ISSN: 0001-5113 AADRAY	ACTA ADRIAT., 53(2): 165 - 180, 2012	UDC: 574.583(262.3)(496.5)591.526

Zooplankton composition and distribution across coastal and offshore waters off Albania (Southern Adriatic) in late spring

Marijana MILOSLAVIĆ[1*], Davor LUČIĆ[1], Jakica NJIRE[1], Barbara GANGAI[1], Ivona ONOFRI[1], Rade GARIĆ[1], Marko ŽARIĆ[1], Fundime MIRI OSMANI[3], Branka PESTORIĆ[4], Enkeleda NIKLEKA[2] and Spase SHUMKA[2]

[1] Institute for Marine and Coastal Research, University of Dubrovnik, D. Jude 12, 20000 Dubrovnik, Croatia

[2]Agricultural University of Tirana, Tirana, Albania

[3] Research centre of Flora and Fauna, Faculty of Natural Sciences, University of Tirana, Tirana, Albania

[4]Institute of Marine Biology, Kotor, Montenegro

****Corresponding author, e-mail: marijana.miloslavic@unidu.hr***

We present for the first time composition, numerical abundance and vertical structure of micro- and mesozooplankton in the Albanian coastal and open sea region. Zooplankton was sampled at six stations on the 75-km long continental shelf slope transect in May 2009. The most numerous microzooplankton were copepod nauplii (maximum: 39 ind. L^{-1}), followed by calonoid and cyclopoid copepodites (maxima: 5 and 4 ind. L^{-1}, respectively). The most abundant of fourteen tintinnid species was Tintinnopsis radix*, found in the surface to 50 m layer. The species composition of the coastal and open sea mesozooplankton was similar to that previously reported for the south Adriatic Sea. The copepod* Oithona similis *was the dominant species at all stations, followed by* Oithona plumifera*,* Acartia clausi*,* Paracalanus parvus*,* Oithona nana *and cyclopoida-oncaeids at the shallower coastal stations, and* Clausocalanus pergens*,* Oithona plumifera *and* Oithona nana *offshore. Mesozooplankton diversity rose considerably from the coast to the open sea. Mesozooplankton abundance exhibited the opposite trend, with the maximum (2286 ind. m^{-3}) noted at the shallowest station. Findings of typically open sea tintinnid and copepod species at the coastal station indicate the high influence of currents from the open sea area during our investigation. Our results suggest the low influence of fresh water on zooplankton population densities, even at the shallow stations where penetration of fresh water in the surface layers was notable.*

Key words: microzooplankton, mesozooplankton, species diversity, Mediterannean Sea

INTRODUCTION

The Adriatic Sea is a semi-enclosed sea, forming a separate sub-region within the Mediterranean Sea. The Southern Adriatic region is deep and oligotrophic (FAGANELI *et al*., 1989). Nutrients are supplied mainly via intrusions of the Ionian Surface Water and Levantine Intermediate Water, which periodically stimulate intense phytoplankton bloom episodes in the centre of the Southern Adriatic cyclonic gyre (GAČIĆ *et al*., 2002; MOROVIĆ *et al*., 2004). The dynamics of both the Southern Adriatic and Ionian Sea are intimately linked by means of the Bimodal Oscillating System mechanism that changes the circulation of the North Ionian Gyre from cyclonic to anticyclonic and *vice versa*, on decadal time scales (CIVITARESE *et al*., 2010).

In contrast to other areas of the Adriatic Sea, there is still poor knowledge of the hydrographic conditions, plankton production and distributions in waters off Albania. Albanian rivers have not been seriously considered as a physical force or a nutrient source, although these rivers have an average discharge of 1 308 $m^3 s^{-1}$ (CULLAJ *et al*., 2005) and thus could greatly influence the south-eastern coastal area. The first data on the distribution of nutrients, picoplankton and phytoplankton community in the southern Adriatic off Albania are presented by ŠILOVIĆ *et al*. (2011) and VILIČIĆ *et al*. (2010). These studies give the first insight into the fine scale oceanography of the area in which Albanian shelf riverine waters come into contact with the Eastern Adriatic Current. Knowledge of zooplankton is also weak and restricted to the two bays: MIGLIETTA *et al*. (1997) investigated protist and metazoans resting stages of the Butrinto Bay; MOSCATELLO & BELMONTE (2006) presented mesozooplankton species composition and abundance in the Gulf of Vlorë; and MOSCATELLO *et al*. (2011) describe space distribution of microzooplankton in the same bay. SHMELEVA (1964, 1965, 1969) collected some zooplankton samples in the border area of Albanian open sea waters, focused mostly on the qualitative composition and description of the small copepod species of the genera Calocalanus and Oncaea.

The aim of this study is to present for the first time information on (1) microzooplankton and (2) mesozooplankton communities along the coastal-open sea transect of the waters off Albania. For provide this aims, we selected 6 stations along transect from the coastal area to the deep open sea Albanian waters. Although short time sampling (May 2009), we hypothesized that we could recognize the influence of the river plume and/or the open sea on the zooplankton community.

MATERIAL AND METHODS

Study area

The Albanian coastal zone is a narrow shelf area smoothly sloping into the Southern Adriatic Pit. Circulation of this area is greatly influenced by the inflowing Eastern Adriatic Current (Ionian Surface Water and Levantine Intermediate Water), relatively large amounts of riverine inflow, and wind action (GAČIĆ *et al*., 2001). In May 2009, increasing sea surface temperature were noted, together with the development of warm patches in response to calm and sunny weather, and the average temperature values appeared generally higher than the average of the six previous years, in particular in the middle of the southern Adriatic basin (VILIČIĆ *et al*., 2010). Detailed description of hydrography conditions over the same period and at the same stations is presented in ŠILOVIĆ *et al*. (2011) and VILIČIĆ *et al*. (2010). According to the above authors, water temperature ranged from 13.3°C (A900, 200 m) to 20.9°C (A200, surface), with thermal stratification in the first 40 m. Salinity varied between 33.8 (A50, surface) and 38.8 (A300, 280 m). Average surface layer salinity gradually decreased from station A900 to the coast, indicating the plume from the Albanian rivers. The 0-150 m layer of stations A50 to A150, as well as the 0-100 m layer of the stations A200 to A1000 was covered by the Ionian surface water, while the core of the Levantine Intermediate Water (Eastern Adriatic Current) ingression was indicated in the layer below 100 m, westward of the A200 station.

Samples collection and analysis

The research was carried out in May 2009 at six stations (A50, A150, A200, A300, A900 and A1000) on a 75-km long transect in a SW (230°) direction from the Drini Bay shelf, passing over its edge and along the continental slope (Fig. 1).

Microzooplankton samples were taken using 5-l Niskin bottles at four to eight depths (0, 5, 20, 50, 75, 100, 200 and 300 m), depending on the station depth. Samples were filtered through 53 µm mesh and preserved with 2.5% neutralized formaldehyde. Tintinnids, nauplii, copepodites and small adult copepods were analysed, only. In the laboratory, the samples were counted in a glass cell of dimensions 7 x 4.5 x 0.5 cm, using an Olympus inverted microscope at magnifications of 100x and 400x. Abundance was expressed as ind. L^{-1}.

Mesozooplankton samples were collected using a Nansen plankton net equipped with a closing system. The average hauling speed of all tows was 0.5 m s^{-1}. Two mesh sizes were used: 125-µm mesh size (40 cm opening) for coastal stations A50 and A150, and 200-µm mesh size (57 cm opening) for offshore stations A200, A300 and A900. Except for station A50, where samples were taken from the bottom to the surface, vertical tows were taken in two oceanographic layers (50–0 m, and from the bottom (or 300 m for stations A300 and A900), to 50 m). Samples were preserved with buffered formaldehyde (2.5% final concentration) until laboratory analysis. Whole samples were analyzed under the Olympus stereomicroscope. Taxonomic determination was performed at the lowest possible taxonomic level. Mesozooplankton abundance was expressed as ind.m^{-3}.

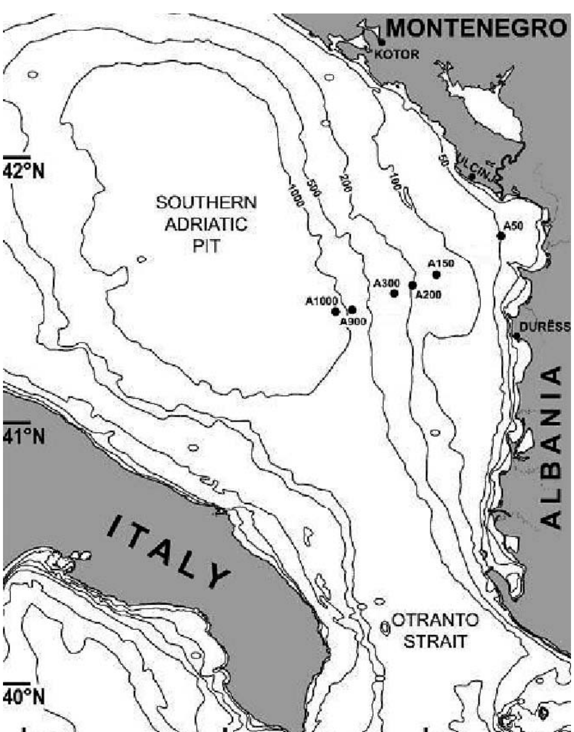

Fig. 1. Study area with the sampling stations

Data were contoured with the graphical program Surfer 7 for Windows (Golden Software). Mann-Whitney's nonparametric test was used to compare the abundances between stations. Diversity was estimated, at species or genus level, from each station, calculating the Shannon–Weaver diversity index (H'; SHANNON & WEAVER, 1949), using the PRIMER 5 software (CLARKE & WARWICK, 2001).

RESULTS

Microzooplankton

The highest total microzooplankton abundance of 63 ind. L^{-1} was noted at the surface at A50 (Fig. 2). Abundances decreased with depth, and towards the open sea. However, according to a Mann–Whitney test, there was no significant difference in abundance between stations.

The most abundant of fourteen tintinnid species (Table 1) was *Tintinnopsis radix*, with a maximum of 36 ind. L^{-1} at A300. This species was found from the coastal stations to A300, with a considerable range of vertical distribution from surface to 200 m depth. Other tintinnids were less numerous. The highest abundance of 4 ind. L^{-1} was recorded for *Tintinnopsis nana* only at the surface of station A50. Vertical distributions of most of other tintinnids were restricted to the zone above 50 m depth (Fig. 3). *Xystonella lohmanni* and *Dadayiella ganymedes* were recorded between 50 and 100 m, and *Salpingella glockentoegeri* below 100 m depth. Species found only in the open sea (A300-A1000) were: *Protorhabdonella curta*, *Xystonella lohmanni*, *Dictyocista muelleri*, *Dadayiella ganymedes* and *Salpingella glockentoegeri*.

Table 1. Distribution of tintinnid species according to the depth range (m) and maximum abundance (ind. L^{-1})

SPECIES	A50		A150		A200		A300		A900		A1000	
	depth range (m)	max. abund. (ind. L^{-1})	depth range (m)	max. abund. (ind. L^{-1})	depth range (m)	max. abund. (ind. L^{-1})	depth range (m)	max. abund (ind. L^{-1})	depth range (m)	max. abund. (ind. L^{-1})	depth range (m)	max. abund. (ind. L^{-1})
Codonella aspera			5-20	1	5-75	1	100	1	5	1		
Tintinnopsis levigata	surface	1										
Tintinnopisis nana	surface	4										
Tintinnopsis radix	0-20	3	surface	1	0-200	1	0-50	36				
Epiplocylis undella			20	1					20	1		
Protorhabdonella curta							50	1				
Rhabdonella spiralis	20	1			20	1					0-20	2
Xystonella lohmanni									75	1		
Dictyocysta elegans			20	1								
Dictyocysta muelleri											100	1
Dictyocysta mitra			20	1					surface	1		
Dadayiella ganymedes							50	1	75	1		
Eutintinnus fraknoi	surface	1										
Salpingella glockentoegeri					50-100	1			200	1		

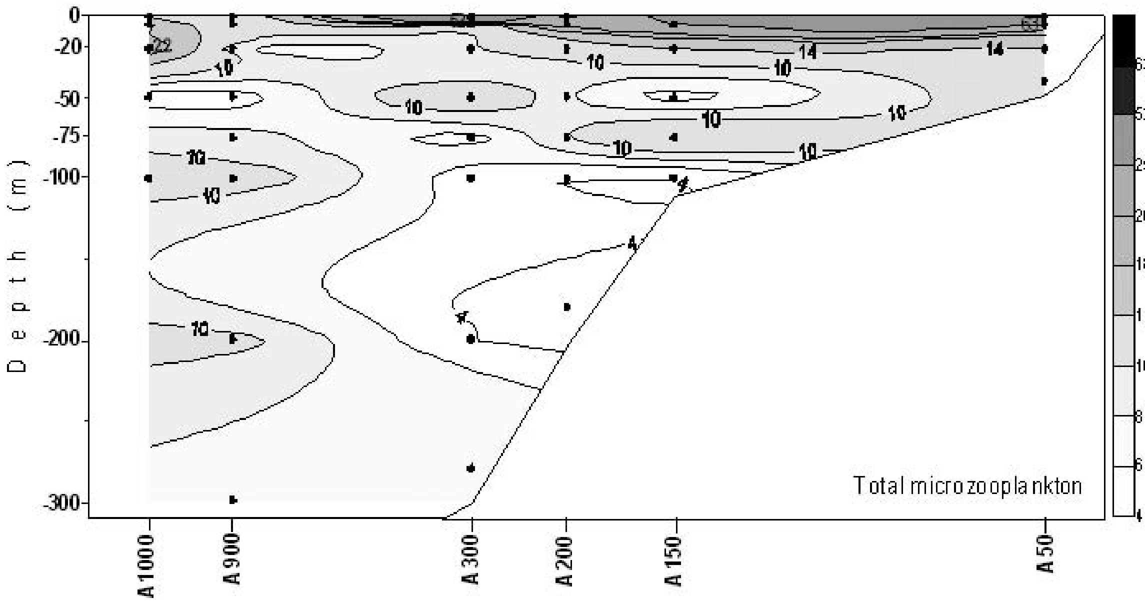

Fig. 2. Distribution of total microzooplankton along the profile (ind.L^{-1})

The most numerous microzooplankton metazoans were copepod nauplii with a maximum of 39 ind. L^{-1} at A50. Abundance decreased from the coastal stations toward open sea stations, and from the surface to deeper layers (Fig. 3). Abundance of the other microzooplankton metazoans (copepodites and small adult copepods) was lower then nauplii densities, with maximum of 10 ind. L^{-1} recorded at 20 m at A1000 station. We recorded five small copepod species: *Oithona nana*, *Oithona similis*, *Monothula subtilis*, *Oncaea waldemari* and *Microsetella norvegica*.

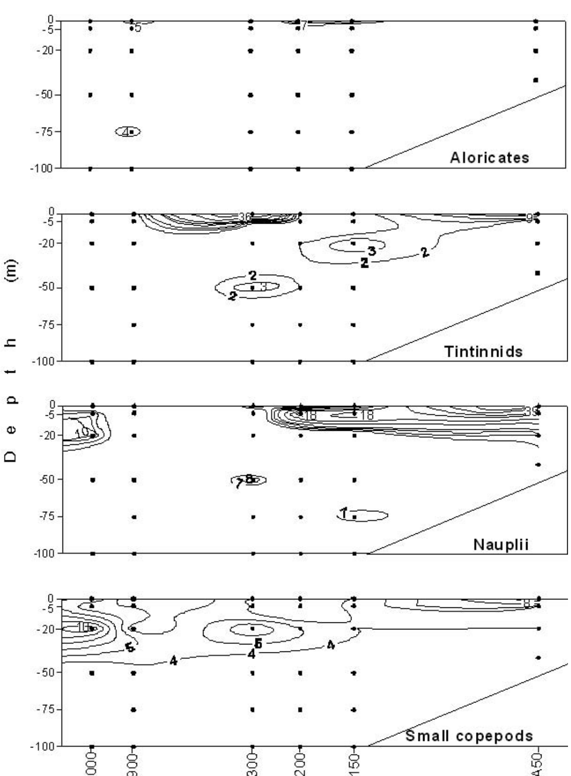

Fig. 3. Distribution of microzooplankton groups along the profile (ind.L^{-1})

Mesozooplankton

We identified a total of 97 mesozooplankton taxa (Table 2). Species numbers were lowest in the coastal region (A50 and A150), where 35 taxa were noted. The highest species richness was found in the deep layer of station A900, were we found a total of 51 taxa (26 Copepoda, five Hydromedusae, six Calycophorae, five Euphausiacea, three Appendicularia, three Chaetognatha, two Pteropoda and one Hyperiidea). The Shannon–Wiener diversity index ranged from 1.6 to 2.9, with generally lower values at the coastal region and in the upper layers of the open sea stations (Fig. 4).

Coastal stations

At the coastal area the highest abundance of 2286 ind. m^{-3} was found at station A50 (Fig. 5). Copepods distinctly dominated and contributed 92-99% to total mesozooplankton abundance.

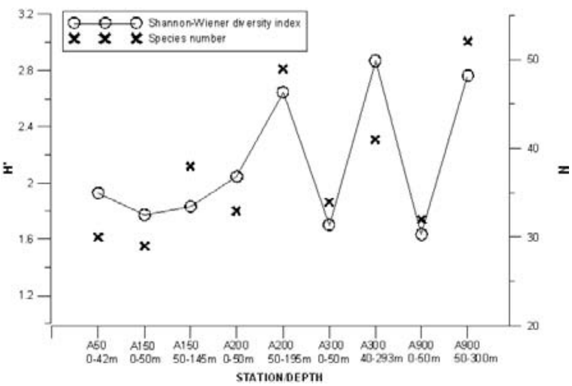

Fig. 4. Shannon–Wiener diversity index (H') and number of species (N) at the investigated stations in the upper and bottom layer

The average contribution of the copepodite stages in the total copepod numbers was 40%. *Oithona similis* was by far the most abundant species (22% of the total mesozooplankton abundance), followed by *Oithona plumifera* (8,1%), *Acartia clausi* (4,63%), *Paracalanus parvus* (3,95%), *Oithona nana* (3,84%) and cyclopoida-oncaeids (2,77%). Among the other groups, higher values of doliolids and pteropod *Limacina trochiformis* were recorded (Table 2). Here we also found higher abundance of some typical open sea species such as hydromedusae *Aglaura haemistoma* and copepods *Paraeuchaeta hebes*, *Candacia giesbrechti*, *Scolecithrix bradyi* and *Lucicutia flavicornis.*

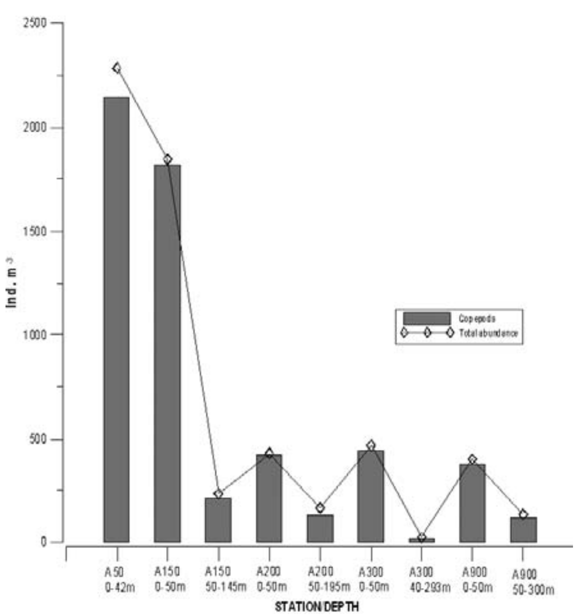

Fig. 5. Total abundances and copepod abundances at the investigated stations in the upper and bottom layer

Open sea stations

Total mesozooplankton values ranged from 405 ind. m^{-3} to 469 ind. m^{-3} in the 0–50 m layer of the offshore stations (A200–A900), and decreased at the deeper layer, from 170 ind. m^{-3} (A200) to 25 ind. m^{-3} (A300). Copepods were dominant mesozooplankton group with average contribution of 90%. At the offshore stations *O. similis* was still the most abundant species (21.7% of the total mesozooplankton abundance), followed by *Clausocalanus pergens*, *O.plumifera*, *O. nana*, cyclopoida-oncaeids, *Corycaeus spp*. and *Ctenocalanus vanus*. Among other groups, high values were noted for hyperid *Phronima sp*. (9,71 ind. m^{-3}) and appendicularia *Oikopleura longicauda* (6,18 ind. m^{-3}) at deeper layer of A200, and chaetognath *Mesosagitta minima* (10,24 ind. m^{-3}) at surface layer of A300.

DISCUSSION

In this study, we present for the first time composition, numerical abundance and vertical structure of micro- and mesozooplankton in the Albanian coastal and open sea region. Microzooplankton exhibit diverse diet composition and was able to switch between a preferably herbivorous to an omnivorous diet in response to the seasonal variations of the available food items (ALMEDA *et al.,* 2011). The highest microzooplankton value was found at the surface of A50 station, coinciding with the maximum of chlorophyll *a*, diatoms and heterotrophic nanoplankton (ŠILOVIĆ *et al.*, 2011; VILIČIĆ *et al.*, 2010). Our maximum of microzooplankton was similar to the maximum values found at stations located along the eastern coast of the Adriatic (KRŠINIĆ, 1980), but lower than those detected in the northern Adriatic area (KRŠINIĆ, 1995; FONDA UMANI *et al.*, 2005). However, we found high densities of tintinnids at the offshore station A300, in accordance with the maxima of dinoflagellate and picoheterotroph abundance at the same

Table 2. Mesozooplankton taxa found across the Albanian boundary zone with the abundance values (ind. m^{-3})

Taxa (C=coastal, O=open sea, CO=coastal and open sea species)		Station (A=0-50m, B=below 50m)								
		A 50	A 150		A 200		A 300		A 900	
		A	A	B	A	B	A	B	A	B
Hydromedusae										
Rhabdoon singulare	O									0,57
Obelia sp.	C	0,76								
Eirene viridula	CO									0,13
Liriope tetraphylla	CO							0,03		
Aglaura hemistoma	O	0,76	10,24		0,22		0,16	0,03		
Persa incolorata	O					0,22		0,13		
Rhopalonema velatum	O		0,32	0,08	0,48	0,22	0,08	0,02	0,64	0,51
Solmundella bitentaculata	O									0,51
Solmissus albescens	O					0,03				0,18
Calycophorae										
Lensia conoidea	O					0,06				0,13
Lensia multicristata	O									0,06
Lensia subtilis	O		0,64	0,67	0,32	0,88	0,16	0,06	0,32	0,26
Lensia meteori	O							0,03		0,51
Muggiaea atlantica	C									0,03
Eudoxoides spiralis	O		1,28	0,34		0,88	0,32		0,16	0,06
Sphaeronectes koellikeri	CO	1,52				0,06		0,25		
Sphaeronectes irregularis	O			0,17						
Sphaeronectes fragilis	O					0,06				
Pteropoda										
Limacina inflata	CO	1,52	1,28	0,17	0,64	0,44	0,64	0,03	5,12	0,51
Limacina trochiformis	CO	24,38							0,32	
Creseis acicula	C	3,05								
Creseis virgula	C					0,03				
Hyalocylix spp.	O									0,03
Cladocera										
Evadne spinifera	C	1,52								
Copepoda										
Calanus helgolandicus	CO	3,81	5,12	2,02	1,28	0,44	0,16			
Mesocalanus tenuicornis	CO			0,67	0,16	0,88	0,64	0,25	0,32	0,13
Nannocalanus minor	O		0,16		0,16		2,56			
Pareucalanus attenuatus	O		0,32	2,69	0,08	0,03		0,02	0,24	0,26
Paracalanus denudatus	CO				0,64					
Paracalanus parvus	CO	60,95	153,60	1,35	3,84		12,8			
Calocalanus spp.	CO		1,28		2,56	4,41	0,24	0,25		
Mecynocera clausi	O	12,19	20,48	2,69	10,24	2,65	5,12	0,51	0,64	
Clausocalanus lividus	O			0,17						0,03

Clausocalanus arcuicornis	CO	0,76	10,24	5,39	3,84	0,33	0,64	0,51	5,12	1,02
Clausocalanus jobei	CO		5,12		5,12	0,88	2,56			
Clausocalanus paululus	O			1,35		8,83	2,56	0,76	2,56	8,7
Clausocalanus pergens	O			2,69	2,56	1,77	1,28	1,77	92,16	6,66
Clausocalanus furcatus	CO	12,19	10,24	0,34	5,12	0,88	2,56	0,06	7,68	0,51
Ctenocalanus vanus	CO	6,1	5,12	1,35	17,92	0,88	7,68	1,26		
Aetideus armatus	O			0,17				0,13		
Euchirella messinensis	O							0,25	0,08	0,03
Euchaeta acuta	O								0,16	
Pareuchaeta hebes	O	12,19	5,12	1,35	2,56	2,65	1,28	0,25	2,56	0,51
Euchaeta marina	O		0,16	0,08		0,03		0,13	0,08	
Scolecithrix bradyi	O			0,34		0,22				0,13
Scolecithricella spp.	O							0,25		0,06
Centropages typicus	CO	12,19	5,12	0,34	1,6					
Centropages kröyeri	C	0,38								

Table 2. Mesozooplankton taxa found across the Albanian boundary zone with the abundance values (ind. m^{-3})

Taxa (C=coastal, O=open sea, CO=coastal and open sea species)		Station (A=0-50m, B=below 50m)								
		A 50	A 150		A 200		A 300		A 900	
		A	A	B	A	B	A	B	A	B
Isias clavipes	C	0,19								
Temora stylifera	CO	0,38								
Pleuromamma abdominalis	O						2,56		0,48	1,54
Lucicutia flavicornis	O			0,67		2,65		0,13	2,56	5,63
Lucicutia ovalis	O									0,13
Heterorhabdus papilliger	O			0,17		0,03			2,56	
Haloptilus acutifrons	O			0,17						1,54
Haloptilus longicornis	O				0,32	0,44	1,28	0,51	0,64	3,07
Candacia giesbrechti	O	3,05		0,08	5,12			0,02		0,06
Candacia tenuimana	O					0,03				
Acartia clausi	C	48,76	61,44	0,67	7,68		0,32			
Oithona atlantica	O				0,16	0,22	0,64			
Oithona nana	CO	109,71	81,92	5,39	23,04	1,77	7,68	0,25	1,28	2,56
Oithona similis	CO	512	430,08	61,98	157,44	31,78	158,72	4,05	79,36	10,75
Oithona plumifera	CO	24,38	30,72	51,2	12,8	23,04	0,51			
Oithona setigera	O				7,68		0,64	1,01	0,64	12,8
Sapphirina spp.	O			0,17				0,09		0,51
Cyclopoida-oncaeids	CO	158,48	20,48	0,67	16,64	7,94	5,12	0,25	0,64	5,12
Corycaeus spp.	CO	73,14	5,12	0,34	11,52	0,88	7,68	1,26	0,16	4,61
Euterpina accutifrons	C	12,19			1,28					13,47
Macrosetella gracilis	CO	3,05	0,32	1,35		0,88	0,32			0,51

Clytemnestra rostrata	CO			0,34		0,22			5,12	
Mormonilla minor	O							0,38	5,12	2,56
Hyperiidea	O									
Hyperia glabra	O					0,03				
Phoronima sp.	O					9,71				
Vibilia sp.	O								0,32	
Eupronoe sp.	O									0,13
Euphausiacea larvae										
Stylocheiron abbreviatum	O					0,06	0,32			0,02
Euphausia krohnii	O					0,03			0,64	0,08
Thysanoessa gregania	O									0,06
Thysanopoda aequalis	O									0,02
Stylocheiron longicorne	O									0,05
Chaetognatha										
Sagitta enflata	CO		0,64		0,16		0,16			
Sagitta minima	CO	3,05	2,56		0,96	0,22	10,24	0,13	0,08	
Sagitta setosa	C	0,19			1,28					
Sagitta serratodentata	O					0,44		0,03		0,51
Sagitta decipiens	O		0,32							0,06
Sagitta lyra	O			0,17		0,88			0,08	0,26
Appendicularia										
Oikopleura dioica	C		0,64	0,17		0,11				
Oikopleura longicauda	CO			0,34	0,64	6,18	0,16	0,25		
Oikopleura fusiformis	CO	1,52		3,37				0,03		
Oikopleura villafrancae	O					1,77		0,06		
Oikopleura parva	O					0,22				
Oikopleura albicans	O								0,16	0,06
Appendicularia sicula	O							0,02		
Fritillaria aequatorialis	O							0,06		
Fritillaria borealis	CO					1,77		0,25		0,06
Fritillaria pellucida	CO									0,77
Doliolids	CO	36,57		0,34	0,32	0,88	0,64	0,13	0,16	0,02

station (VILIČIĆ *et al.*, 2010). Metazoans were more abundant at A1000. Total microzooplankton abundances were higher than previously recorded for the open Adriatic Sea (KRŠINIĆ, 1998; KRŠINIĆ & GRBEC, 2002, 2006). These differences in abundance could be derived from the sampling methods: in previous investigations of the open sea station, samples were taken with 53 µm closing Nansen net for different layers (the minimum layer was 50 m of water column).

Among tintinnids, only 14 species were found in the present study, whereas KRŠINIĆ (2010) encountered 101 species in the Adriatic Sea. The smaller number of species identified in our study could be due to our methodology (use of smaller volumes) and restricted sampling period (one month). The species *Tintinnopsis radix* was the most numerous with maximum abundance of 36 ind L^{-1} at the offshore station A300. The highest known abundance of this estuarine tintinnid along Adriatic coast was 34 ind. L^{-1} (KRŠINIĆ, 2010), and this is the first record of this species in the open southern Adriatic waters. This phenomenon coincides with the higher salinity and temperature, similar to the accumulation of dinoflagelates (VILIČIĆ *et al.*, 2010), whilst increased ammonium concentration in the surface (VILIČIĆ *et al*., 2010) is interpreted as intensive zooplankton grazing. Other tintinnids were less numerous. The presence of the typically open sea species *Rhabdonella spiralis*, *Codonella aspera*, *Epiplocylis undella*, *Dictyocysta elegans* and *Dictyocysta mitra* at the coastal stations could indicate the influence of currents from the open sea area on the coastal area during our investigation. Vertical distribution of all noted species corresponded with previous descriptions of their bathymetric distribution (KRŠINIĆ, 2010).

Nauplii were the most abundant microzooplankton group and their abundance decreased from the coastal area towards the open sea, and below 20 m depth. In contrary, at the open sea stations high quantitative contribution for small adult copepods was detected. All of these findings are in agreement with previous investigations of the southern Adriatic (KRŠINIĆ, 1998; KRŠINIĆ & GRBEC, 2002). The densities for the whole micrometazoan community were in the same range reported for oligo- and mesotrophic waters (CALBET *et al*., 2001), but lower than in more productive areas (LUČIĆ *et al*., 2003).

We found low mesozooplankton values at the coastal stations, despite the fact that we used plankton net with small mesh size (125 µm). The finer net was used due to the nature of the study area and riverine influence on the abundance of coastal species. Therefore, we expected higher values of the small coastal species that pass through the coarser plankton nets, which were documented by KRŠINIĆ & LUČIĆ (1994) and RICCARDI (2010). Compare with the previous results of mesozooplankton sampled with the 125 µm mesh size along the eastern Adriatic coast, our noted maximum of 2286 ind. m^{-3} is several times smaller. VIDJAK *et al.* (2007, 2009) noted range between 3000–7000 ind. m^{-3} of total mesozooplankton at Neretva Channel, and between 5000-45 000 ind. m^{-3} along the Krka river estuary, both during spring. Despite the fact that the amount of fresh water in the Albanian rivers is slightly lower than in the river Po (CULLAJ *et al*., 2005), mesozooplankton densities between those two regions are incomparable: in spring, the total mesozooplankton abundance of the northern Adriatic is usually more than 10 000 ind.m^{-3} (FONDA UMANI *et al*., 2005; KAMBURSKA & FONDA UMANI, 2009; CAMATTI *et al*., 2008), although samples were taken with 200 µm mesh size. Observed values of the mesozooplankton at the coastal stations A50–A150 correspond with those found in the other oligotrophic coastal regions of the Mediterranean, were zooplankton were taken with the 200 µm mesh size, such as the Patraikos Gulf and Saranikos Gulf in the Aegean Sea (CHRISTOU, 1998; RAMFOS *et al*., 2006), or Gulf of Naples (RIBERA D'ALCALA *et al*., 2004; MAZZOCCHI *et al.,* 2011).

Mesozooplankton of the Adriatic Sea is characterized by an increase in total number of species from north to south and outwards from the coast (FONDA UMANI, 1996). We also noted high species diversity at the offshore stations. All of species identified at the offshore stations (A200-A900) were previously recorded for the southern Adriatic open sea, with a similar abundance and bathymetric distribution (for gelatinous zooplankton: see BATISTIĆ *et al*., 2004; BENOVIĆ *et al*., 2005; LUČIĆ *et al*., 2011; and for crustaceans and zooplankton: see HURE, 1961; HURE & SCOTTO DI CARLO, 1969; HURE *et al*., 1980; HURE & KRŠINIĆ, 1998). Mesozooplankton abundances were always between 500-1000 ind. m^{-3} for the spring time (HURE *et al*., 1980; BENOVIĆ *et al*., 2005; TURK *et al*., 2012). These results indicate the stability of zooplankton communities of the open southern Adriatic region.

Epipelagic mesozooplankton communities in the open Adriatic Sea are highly diversified in terms of taxonomic composition, but copepods represent the major group both in terms of abundance and biomass. These bulks are concentrated in the upper 100 m layer and play a major role in biological processes, based on the linkage with phyto- and microzooplankton in the euphotic zone (LONGHURST & HARRISON, 1989). The use of the smaller mesh sizes highlighted the importance of the small-sized copepods in Mediterranean coastal waters. A few small-sized species and species–rich genera of calanoids (*Clausocalanus, Calocalanus* and *Ctenocalanus*), cyclopoida-oithonids and cyclopoida-oncaeids, together with their copepodites, account for the bulk of copepod abundance and biomass in the epipelagic layers of the Mediterranean Sea (ZERVOUDAKI *et al*., 2007; SIOKOU-FRANGOU *et al*., 2010). Our findings confirm previous investigations, with numerical dominance of the copepod coastal form *Oithona similis*, which is considered as the most abundant copepod in the world's oceans (BIGELOW, 1926). However, considering these are the first studies of the mesozooplankton in the open waters off Albania, our intention was to show results that are comparable with the previous investigations of the open waters of the Adriatic Sea (HURE, 1961; HURE & SCOTTO DI CARLO, 1969; HURE *et al*., 1980; HURE & KRŠINIĆ, 1998). Similarly to some tintinnids, some open sea copepod species were recorded at the shallow stations (e. g. *Euchaeta hebes*, *Candacia giesbrechty*, *Scolecithrix bradyi* and *Lucicutia flavicornis*).

Our study indicate that zooplankton distribution was greatly influenced by the circulation pattern prevailing in the southern Adriatic because of the influence of the Levantine Intermediate Water and East Adriatic Current forcing, as were documented for picoplankton (ŠILOVIĆ *et al*., 2011) and phytoplankton (VILIČIĆ *et al*., 2010). Our results on zooplankton abundance confirmed oligotrophic characteristics of the Albanian coastal and open sea waters, although this area is under the constant influence of significant quantities of fresh water. The observed micro- and mesozooplankton densities coincide with low nutrient and chlorophyll concentrations, as well as with low nanoplankton and bacterial abundance recorded during the same cruise (ŠILOVIĆ *et al*., 2011; VILIČIĆ *et al*., 2010).

ACKNOWLEDGEMENTS

This work was part of the "Norwegian Cooperation Program on research and higher education with the countries on the Western Balkans" and was funded by the project: "Marine science and coastal management in the Adriatic, Western Balkan. An Education and research network (yrs. 2006-2009)". The research was partly supported by the Ministry of Science, Education and Sport of the Republic of Croatia (project 275-0982705-3047).

REFERENCES

ALMEDA, R., A. CALBET, M. ALCARAZ, E. SAIZ, I. TREPAT, L. ARIN, J. MOVILLA & V. SALÓ. 2011. Trophic role and carbon budget of metazoan microplankton in northwest Mediterranean coastal waters. Limnol. Oceanogr., 56(1): 4154–30.

BATISTIĆ, M., F. KRŠINIĆ, N. JASPRICA, M. CARIĆ, D. VILIČIĆ & D. LUČIĆ. 2004. Gelationous invertebrate zooplankton of the South Adriatic: species composition and vertical distribution. J. Plankton Res., 264: 4594–74.

BENOVIĆ, A., D. LUČIĆ, V. ONOFRI, M. BATISTIĆ & J. NJIRE. 2005. Bathymertic distribution of medusae in the open waters of the middle and south Adriatic Sea during spring 2002. J. Plankton Res., 27: 798–9.

BIGELOW, H.B. 1926. Plankton of the offshore waters of the Gulf of Maine. Bull. U.S. Bur. Fish., 40: 1–507.

CALBET, A., S. GARRIDO, E. SAIZ, M. ALCARAZ & M. DUARTE. 2001. Annual zooplankton succession in coastal NW Mediterranean waters: the importance of the smaller size fractions. J. Plankton Res., 23(3): 3193–31.

CAMATTI, E., A. COMASHI, A.D. OLAZABAL & S. FONDA UMANI. 2008. Annual dynamics of the mesozooplankton communities in a highly variable ecosystem (North Adriatic Sea, Italy). Mar. Ecol., 29(3): 387–398.

CHRISTOU, E. 1998. Interannual variability of copepods in a Mediterranean coastal area (Saronikos Gulf, Aegean Sea). J. Mar. Syst., 15: 5235–32.

CIVITARESE, G., M. GAČIĆ, M. LIPIZER & G.L.E. BORZELLI. 2010. On the impact of the Bimodal Oscillating System (BiOS) on the biogeochemistry and biology of the Adriatic and Ionian Seas (Eastern Mediterranean).

Biogeosciences, 7: 3987–3997.

CLARKE, K.R. & R.M. WARWICK. 2001. Change in marine communities: an approach to statistical analysis and interpretation, 2nd edition. PRIMER-E, Plymouth, UK, 172 pp.

CULLAJ, A., A. HASKO, A. MIHO, F. SCHANZ, H. BRANDL & R. BACHOFEN. 2005. The quality of Albanian natural waters and the human impact. Environ. Int., 31: 1331–446.

FAGANELI, J., M. GAČIĆ, A. MALEJ & N. SMODLAKA. 1989. Pelagic organic matter in the Adriatic Sea in relation to winter hydrographic conditions. J. Plankton Res., 11: 1129–1141.

FONDA UMANI, S. 1996. Pelagic production and biomass in the Adriatic Sea. Sci. Mar., 60(2): 65–77.

FONDA UMANI, S., L. MILANI, D. BORME, A. DE OLAZABAL, S. PARLATO, R. PRECALI, R. KRAUS, D. LUČIĆ, J. NJIRE, C. TOTTI, T. ROMAGNOLI, M. POMPEI & M. CANGINI. 2005. Inter-annual variations of planktonic food webs in the northern Adriatic Sea. Sci. Total Environ., 353: 218–231.

GAČIĆ, M., P.M. POULAIN, M. ZORE-ARMANDA & V. BARALE. 2001. Overview. In: Cushman-Roisin, B., Gačić, M., Poulain, P. M., Artegiani, A. (Editors). Physical Oceanography of the Adriatic Sea. Kluwer Academic Publishers, Dordrecht, pp. 1–42.

GAČIĆ, M., G. CIVIRATESE, S. MISEROCCHI, V. CARDIN, A. CRISE & E. MAURI. 2002. The open-ocean convection in the Southern Adriatic: a controlling mechanism of the spring phytoplankton bloom. Cont. Shelf Res., 22: 1897–1908.

HURE, J. 1961. Dnevna migracija i sezonska vertikalna raspodjela zooplanktona dubljeg mora (Diel migration and seasonal vertical distribution of zooplankton in deeper sea). Acta Adriat., 9: 1–59.

HURE, J. & B. SCOTTO DI CARLO. 1969. Diurnal vertical migration of some deep water copepods in the Southern Adriatic (East Mediterranean). Pubbl. Staz. Zool. Napoli, 37: 581–598.

HURE, J., A. IANORA & B. SCOTTO DI CARLO. 1980. Spatial and temporal distribution of copepod communities in the Adriatic Sea. J. Plankton Res., 2: 295–316.

HURE, J. & F. KRŠINIĆ. 1998. Planktonic copepods of the Adriatic Sea. Spartial and temporal distribution. Nat. Croat., 7(Suppl. 2): 1–135.

KAMBURSKA, L. & S. FONDA UMANI. 2009. From seasonal to decadal inter-annual variability of mesozooplankton biomass in the Northern Adriatic Sea (Gulf of Trieste). J. Mar. Syst., 78: 490–504.

KRŠINIĆ, F. 1980. Comparison of methods used in micro-zooplankton research in neritic waters of the Eastern Adriatic. Nova Thalassia, 4: 91–106.

KRŠINIĆ, F. 1995. Changes in the microzooplankton assemblages in the northern Adriatic Sea during 1989 to 1992. J. Plankton Res., 17: 935–953.

KRŠINIĆ, F. 1998. Vertical distribution of protozoan and microcopepod communities in the South Adriatic Pit. J. Plankton Res., 20: 1033–1060.

KRŠINIĆ, F. 2010. Tintinnids (Tintinnida, Choreotrichia, Ciliata) in the Adriatic Sea, Mediterranean. Part I. Taxonomy. Institute of Oceanography and Fisheries. Split, Monograph no.4, 186 pp.

KRŠINIĆ, F. & B. GRBEC. 2002. Some distributional characteristics of small zooplankton at two stations in the Otranto Strait (Eastern Mediterranean). Hydrobiologia, 482: 119–136.

KRŠINIĆ, F. & B. GRBEC. 2006. Horizontal distribution of tintinnids in the open waters of the South Adriatic (Eastern Mediterranean). Sci. Mar., 70(1): 77–88.

KRŠINIĆ, F. & D. LUČIĆ. 1994. Mesozooplankton sampling experiments with the "Adriatic" sampler: differences of the catch between 250 and 125 µm mesh netting gauze. Est. Coast. Shelf Sci., 38: 113-118.

LONGHURST, A.R. & W.G. HARRISON. 1989. The biological pump: profiles of plankton production and consumption in the upper ocean. Prog. Oceanogr., 22: 47–123.

LUČIĆ, D., J. NJIRE, M. MOROVIĆ, R. PRECALI, D. FUKS & J. BOLOTIN. 2003. Microzooplankton in the open waters of the northern Adriatic Sea from 1990 to 1993: The importance of copepod nauplii densities. Helgol. Mar.

Res., 57: 73–81.

LUČIĆ, D., A. BENOVIĆ, M. BATISTIĆ, M. MOROVIĆ, I. ONOFRI, J.C. MOLINERO, T. KOGOVŠEK, B. GANGAI & M. MILOSLAVIĆ. 2011. A short-term investigation of diel vertical migrations of the calycophoran Siphonophora in the open south Adriatic Sea (July 2003). Acta Adriat., 52(2): 159–172.

MAZZOCCHI, M.G., P. LICANDRO, L. DUBROCA, I.D. CAPUA & V. SAGGIOMO. 2011. Zooplankton associations in a Mediterranean long-term time-series. J. Plankton Res., 33(8): 1163–1181.

MIGLIETTA, A.M., G. BELMONTE & L. HASANI. 1997. Studi di resistenza di organismi planctonici presenti nei sedimenti del lago costiero di Butrinto (Albania meridionale). (Studies of resistance of planktonic organisms present in the sediments of coastal lake Butrint (Sounthern Albania) Biol. Mar. Medit., 4: 594–596.

MOROVIĆ, M., B. GRBEC & I. MARASOVIĆ. 2004. Changed patterns of remotely sensed chlorophyll a in the Adriatic-influence of meteorological conditions. Gayana (Concepción), 68: 405–410.

MOSCATELLO, S. & G. BELMONTE. 2006. A preliminary plan for the study of zooplankton in the Gulf of Vlorë (Albania). Thalassia Salentina, 29: 63–70.

MOSCATELLO, S., C. CAROPPO, E. HAJDERI & G. BELMONTE. 2011. Space Distribution of Phyto- and Microzooplankton in the Vlora Bay (Southern Albania, Mediterranean Sea). J. Coast. Res., 58: 80-94.

RAMFOS, A., S. ISARI, S. SOMARAKIS, D. GEORGOPOULOS, C. KOUTSIKOPOULUS & N. FRAGOPOULU. 2006. Mesozooplankton community structure in offshore and coastal waters of the Ionian Sea (eastern Mediterranean) during mixed and stratified conditions. Mar. Biol., 150: 29–44.

RIBERA D'ALCALA, M., F. CONVERSANO, F. CORATO, P. LICANDRO, O. MANGONI, D. MARINO, M.G. MAZZOCCHI, M. MODIGH, M. MONTESOR, M. NARDELLA, V. SAGGIOMO, D. SARNO & A. ZINGONE. 2004. Seasonal patterns in plankton communities in a pluriannual time series at a coastal Mediterranean site (Gulf of Naples): an attempt to discern recurrences and trends. Sci. Mar., 68(1): 65–83.

RICCARDI, N. 2010. Selectivity of plankton nets over mesozooplankton taxa: implications for abundance, biomass and diversity estimation. J. Limnol., 69(2): 287-296.

SHANNON, C.E. & W. WEAVER. 1949. The Mathematical Theory of Communication, 1st edition. University of Illinois Press, Urbana,117 pp.

SHMELEVA, A.A. 1964. New Copepoda species in the Adriatic Sea and features of their distribution in connection with hydrological conditions. Oceanologia, 4: 1066-1071.

SHMELEVA, A.A. 1965. New species of the planktonic copepods from the Adriatic Sea. Bull. Inst. Oceanogr., 65: 1-15.

SHMELEVA, A.A. 1969. Especes nouvelles du genre *Oncaea* (Copepoda, Cyclopoida) de la mer Adriatique (New species of *Oncaea* (Copepoda, Cyclopoida) in Adriatic) Bull. Inst. Oceanogr., 68: 3-25.

SIOKOU-FRANGOU, I., U. CHRISTAKI, M.G. MAZZOCHI, M. MONTESOR, M. RIBERA D'ALCALA, D. VAQUE & A. ZINGONE. 2010. Plankton in the open Mediterranean Sea: a review. Biogeosciences, 7: 1543-1586.

ŠILOVIĆ, T., Z. LJUBEŠIĆ, H. MIHANOVIĆ, G. OLUJIĆ, S. TERZIĆ, Ž. JAKŠIĆ & D. VILIČIĆ. 2011. Picoplankton composition related to thermohaline circulation: the Albanian boundary zone (southern Adriatic) in late spring. Est. Coast. Shelf Sci., 91(4): 519–525.

TURK, V., D. LUČIĆ, S. TERZIĆ, T. TINTA, A. BENOVIĆ & A. MALEJ. 2012. The epiplankton community in the southern Adriatic:Multiple trophic levels along the south–north and inshore-offshore gradient. Acta Adriat., (this volume).

VIDJAK, O., N. BOJANIĆ, G. KUŠPILIĆ, Z. NINČEVIĆ GLADAN & V. TIČINA. 2007. Zooplankton community and hydrographic properties of the Neretva Channel (eastern Adriatic Sea). Helgol. Mar. Res., 61: 267–282.

VIDJAK, O., N. BOJANIĆ, G. KUŠPILIĆ, B. GRBEC, Ž. NINČEVIĆ GLADAN, S. MATIJEVIĆ & I. BRAUTOVIĆ. 2009. Population structure and abundance of zooplankton along the Krka river estuary in spring 2006. Acta Adriat., 50(1): 45-58.

VILIČIĆ, D., T. ŠILOVIĆ, M. KUZMIĆ, H. MIHANOVIĆ, S. BOSAK, I. TOMAŽIĆ & G. OLUJIĆ. 2010. Phytoplankton distribution across the southeast Adriatic continental and shelf slope to the west of Albania (spring aspect). Environ. Monit. Assess., 177(1–4): 593–607.

ZERVOUDAKI, S., E.D. CHRISTOU, T.G. NIELSEN, I. SIOKOU-FRANGOU, G. ASSIMAKOPOULOU, A. GIANNAKOUROU, M. MAAR, K. PAGOU, E. KRASAKOPOULOU, U. CHRISTAKI & M. MORAITOU-APOSTOLOPOULOU. 2007. The importance of small-sized copepods in a frontal area of the Aegean Sea. J. Plankton Res., 29: 317-338.

Received: 23 February 2012
Accepted: 16 May 2012

Sastav i raspodjela zooplanktona duž obalnih i otvorenih voda Albanije (južni Jadran) u kasno proljeće

Marijana MILOSLAVIĆ[1*], Davor LUČIĆ[1], Jakica NJIRE[1], Barbara GANGAI[1], Ivona ONOFRI[1], Rade ŽARIĆ[1], Marko ŽARIĆ[1], Fundime MIRI OSMANI[3], Branka PESTORIĆ[4], Enkeleda NIKLEKA[2] i Spase SHUMKA[2]

[1] *Institut za more i priobalje, Sveučilište u Dubrovniku, D. Jude 12, 20000 Dubrovnik, Hrvatska*

[2] *Poljoprivredni fakultet Sveučilišta u Tirani, Albanija*

[3] *Centar za proučavanje flore i faune, Fakultet prirodnih znanosti, Sveučilište u Tirani, Albanija*

[4]Institut za biologiju mora, Kotor, Crna Gora

*Kontakt adresa, e-mail: *marijana.miloslavic@unidu.hr*

SAŽETAK

Po prvi put su prikazani sastav, abundancija i vertikalna struktura mikro- i mezozooplanktona u albanskim obalnim i otvorenim vodama. Istraživanje je obavljeno na šest postaja duž 75 km dugom transektu od šelfa do kontinentskog slaza. Najbrojniji predstavnici mikrozooplanktona su bili kopepodni naupliji (maksimum: 39 ind. L^{-1}), iza kojih su slijedili kalanoidni i ciklopoidni kopepoditi. Od 14 zabilježenih vrsta tintinida, najbrojnija je bila vrsta *Tintinnopsis radix,* nađena od površine do 50 m dubine. Sastav zajednice mezozooplanktona obalnog i otvorenog mora u skladu je s prijašnjim istraživanjima južnog Jadrana. Kopepod *Oithona similis* bila je dominantna vrsta na svim istraživanim postajama. Na plićim postajama slijede je vrste *Oithona plumifera*, *Acartia clausi*, *Paracalanus parvus, Oithona nana* i cyclopoida-oncaeids, a u otvorenim vodama vrste *Clausocalanus pergens*, *Oithona plumifera* i *Oithona nana.* Bioraznolikost mezozooplanktona značajno raste od obale prema otvorenom moru. Nasuprot tome, najveća gustoća mezozooplanktona (2286 ind. m^{-3}) zabilježena je na najplićoj postaji. Prisutnost karakterističnih vrsta tintinida i kopepoda otvorenog mora na obalnim postajama ukazuju na utjecaj struja otvorenog mora za vrijeme ovog istraživanja. Naši rezultati ukazuju da povećani upliv slatke vode nije znatno utjecao na gustoću zooplanktonskih populacija čak i na plitkim postajama gdje je prodor slatke vode u površinskim slojevima osobito izražen.

Ključne riječi: mikrozooplankton, mezozooplankton, bioraznolikost vrsta, Sredozemno more