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Community Structure of Rotifera, Cladocera and Copepoda in Beymelek Lagoon and Kaynak Lake (Antalya, Turkey): A Preliminary Study

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Abstract.- The aim of the present study was to determine Rotifera, Cladocera and Copepoda community structure and some physical and chemical variables in Beymelek Lagoon, and Kaynak Lake feeding the lagoon. In total, nine stations representing characteristic features of study areas were sampled monthly between February 2006 and January 2007. Totally, 20 taxa belonging to Rotifera, Cladocera and Copepoda were determined in Beymelek Lagoon and Kaynak Lake. Seven Rotifera, three Cladocera and ten Copepoda taxa were identified. Copepoda was found as predominant taxonomic group in respect to Rotifera and Cladocera. Among copepods, *Canuella perplexa* T & A. Scott, 1893, *Ectinosoma melaniceps* Boeck, 1865 were new records for Copepoda fauna of Turkish inland waters.

Keywords: Rotifera, Cladocera, Copepoda, lagoon, Mediterranean, Antalya, Turkey

INTRODUCTION

Coastal lagoons representing a transitional zone among land, freshwater and sea are, in general, shallow and highly productive aquatic ecosystems. They are separated or partially isolated from the oceans or seas by coastal barriers with one or more inlets (Cioffi and Gallerano, 2001; Newton and Mudge, 2003; Perez-Ruzafa *et al*., 2005). These ecosystems are continuously exposed to freshwater and marine interactions. The coastal lagoons also play a significant role as spawning and feeding areas for many fish, invertebrates and migratory birds (Breber *et al*., 2008; Razinkovas *et al*., 2008). Coastal lagoons represent 13% of the worldwide coastal areas, but they are not equally widespread in the different coastal areas (Moulliet *et al*., 2005). Most of the coastal lagoons are located along the Atlantic and Mediterranean coasts of southern Europe as well as in deltaic areas of the Black Sea and along the south-eastern Baltic coast (Newton and Mudge, 2003; Aliaume *et al*., 2007). Turkey has seventy-two lagoons, seventeen of which are located along Mediterranean coastline (STM, 1997).

Zooplankton is among the most important components of the aquatic ecosystems, playing a major role in energy transfer between the phytoplankton and the various economically important fish populations (Mageed, 2006). In aquatic ecosystems main groups of zooplankton are Rotifera and Crustacea (Cladocera and Copepoda).

In Turkey a number of studies have been performed on the species diversity, abundance and distribution of zooplankton especially in freshwater ecosystems (Güher and Kırgız, 2004; Ustaoğlu, 2004; Ustaoğlu *et al.,* 2005; Bozkurt, 2007; Kaya and Altındağ, 2007, 2009; Altındağ *et al*., 2009a,b). On the other hand, a few reports have also been published on zooplankton of coastal lagoons and/or brackish water systems of Turkey focusing mainly on lagoons of Black Sea region, Aegean region and Marmara region (Demirhindi, 1972; Gündüz, 1989, 1991a,b; Emir, 1990; Güher, 1999; Bekleyen and Taş, 2008). But no detailed study on zooplankton was performed in lagoons of Mediterranean region as yet. Although studies on fisheries, fishing activities, macrobentic algae were carried out in our study area (Anonymous, 1984; Atar *et al*., 2002; Yağcı (Apaydın) and Turna, 2002; Atar and Seçer, 2003; Yağcı (Apaydın), 2006; Emre *et al*., 2009, 2010), but knowledge on the lagoon zooplankton is still insufficient (Anonymous, 1984; Yalım, 2004). Therefore, the main aim of this study is to reveal the community structure of Rotifera, Cladocera and Copepoda and some physical and chemical variables in Beymelek Lagoon and Kaynak Lake.

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MATERIALS AND METHODS

Study sites

Beymelek Lagoon is located in the south-west coast of Turkey (30° 04' E, 36° 16' N) (Fig. 1). Beymelek Lagoon has a total surface area of 255 ha. It is a shallow lagoon with a mean depth of about 1.6 m and 3.5 m maximum depth. It is connected to the Mediterranean Sea by one inlet. Beymelek Lagoon receives brackish water from Kaynak Lake which is connected to the lagoon by a small channel. It is situated at the north-west of Beymelek Lagoon (30° 02' E, 36° 15' N) and a total surface area is 6 ha with depth ranging from 2 to 5 m (Anonymous, 1984) (Fig. 1).

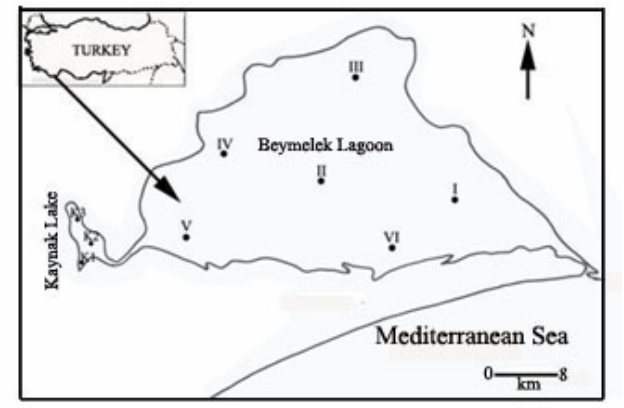

Fig. 1. Location of sampling stations in Beymelek Lagoon and Kaynak Lake.

Sampling and analysis

Samples were collected monthly from February 2006 to January 2007. Six sampling stations in Beymelek Lagoon (I-VI) and three sampling stations in Kaynak Lake (K1, K2, K3) reflecting characteristics of Beymelek Lagoon and Kaynak Lake, were selected (Fig. 1). The coastline of the east of the lagoon is stony, the north is rock, and the west and south are sandy and soil (Anonymous, 1984). Station I was located at a distance of 500 m from the fish barriers. Station II was situated near the middle of the lagoon, which is the deepest part. Station III, IV and VI were located at the north, north-west and south of the lagoon, respectively. Station V was 500 m away from the Kaynak Lake, which is connected to the lagoon with a small channel. There were three stations in the Kaynak Lake. Station K1 and K3 were situated at south-west and north of the lake. However, station K2 is at middle of the lake.

The rotifer, cladoceran and copepod samples were hauled with a 55 μm mesh plankton net horizontally, and vertically from the bottom (2.5-3 m) to the surface in each sampling station.The samples were collected in 350 ml plastic bottles and immediately fixed with 4% formalin solution. The taxa were identified by using Kolisko (1974), Koste (1978) for Rotifera, Margaritora (1983), Negrea (1983) and Smirnov (1996) for Cladocera, Rose (1933), Dussart (1967, 1969), Kiefer (1978) and Huys *et al*. (1996) for Copepoda.

Water temperature, pH, conductivity (EC), salinity and dissolved oxygen (DO) were measured monthly in water samples taken from 0.3 m below the surface in the field using digital equipments (YSI dissolved oxygen meter, YSI pH meter).

Hierarchical cluster analysis (Pearson coefficient similarity index; group average) was calculated between the stations for Rotifera, Cladocera and Copepoda taxa in Beymelek Lagoon and Kaynak Lake. For the statistical cluster analysis, MVSP 3.1 demo version was used in this study.

RESULTS

The mean values of some physical and chemical variables of water recorded according to stations are given in Table I. The mean values of water temperature in Beymelek Lagoon and Kaynak Lake varied from 20.4 to 22.8°C and from 17.3 to 18.0°C, respectively. pH values in Beymelek Lagoon and Kaynak Lake were between 7.7 and 8.0 and 7.3 and 7.6, respectively. The electrical conductivity values in Beymelek Lagoon and Kaynak Lake waters changed from 17.4 to 20.7 and from 11.3 to 11.7 mS/cm, respectively. Salinity ranged between ‰12.6 and ‰ 14.1 in Beymelek Lagoon and ‰8.3 and ‰8.6 in Kaynak Lake. The mean values of dissolved oxygen in Beymelek Lagoon and Kaynak Lake ranged from 7.8 to 9.6 and from 7.0 to 7.7, respectively (Table I).

Table I.- Mean values (minimum-maximum) of physico-chemical variables recorded in the stations

Physico chemical variables	Stations								
	K1	K2	K3	I	II	III	IV	V	VI
Temperature(°C)	18.0 (15.7-24.7)	18.0 (14.6-24.8)	17.3 (14.9-20.6)	22.8 (13.4-31.9)	22.1 (13.4-30.8)	22.6 (13.3-30.9)	21.8 (13.5-30.1)	20.4 (14.9-26.2)	22.3 (12.5-30.7)
pH	7.3 (7.1-7.8)	7.5 (7.2-7.7)	7.6 (7.2-8.2)	7.9 (7.6-8.2	7.9 (7.7-8.2)	7.9 (7.4-8.3)	7.8 (7.5-8.2)	7.7 (7.5-7.9)	8.0 (7.7-8.3)
Conductivity (mS/cm)	11.3 (7.2-12.9)	11.7 (5.1-13.2)	11.4 (7.9-13.5)	19.7 (17.4-22.9)	19.0 (17.2-22.3)	19.5 (14.8-24.8)	17.4 (10.5-21.3)	17.5 (12.5-21.9)	20.7 (17.0-25.3)
Salinity (‰)	8.3 (6.5-9.2)	8.6 (6.0-9.8)	8.3 (6.0-9.5)	13.6 (10.1-16.0)	13.3 (10.0-15.8)	13.9 (10.3-15.8)	12.8 (10.8-15.0)	12.6 (11.0-14.0)	14.1 (11.5-16.0)
Dissolved O_2 (mg O_2/L)	7.0 (5.2-9.2)	7.5 (6.1-11.6)	7.7 (4.9-11.7)	8.8 (7.1-10.4)	9.1 (7.2-11.0)	9.6 (7.7-11.9)	7.8 (6.7-9.7)	8.5 (6.0-10.2)	8.9 (7.4-10.4)

A total of 20 taxa belonging to Rotifera, Cladocera and Copepoda were recorded during the present study. The list of Rotifera, Cladocera and Copepoda taxa identified in the lagoon and the lake is shown in Table II. The seasonal succession of Rotifera, Cladocera and Copepoda taxa according to the localities is shown in Table III while the distribution of Rotifera, Cladocera and Copepoda taxa according to the stations is presented in Table IV.

Table II.- List of Rotifera, Cladocera and Copepoda taxa found in the lagoon and the lake

ROTIFERA Cuvier, 1798

Class: Eurotatoria De Ridder, 1957
Subclass: Monogononta Plate, 1889
Order: Plomia Hudson and Gosse, 1886
Family: Brachionidae Ehrenberg, 1838
Keratella quadrata (O.F. Müler, 1786)
Brachionus rotuntiformis (O.F. Müler, 1786)
B. quadridentatus Hermann, 1783
Notholca acuminata (Ehrenberg, 1832)

Family: Gastropodidae Harring, 1913
Ascomorpha saltans Bartsch, 1870

Order: Floscullariacea Harring, 1913
Family: Filinidae Harring and Myers, 1926
Filinia longiseta (Ehrenberg, 1834)

Family: Hexarthridae Bartos, 1959
Hexarthra fennica (Levander, 1892)

CRUSTACEA Brünnich, 1772

Class: Branchiopoda Latreille, 1829
Subclass: Phyllopoda Preuss, 1951
Order: Diplostraca Gerstaecker, 1866
Suborder: Cladocera Latreille, 1829
Family: Chydoridae Stebbing, 1902
Chydorus sphaericus (O.F. Müller, 1785)
Pleuroxus aduncus (Jurine, 1820)
Alona rectangula Sars, 1861

Class: Maxillopoda Dahl, 1956
Subclass: Copepoda (Milne Edwards, 1840)
Order: Calanoida Sars, 1903
Family: Paracalanidae Giesbrecht, 1893
Mecynocera clausi I.C. Thompson, 1888
Paracartia latisetosa (Krichagin, 1873)

Order: Cyclopoida Burmeister, 1835
Family: Cyclopidae Rafinesque, 1815
Haliocyclops neglectus Kiefer, 1935
Megacyclops viridis (Jurine, 1820)

Order: Poecilostomatoida Burmeister, 1835
Family: Corycaeidae Dana, 1852
Farranula rostrata (Claus, 1863)

Order: Harpacticoida Sars, 1903
Family: Canuellidae Lang, 1944
Canuella perplexa T & A. Scott, 1893

Family: Darcythompsoniidae Lang, 1936
Leptocaris brevicornis (Van Douwe, 1904)

Family: Ectinosomidae Sars, 1903
Ectinosoma melaniceps Boeck, 1865

Family: Tisbiidae Stebbing, 1910
Tisbe sp.
Family: Canthocamptidae Sars, 1906
Nitocra hibernica (Brady, 1880)

Table III.- The seasonal succession of identified Rotifera, Cladocera and Copepoda according to the lagoon and the lake.

	Lagoon	Lake	Spring	Summer	Autumn	Winter
K. quadrata	+	-	-	+	-	-
B. rotuntiformis	+	-	-	+	+	-
B. quadridentatus	+	-	+	-	-	-
N. acuminata	+	-	-	-	+	+
A. saltans	+	-	-	-	+	+
F. longiseta	-	+	+	+	-	-
H. fennica	+	-	-	+	+	-
C. sphaericus	+	+	+	-	-	+
P. aduncus	+	+	+	-	-	+
A. rectangula	+	+	+	-	-	+
M. clausi	+	-	+	-	-	-
P. latisetosa	+	+	+	+	+	+
H. neglectus	+	+	+	+	+	+
M. viridis	+	+	+	-	-	+
F. rostrata	+	-	+	-	-	-
C. perplexa	+	+	+	+	+	+
L. brevicornis	-	+	+	-	+	+
E. melaniceps	+	+	+	+	+	+
Tisbe sp.	+	-	+	-	+	-
N. hibernica	+	+	+	+	-	+

Table IV.- Distribution of the Rotifera, Cladocera and Copepoda taxa according to the stations.

	I	II	III	IV	V	VI	K1	K2	K3
K. quadrata	+	-	-	+	-	+	-	-	-
B. rotuntiformis	+	+	+	+	+	+	-	-	-
B. quadridentatus	+	-	-	+	-	-	-	-	-
N. *acuminata*	-	-	+	-	-	-	-	-	-
A. saltans	-	-	+	-	-	-	-	-	-
F. longiseta	-	-	-	-	-	-	+	-	-
H. fennica	+	+	-	+	+	-	-	-	-
C. sphaericus	-	+	+	+	+	+	+	+	+
P. aduncus	+	+	+	+	-	-	+	+	+
A. rectangula	-	+	+	+	+	+	+	+	+
M. clausi	-	+	-	-	-	-	-	-	-
P. latisetosa	+	+	+	+	+	+	+	+	+
H. neglectus	-	-	-	-	+	+	+	+	+
M. viridis	-	+	+	-	+	+	+	+	-
F. rostrata	-	+	-	-	-	-	-	-	-
C. perplexa	+	-	+	+	+	+	+	+	+
L. brevicornis	-	-	-	-	-	-	+	+	-
E. melaniceps	-	+	+	-	+	+	+	+	+
Tisbe sp.	-	+	-	+	-	-	-	-	-
N. hibernica	-	-	-	-	+	+	+	-	-

Seven taxa of Rotifera, three taxa of Cladocera and ten taxa of Copepoda were determined in the lagoon and the lake (Table II). As we can see in Table III, Beymelek Lagoon comprised a mixture of 18 marine, freshwater and brackish water species. Kaynak Lake comprised 11 freshwater and brackish water species. Both Beymelek Lagoon and Kaynak Lake comprised

mainly a mixture of 9 freshwater and brackish water species. The seasonal succession of Rotifera, Cladocera and Copepoda taxa varied from species to species. Of these, *Paracartia latisetosa*, *Halicyclops neglectus*, *C. perplexa*, *E. melaniceps*, *Nitocra hibernica* and *Leptocaris brevicornis* were recorded almost throughout the year (perennial). Other taxa were seasonal species because of being recorded only one or two seasons. Of these, *Notholca acuminata*, *Ascomorpha saltans* were observed merely in autumn and winter months. *Filinia longiseta* and *Tisbe* sp. were observed in spring and summer months. *Keratella quadrata*, *Brachionus rotuntiformis*, *Hexarthra fennica* were observed in summer and autumn months. *Chydorus sphaericus, Pleuroxus aduncus, Alona rectangula* and *M. viridis* were observed in winter and spring months. However, two marine species *Farranula rostrata* and *Mecynocera clausi* were observed only in spring months.

As one can see in Table IV, *K. quadrata*, *B. rotuntiformis*, *B. quadridentatus*, *N. acuminata*, *A. saltans* and *H. fennica* were observed only in some stations of the lagoon, whereas *F. longiseta* was observed only in the station K1 of Kaynak Lake. All cladocerans and among copepods, *P. latisetosa*, *C. perplexa*, *E. melaniceps* were observed almost in all stations. *M. viridis*, *H. neglectus* and *N. hibernica* were observed in some stations of the lagoon and the lake. While *Tisbe* sp. was observed in stations II and IV of the lagoon, *F. rostrata* and *M. clausi* were observed only in station II of the lagoon. *L. brevicornis* was determined in only in Kaynak Lake stations.

Cluster analysis grouped the stations in terms of the waterbodies with the highest similarities, ie. Beymelek Lagoon and Kaynak Lake. Stations were clustered in subsequent interactions and the results are shown in Figure 2. A distinctive association of the Rotifera, Cladocera and Copepoda taxa were represented with each cluster and the analysis explained five associations: one association in Kaynak Lake stations and four associations in the lagoon stations (Fig. 2).

The stations of Kaynak Lake placed in the same group. K2 and K3 showed the higher similarity than K1. There were seven common species between these three stations: *C. sphaericus, P. aduncus, A. rectangula, P. latisetosa, H. neglectus, C. perplexa* and *E. melaniceps*.

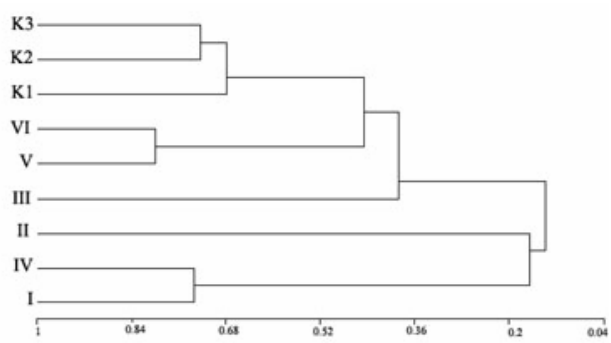

Fig. 2. Cluster diagram based on occurrences of Rotifera, Cladocera and Copepoda taxa recorded at each stations

Clustering analysis showed that the lagoon contained different regions depending on the inlet from Kaynak Lake and marine. The lagoon had four association. First association included stations I and IV, second association station II, third association station III and last association stations V and VI. There was a significant similarity between the stations I and IV, located in close to the sea outlet of the lagoon and in the north-west of lagoon respectively. They had the following common species: *K. quadrata, B. rotuntiformis, B. quadridentatus, H. fennica*, *P. aduncus*, *P. latisetosa* and *C. perplexa*. Second station representing the centre and deepest part of the lagoon and station III located at the farthest point to the sea outlet of lagoon had very low similarity with both between themselves and the other stations. Marine species were recorded only at station II. Station V located in close to the lake entrance and station VI located in the south of lagoon and in the flow direction had a significant similarity. These stations had nine species including *B. rotuntiformis*, *C. sphaericus*, *A. rectangula*, *P. latisetosa*, *H. neglectus*, *M. viridis*, *C. perplexa*, *E. melaniceps* and *N. hibernica*.

DISCUSSION

In this study, the recorded temperature values in the lagoon and the lake are higher than that of Anonymous (1984). But Yağcı (Apaydın) (2006)

was determined higher temperature values than the recorded temperature values in this study. It may be explained that the air temperature showed differences by the years. The temperature values in Beymelek Lagoon were found to be similar to the other Mediterranean coastal lagoons (Gouze *et al*., 2008; Hlaili Sakka *et al*., 2008). The recorded conductivity and salinity values showed that Beymelek Lagoon and Kaynak Lake are brackish water bodies. The recorded conductivity and salinity values in this study showed similarity with the recorded conductivity values in the lagoons by Anonymous (1984). However mean of conductivity values of the lake was recorded higher than that of Anonymous (1984). The salinity values were recorded by Yağcı (Apaydın) (2006) were determined higher than that of this study. The recorded salinity values in the lagoon and the lake are lower compared to the other coastal lagoons located along the Mediterranean shore (Cioffi and Gallerano, 2001; Orfanidis *et al*., 2005; Gouze *et al*., 2008; Hlaili Sakka *et al*., 2008; Specchiulli *et al*., 2010). The recorded pH values in this study showed similarity with the recorded pH values in the lagoons by Anonymous (1984) and Yağcı (Apaydın) (2006). pH values in the lagoon reflects more marine water character. Dissolved oxygen values in the lagoon were found to be similar in both this study and Anonymous (1984). However, the recorded dissolved oxygen values in the lake were determined higher than the dissolved oxygen values of Anonymous (1984).

A total of 20 taxa representing Rotifera, Cladocera and Copepoda were recorded in the study areas while previously 2-6 taxa were recorded (Yalım 2004, two taxa (*M. viridis* and *Daphnia curvirostris*); Anonymous 1984, six taxa in only genus level). However, *D. curvirostris* recorded by Yalım (2004) was not observed during the present study. Herzig (1987) and Feike and Heerkloss (2008) declared that the seasonal succession of different zooplankton species varies from year to year. Some species can be found every year, the others may appear in some years or be completely disappear in other years.

All the taxa, except *M. viridis*, were the first records for the study area. Of these, *C. perplexa*, *E. melaniceps* belonging to Harpacticoida, Copepoda, were identified as new records for Turkish inland waters. Karaytuğ and Sak (2006) recorded *C. perplexa*, *E. melaniceps* from the beaches of Marmara Sea and Aegean Sea of Balıkesir Province. In our study, these species were recorded for the first time in the brackish waters.

Copepods were the dominant and common taxonomic group in the lagoon and the lake, followed by Rotifera and Cladocera. Similarly, in the investigations on zooplankton community copepods were found as the dominant group in majority of Mediterranean coastal lagoons and wetlands by El-Shabrawy (2006), Mageed (2006) and Martinoy *et al*. (2006). In addition, Ramdani *et al*. (2001) reported that copepods were the dominant group in some brackish water lakes with marine connection. Majority of copepods identified in this study area were comprised cosmopolitan, euryhaline, and some meiobenthic forms. Of these, *P. latisetosa, C. perplexa*, *E. melaniceps* are recorded frequently in marine, estuaries, brackish water and salted lagoon ecosystems (Dussart, 1967; Huys *et al*., 1996; El-Shabrawy and Belmonte, 2004). *H. neglectus*, *L. brevicornis* and *N. hibernica* are found commonly in freshwater, coastal brackish water, estuaries and salted ponds (Dussart, 1967, 1969; Bozkurt, 2007). *M. viridis* living in freshwater and brackish water can tolerate salinity up to 18‰ (Dussart, 1969; El-Shabrawy and Belmonte, 2004). *M. clausi*, *F. rostrata* and *Tisbe* sp. from the species of marine origin, were observed rarely in the lagoon because of likely low tolerance to low salinity.

All cladocerans and most of rotifers identified in the study area are found commonly in continental freshwaters and slight brackish waters (Koste, 1978; Margaritora, 1983; Smirnov, 1996; Ramdani *et al*., 2001; Feike and Heerkloss, 2008). These taxa were observed in a short period (2 or 3 months) in the lagoon and the lake. Main ecological factors including temperature, conductiviy and salinity have a strong influence on seasonal successions and distributions of the zooplankton groups (Mageed, 2006; Feike and Heerkloss, 2008). However, we believe that the seasonal succession of the zooplankton can not be explained only by abiotic factors. Many fish and macroinvertebrates fed on plankton were found in the lagoon and the lake. Therefore, species or communities interactions, such

as predation pressure by planktivorous fish and invertebrates also should be taken into consideration.

Up to date, this study is the most detailed investigation on the zooplankton (Rotifera, Cladocera and Copepoda) community structure of the lagoon. The results of the present study on the zooplankton community and other ecological variables may help to evaluate future changes in the lagoon ecology and make contribution to the lagoon management.

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