Hidromeduze iz srednjega in južnega Jadrana v letih 1939 in 1940. – *Acta Adriatica*, 3(9):275-348.

BEAUGRAND, G., IBÁÑEZ,F., LINDLEY,J.A. & REID,P.C., 2002. Diversity of copepods in the North Atlantic and adjacent seas: species associations and biogeography. *Marine Ecology Progress Series* 232:179-195.

BENOVIĆ,A. & ONOFRI,V. 1983. Prilog poznavanju mrežnog zooplanktona Kotorskog zaljeva. *Studia Marina*, (13–14):119–125.

CAR,L. 1895/96. Copepodni plankton iz Jadranskog mora. *Glasnik hrvatskog narav. društva*, 8:145–150.

FRÜCHTL,F. 1920. Planctoncopepoden aus der nordlichen Adria.– *Sitzungsber.K.Akad.Wien.* 129:463–509.

FRÜCHTL,F. 1924. Beitrag zur Kenntnins der qualitativen und quantitativen Verbreitung nordadriatischer Planctoncopepoden und ihrer Epibionten. *Sitzungsber.K.Akad.Wien.* 132:195–223.

FURNESTIN,M.L., 1957. Chaetognathes et Zooplancton du secuteur Atlantique Marocain. *Rev. Trav. Inst. Pêche marit. Paris*, 21(2):366

GAMULIN,T., 1938. Prilog poznavanju planktonskih kopepoda Boke Kotorske. *Godišnjak Oceanografskog instituta*, 1:1–13.

GAMULIN,T., 1939. Kvalitativn i kvantitativna istraživanja planktonskih kopepoda u istočnim obalnim vodama srednjega Jadrana u godini 1936/37., Jugoslovenska Akademija Znanosti i Umjetnosti*, Prirodoslovna istraživanja.* 22:97-180.

GAMULIN,T. 1948. Prilog poznavanju zooplanktona srednjedalmatinskog otočnog područja. *Acta Adriatica*. 3(7):159-194.

GAMULIN,T. 1979. Zooplankton istočne obale Jadranskog mora. *Acta Biologica*, 8/j – 10, prirodoslovna istraživanja 43:177-217.

GRAEFFE, E. 1900. Ubersicht der fauna des Golfes von Triest. – V. Crustacea. – *Arh. Zool. Inst. Wien*. 13:33-77.

GRANDORI,R. 1910. Sul materijale planktonico raccolto nella 2[a] crociera oceanografica. *Boll. Com. Talass*. 6.

GRANDORI,R. 1913. Copepodi pelagici raccolti nell Adriatico nelle crociere III–VIII del R.C.*Talassia Italiana.* 28:1–63.

GRANDORI,R. 1914. Studi biologici sul plankton della Laguna Veneta e dell'Alto Adriatico. *Atti Acad. Sc. Veneto – Trent. – Istriana*. 6.

HURE,J. & SCOTTO di CARLO,B. 1969. Copepodi pelagici dell'Adriatico settentrionale nel periodo gennaio–dicembre 1965. *Pubbl.Staz.Zool.Napoli*. 37:173–195.

HURE,J. & SCOTTO di CARLO,B. 1970. Distribuzione e frequenza delle specie del genere *Clausocalanus* GIESBRECHT 1888(*COPEPODA–CALANOIDA)* nel golfo di Napoli e nell'Adriatico meridionale. *Pubbl.Staz.Zool.Napoli*. 38:239–304.

HURE,J., IANORA,A. & SCOTTO di CARLO,B. 1980. Spatial and temporal distribution .of communities in the Adriatic Sea. *Journal of Plankton Research*. 2(4):295-316.

LEDER,H. 1917. Einige Beobachtungen über das winterplankton in Triester Golf (1914). – *Int. Revue*. 8:1-21.

ONOFRI, V., 1984. Mrežni zooplankton Malostonskog i Neretvanskog kanala u godini 1979-1980. *Magistarski rad, PMF Sveučilišta u Zagrebu*. 1-77.

PESTA,O. 1920. Die Planctoncopepoden der Adria. – Zool. *Jahrbücher.* 43:471-660.

REGNER,D. 1973. Sezonska raspodjela kopepoda u srednjem Jadranu u 1971. *Ekologija*. 8(1):139-146.

REGNER,D. 1979. On the copepods diversity in the Central Adriatic in 1971. Rapp. Comm. int. Mer Médit. 23(9):95–96.

STEUER,A. 1933. Die "Arten" der Cladocerengattung Penilia DANA *Mitt.Zool.Austria Berlin*. 19:80-83.

VUKANIĆ,D. 1971. Kopepodi Bokokotorskog zaliva. *Studia Marina*. 5:21–60.

VUKANIĆ,D. 1975. Prilog poznavanju zooplanktona obalnih voda južnog Jadrana. *Ekologija/Acta Biologica Jugoslavica/*. 10(1):79–106.

VUKNIĆ,D. 1977. Quelques donnèes soncernant les recherches sur les zooplanctons effectuèes dans la baie de Mali Ston (Adriatique moyenne) en 1971 et 1972. *Rapp. Comm. int. Mer Médit.* 24(10):105-107.

VUKNIĆ,D. 1979 Prilog poznavanju planktonskih kopepoda Malostonskog zaliva. *Ekologija*. 14(1):11–26.

VUKANIĆ, D., DOBROSAVLJEVIĆ, M. & DUTINA, M. 1979. Prilog poznavanju hidrografskih prilika i planktona Kotorskog zaliva. *Knjiga I,Drugi kongres ekologa Jugoslavije*. 1977–1986.

VUKANIĆ,D. 1983. Prilog istraživanjima planktonskih kopepoda kod ušća rijeke Bojane (estuarsko područje). Zbornik radova: *III Kongres ekologa SFR Jugoslavije, Sarajevo*. I(B):21–26.

VUKANIĆ,D. 1988. Sezonska raspodjela populacija planktonskih kopepoda jugoistočnog područja južnog Jadrana s posebnim osvrtom na dnevno–noćne migracije. *PMF–Zagreb*. 1-257. (Doktorska disertacija)

VUKANIĆ,D. 1996. O hidrografskim i produkcionim karakteristikama Jadrana sa osvrtom na Crnogorsko primorje. *ECOLOGICA, Posebno izdanje*. 3:57-62.

VUKANIĆ,D. 2000. Osvrt na hidrografske karakteristike i zooplankton jugoistočnog područja južnog Jadrana. *Bilten Jugslovensko Društvo za Zaštitu Voda*. 114–115:4–21.

VUKANIĆ,D., 2002 : Seasonal rhythm of vertical distribution of copepods in deep waters of south Adriatic. *Studia Marina.* 23(1):7–14.

VUKANIĆ,V. 2003a. *Penilia avirostris* – indikator oslađenih i eutroficiranih voda. *32. Koferencija o aktuelnim problemima zaštite voda ''VODA 2003'' sa međunarodnim učešćem, Zlatibor, 6-11. jun 2003*. 387-390.

VUKANIĆ,V. 2003b. Pregled sistematsko – ekoloških istraživanja zooplanktona Bokokotorskog zaliva. *Zbornik prirodno-matematičkih nauka, Banja Luka*. 3(4-5):11-57.

VUKANIĆ,V. 2004. Kladocere Bokokotorskog zaliva tokom 2002. godine. *Zbornik prirodno – matematičkih nauka*, *Banja Luka*. 23-36.

VUKANIĆ,V. & VUKANIĆ,D. 2005. Seasonal abundance of species from the genus *Oithona* in Boka Kotorska Bay during 2002. *34 Konferencija o aktuelnim problemima korišćenja i zaštite voda ''VODA 2005'' Kopaonik*. 361-366.

VUKANIĆ,V, 2006: Zooplankton studies in the Boka Kotorska Bay during 2002 – Hydromedusae (Cnidaria). *Natura Montenegrina;* 5:37-47.

VUKANIĆ, V., 2008: Biodiversity studies of zooplankton community in coastal waters of southern Adriatic - Bay of Kotor Bay, ICES WKZEM Report 2008, ICES Oceanography Committee, ICES CM 2008/OCC: 10; Ref.ACOM (Report of the Joint ICES / CIESM Workshop to Compare Zooplankton Ecology and Methodologies between the Mediterranean and the North Atlantic (WKZEM)), Heraklion, Crete, Greece, 27-30. October 2008. p.69-70.

VUKANIĆ,D.V, 2012: Zooplankton of the Bojka Kotorska Bay – ekology, biodiversity, environment protection – Montenegrin Academy of Sciences and Arts, Special ed. (Monographies and Studies) Vol.96; The Section of Natural Sciences Vol.38. p.1-195.

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