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RESEARCH ARTICLE ARAŞTIRMA MAKALESİ

Effects of physicochemical factors and Chlorophyll *a* on diel changes in vertical distribution of zooplankton in a eutrophic reservoir (Tahtalı Reservoir, NW Turkey)

Ötrofik bir rezervuarda (Tahtalı, Kuzeybatı Türkiye) fizikokimyasal faktörler ve klorofil *a*'nın zooplanktonun günlük dikey dağılımına etkisi

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Özet: Son yıllarda dünya çapında artış göstermesine rağmen, sulama amacıyla yapılan su kütlelerinde zooplankton komünitesinin bölgesel ve zamana bağlı değişimleri çok az ilgi görmüştür. Bu çalışmanın amacı, ötrofik bir rezervuarın su kolonunda zooplanktonun dikey dağılımının günlük değişimlerini ortaya çıkarmak ve hangi çevresel ve biyolojik faktörlerin bu dağılımı etkilediğini saptamaktır. Tüm fizikokimyasal ve biyolojik (Klorofil a ve zooplankton türleri) değişkenler genel olarak yüzeyden 4,5-6,0 m derinliğe kadar azalma ve bu noktadan itibaren dikey su kolonunda dibe doğru artış şeklinde benzer bir durum göstermiştir, Copepoda'nın en bol taksa olduğu bunu Cladocera ve Rotifera'nın takip ettiği toplam 15 zooplankton taksonu belirlenmiştir. Rotifera ve Copepod nauplii'nin dağılımı besin tuzları ve klorofil a ile temsil edilen besin konsantrasyonları ile ilişkiliyken, Cyclopoid ve Cladoceranların dikey göçünü etkileyen en etkin faktörler su sıcaklığı, bulanıklık ve askıda yük yoğunluğu olmuştur. Rezervuarda, çalışılan zooplankton komünitesinin bolluğu üzerinde günlük değişimler ve derinlik önemli etkiye sahiptir. Çalışmanın sonucunda farklı çevresel faktörlerde öngörülemeyen değişimlerin, rezervuardaki zooplanktonun dağılımınına olan etkileri ortaya konmuştur.

***Anahtar kelimeler*:** Zamansal ve bölgesel dağılım, besin tuzları, rotiferler, krustaseler, çevresel faktörler, yapay su kütleleri.

Abstract: Despite recent worldwide increase, artificial water bodies have received little attention for spatial and temporal distribution of their zooplankton communities. Aim of the present study was to reveal diel variations in vertical distribution of zooplankton in water column of a eutrophic reservoir and to detect which environmental and biological factors affect this distribution. All physicochemical and biological (Chlorophyll a and zooplankton species) variables showed a similar pattern, generally a decrease from the surface to depths of 4.5–6.0 m and a rise from this point to the deepest part of the vertical water column. In total, 15 zooplankton taxa were determined being Copepoda the most abundant taxa, followed by Cladocera, and Rotifera. Water temperature, turbidity and suspended load concentration were the most influential factors for the vertical migration of Cyclopoids and Cladocerans whereas the distribution of Rotifers, and Copepod nauplii were related to nutrients, and food concentrations represented by chlorophyll a. Diel changes and depth had significant impact on the abundance of studied zooplankton community in the reservoir. Result of the study revealed variable distribution patterns of zooplankton under effect of different environmental factors in an unpredictable reservoir.

Keywords: *Temporal and spatial distribution, nutrients, rotifers, crustaceans, environmental factors, artificial water bodies*

INTRODUCTION

Studies in zooplankton ecology usually focus on characterization and quantification patterns of spatial variability of zooplankton (Pinel-Alloul, 1995; Bini *et al*., 1997). Therefore, vertical migration of zooplankton has largely been documented in literature from various kinds of environments. Modifying and inducing these migrations are associated with many abiotic and biotic factors, such as light, temperature, oxygen, nutrients, invertebrate and fish predation, and the available food conditions (Leibold, 1991). Furthermore, the role of competition between particular zooplankton species or groups, and between zooplankton and other freshwater organisms, cannot be rule out (Wickham and Gilbert, 1990).

Although diel vertical migration (DVM) pattern of zooplankton has been widely explained by predation pressure of visually orienting predators, physicochemical properties of the water and particularly temporal nutrient availability in the water column should also be important aspects in this common zooplankton behavior (Lampert, 1993) because zooplankton provides a flow of energy through the food chain, and they are strongly affected by environmental alterations directly or indirectly (Berzins and Pejler, 1987; Mikshi, 1989). Especially in unstable water bodies such as newly established reservoirs, contribution of zooplankton communities would be much more significant for energy and nutrient flow in the food web (Bonecker *et al*., 2007). Indeed, nutrient amount in the water column can be affected by several mechanisms including size and abundance of zooplankton communities; stronger migrations of larger Cladocerans than smaller ones, presence of thermocline layer, nutrient intake at the daytime by zooplankton and uptake at night (Wright and Shapiro, 1984; Dini *et al*., 1987).

Diel changes in vertical distribution of zooplankton have been relatively less studied in artificial water bodies such as reservoirs and ponds despite their recent increase in worldwide scale and variable ecological structures (Bozkurt and Dural, 2005; Guevara *et al*., 2009). Given rapid changes in environmental variables caused by mainly water level fluctuations and nutrient inflow, man-made reservoirs offer unique opportunities to understand ecological dynamics of these environments focusing the role of biotic and abiotic factors on the interactions of living organisms. To this end, DVM of zooplankton in a recently created reservoir, Tahtalı reservoir was recently studied only with some restricted variables, such as conductivity, water temperature, turbidity, dissolved oxygen, water transparency, pH and Chlorophyll *a* (Dorak *et al*., 2013). According to the results of that study, however, it was not determined any clear migration pattern. For this reason, a new study at the same area but different times with more variables including nutrients, to investigate DVM in the reservoir was planned. It was aimed with this way that it could also be possible to clarify the effect of nutrients on the DVM of zooplankton community. For this purpose, in the present study by studying in the same reservoir our specific goals to elucidate: (i) spatial and temporal diel distribution of zooplankton in water column and (ii) which environmental and biological factors affect this distribution.

MATERIAL AND METHODS

Study Area

The Tahtalı Reservoir is a small reservoir (surface area of 1.6 km2), which was created with the aim of irrigation and flood control. It is located 30 km from the city of Kocaeli in the district of Derince (Figure 1). The reservoir has a eutrophic character because of frequent nutrient inflows from surrounding residential areas and intense agricultural activities. Its average depth is quite variable due to frequent water level fluctuations varying between approximately 1 and 5 m. Two relatively large streams and a couple of small seasonal streams feed the reservoir. However, the reservoir shows very unstable and unpredictable ecological character because of its deep draft and human interventions (e.g. mainly nutrient inflow and water droughts for agricultural use).

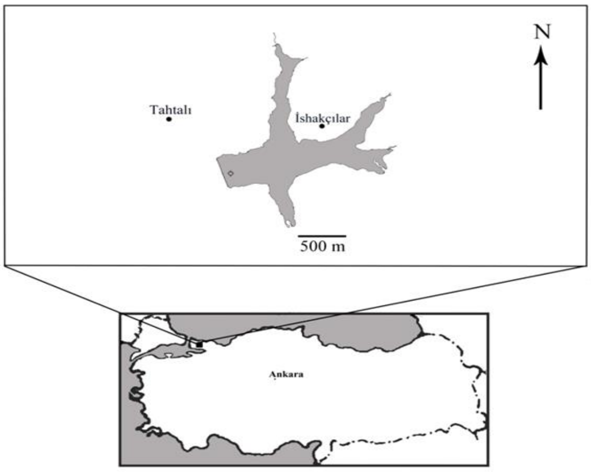

Figure 1. Study area and sampling station.

Zooplankton and Water Sampling

Since the reservoir suffers from constant water level fluctuations, the deepest part of the reservoir is quite variable. Hence, we took the samples between 6 and 8 May 2011, which was the best suitable time allowing vertical migration of zooplankton in a maximum 9 m deep-water column throughout the year. The samples were collected for a 24-h period at 4-h intervals starting from 07 00 hours on 6 May 2011. Sampling was done from the surface to the deepest part of the water column (9 m) and repeated at 1.5-m intervals. Zooplankton was collected in each interval by filtering 5 L of water through plankton net with 55 μm mesh size, preserved with 4% formaldehyde solution immediately and then identified under a binocular microscope and counted under an inverted microscope. All the zooplankton densities are presented as number of individuals per five litre (ind. 5 L-1) (Czerniawski and Pilecka-Rapacz, 2011). The following references were used to identify the species: Dussart (1967, 1969), Koste (1978) and Margaritora (1983).

Water samples for environmental variables were taken simultaneously with zooplankton samples from each sampling depth. Water samples were collected vertically using a 5-L van Dorn bottle. Conductivity (EC), water temperature, turbidity, pH, and dissolved oxygen (DO) measurements were recorded in situ with a multiparameter (YSI 650 MDS). Water transparency was determined using a Secchi disc (sd) and was used for the calculation of the euphotic zone (Parsons *et al*., 1977). To determine Chlorophyll *a* (Chl *a*) content, water samples were filtered and extracted through ethanol. After centrifugation, absorbance was measured before and after acidification in a spectrophotometer and then calculated (Nusch, 1980). The suspended load concentration (SPM) was determined in the laboratory on a 47-mm cellulose acetate filter with a 0.45 μm pore diam. Samples for nutrient analysis were pre-filtered. Nitrite (NO_2-N), nitrate (NO_3-N), orthophosphat (PO_4-P), total phosphorus (TP) and silica (SiO_2) were detected spectrophotometrically following APHA (1989).

Statistical Analyses

In order to approximate better to normal distributions, abiotic and biotic variables were log-transformed (log (x + 1)). Relationships among environmental variables, Chl a, and zooplankton were tested by Pearson's correlation factor (Zar, 1999). Spatial and temporal variations of zooplankton species, Chl a, and physicochemical values were tested by analysis of variance (ANOVA). To determine the effects of spatial (depth) and temporal (time of the day (day/night)) variations on environmental factors and zooplankton communities, multivariate analysis of variance (MANOVA) was conducted. All of these statistical analyses were performed using SPSS 19.0. Canonical ordination was performed to appraise the association of zooplankton with environmental factors. The species data matrix was first analysed by detrended correspondence analysis (DCA) to determine their distribution pattern (linear or unimodal). The length of the gradient (SD < 2) showed that the linear method (redundancy analysis: RDA) was appropriate (ter Braak and Smilauer, 2002). In this study, there were 13 measured environmental variables, Chl a and six samples (after averaging the data sets on each sampling occasion). Downweighting of rare species was performed. The biological data and environmental variables in RDA were log (x+1)-transformed. To guard against interpretation of spurious axes, the statistical significance of the first and all the ordination axes were tested by Monte Carlo permutation test (999 unrestricted permutations). Because large values of Variance Inflation Factors are (VIF) indicators of multicollinearity, and RDA analysis is affected by highly correlated variables, VIF was measured to determine collinearity. As a rule of thumb, if VIF of a variable exceeds 20 that variable is said to be highly collinear. Therefore, variables with high variance inflation factors (VIF>20) were eliminated from the RDA analysis (ter Braak and Smilauer, 1998). The computer program Canoco 4.5 performed DCA and RDA analyses for Windows.

RESULTS

Physical and Chemical Factors and Chlorophyll *a* Distribution

All physicochemical and Chl *a* values showed a similar pattern, generally a decrease from the surface to depths of 4.5–6.0 m and a rise from this point to the deepest part of the vertical water column (Figure 2). There were mostly significant correlations among environmental parameters (Pearson, $P < 0.05$) (Table 1). Regarding temporal variation of environmental variables, significant differences were determined only for pH and TP values (ANOVA, $P < 0.05$). Depending on depth, significant differences were detected for all environmental variables, except for o-PO_4, TP, SPM, Secchi disc depth, and euphotic zone (ANOVA, $P < 0.05$). Euphotic zone and Secchi disc values did not change according to the time of the sampling (ANOVA, $P < 0.05$). It was between 1.84 m and 4.27 m for the euphotic zone, and 0.68 m and 1.58 m for Secchi disc. MANOVA indicated the significant effects of time of day (day/night) (Wilks'λ = 0.146, $F_{(12, 17)} = 8.311$, $P = 0.000$) and depth on abiotic factors and Chl a (Wilks'λ = 0.000, $F_{(72, 98.394)} = 4.580$, $P = 0.000$) (MANOVA, $P < 0.05$). However, the combined effects of time of day and depth did not show any significant impact on physicochemical parameters and Chl *a* (Wilks'λ = 0.080, $F_{(72, 98.394)} = 0.807$, $P = 0.830$) (MANOVA, $P > 0.05$).

Zooplankton Composition, Abundance, and Vertical Distribution

During the sampling period 15 taxa were determined (Table 2). Copepoda was the most abundant taxa (53%), followed by Cladocera (33%), and Rotifera (14%). Copepoda was represented by 3 species and Copepod nauplii. *Cyclops abyssorum* was the most abundant species for the Copepoda (12.821% of the total zooplankton), and followed by *Metacyclops stammeri* 7.485% of the total zooplankton), Metacyclops gracilis (3.505% of the total zooplankton), respectively. From Cladocera, *Bosmina longirostris* (16.540% of the total zooplankton) was the dominant species while Alona rectangula (0.148% of the total zooplankton) was encountered in small numbers. Within the Rotifera group the most observed species were predator species, *Asplancha priodonta* (2.678% of the total zooplankton), *Polyarthra vulgaris* (2.342% of the total zooplankton), and *Filinia terminalis* (1.477% of the total zooplankton), respectively. Some other rotifer species appeared in the plankton samples in low numbers. They were *Brachionus angularis*, *B. calycifloris*, *B. diversicornis*, *Euchlanis dilatata*, *Keratella cochlearis*, *Pompholyx sulcata*, and *Synchaeta pectinata*. All zooplankton species declined in abundance in the water column until the depth of 6 m and then relatively increased again towards the deepest part of the water (9 m) (Figure 3).

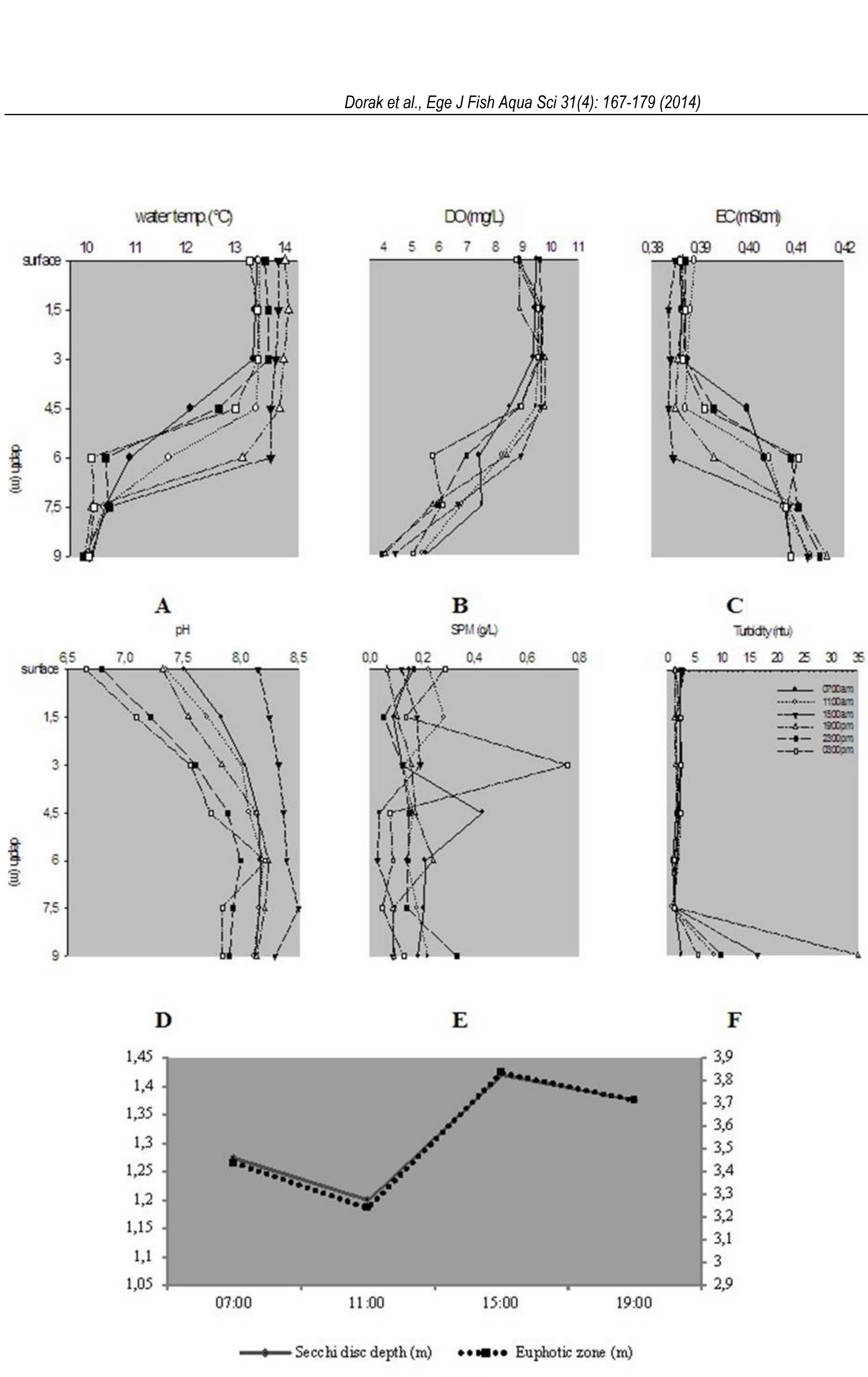

Figure 2. The vertical distribution of physical variables of A) water temperature, B) dissolved oxygen (DO), C) electrical conductivity (EC), D) pH, E) suspended particulate matter (SPM), F) turbidity and G) Secchi disc depth and euphotic zone, denoted by time of the sampling.

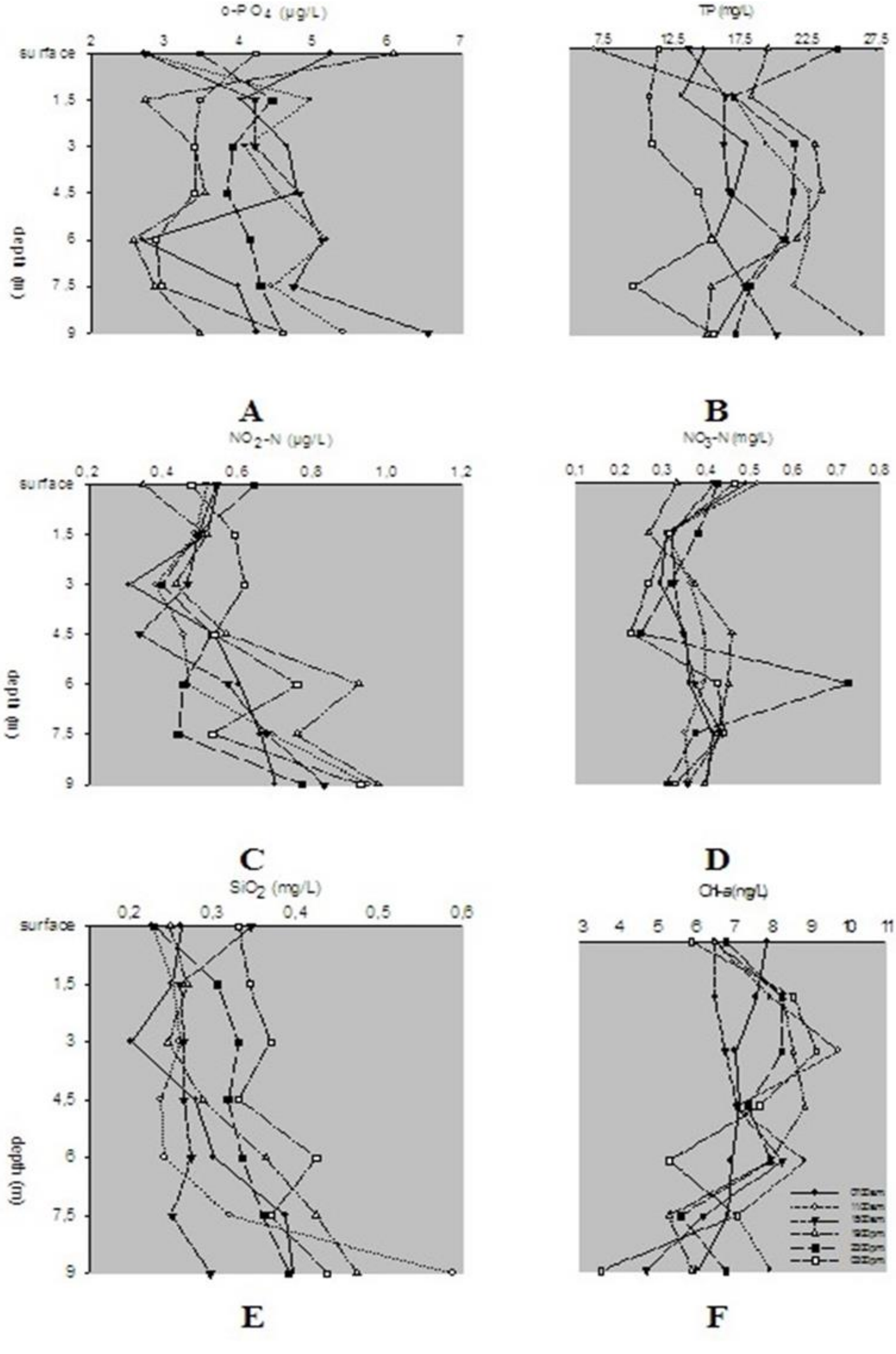

Figure 2 continued. The vertical distribution of chemical parameters of A) o-PO_4, B) TP, C) SiO_2, D) NO_2-N, E) NO_3-N, and F) Chlorophyll *a* (Chl *a*), denoted by time of the sampling.

Table 1. Correlation (r) between physicochemical variables and Chl a from Tahtalı Reservoir (Kocaeli, Turkey).

Pearson's Correlation (p<0.01; *p< 0.05; ns: no significance)**														
	Water temperature	EC	pH	DO	Turbidity	Secchi disc	Chl *a*	o-PO_4	TP	NO_3-N	NO_2-N	SiO_2	SPM	Euphotic zone
Water temperature	1	**-0.967****	**-0.268***	**0.905****	**-0.324****	**0.635***	**0.327****	ns	ns	ns	**-0.450****	**-0.511****	ns	**0.635***
EC		1	**0.312****	**-0.918****	**0.406****	ns	**-0.332****	ns	ns	ns	**0.478****	**0.534****	ns	ns
pH			1	**-0.253***	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
DO				1	**-0.534****	**0.637***	**0.394****	ns	ns	ns	**-0.541****	**-0.572****	ns	**0.637***
Turbidity					1	**0.923***	ns	ns	ns	ns	**0.428****	**0.406****	ns	ns
Secchi disc						1	ns	**0.907***	ns	ns	ns	ns	ns	**1.000****
Chl *a*							1	ns	ns	ns	**-0.382***	ns	ns	ns
o-PO_4								1	**0.320***	ns	ns	ns	ns	**0.907***
TP									1	ns	ns	ns	ns	ns
NO_3-N										1	ns	ns	ns	ns
NO_2-N											1	**0.526****	ns	ns
SiO_2												1	ns	ns
SPM													1	ns
Euphotic zone														1

Significant correlations in bold (***P*<0.01,**P*<0.05; *n*=42).

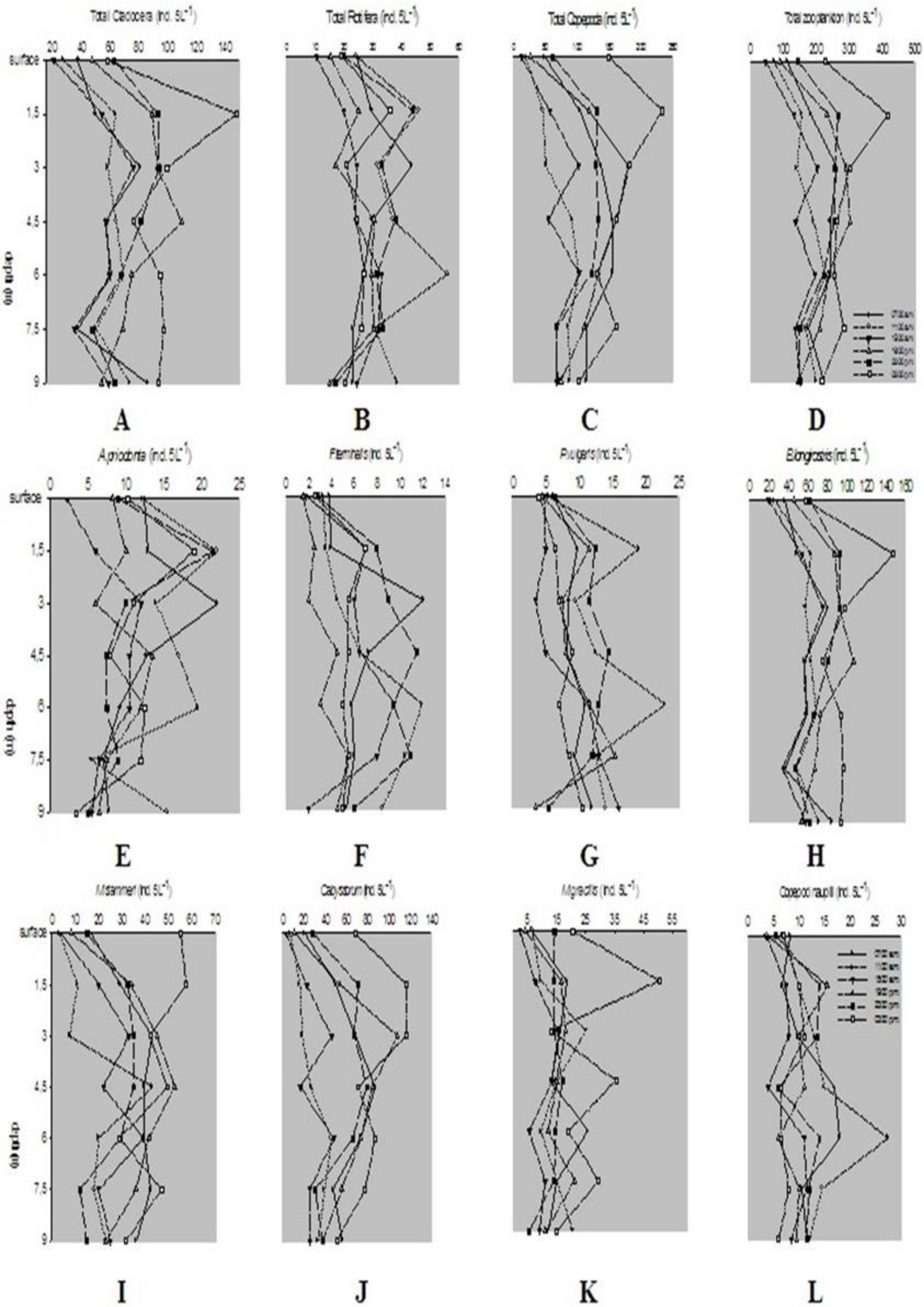

Figure 3. The vertical distribution of A) Total Cladocera, B) Total Rotifera, C) Total Copepoda, D) Total Zooplankton, E) *A.priodonta*, F) *F.terminalis*, G) *P.vulgaris*, H) *B.longirostris*, I) *M.stammeri*, J) *C.abyssorum*, K) *M.gracilis*, l) Copepod nauplii; denoted by the time of sampling.

Table 2. Classifications of the zooplankton species identified in the study area (Ustaoğlu, 2004).

Rotifera	
Asplanchna priodonta Gosse, 1850	**Cladocera**
Brachionus angularis Gosse, 1851	*Alona rectangula* Sars,1862
Brachionus calyciflorus Pallas, 1766	*Bosmina longirostris* (Müller,1776)
Brachionus diversicornis (Daday, 1883)	
Euchlanis dilatata Ehrenberg,1832	**Copepoda**
Filinia terminalis (Plate, 1886)	*Cyclops abyssorum* Sars, 1863
Keratella cochlearis (Gosse, 1851)	*Metacyclops gracilis* Lilljeborg, 1853
Pompholyx sulcata Hudson, 1885	*Metacyclops stammeri* Kiefer, 1938
Polyarthra vulgaris Carlin, 1943	
Synchaeta pectinata Ehrenberg, 1832.	

Regarding sampling times, significant differences were determined for all zooplankton taxa (ANOVA, $P < 0.05$). Depending on depth, there were significant differences for all zooplankton taxa except *P. vulgaris* and *M. gracilis* (ANOVA, $P < 0.05$). According to the statistical analyses, time of day (day/night) (Wilks'λ = 0.333, $F_{(11, 18)} = 3.281$, $P = 0.012$), and depth significantly impacted the abundance of zooplankton (Wilks'λ = 0.028, $F_{(66, 101.771)} = 1.457$, $P = 0.043$) (MANOVA, $P < 0.05$), whereas they jointly had no effect on zooplankton abundances (Wilks'λ = 0.060, $F_{(66, 101.771)} = 1.064$, $P = 0.384$) (MANOVA, $P > 0.05$).

Physicochemical and Biological Association

The correlations between abundances of the selected zooplankton species and groups, and environmental parameters showed that only some resulting values were high enough of statistical significance (Table 3). Total Copepoda had significant relationship with Chl *a* (r = 0.328, P = 0.034) and o-PO_4 (r = -0.328, P = 0.034). Copepod *C. abyssorum* significantly correlated with Chl *a* (r = 0.344, P = 0.026) and PO_4 (r = -0.339, P = 0.028), and *M. gracilis* showed significant correlation with o-PO_4 (r = -0.339, P = 0.028), while Copepod nauplii correlated with Chl *a* (r = 0.361, P = 0.019) and o-PO_4 (r = 0.315, P = 0.042). *M. stammeri* abundance showed no significant correlations with any environmental variable. Total Rotifera was significantly correlated with Chl *a* (r = 0.394, P = 0.010) and TP (r = 0.310, P = 0.046). *A. priodonta* abundance was inversely related to the EC (r = -0.332, P = 0.032) and NO_2-N (r = -0.350, P = 0.023), on the other hand it showed a positive significant relationship with water temperature (r = 0.343, P = 0.026), DO (r = 0.440, P = 0.004), and Chl *a* (r = 0.517, P = 0.000). *F. terminalis* was significantly correlated with pH (r = 0.320, P = 0.039). *P. vulgaris* had significant positive correlation with EC (r = 0.334, P = 0.031), TP (r = 0.432, P = 0.004, and it was inversely related with water temperature (r = -0.311, P = 0.045). Total Cladocerans and *B. longirostris* were significantly correlated with Chl *a* (r = 0.332, P = 0.032; r = 0.328, P= 0.034, respectively). No significant correlations were obtained between any taxa and turbidity, Secchi disc depth, NO_3-N, SiO_2, SPM, and euphotic zone (Table 3).

In the present study, high VIF values were determined for water temperature, EC, DO, and euphotic zone (VIF > 20). These variables were co-varied with other variables (Pearson correlation r > 0.60, P < 0.05). Therefore, EC, DO, and euphotic zone variables were removed, and VIF values of residual variables are suitable to use in the same analysis (ter Braak and Smilauer, 1998). The significant last RDA model produced in this study did not have variables that have VIF values higher than four. With the presentation of first four synthetic gradients to RDA, the first two eigenvalues explained 50.7% of the cumulative variance of species data. Furthermore, the species-environment correlations of axis I (0.843) and axis II (0.684) were high. The first four environmental variables clarified 49.3% of the total variance in species data. The Monte Carlo permutation test was significant on the first axis (F-ratio = 23.084, P-value = 0.001) and all axes (F-ratio = 3.250, P-value = 0.001). In Figure 4, the upper quadrant was entirely qualified to the distribution of rotifers and the lower one mainly to the distribution of zooplanktonic crustaceans (Cladocera and Copepoda). Similarly, in Figure 4, the upper quadrant was to the distribution of samples taken at daylight (07:00, 11:00, 15:00), while the lower one was completely to the distribution samples taken at night (19:00, 23:00, 03:00). Samples taken at daylight were characterized by higher number of rotifers and Copepod nauplii, whereas samples taken at night were characterized by higher abundance of zooplanktonic crustaceans. According to the RDA results, TP, Chl *a*, pH, o-PO_4, and NO_3-N were associated mainly with rotifers and copepod nauplii, while zooplanktonic Crustaceans were associated with SPM, SiO_2, turbidity, Secchi disc depth, and water temperature.

Table 3. Correlation (r) between physicochemical variables, and selected zooplankton species and major zooplankton groups abundance from Tahtalı Reservoir (Kocaeli, Turkey).

	A.prio.	*F.term.*	*P.vulg.*	*B.long.*	*C.abys.*	*M.grac.*	*M.stam.*	naup.	t.cope	t.roti.	t.clado.
W.temperature	**0.343***	-0.244	**-0.311***	0.087	0.015	-0.049	0.060	-0.217	0.004	0.007	0.086
EC	**-0.332***	0.224	**0.334***	-0.096	-0.029	0.001	-0.111	0.261	-0.033	0.005	-0.095
pH	-0.214	**0.320***	0.287	-0.241	-0.172	-0.244	-0.075	0.212	-0.155	0.122	-0.236
DO	**0.440****	-0.067	-0.193	0.119	0.137	0.080	0.147	-0.081	0.137	0.178	0.117
Turbidity	-0.198	-0.143	-0.122	-0.089	-0.166	-0.136	-0.144	-0.047	-0.179	-0.244	-0.090
Secchi disc	0.681	0.384	-0.689	0.123	-0.113	-0.727	-0.085	-0.497	-0.260	0.472	0.102
Chl-*a*	**0.517****	0.150	0.108	**0.328***	**0.344***	0.218	0.168	**0.361***	**0.328***	**0.394****	**0.332***
o-PO_4	0.153	0.214	0.237	-0.179	**-0.339***	**-0.339***	-0.268	0.092	**-0.328***	0.247	-0.179
TP	0.014	0.271	**0.432****	-0.001	-0.118	-0.223	-0.063	**0.315***	-0.094	**0.310***	0.007
NO_3-N	-0.088	-0.075	0.006	-0.285	-0.158	-0.202	-0.103	0.070	-0.158	-0.055	-0.284
NO_2-N	**-0.350***	-0.153	0.132	-0.004	-0.011	-0.038	0.025	-0.055	-0.009	-0.204	0.003
SiO_2	-0.278	0.053	0.041	0.171	0.150	0.180	0.122	-0.056	0.150	-0.165	0.177
SPM	0.042	-0.055	-0.101	0.059	0.302	-0.114	0.108	0.163	0.219	-0.102	0.059
Euphotic zone	0.681	0.384	-0.689	0.123	-0.113	-0.727	-0.085	-0.497	-0.260	0.472	0.102

Significant correlations in bold (**P<0.01,*P<0.05; n=42)

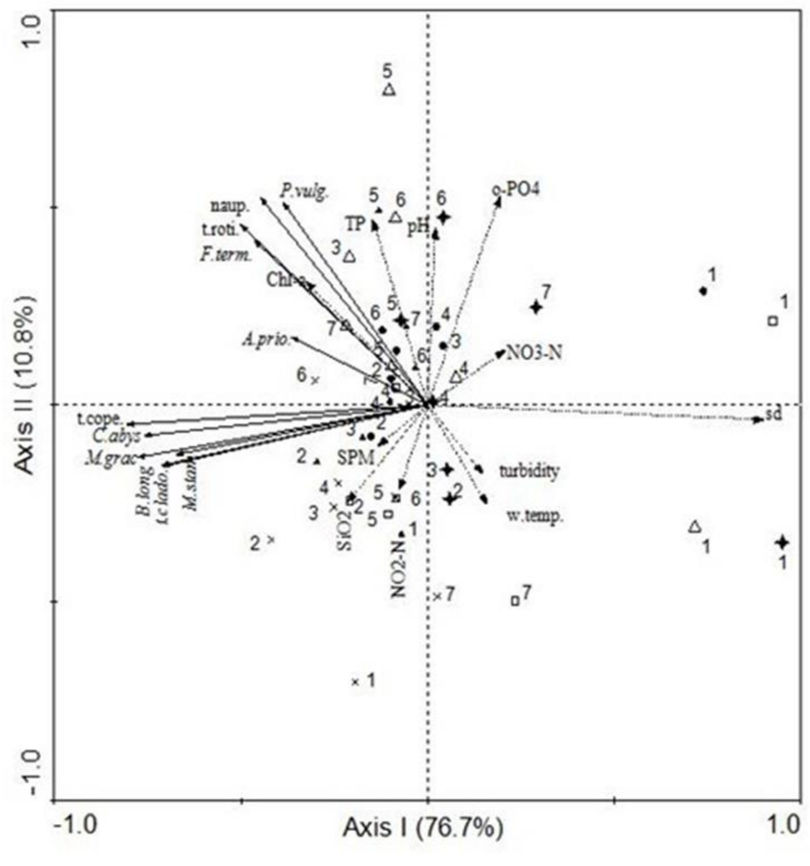

Figure 4. RDA ordination plot for zooplankton taxa, factors (environmental variables), sampling times and depths. Sampling stations in RDA plot indicated with 07:00: filled circle, 11:00: triangle15:00: filled star, 19:00: square, 23:00: filled triangle, 03:00: cross; sampling depths in RDA plot indicated with surface water: 1; 1.5 m depth: 2; 3.0 m depth: 3; 4.5 m depth: 4; 6.0 m depth: 5; 7.5 m depth: 6; 9.0 m depth: 7. Taxa in RDA plot indicated with abbreviation instead of arrows: *Asplanchna priodonta-A. prio.; Filinia terminalis-F. term; Polyarthra vulgaris-P..vulg.; Bosmina longirostris-B. long.; Metacyclops stammeri-M. stam.; Metacyclops gracilis-M. grac.; Cyclops abyssorum-C. abys.*; Copepod nauplii-naup; Total Copepoda-t. cope.; Total Cladocera-t. clado.; Total Rotifera-t. roti.

DISCUSSION

Results of this field study determined the vertical distribution pattern of zooplankton in Tahtalı Reservoir over a 48-h period in late spring. It also displayed the effect of causal environmental factors on distribution of zooplankton in the sampled water column.

Water quality is an important aspect for survival and reproduction of colonizing individuals in terms of biological recovery (Gray and Arnott, 2009). Distribution of vertical temperatures indicated no thermal stratification in the reservoir. According to the results, decreases in Chl *a* content towards the bottom in the water column may be indicative of reduced algal biomass. This was probably due to the decreased transparency and phosphorus levels, also high SPM, which were measured at the bottom. The EC showed significant differences depending on depth. The increases in EC and turbidity levels might indicate the re-suspension of particulate metals and their release from the sediment to the aqueous phase. EC values are affected by human-induced pollution, and tend to increase with increasing pollution (Reavie and Smol, 1998). Due to the increase in farming around the reservoir area during the study period, nutrients concentrations increased, and so that has led to the increase in EC values towards the bottom in the water column. In the present study, an increasing trend for levels of nutrients after 6 m depth towards the deepest part of the water (9 m) partly due to the trophic state of reservoir. This suggests that sediment of the study area was not the main source of various nutrients and intense agricultural activities around reservoir might be partly responsible for the nutrient enrichment of the reservoir. On the other hand, another reason of this may be the water abstraction for irrigation by a pipe located at the 6-m depth.

In the present study, most of the identified taxa (*A. priodonta*, *B. angularis*, *B. calyciflorus*, *E. dilatata*, *F. terminalis*, *K. cochlearis*, *P. vulgaris*, *S. pectinata*, *A. rectangula*, and *B. longirostris*) are cosmopolitan species (Kaya and Altındağ, 2007; Ustaoğlu *et al*., 2012). Among the zooplanktonic species identified in the study area; *Brachionus spp*., *E. dilatata*, *F. terminalis*, *K. cochlearis*, *B. longirostris* are typical species of eutrophic waters (Kolisko, 1974; Sláděcek, 1983; Apaydın-Yağcı and Ustaoğlu, 2012). Further, recorded zooplankton species such as *K. cochlearis*, *P. vulgaris*, *Asplanchna spp*., and *B. longirostris* in the Tahtalı Reservoir are common species encountered in temperate reservoirs of Turkey (Bozkurt and Dural, 2005; Demir, 2005; Bozkurt and Sagat, 2008). However, we also collected some previously unreported taxa (*A. rectangula* and *S. pectinata*) in our study and found no mention by others of their presence in the Tahtalı Reservoir (e.g. Dorak *et al*., 2013). However, Dorak *et al*. (2013) reported more abundant and diverse zooplankton groups than that found the present study. This variation between the studies from the same reservoir can be attributed to sampling time and water temperature.

Our samplings clearly indicated that all zooplankton species declined in abundance in the water column until the depth of 6 m and then relatively increased again towards the deepest part of the water (9 m). For reservoirs, densities of zooplankton are regulated by rain intensity, phytoplankton productivity, wind action and predation (Nogueira *et al*., 1999; Roldán and Ruíz, 2001). However, it is not possible to quantify the impact of predators on the zooplankton in Tahtalı reservoir, as we do not have sufficient data about the influence of planktivorous fish. Indeed, crustacean zooplankton (*B. longirostris* and Cyclopoid Copepods) occupied mostly the upper layers (to the depth of 6 m) at night (19:00, 23:00, and 03:00), occurring in lower numbers in the deeper ones. On the other hand, crustacean zooplankton increased from 1.5 m depth to 6 m depth at day sampling (07:00, 11:00, and 15:00), but the abundances of species were lower than the night samplings, except than Copepoda nauplii. Many Cyclopoid Copepods change their feeding habits during development. Cyclopoid nauplii are obligate herbivores (Pourriot and Lescher-Moutoué, 1983) while older stages are usually omnivores. The fact that one finds only a portion of the local species pool in any habitat can be attributed either to chance or to the presence of predators, competitors, or unsuitable environmental conditions. Nauplii should migrate to feed on algae where they are most abundant, whether in the upper layers during the day or the deeper ones at night (Perticarrari *et al*., 2004), as the distribution of Cyclopoid nauplii at the present study. The determined most abundant Cyclopoid *C. abyssorum* is regarded as markedly carnivorous (Hansen and Santer, 1995). They have limited ability to produce eggs when fed only on small algae (Hansen and Santer, 1995). The other Cyclopoids were determined less abundant than *C. abyssorum*. *M. stammeri* was described or recorded as stygobiont specimen of Cyclopoid Copepod (Pesce, 1985). The character of this species clarified their low abundance in the study period. As follows, at the sampling time the air temperature was not high enough to dissolve the snow on the mountain peaks, which support to the ground waters. According to Ustaoğlu *et al*. (2001) *M. gracilis* has a regenerated population when the water temperature becomes >18 °C. In the present study, water temperature varied from 9.9 to 14.6 °C. This result may explain the low abundance of *M. gracilis*. The distribution and abundance of Cyclopoid Copepods were the result of a counteracting stimulus represented by low DO concentrations beneath 7.5 m, and to avoid from predators. Avoidance of poorly oxygenated layers by migratory crustaceans is common and has been reported for other studied water bodies (Perticarrari *et al*., 2004). The daylight distribution of Cyclopoids might be the result of water transparency, and high DO concentration. On the other hand, the dominance of Cyclopoids may explain, that copepods are more successful than Cladocerans in facing predation pressure in the reservoir due to their ability to change from nocturnal to reverse migration, i.e. they are not the main microcrustacean prey of fish.

The abundance of *B. longirostris* is usually controlled by the abundance of flagellated algae. *B. longirostris* abundance in lakes typically is bimodal with peaks in early summer and early autumn (Demott, 1989). In the present study, the occurrence trend exhibited by *B. longirostris* was similar to the other studies. High winds, which are common at the sampling time in our study area in the reservoir, may create enough turbulence to further mix the water. Alternatively, our results may suggest that food limitation may have been a factor in decline of *B. longirostris*. Chl *a* concentration, a measure of algal biomass, decreased from the surface to the bottom at the sampling station. Similarly, the abundance of zooplankton decreased from the surface to the bottom. This decline can be attributed to food limitation. Bosmina remains almost exclusively in the middle of water column (Horppila, 1997).

Diurnal migrations of rotifers were limited varying temperature, food and oxygen levels. Nevertheless, the amplitude of vertical migration of rotifers is related to the animal body size (Karabin and Ejsmont-Karabin, 2005), and it was observed that amplitude of daily migrations of several rotifer species ranging between 0.2 and 5.6 m (Miracle, 1977). In the present study, the abundances of rotifers were higher at daylight sampling than night, and they occupied mostly from surface to the depth of 6 m at all sampling times. The majority of rotifers arrived their maximum densities near the surface water, but it was reported that with the increase in depth amount of rotifers decreases (Kolisko, 1974), as observed in our study. Significant correlation between Chl a concentrations and rotifer densities suggest that the factor that triggers vertical migrations of Rotifera is food resource including both its quality and quantity. Distribution of Rotifera in the upper layers of the water was due to the temperature preferences of rotifers. This relatively a high-temperature layer allows development and reproduction of thermophilic species an optimum level (Zotina *et al*., 1999).

High level of nutrient concentrations, water temperature and zooplankton have previously been reported to be closely associated in several studies (e.g. Park and Marshall, 2000). Interactions among these variables lead an altered food web (Anderson *et al*., 2002). Since the Tahtalı Reservoir is a eutrophic reservoir, phytoplankton production is expected to be high and sufficient for herbivorous zooplankton feeding. Moreover, the sampling was carried out in early spring, a time when edible phytoplankton peaked. Inorganic nitrogen such as NO_2-N, and NO_3-N can help increase the rotifer density. Copepoda were also affected indirectly by NO_2-N and NO_3-N. The inversely relationship between Copepoda, Chl *a*, and NO_3-N explained that the food preference of identified Copepoda species at the study area was not phytoplankton. *B. longirostris* was the most abundant Cladoceran specimen at the present study. Being dominant of larger Cladocera is indicative of its competitive superiority over smaller species. This is the case when nutrients becomes limited because smaller species have higher limiting thresholds than larger Cladocerans (Brooks and Dodson, 1965) hence competition between small and large species are highly depended on the nutrient levels available, which provide proper conditions for smaller individuals to reproduce and grow when they are abundantly found in the water column. This situation could explain the negative relationship between nitrate with *B. longirostris* and total Cladocera.

In conclusion, the results of this study have indicated that species detected in the Tahtalı Reservoir are indicators of eutrophic waters, confirmed by the dominant zooplankton group (Cyclopoids) and physicochemical factors of the water in the reservoir and the distribution of each zooplankton groups were associated with different environmental parameters. The results also suggested that the vertical migration of the crustacean zooplankton (Cyclopoids and Cladoceran) was related to abiotic factors, such as water temperature, turbidity, and SPM, whilst the distribution of Rotifers, and earlier Cyclopoid stages (Copepod nauplii) were related to nutrients, and food concentrations represented by chlorophyll a. However, as most other reservoirs worldwide, Tahtalı Reservoir is frequently used for irrigation and suffer from severe droughts because of climate regime of the region therefore its physical structure is not uniform and temperature, oxygen levels, and nutrient composition showed unpredictable changes throughout the year. Indeed, the composition, abundance and spatial distribution of the zooplankton communities are strongly related to their trophic state and the degree of biological interactions (Matsumura-Tundisi, 1997). Hence, studies on zooplankton dynamics should be considered very important component of understanding the real pattern of trophic interactions and helping management practices in reservoirs.

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