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Planktonic-based assessment of the landside-dammed lake (Erzurum-Turkey)

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Abstract

The aim of this study was to identify the variation of plankton communities in the Tortum Lake. Changes in phytoplankton and zooplankton communities in relation to the abiotic environment were analyzed using multivariate analysis. Water samples were taken monthly from three sampling points of the Tortum Lake between June 2012 and May 2013. Water temperature (5.28-23.05°C), dissolved oxygen (1.54-13.68 mgL^{-1}), and pH (7.22-9.01) were measured in situ. Chlorophyll-a and total orthophosphate concentrations ranged from 0.18 to 5.70 mgL^{-1} and from 0.01 to 0.00 mgL^{-1}, respectively. In the Tortum Lake, *Ceratium hirundinella* (18%), *Botryococcus braunii* (51%), *Chlamydomonas microsphaerella* (25%), *Microcystis aeruginosa* (7%), *Melosira varians* (1%), *Monoraphidium contortum* (1%), Copepoda (66%), Daphnia (33%) and Keratella (1%) were found. Some species such as *M. aeruginosa* were increased by organic and inorganic pollution in Tortum Lake.

Keyworld: Phytoplankton, Zooplankton, Biodiversity index, Tortum Lake, Multivariate analysis

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Introduction

The composition and biomass of phytoplankton and zooplankton species in lakes depend on a complex combination of factors, such as temperature, light and availability of nutrients (Dantas *et al*., 2012). Seasonal and spatial variations of plankton composition are affected by coastal structure, top-and bottom currents and predators (Tanyolac, 2009).

Phytoplankton use as orthophosphate ions for growth so that it is responded to decreased phosphorus. This is partly due to community resilience (Padisak *et al.*, 2003).

Zooplankton grazing usually provokes a decrease in phytoplankton biomass; however, some inedible algae may increase their abundances in a lake during active grazing phases because of the effect of the selective feeding, and therefore, they can take advantage of the availability of nutrients when the competition pressure with counterpart algae diminishes (Queimalin *et al*., 1998). Zooplankton composition, in turn, also determines the responses of the grazing pressure on phytoplankton. Particularly, microphagous and macrophagous zooplankton may exert a different top–down impact on the phytoplankton community (Sommer *et al*., 2003).

Diversity indices such as Shanon-Weaner index appeared to detect significant differences in the structure of the communities (Offem *et al.*, 2011).

The three main categories of zooplankton found in Minneapolis lakes are rotifers, copepods and cladocerans. Rotifers tend to be the smallest among the types. Despite their small size, they are important in the aquatic food web because of their abundance, distribution and a wide range of feeding habits. Copepods and cladocerans are larger zooplankton and members of the class of Crustacea. Copepods are the most diverse group of crustaceans. Rotifer plays an important role in aquatic ecosystems mainly because of their enormous reproductive potential. There is a negative relation between the ratio of rotifers and macrozooplankton as versus the ratio of small algae (Bronmark and Hansson, 2005)

In the Kuzgun Reservoir, Bacillariophyta was the dominant group, followed by Chlorophyta and Dinophyta. The dominant species were *Synedra delicatissima, Asterionella formosa, Fragilaria crotonensis, Cyclotella kiitzingiana, Cyclotella ocellata, Oocystis borgei, Staurastrum longiradiatum, Ankistrodesmus falcatus, Ceratium hirundinella,* and *Peridinium inctum.* Maximum phytoplankton density was observed in late spring (Gurbuz *et al*., 2004).

According to Demir *et al*. (2013), the examination of functional groups of phytoplankton communities in Lake Mogan seemed to be a useful method for ecological status and may provide evidence for further examinations between the Q quality index and the ecological condition of other Turkish lakes.

Tortum Lake, the biggest landslide lake with surface area 6.63 km^2, located in the East Anatolia Region of Turkey and 92 km from the Erzurum city (Altuner, 1982; Orhan and Karahan, 2010). The aims of the present study were to determinate the changes of phytoplankton composition by using multivariate analysis with zooplankton composition and some physico-chemical data.

Materials and methods

Study site

The Tortum Lake is located in the northeast part of Turkey. The lake with 11 km length and 0.77 and 1 km width, is at 1000 m above sea level. The lake has an area of 6.77 m^2, the volume of 223×10^6 m^3, an average depth of 110 m. The amount of sediment reaching the basin of the Tortum Lake is estimated to be 2.5 million m^3. The lake vanishes quickly as a result of sedimentation and some calculations revealed that the lake will be completely disappeared in 250-300 years (Altuner, 1982; Kıvrak, 2006).

Sampling and laboratory procedures

Plankton and water samples were monthly collected from 3 different stations (1st site 40° 37' 10" N and 40° 37'37" E; 2ed site 40° 37'6" N and 41° 37' 35" E; 3rd site 40° 39' 7" N and 41° 39' 29" E) between June 2012 and May 2013 (Fig. 1). Water temperature (°C) (Thermo Orion 3 Star), dissolved oxygen (mgL^{-1}) (DO) (Thermo Orion 3 Star) and pH (Thermo Orion 3 Star) were measured in situ. Chlorophyll-a concentration (mgL^{-1}) was determined by the acetone extraction method using a spectrophotometer (Beckman Coulter DU 730) (Strickland and Parsons, 1972).

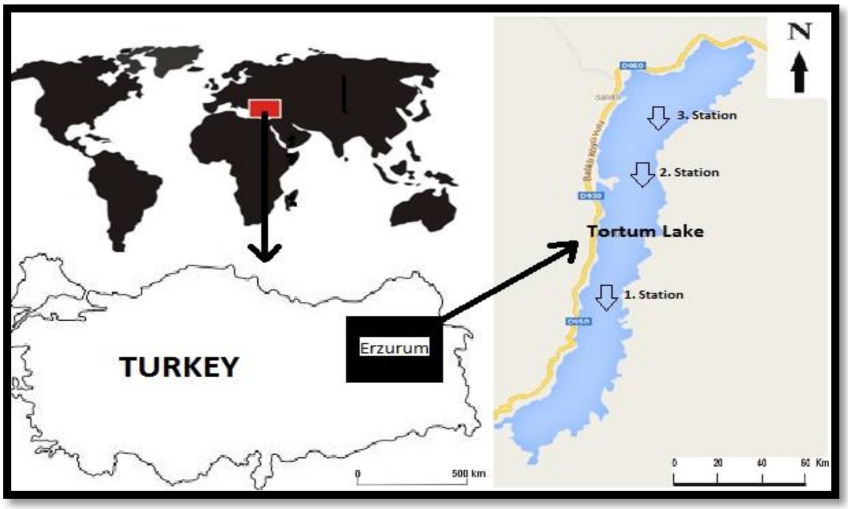

Figure 1: Map of the sampling site locations.

Total hardness ($mgL^{-1}CaCO_3$), Ca-hardness (mgL^{-1} $CaCO_3$), Mg-hardness ($mgL^{-1}CaCO_3$) and total orthophosphate (PO_4-P, mgL^{-1}) were calculated by standard methods (APHA, 1995).

Phytoplankton samples were fixed using Lugol's iodine. Zooplankton samples were fixed in 4% formaldehyde. The common taxonomic literature was used for phytoplankton taxa (Krieger, 1932; Round, 1953; Cramer, 1991; Kelly, 1997; John *et al*., 2002). Zooplankton taxa were identified according to Smirnov (1974), Segers (1993) and Dussart (1969). Phytoplankton counts were carried out by the inverted microscope (Utermohl, 1958). Cell dimension of algae was measured with a Zeiss microscope. Total phytoplankton bio-volume was estimated by the corresponding geometrical form (Hillebrand *et al*., 1999; Sun and Liu, 2003) using the 1 mm^3 m^{-3} of algal volume to 1 mg wet weight m^{-3} biomass calculation. Cell dimension of zooplankton was calculated with the stereomicroscope. Total zooplankton bio-volume was calculated the corresponding geometrical form (Akbay, 1982).

Biodiversity indices

Shannon-Weiener (H') index was considered for the present study. This index is applied to biological systems which are derived from a mathematical formula by Shannon (1948) (Turkmen and Kazancı, 2010):

$$H' = -\sum_{i=1}^{S} p_i \log_e p_i$$

where: pi: ni/n

s: a total number of species and

pi: number of individuals belonging to i species (ni) / total number of individuals (n) (Hill, 1973; Krebs, 1998; Kwak and Peterson, 2007; James and Aderaje, 2010).

Statistical analysis

The relationship between environmental variables and phytoplankton and zooplankton assemblages was analyzed using canonical correspondence analysis (CCA). CCA is useful for identifying environmental variables which are important in determination of community composition and the role of spatial variation in the communities (Black *et al*., 2004). In the multivariate analysis, the matrix abiotic data, phytoplankton communities and zooplankton communities were accounted for each station using the XLSTAT program (Braak and Smilauer, 2002). For hierarchical cluster analysis, the similarity between species and sites were calculated and a one-way ANOVA test was used to find the statistical differences in the physical and chemical variables using the SPSS software (version 20).

Results

In this study, it was observed the positive interaction between water quality parameters and plankton biomass in the Tortum Lake.

Chlorophyll-a ranged from 5.70 to 0.18 mgL^{-1}, pH from 9.01 to 7.22, temperature from 23.05 to 5.28 °C, dissolved oxygen from 13.68 to 1.54 mgL^{-1}, total orthophosphate from 0.01 to 0.00 mgL^{-1}, total hardness from 16.90 to 9.4 mgL^{-1} $CaCO_3$, Mg-hardness from 27.17 to 6.42 mgL^{-1} $CaCO_3$, and Ca-hardness from 9.64 to 5.72 mgL^{-1} $CaCO_3$, respectively (Table 1).

In our study, *C. hirundinella* (18%), *B. braunii* (51%), *C. microsphaerella* (25%), *M. aeruginosa* (7%), *M. varians* (1%), *M. contortum* (1%), Copepoda (66%), Daphnia (33%) and Keratella (1%) were found. In addition, phytoplankton biomass was calculated between 0.12 mgL^{-1} and 34.19 mgL^{-1} and zooplankton biomass range 0.08 mgL^{-1} to 36.72 mgL^{-1} (Fig. 3).

Chlorophyll-a value reached a peak during the months not only in March but also in June. Even though *B. braunii* and *C. microsphaerella* were reduced on phytoplankton biomass; *M. aeruginosa* was increased in phytoplankton biomass between January and April (Fig. 3).

The result of CCA based on eight variables are given in the table and illustrated in the figure. The proportion of species variance is explained by each axis. For ecological data the percentage of explained variance is usually low. The plankton communication had an eigen-value of 0.26 explaining 99.4% and environmental parameters had 0.001 explaining 0.46% variability (Tables 2 and 3).

Discussion

The present study showed that phytoplankton and zooplankton biomass was affected by temporal and spatial changes of water quality parameters (Fig. 2). According to of the obtained data on Chlorophyll-a, pH, temperature, dissolved oxygen (DO), total orthophosphate (PO_4-P), total hardness (TH), Mg-hardness and Ca-hardness, Tortum Lake is classified as the oligotrophic lake (Table 1) (Wetzel, 2001).

Kıvrak (2006) found *C. hirundinella, C. krammeri. C. glomerata* and *C. microsphaerella* in the Tortum Lake between 2002 and 2003. In addition, Bacillariophyta and Cyanobacteria (*M. aeruginosa*) were identified in 1982 (Akbay, 1982). In our study, *B. braunii* was identified the highest level in the lake, whereas *M. varians* and *M. contortum* were found the lower level (Fig. 3). Phytoplankton composition seems to respond quickly not only to the seasonal changes of environmental parameters but to anthropogenic disturbances. Phytoplankton communities are located in a competitive area and changes in water quality lead to the formation of high compositional diversity (Scheffer *et al*., 2003).

The variance of sample scores on each axis reflects the importance of the axis as measured by the mean value whereas the variances of the species scores along the axes are equal (Braak and Verdonschot, 1995).

Table 1: The simple statistic for physico-chemical parameters of Lake Tortum.

Parameter	Site	Mean	SD	Min.	Max.
Chl-a (mgL^{-1})*	1	1.66	1.53	.38	5.30
	2	1.81	1.89	.18	5.70
	3	1.08	.69	.37	2.48
Temp (°C)	1	13.12	5.32	5.95	23.05
	2	13.21	5.55	5.28	19.73
	3	13.44	5.07	5.55	19.53
PO_4-P (mgL^{-1})	1	.004	.003	.00	.01
	2	.003	.004	.00	.01
	3	.003	.004	.00	.01
DO (mgL^{-1})	1	10.06	3.81	1.54	13.48
	2	10.60	3.22	3.38	13.90
	3	10.67	3.51	4.17	13.68
pH	1	8.47	.52	7.22	9.01
	2	8.54	.24	8.21	8.94
	3	8.55	.20	8.23	8.86
Total Hardness (mgL^{-1} $CaCO_3$)	1	11.95	2.54	9.40	16.90
	2	12.25	1.87	10.10	15.88
	3	12.42	2.11	10.68	16.90
Mg-Hardness (mgL^{-1} $CaCO_3$)	1	13.08	5.35	6.42	24.64
	2	12.62	3.63	8.65	22.26
	3	13.65	4.82	8.94	27.17
Ca-Hardness (mgL^{-1} $CaCO_3$)	1	7.04	.84	5.80	8.52
	2	7.20	.88	5.94	9.16
	3	6.82	1.05	5.72	9.64

*Max. maximum. Min. minimum. SD standard deviation. $p<0.05$.

Table 2: Summary statistics for canonical correspondence analysis (CCA).

	F1	F2	F3	F4
Eigenvalue	0.267	0.001	0.000	0.000
Constrained inertia (%)	99.400	0.457	0.131	0.009
Cumulative %	99.400	99.857	99.988	99.996
Total inertia	33.697	0.155	0.044	0.003
Cumulative % (%)	33.697	33.852	33.897	33.900

The first axis was associated with Ca hardness, DO and pH, while the second axis was related to PO_4-P, total hardness, Mg hardness and water temperature. *M. varians* and Copepoda were positioned close to the center of ordination diagram. *M. aeruginosa* and Keratella were positioned on the positive side of the first axis, while *C.hirundinella* and *M.contortum* were positioned on the negative side of the second axis. The Chlorophyll-a in water surface remained the lowest during the fall season in Tortum Lake (Fig. 3). The Chlorophyll-a in water surface remained the highest during the summer season in all stations except the Outfall Bay, where the highest value was recorded in winter (Abdul Azis *et al*., 2003) (Figs. 5 and 6).

Chlorophyll-a is the primary photosynthetic pigment contained in algae.

Table 3: Canonical Correlation Analysis (CCA) of biotic and abiotic variations. The species names are abbreviated to the part in italic as follows: *Ceratium hirundinella* (CER HIR), *Botryococcus braunii* (BOT BRA), *Chlamydomonas microsphaerella* (CHL MIC), *Microcystis aeruginosa* (MIC AER), *Melosira varians* (MEL VAR), *Monoraphidium contortum* (MON CON), Copepoda (COPE), Daphnia (DAPH) and Keretella (KER).

Variables	BOT BRA	MIC AER	CER HIR	CHL MIC	MEL VAR	MON CON	DAPH	COPE	KER
BOT BRA	1	0.789	0.439	0.685	-0.064	0.207	-0.013	0.157	-0.079
MIC AER	0.789	1	0.392	0.718	-0.039	-0.034	-0.088	-0.068	-0.029
CER HIR	0.439	0.392	1	0.662	0.040	-0.060	-0.101	-0.078	0.071
CHL MIC	0.685	0.718	0.662	1	0.014	-0.041	-0.099	-0.073	-0.082
MEL VAR	-0.064	-0.039	0.040	0.014	1	-0.040	0.238	-0.044	-0.091
MON CON	0.207	-0.034	-0.060	-0.041	-0.040	1	-0.101	-0.004	0.195
DAPH	-0.013	-0.088	-0.101	-0.099	0.238	-0.101	1	0.379	-0.215
COPE	0.157	-0.068	-0.078	-0.073	-0.044	-0.004	0.379	1	0.053
KER	-0.079	-0.029	0.071	-0.082	-0.091	0.195	-0.215	0.053	1
Chl-a	-0.128	-0.027	-0.107	-0.083	0.404	0.033	-0.039	0.085	0.156
TOP	0.078	0.016	0.011	0.003	-0.132	-0.117	0.291	0.211	-0.286
Temperature	0.096	-0.061	0.175	0.030	-0.143	0.173	0.090	0.640	0.202
DO	0.071	0.233	0.100	0.222	0.153	-0.331	0.148	-0.297	-0.576
pH	-0.167	-0.320	0.242	0.173	0.153	0.009	-0.130	-0.037	-0.139
TS	-0.188	-0.310	-0.183	-0.144	-0.160	0.353	-0.126	0.081	0.479
Mg	-0.329	-0.280	-0.172	-0.175	-0.003	0.133	-0.161	-0.017	0.411
Ca	0.088	-0.001	-0.083	0.032	0.156	0.508	0.114	0.167	0.489

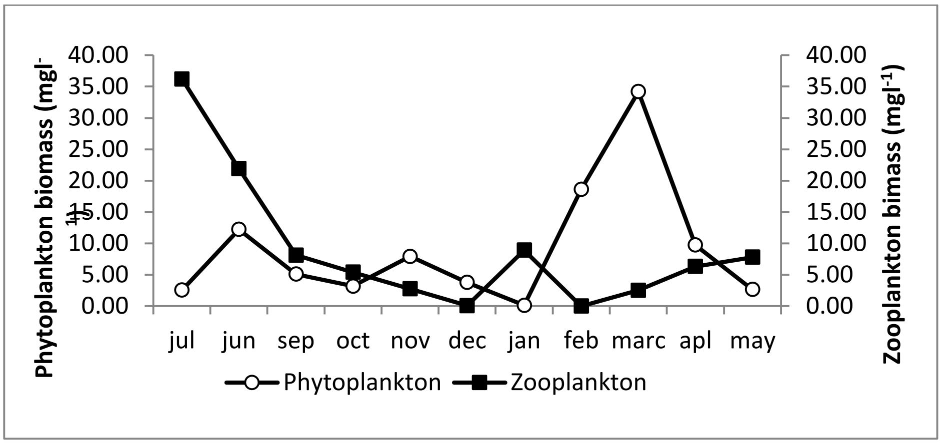

Figure 2: Seasonal variation of phytoplankton and zooplankton biomass.

Because Chlorophyll-a concentration can be easily measured in a water sample, it is a practical common way to estimate the phytoplankton biomass in the water bodies. In our study, the mean Chlorophyll-a was calculated as high value whilst phytoplankton biomass was calculated as less value in May due to grazing pressure by zooplanktons (Fig. 3). According to biodiversity indices, species diversity increased in winter season.

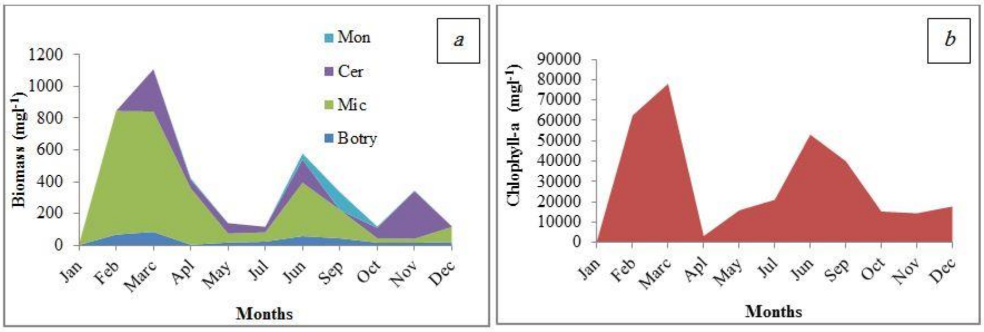

Figure 3: Seasonal variation of phytoplankton biomass (a) (Mon: *Monoraphidium contortum*, Cer: *Ceratium hirundinella*, Mic: *Microcystis aeruginosa* Botry: *Botryococcus braunii*) Seasonal variation of Chla: Chlorophyll-a (b).

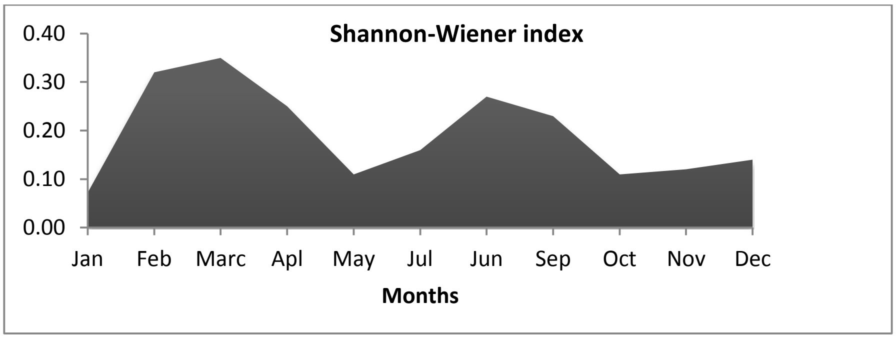

Figure 4: The variation of Shannon-Weiener diversity connects to months.

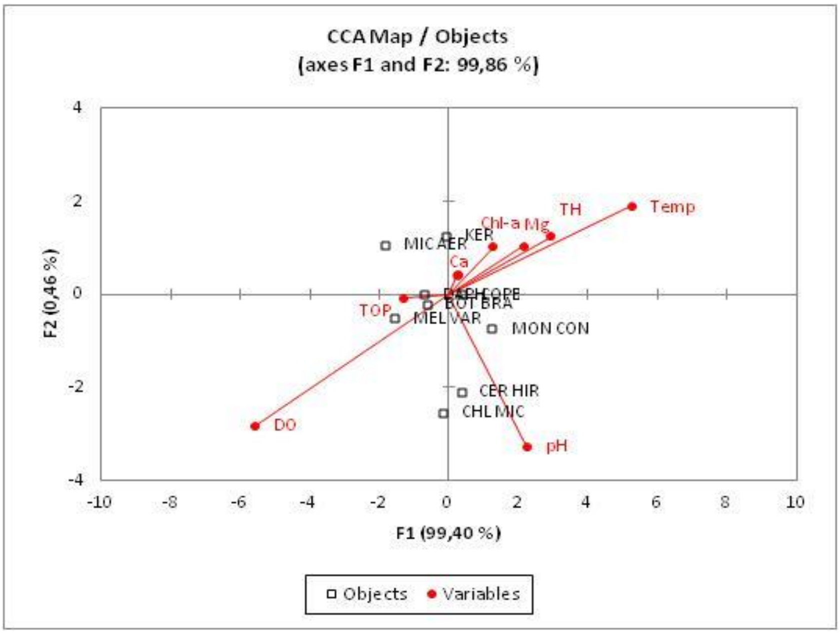

Figure 5: Species-conditional triplot based on a canonical correspondence analysis of the example phytoplankton and zooplankton data displaying 33.69% of the inertia (= weighted variance) in the abundances and 99.4 % of variance in the weighted averages and class totals of species with respect to the environmental variables. The eigenvalues of axis 1 (horizontally) and axis 2 (vertically) are 0.267 and 0.001, respectively; the eigenvalue of the axis 3 (not displayed) is 0.000. Species (triangles) are weighted averages of site scores (circles). Quantitative environmental variables are indicated by arrows. The species names are abbreviated to the part in italic as follows: *Ceratium hirundinella* (CER HIR), *Botryococcus braunii* (BOT BRA), *Chlamydomonas microsphaerella* (CHL MIC), *Microcystis aeruginosa* (MIC AER), *Melosira varians* (MEL VAR), *Monoraphidium contortum* (MON CON), Copepoda (COPE), Daphnia (DAPH) and Keretella (KER).

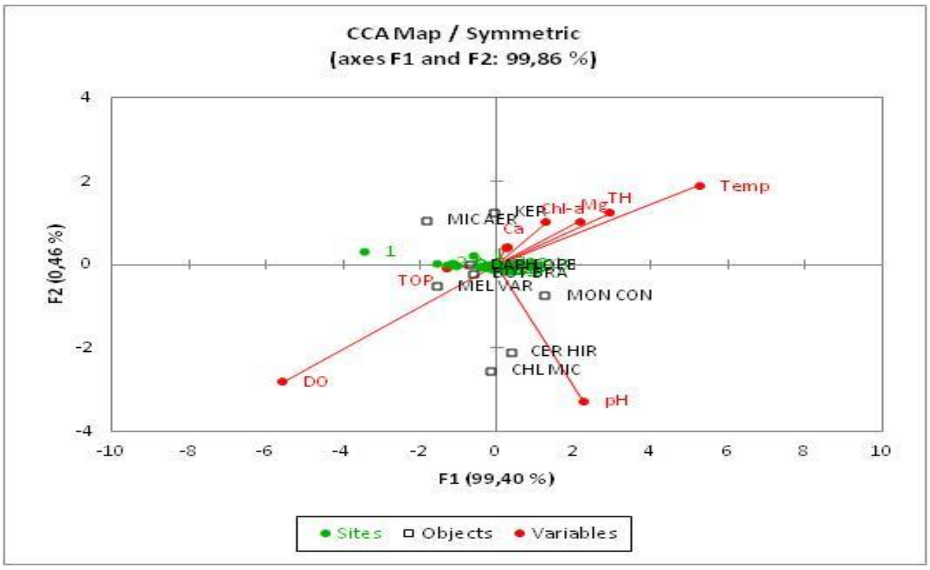

Figure 6: CCA of phytoplankton, zooplankton, environmental parameters and sites in Tortum Lake. The species names are abbreviated to the part in italic as follows: *Ceratium hirundinella* (CER HIR), *Botryococcus braunii* (BOT BRA), *Chlamydomonas microsphaerella* (CHL MIC), *Microcystis aeruginosa* (MIC AER), *Melosira varians* (MEL VAR), *Monoraphidium contortum* (MON CON), Copepoda (COPE), Daphnia (DAPH) and Keretella (KER).

Mostly, the main contributor to phytoplankton biomass was the dinophyte *C. hirundinella*, which is regarded as an indicator of meso-eutrophic waters (Wasielewska, 2006). In this study, some indicators of meso-eutrophic waters were determined such as *C. hirundinella* and *M. aeruginosa*. However, total orthophosphate concentration, total hardness and Ca hardness were found to be lower than the values of meso-eutrophic lakes (Table 3, Fig. 3).

Interaction between phytoplankton biomass and zooplankton biomass were found as negative correlation and statistically significant (r=-0.099, $p<0.05$) (Table 3). There was negative correlation between *C. hirundinella* and Daphnia, but positive correlation between temperature, pH, dissolved oxygen, and total ortophosphorus. The increased algal biomass together with higher water temperatures allow much earlier egg development as well as higher growth rates of protozoans, rotifer and crustacean zooplankton in lakes of temperate zone (Kalff, 2001).

The similarity between months and sites according to both phytoplankton and zooplankton were estimated through a hierarchical classification analysis. This method was also useful to verify the groups obtained from the CCA (Beamuda *et al*., 2010). All stations demonstrated similar characteristic in November, December, February and March. Sites 1 and 3 showed similarity in September, January and April, as well as site 2 and 3 in October and May because of location sites and a threat of domestic waste (Fig. 6).

We concluded that the Tortum Lake was affected by anthropogenic sources. Phytoplankton and zooplankton communities were able to flow the main seasonal changes of physical and chemical conditions in this lake. Our results demonstrated that long-term monitoring programs are needed due to protect the geological structure and eutrophication in this lake. Additionally, further research could be conducted on water bio-physico-chemical parameters and the effect of sediment characteristics on water quality.

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