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Research Article

Ecology of the Testate Amoeba *Arcella discoides* Ehrenberg, 1871 (Amoebozoa: Arcellinida) in the Büyükçekmece Reservoir, Turkey

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Abstract: Testate amoeba *Arcella discoides* Ehrenberg, 1871 is recorded from one of the most important drinking water resources of Istanbul, Büyükçekmece Reservoir in 2019. The study has been carried out during four sampling periods and at six stations. *Arcella discoides* is identified from three stations in only one sampling period, November 2019. According to the Spearman's rank correlation, the abundance of this species has positive correlation with salinity and total dissolved solids and negative correlation with pH, nitrite + nitrate-N and ammonium-N. *Arcella discoides* is recorded for the first time from the Turkish inland waters.

Key words: *Arcella*, ecology, freshwater testate amoebae, new record, Büyükçekmece Reservoir

Introduction

Testate amoebae are free-living heterotrophic protists with the shell-covered amoeboid cells (Wanner 1999, Bobrov 2014). They play an important role in food webs and energy flow (Jassey et al. 2015, Geisen et al. 2016) and are widespread in aquatic and terrestrial environments (Mazei & Tsyganov 2006). Lobose testate amoebae ingest prey such as bacteria, smaller protists, flagellates and ciliates through phagocytosis (Anderson 2016). In addition, some amoeboid protists live in highly contaminated environments with low pH and (or) highly potentially toxic minerals or industrial waste products; therefore, these groups are considered as good indicators of eutrophication processes, domestic and industrial pollution (Escobar et al. 2008, Roe et al. 2010, Anderson 2016).

There are a few studies on recent (Payne et al. 2008, Bobrov 2014, Varol et al. 2015) and fossil (Kutluk & Mazei 2018) testate amoebae in Turkey. The aim of this study is to describe ecological conditions facilitating the development of *A. discoides* in the Büyükçekmece Reservoir, Turkey.

Materials and Methods

The Büyükçekmece Reservoir, which was one of the coastal lagoons of the Sea of Marmara in the past, was disconnected from the sea with an 11.40 m-high earth-filled dam constructed by the General Directorate of State Hydraulic Works (DSI) in 1985 to meet the drinking and utility water requirement of Istanbul (DSI 1985). After the disconnection of the lake from the sea, significant ecological changes have occurred in this lake, especially associated with the reduced

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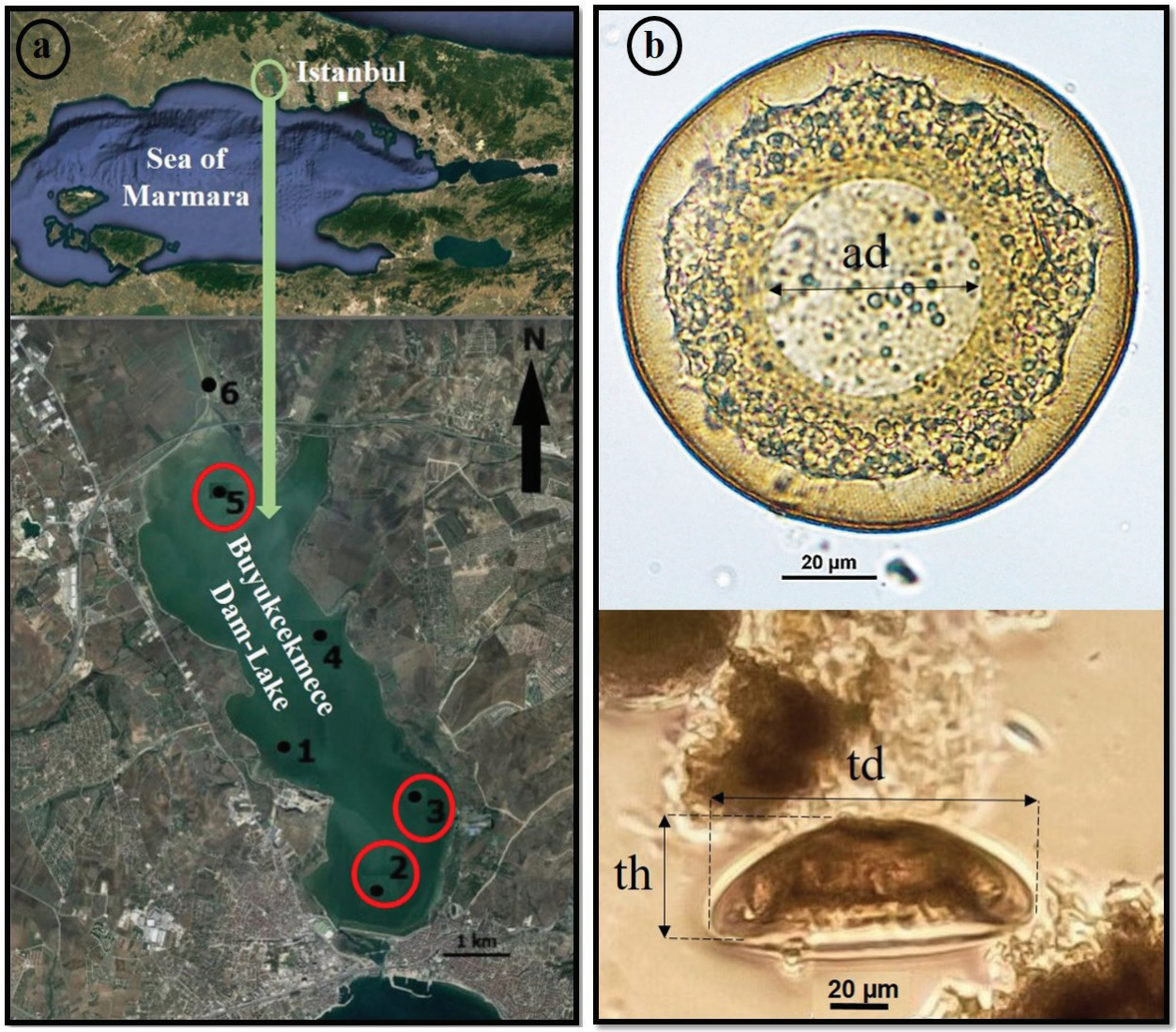

Fig. 1. a. Stations in the Büyükçekmece Reservoir; **b.** Apertural and lateral view of *Arcella discoides*. Abbreviations: ad, aperture diameter; th, test height; td,– test diameter.

salinity of the water. The reservoir provides about 149 hm^3 (17%) of the drinking water for the Istanbul Province (Istanbul Water and Sewerage Administration 2018). The area of the lake is 2850 hectares, the water catchment basin is 622 km^2 (DSI 1985) and its depth is 8.6 m (Gulecal & Temel 2014).

The study was carried out during four sampling periods (February, May, September and November) in 2019. Samples were collected from the surface waters (0.5 m) of six stations (Fig. 1a), using a plankton net with 20 µm mesh sizes and preserved in 4% formaldehyde buffered with borax.

To determine the main physical and chemical variables of the water in the reservoir, water samples were taken with a 3L-water sampler. Water temperature, salinity, dissolved oxygen, pH and total dissolved solids (TDS) were measured with YSI-556 model multiple probe. In order to determine the nutrients, water samples were collected in 100 mL polyethylene bottles and stored at -20 °C in a deep freeze until analysis in the laboratory. The nitrate + nitrite-N (NO_2+NO_3-N) concentration was determined using the cadmium reduction method in a Seal Analytical continuous-flow autoanalyzer 3 (APHA 1999). The ammonium-N (NH_4-N) was measured with the indophenol blue method (Harwood & Kuhn 1970). The phosphate-P (PO_4-P) and silicate-Si were analysed according to Parsons et al. (1984).

Identification of the species were made with Olympus CK2 phase-contrast and BX51 light microscopes using Ogden & Hedley (1980), Mazei & Tsyganov (2006) and Lahr & Lopes (2009) identification guides. Adl et al. (2019) was used for the classification. To determine the quantitative distribution of *A. discoides*, samples were collected from the surface water (0.5 m) of the stations by

Table 1. Physical and chemical variables in the Büyükçekmece Reservoir at different stations and during different months.

Variables	Sampling Periods	1	2	3	4	5	6
Temperature (°C)	February	6.66	6.87	5.01	5.22	5.81	6.80
	May	22.15	21.81	19.12	20.52	22.86	23.87
	September	19.31	18.91	18.21	18.68	18.31	18.33
	November	14.03	13.85	13.61	13.59	13.51	13.56
Salinity (‰)	February	0.29	0.29	0.33	0.29	0.29	0.34
	May	0.29	0.46	0.28	0.28	0.28	0.65
	September	0.56	0.56	0.58	0.56	0.56	0.57
	November	0.57	0.57	0.60	0.57	0.57	0.57
Dissolved oxygen (mg/L)	February	14.38	17.40	14.96	14.54	14.31	25.14
	May	6.38	6.41	7.23	6.49	7.30	7.34
	September	9.61	7.86	9.12	10.91	10.76	12.61
	November	8.22	8.19	11.30	10.91	9.21	9.61
pH	February	8.1	8.2	8.0	8.0	8.2	8.2
	May	8.0	8.0	7.9	7.9	8.1	7.9
	September	7.9	8.0	8.0	7.9	8.0	7.9
	November	7.8	7.8	7.8	7.8	7.8	7.8
TDS (g/L)	February	0.39	0.39	0.39	0.39	0.39	0.46
	May	0.39	0.38	0.38	0.38	0.38	0.44
	September	0.73	0.73	0.76	0.73	0.72	0.75
	November	0.74	0.74	0.77	0.74	0.78	0.74
$NO_2 + NO_3$-N (µg-at N/L)	February	83.73	95.22	91.07	93.46	92.62	87.28
	May	89.03	94.31	96.21	92.62	91.85	85.63
	September	13.00	14.92	12.31	13.58	7.58	1.54
	November	1.65	0.69	1.73	1.65	7.73	6.04
NH_4-N (µg-at N/L)	February	1.26	1.42	0.32	0.95	0.32	0.32
	May	0.16	0.32	0.32	0.47	0.32	4.74
	September	0.39	0.17	0.29	0.19	0.91	0.06
	November	0.12	0.06	0.08	0.37	0.17	0.41
PO_4-P (µg-at P/L)	February	21.13	10.74	9.61	23.17	26.61	30.26
	May	5.43	5.43	6.52	14.70	29.35	79.13
	September	5.78	5.30	5.10	2.35	4.63	4.62
	November	1.84	1.14	0.69	0.98	1.00	2.84
SiO_4-Si (µg-at Si/L)	February	113.74	120.06	114.24	117.75	125.88	166.80
	May	27.28	23.37	9.13	22.47	26.08	85.16
	September	13.76	13.88	6.19	12.68	12.75	13.94
	November	12.72	9.17	2.32	8.04	14.59	16.87

water samplers into 1-L non-transparent bottles and fixed with lugol (Throndsen 1978). The abundance of *A. discoides* in the precipitated samples was determined using the Sedgewick-Rafter counting chamber with a capacity of 1 ml (Semina 1978). Spearman's correlation coefficient (r_s) was used to detect any correlation between the abundance of *Arcella discoides* and the ecological variables (Siegel 1956).

Results

The newly recorded species was identified at three stations (stations 2, 3 and 5) in the Büyükçekmece Reservoir only in November. Diagnostic morphological characters of this testate amoeba species are described below and original photographs are presented (Fig. 1b).

Classification: supergroup Amoebozoa Lühe, 1913, sensu Cavalier-Smith, 1998; phylum Tubu-

Table 2. Spearman's rank correlation matrix showing the results of correlation analyses between abundance of *Arcella discoides* and ecological variables. Legend: $^{**}P < 0.01$, $^{*}P < 0.05$; Temp: Temperature, Sal: Salinity, DO: Dissolved oxygen, TDS: Total dissolved solids

	Temp	Sal	DO	pH	TDS	NO_2+NO_3-N	NH_4-N	PO_4-P	SiO_4-Si
Sal	.012								
DO	-.829**	.021							
pH	.145	-.435*	.063						
TDS	-.256	.872**	.234	-.503*					
NO_2+NO_3-N	.063	-.790**	-.071	.490*	-.858**				
NH_4-N	-.105	-.328	.209	.324	-.472*	.476*			
PO_4-P	-.274	-.392	.208	.200	-.452*	.434*	.492*		
SiO_4-Si	-.301	-.527**	.339	.534**	-.555**	.604**	.466*	.719**	
Abundance of *A. discoides*	-.179	.415*	-.023	-.501*	.500*	-.416*	-.477*	-.213	-.343

linea Smirnov et al., 2005; class Elardia Kang et al., 2017; order Arcellinida Kent, 1880; family Arcellidae Ehrenberg, 1843; genus *Arcella* Ehrenberg, 1832; *Arcella discoides* Ehrenberg, 1871.

The genus *Arcella* is one of the largest testacean genera whose tests are made up by chitinous secreted material. They have a single main opening. Test is yellowish brown. Circular aperture centrally placed on ventral side and surrounded by numerous small pores. Aperture diameter 46–58 µm, shell diameter 108–131 µm. Shell is disc-shaped in lateral view, 32–38 µm high; shell height/ diameter ratio 0.275–0.317.

The abundance of this species varied between 20, 30 and 50 individuals per litre at stations 2, 3 and 5, respectively. When *A. discoides* was found in the surface waters of the sampled stations, the water temperature ranged 13.5–13.9 ºC and the salinity was 0.6 ‰. The dissolved oxygen was 8.2–11.3 mg/L. The values of the other environmental parameters was as follows: pH – c. 7.8; total dissolved solids – 0.7–0.8 g/L; NO_2+NO_3-N – 0.7–7.7 µg-at N/L; NH_4-N – 0.1–0.2 µg at N/L; PO_4-P – 0.2–0.3 µg-at P/L; SiO_4-Si – 2.3–14.6 µg-at Si/L (for variations, see Table 1).

According to the Spearman's rank correlation coefficient (Table 2), the abundance of *A. discoides* was positively related with salinity and TDS ($P < 0.05$), while there was a negative relationship with pH, NO_2+NO_3-N and NH_4-N ($P < 0.05$). In particular, decrease in nitrogen and pH amounts was noticeable in November 2019. Although there was a positive correlation between salinity and the abundance of *A. discoides*, it is considered that there is no significant difference in terms of the salinity values, since the alteration between the sampling periods is less than 0.3‰.

Discussion

The genus *Arcella* is common and widespread (Deflandre 1928, Ogden & Hedley 1980). All species in this genus have two or more vesicular nuclei (Tsyganov et al. 2016) and this feature is characteristic for the genus. The species identified from the Büyükçekmece Reservoir is characterised by shell height/shell diameter ratio of 0.2–0.3 that falls into the 'short teste' group distinguished by Deflandre (1928). Patterson (1996) stated that the genus *Arcella* is colourless, but the species of the genus are becoming brown when they absorb metal salts from the environment. In our study, the species was yellowish-brown.

Nitrogen and pH were low in November when the species was observed and correlation showed negative relationship. Similar to our findings, the abundance of *A. discoides* was reported to show a positive relationship with TDS and a negative correlation with pH in a study conducted in Bhereki beel (Sharma & Hatimuria 2017). Moreover, Biyu (2000) stated that testaceans were abundant in autumn and *A. discoides* was observed in autumn and early summer (Kamble et al. 2013). According Mishra & Saksena (1990), this species is dominant in spring. As can be seen, *A. discoides* may vary in different habitats and different periods in terms of abundance. It is known that environmental conditions and hydrodynamic characteristics of the environment influence the richness, abundance and dominance pattern of the testate amoebae communities (Schwind et al. 2016).

We show that the abundance of *A. discoides* is correlated with water conductivity. In a study, in which the chemical content of rainwater on the lake was determined (Basak & Alagha 2004), it has been

observed that cation concentrations (i.e. Al^{3+}, Fe^{3+} and Ca^{2+}) are high due to the activity of a cement factory in the region, which used calcium-, silicon-, iron- and aluminium-rich ores. In a study that examined the air pollution in the region of our study (Karaca et al. 2006), it has been reported that chrome concentrations are high. These cations have the ability to accumulate in the water environments. The presence of the genus *Arcella* may indicate the presence of domestic or industrial pollution in the area studied by us. However, further studies are needed for comprehensive understanding of the indicator importance of this newly-discover species in Turkish inland waters.

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