RESEARCH ARTICLE **(Open Access)**

Variations in the body shape of the rotifer *Keratella quadrata* (Müller, 1786) in selected Albanian lagoons

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Abstract

Seasonal/temporal variation in body shape, often termed cyclomorphosis, occurs in several zooplankton groups, including rotifers. Such variation is common within the genus *Keratella,* mainly involving changes in body and spine lengths. Changes in body shape of the rotifer *Keratella quadrata* in three important brackish water bodies (Karvasta, Narta and Butrinti) were recorded over the course of half a year (mid-November 2013 to mid-June 2014). Specimens of *Keratella* from samples were removed, mounted in 40 % glycerol on microscope slides under cover slips, and measured at a magnification of 1,000, with oil immersion, using an ocular micrometer with a graduation interval of 1.33 µm. Following our data records body and caudal spine lengths increased from November until the end of February, and then decreased until June. Such changes were not significantly correlated consistently positively or negatively to water temperature, pH, conductivity, food levels or total number of copepod numbers. Following individuals recoded during investigations during the winter season individuals corresponded most closely to the literature descriptions of the group or subspecies *quadrata,* while those present during the spring-summer shows the form, group or variety *dispersa.* The first half of the study period was characterized by water of relatively low temperature, low pH and high conductivity, while, for the second half, temperature and pH increased and conductivity decreased. Standard methods for sampling and analyses for physical and chemical parameters were implemented. Further elaboration of the existing data and further works will enable a deeper and more detailed knowledge on the situation of different living community clusters and the environmental state of the lagoons of Albania.

Keywords: Albanian lagoons; zooplankton; rotifer; cyclomorphosis; transitional water.

1. Introduction

The increased deteriorating quality of surface waters is a common and global problem all over the world. It covers all type of water bodies including lakes and rivers as well as brackish coastal lagoons and estuaries [11]. Coastal and brackish waters of Adriatic Sea are specific environments that face particular impacts. Mediterranean lagoons with their constant contact between marine and continental forces cause significant variations and differences in salinity [17]. Furthermore, their limited depth in relation to their large surface areas gives rise to a specific set of hydrodynamic conditions. This has an impact both on the physical and chemical parameters of the aquatic environment and on aquatic organisms [17]. Mediterranean coastal brackish waters, including Albanian lagoons have always been exposed to the inflow of nutrients from drainage basins, a process that has intensified significantly in the last several decades as a consequence of human activities and rapid increase of human settlements. On the other hand coastal waters are among the most productive marine environments; where anthropogenic inputs from rivers, runoff and sewage systems often result in more eutrophic conditions [15, 20]. In recent decades urban coastal settlements exert strong pressures on the environment, and coastal zones around the globe are showing increasing evidence of degradation due to human activities, which subsequently influence the living resources and human health [4].

Numerous plankton invertebrates are phenotypically plastic and respond to predator chemicals, called kairomones, by developing defenses that reduce the risk of predation [8]. Defenses induced by various invertebrate or vertebrate predators have been extensively studied in *Daphnia* and several genera of rotifers

[3,6,7,8,9,10,13,14]. In *Daphnia*, the defenses may be changes in morphology (e.g. body size, development of neck teeth, elongated tail spin, enlarged helmet), behavior (e.g. initiation of diel vertical migration, enhanced escape response, aggregation) or life history (e.g. age or size at first reproduction, fecundity, initiation of diapause) [10]. In rotifers, all known predator-induced defenses are morphological and involve the development and elongation of spines, while Roche (1993) did not found any correlation, positive or negative with couple of environmental factors. Following Gilbert (2013), the environmental costs, or plasticity costs resulting from the evolution of mechanisms for detecting and responding to predators, may explain why long spines in some rotifers are an inducible rather than a constitutive defense.

2. Material and Methods

Zooplankton sampling was carried out in the period of 2014-2015 covering months with sampling in a not regular way: December 14, January, March, April, June and July 2015. The samples were collected using a vertically towed conical net (40 cm diameter, 1 m length, 50 μm mesh-size) equipped with a closing mechanism. The hauls were conducted in one interval form the bottom to the surface approximately 0-2 m. All sampling was carried out during daylight hours. Filtered water volume was estimated using a Hydro-Bios flow meter attached to the mouth of the net. Sample fixation took place immediately after collection in a 4% borax-buffered formaldehyde solution.

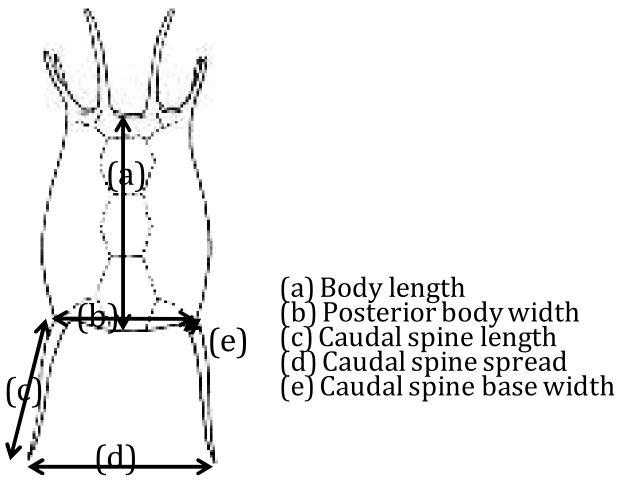


Figure 1. Diagram showing the morphological measurements made.

Identification and enumeration of zooplanktonic taxa was performed at the laboratory under a inverted microscope under up to 400x magnification. Species identification was based on the keys of Ruttner–Kolisko (1974) for rotifers and Balech (1959) and Trégouboff & Rose (1978) for tintinnids. Zooplankton abundance was calculated in terms of density (ind l^{-1}) from aliquots taken with a Folsom splitter. Aliquot size ranged from 1/1 (whole sample) to 1/64, depending on the density of zooplankton organisms in the sample. In addition, for the estimation of the density of the smaller groups, the whole sample (total volume of 100 ml) was investigated under the microscope in modified Sedwick- Rafter cells. Copepod exuvia and dead copepod carcasses (e.g. copepods in advanced decayed condition) were identified and counted for each sub-sample, but they were not included in zooplankton abundance.

Specimens of *Keratella* from both qualitative and quantitative samples were removed, mounted in 40% glycerol on microscope slides under cover slips, and measured at a magnification of 1,000, with oil immersion, using an ocular micrometer with a graduation interval of 1.33 μm (Fig. 1). The relationships between body and caudal spine lengths and environmental factors as a *K. quadrata* features ranks correlation.

3. Results and Discussion

The three common groups of of metazooplankton are represented in Lagoons of Karavasta, Narta and Butrint: copepods, cladocerans and rotifers. Both groups of copepod and cladoceran species found in the lagoons are common in the wider Adriatic costal and transitional water and with fairly good distribution. The presence of rotifers in the plankton of the transitional water appeared to be the most diverse metazooplankton group in three considerd lagoons with 12 taxa.

Nine of the identified species are regarded as indicators of high water trophicity (Table 2). In the qualitative structure, the predominant species at the majority of stations was *Keratella quadrata*, and its proportion in the total number of rotifers ranged from 20.2% to 74.8%. The following species made up a substantial proportion of the total rotifer number were *Filinia longiseta, Gastropus stylifer, Brachionus calyciflorus, Pleosoma hudsoni,* etc.

Table 1. Changes in physical and chemical features of the pond water with time

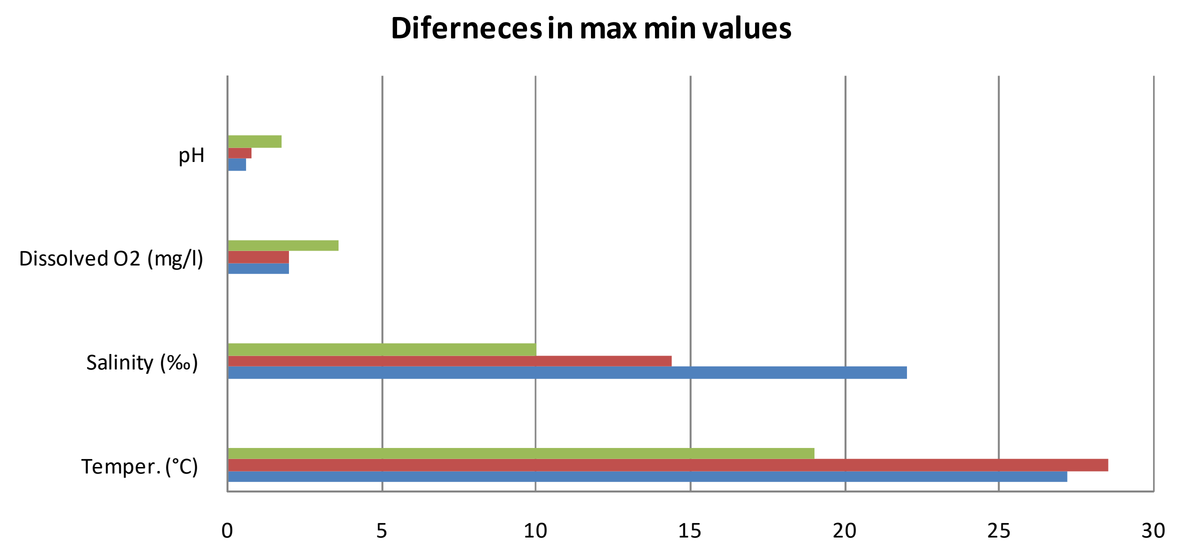
Lagoon	Temper. (°C)		Salinity (‰)		Dissolved O2 (mg/l)		pH	
	Max. Wint	Max. Summ	Max. Wint	Max. Summ	Max. Wint	Max. Summ	Max. Wint	Max. Summ
Karavasta	6.8	34	32	54	11.23	9.2	7.88	8.5
Narta	6.5	35	33.58	48	11	9	7.8	8.6
Butrinti	9	28	25	35	6.2	9.8	7.9	8.7

In the table 1 are shown different groups of metazooplankton present in Lagoons of Karavasta, Narta and Butrint.

Table 2. List of the zooplankton taxa recorded in three Lagoons

	Karavasta	**Narta**	**Butrint**
ROTIFERS Bdelloida			
Brachionus calyciflorus (Pallas, 1766)	*	*	*
Conochilus unicornis (Rousselet, 1892)	*	*	
Filinia longiseta (Ehrenberg, 1834)	*		
Gastropus stylifer (Imhof, 1891)	*	*	*
Kellicottia longispina (Kellicott, 1879)	*	*	*
Keratella quadrata (Müller, 1786)	*	*	*
Lecane sp.	*		
Ploesoma hudsoni (Imhof, 1891)	*	*	*
Synchaeta sp.	*		
COPEPODA Calanoida			
Calanipeda aquaedulcis (Kritchagin, 1873)	*	*	
Paracartia latisetosa (Kritchagin, 1873)	*		*
Harpacticoida			
Euterpina acutifrons (Dana, 1847)	*		
Harpacticus gracilis (Claus, 1863)	*	*	*
Microsetella sp.	*		
Cyclopoida			
Oithona nana (Giesbrecht, 1893)	*	*	*
Nauplii	*	*	*
CLADOCERA			
Podon sp. (Lilljeborg, 1853)	*	*	
PROTOZOA Tintinnids			
Favella ehrenbergii (Claparéde & Laachmann, 1858)	*	*	*
POLYCHAETE LARVAE	*	*	*

One of the protection strategy often used by prey is morphological defenses. Several morphological features such as lorica, spine and body size are important morphological structures protecting rotifers against predators [21, 23]. This has been earlier identified for different plankton species in the Blakan Lakes by Shumka (2018). When feeding on rotifer prey with rigid lorica and long spines, it generally takes a much longer time for invertebrate predators, such as copepod and *Asplanchna*, to handle and ingest the prey rotifer, which reduces selective rate [24]. In Albanian lakes, cyclopoid copepods (as *Mesoyclops leuckarti*) often capture individuals of *Keratella cochlearis*, but usually release them unharmed, being unable to reach the soft parts within their lorica. So rotifer preys such as *Keratella* and *Brachionus* are well defended against invertebrate predators because the opening of their lorica is small and protected by spines [5].



	Temper. (°C)		Salinity (‰)		Dissolved O2 (mg/l)		pH	
Butrinti	19		10		3.6		1.8	
Narta	28.5		14.42		2		0.8	
Karavasta	27.2		22		2.03		0.62	

Figure 1. Differences in values of main chemical features

Following our data records body and caudal spine lengths increased from November until the end of February, and then decreased until June. Such changes were not significantly correlated consistently positively or negatively to water temperature, pH, conductivity, food levels or total number of copepod numbers (Table 2, Figure 1). Following individuals recoded during investigations during the winter season individuals corresponded most closely to the literature descriptions of the group or subspecies *quadrata,* while those present during the spring-summer shows the form, group or variety *dispersa.*

In many specimens, the left caudal spine was shorter than the right. Because both spines varied with time and body size in a similar manner and the average difference in length was less than 3 µm*,* while only the right spine length data are presented in the Figures xxxx.

The anterior spines also showed changes, but were not measured in detail because of the difficulty due to their curvature; these spines showed length change trends similar to the caudal one.

In the figure 2, are presented the hanges in body and caudal spine lengths with time, while in the figure 3 are shown the rRelationship between body length and caudal spine spread (expressed as a percentage of body length). Following our records there is a similar patterns over the time an dconsidered paarmeters.

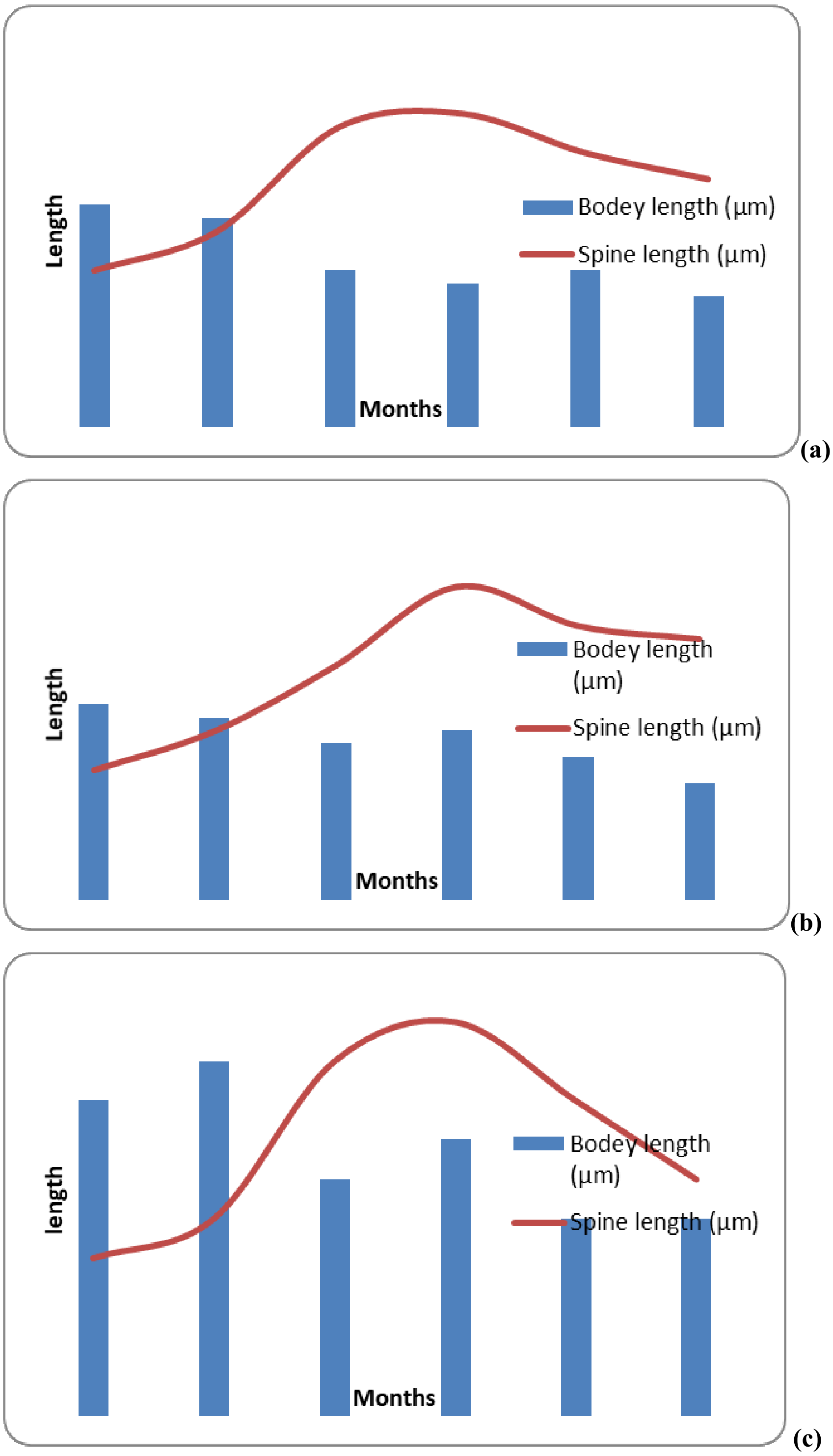
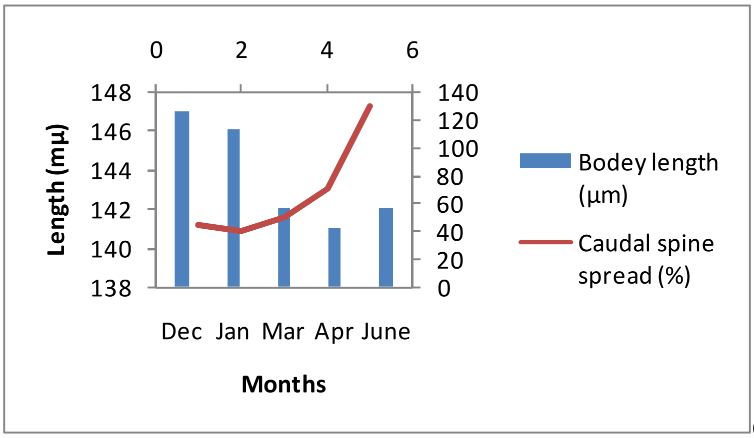
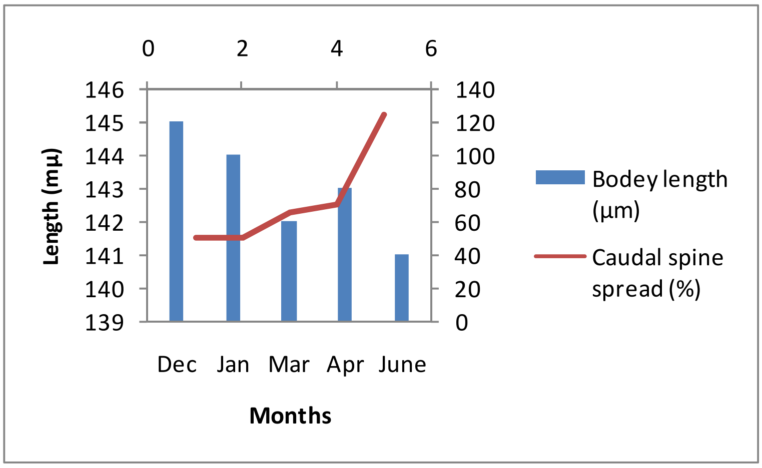


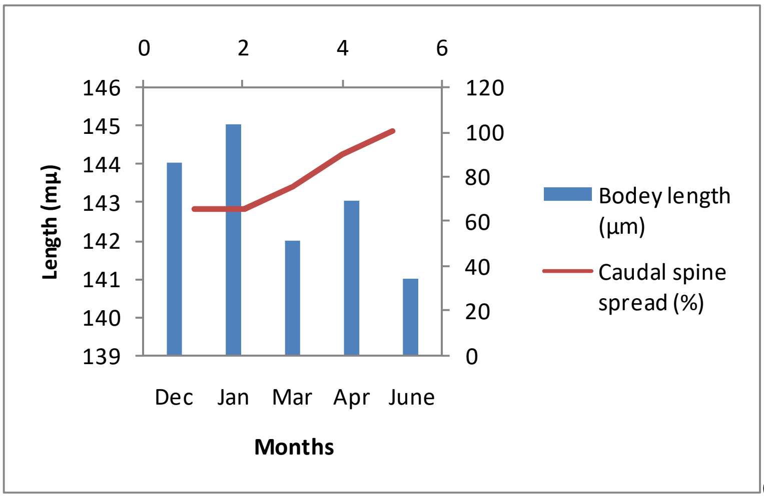
Figure 2. Relationship between body length and spine length (a-Karavasta, b-Narta and c-Butrinti)



(a)



(b)



(c)

Figure 3: Relationship between body length and caudal spine spread (expressed as a percentage of body length) (a-Karavasta, b-Narta and c-Butrinti)

The most increased values of caudal spine (154 µm), are recorded in Narta Lagoon, and followed by Karavasta and then Butrinti. The caudal spine in case of Karavasta was at 138% of the total length, while the lower level of 102% has been recorded in case of Butrinti (Figure 3). In this survey, none of the environmental features measured were significantly correlated consistently positively or negatively with the changes in body and spine lengths recorded during the entire course of the study. Similar results are presented by Roche (1993).

It has to be noted that during most of the year, small invertebrate predators dominate, suggesting that it may be adaptive for prey rotifers, such as *K. quadrata*, to induce long spines. Since fish reproduce only once per year at high latitudes, rotifers have to respond to fish larvae during a short period of the year before the fish grow large enough to shift to larger sized food items [12, 24]. In the case of Albanian Lagoons, the increased spines period is corresponding to the large presence of fish larvae, since they are considered as the most productive e aquatic ecosystems.

4. Conclusions

The survey recognizes that the sampling period was not regular in terms of covering all months. A more detailed study of the *Keratella* population in these and other water bodies would be required using shorter sampling intervals and measuring larger numbers of animals on each date, over the entire annual cycle. This will enable detailed statistical analysis. Laboratory experiments need to be carried out to investigate the effects of varying environmental factors (including predators) on the morphological changes occurring during the growth of individual animals and from generation to generation.

5. Acknowledgements

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6. References

1. Balech E: **Tintinnoinea del Mediterraneo.** Trabajos de Instituto Español de Oceanografía 1959, **28**: 1-88.
2. Carli A, Crisafi P: **Guide per il riconoscimento delle specie animali delle acque lagunari e costiere italiane.** AQ/1/230. Copepodi lagunari. Consiglio Nazionale delle Ricerche, 1983: **11**.
3. De Meester L, Dawidowicz P, Van Gool E: **Ecology and evolution of predator-induced behavior and diel vertical migration.** In: Tollrian, R. and Harvell, C.D. (eds), The Ecology and Evolution of Inducible Defenses. Princeton University Press, Princeton, NJ, 1999: 160–176
4. Duarte M, Conley J, Carstensen K, Sanches-Camacho I: **Return to Neverland: Shifting Baselines Affect Eutrophication Restoration Targets.** Estuar. Coasts 2009, **32**: 29–36.
5. Gilbert J, Williamson E: **Predator-prey behavior and its effect on rotifer survival in associations of Mesocyclops edax, Asplanchna girodi, Polyarthra vulgaris, and Keratella cochlearis. Oecologia** 1978, **37**(1): 13-22.
6. Gilbert JJ: **Kairomone-induced morphological defenses in rotifers.** In: Tollrian, R. and Harvell, C. D. (eds), The Ecology and Evolution of Inducible Defenses. Princeton University Press, Princeton, New Jersey, 1999: 127–141.
7. Gilbert JJ: **Spine development in *Brachionus quadridentatus* from an Australian billabong: genetic variation and induction by *Asplanchna***. Hydrobiologia 2001, **446/447**: 19–28.
8. Gilbert JJ: **Predator-specific inducible defenses in the rotifer Keratella tropica**. Freshwat. Biol 2009, **54**: 1933–1946.
9. Gilbert JJ: **Temperature, kairomones, and phenotypic plasticity in the rotifer Keratella tropica (Apstein, 1907)**. Hydrobiologia 2011, **678**: 179–190.
10. Gilbert JJ: **The cost of predator-induced morphological defense in rotifers: experimental studies and synthesis**. Journal of Plankton Reserach. 2011, **35**(3): 461–472.
11. Gutkowska A, Paturej E, Kowalska E: **Rotifer trophic state indices as ecosystem indicators in brackish coastal waters.** Oceanologia 2013, **55**(4): 887–899.
12. Hansson A, Nicolle A, Graneli W, Hallgren P, Kritzberg E, Persson A, Bronmark C: **Food-chain length alters community responses to global change in aquatic systems**. Nature Climate Change 2013, **3**(3): 228-233.
13. Lass S, Spaak P: **Chemically induced anti-predator defences in plankton: a review.** Hydrobiologia 2003, **491**: 221–239.
14. Larsson P, Dodson S: **Chemical communication in planktonic animals.** Arch. Hydrobiol 1993, **129**: 129–155.
15. Levinton GS: **Marine biology, function, biodiversity, ecology**. Oxford University Press, 1995, New York; 1995.

16. Marques SC, Azeiteiro UM, Leandro SM, Queiroga H, Primo AL: **Predicting zooplankton response to environmental changes in a temperate estuarine ecosystem**. Marine Biology 2008, **155**(5): 531-541.
17. Paturej E, Goździejewska A: **Zooplankton-based assessment of the trophic state of three coastal lakes** – Łebsko, Gardno, and Jamno, Bull. Sea Fish. Inst 2005, **3**(166): 7–26.
18. Roche K.: **Temporal variation in the morphology of the rotifer Keratella quadrata (Miiller, 1786)**. Annls Limnol. 1993, **29**(2): 119-127
19. Ruttner-Kolisko A: **Plankton Rotifers.Biology Taxonomy.** E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart; 1974.
20. Shumka S, Špoljar M, Tasevska, O: **The Zooplankton of Lake Skadar/Shkodra: Species Diversity and Abundance**. In: Pešić V, Kostianoy AG, Karaman GS (eds) The Skadar/Shkodra Lake environ ment. Springer, New York, In press.
21. Stemberger S, Gilbert J: **Multiple-species induction of morphological defenses in the rotifer Keratella testudo**. Ecology, 1987, **68**(2): 370-378.
22. Trégouboff G, Rose M: **Manuel de Planctonologie Méditerranéenne.** Centre National de la Recherche Scientifique, Paris; 1978.
23. Williamson E: **Predator-prey interactions between omnivorous diaptomid copepods and rotifers**: The role of prey morphology and behavior. Limnology and Oceanography, 1978, 32(1): 167-177
24. Zhang H: **Multiple stressors in rotifer communities: Effects of predation, climate change, and brownification Lund:** Lund University, 2017.