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Research Article

Investigation of groundwater zooplankton fauna from water wells in Yayladağ district of Hatay Province in Turkey

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Keywords

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ABSTRACT

Some water quality parameters (water temperature, conductivity and pH) and zooplankton fauna were investigated in 10 water wells. Fourteen (14) species of Rotifera (46.67%), 10 species of Copepoda (33.33%), and 6 species of Cladocera (20%) were recorded. It was observed that the most widely distributed species are *Rotaria neptunia* (7 wells), *Keratella quadrata* (5 wells), *Daphnia curvirostris* (8 wells), *Coronatella rectangula* (in 6 wells), *Chydorus sphaericus* and *Pleuroxus aduncus* (5 wells each), *Megacyclops viridis* (8 wells) and *Tropocyclops prasinus* (in 6 wells). Most species (14 species) were found in well 8, followed by wells 3, 5, 7 and 9 with 11 species. There was a significant and positive relationship between zooplankton species diversity, abundance, and water quality parameters. It can be concluded that some of the rotifer and cladocer species and most of the copepod species in the study are groundwater compatible species.

Introduction

Well water is used for drinking and irrigation by the vast majority of the rural population in Turkey as well as other domestic uses. Wells can be located at different depths depending on the water table.

Groundwater does not only provide water for human consumption but also habitats that supports a diverse range of species dominated by freshwater zooplankton, such as rotifers, cladocerans, and copepods (Brancelj et al., 2013).

Groundwater fauna are those that live in groundwater systems or aquifers such as caves, fissures and caverns (Lopes et al., 1999). Extensive studies on groundwater fauna have been conducted in many countries around the world (Zektser and Everett 2004), and because many of these species are native to specific regions and individual caves, they have become an important focus for the protection of groundwater systems (Doveri, et al., 2015).

For more than 250 years, groundwater fauna from cracks and intergranular aquifers has been researched (Botosaneanu, 1986). Over 6700 stigobites have been identified worldwide to date (Galassi, 2001; Galassi et al., 2009) and Europe is home to approximately 1800 stigobites (Gibert and Culver, 2009). In the 1990s, the number of ecological studies in groundwater ecosystems, particularly in intergranular aquifers, increased dramatically (Hancock et al., 2005; Danielopol and Griebler, 2008). The hyporean zone has received extensive research in the past and present (Boulton et al., 2003; Di Lorenzo et al., 2013) while deeper aquifer zones, such as the phreatic zone, have received relatively little attention and remain a research frontier for freshwater ecology (Larned, 2012). Limited number of faunal and ecological studies indicated that the deeper parts of the groundwater zone are habitats with very specific fauna (Stoch et al., 2009; Di Lorenzo et al., 2013) but detailed information is still lacking.

Zooplankton are important in freshwater ecosystems because they act as a link between primary producers and top consumers. Moreover, zooplankton is a good bioindicator due to its sensitivity to environmental conditions (Papa et al., 2012; Papa and Briones, 2014), which makes it a suitable indicator of environmental change that can be used to determine the current ecological status of most freshwater ecosystems.

Freshwater zooplankton research in Turkey concentrated mainly on surface waters such as rivers and lakes with little or no attention given to groundwater and groundwater-dependent ecosystems such as caves, open wells, springs and piped

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groundwater pumps. Diversity of freshwater zooplankton in surface waters has been said to parallel that in groundwater ecosystems, especially for copepods (Galassi et al., 2009). Groundwater diversity studies, like surface water studies, can provide information needed to maintain sustainable biodiversity for this type of ecosystem, as well as useful biological indicators of connectivity between subsurface and surface waters.

Based on the observed research deficiencies, zooplankton fauna and some water quality parameters were investigated in 10 water wells in Yayladağı district of Hatay Province to determine groundwater zooplankton in Turkey.

Materials and Methods

Water sampling and analysis

Water temperature (°C) was determined in-situ with a model YSI-52 oxygen meter, pH with a model YSI 600 pH meter, and conductivity (µS cm^{-1}) with a model YSI-30 salinometer.

Zooplankton Sampling and Analysis

Zooplankton samples were collected by vertical hauls of a standard mesh (60 µm mesh) in four seasons–summer (June 2019), fall (November 2019), winter (February 2020) and spring (May 2020) from 10 different water wells located within the borders of the Yayladağı District of Hatay Province (Figure 1). Table 1 shows the sampling coordinates of the wells, the depth of the wells from the surface to the bottom, the water depth at the time of sampling, and the well widths.

A 0.5 kg metal weight was attached to the bottle of the net and the net was lowered to the bottom of well. The net was used to stir the well water vigorously to enable proper mixing of the zooplankton in the benthic layers with the water. The net was then raised, and 10 replicates were collected at each well.

After sampling, the zooplankton samples were fixed and preserved in 4% formalin, and later examined in a mixture of distilled water and glycerol.

Zooplankton species were examined and identified using an inverted microscope and a binocular microscope (Olympus CH40). The specimens were identified using Borutsky (1964), Scourfield and Harding (1966), Dussart (1969), Damian-Georgescu (1970), Ruttner-Kolisko (1974), Smirnov (1974), Kiefer (1978), Koste (1978), Negrea (1983), Korinek (1987), Segers (1995), and Galassi and De Laurentiis (2004).

The zooplankton fauna was estimated by occurrence rather than counting method. They were rated as absent (-), very little (┴), little (+), abundant (++), and very abundant (+++).

Results

Water temperature varied between 12.48±1.47°C (winter) and 21.21±0.96°C (summer), with an annual mean of 18.05±3.70°C (Table 2). The pH value did not change significantly among the wells. The maximum, minimum, and annual mean pH values were 8.59±0.23 (spring), 8.02±0.46 (winter) and 8.29±0.38 respectively (Table 2). The conductivity value ranged from 505.30±186.52 µS cm^{-1} (winter) to 649.00±190.87 µS cm^{-1} (spring) with an annual mean value of 610.18±185.77 µS cm^{-1} (Table 2).

Fourteen (14) species of Rotifera (46.67%), 10 species of Copepoda (33.33%), and 6 species of Cladocera (20.00%) were recorded in the wells (Table 3). A total of 10 families were recorded among Rotifera. Brachionidae was the richest family with 4 species, followed by Lecanidae with 2 species each. Other families, Gastropodidae, Notommatidae, Lepadellidae, Mytilinidae, Synchaetidae, Testudinellidae, Hexarthridae and Philodinidae were each represented by one species. Three families were recorded among Cladocera. Chydoridae was the richest family with 4 species, and the other two families (Daphnidae and Bosminidae) were represented by one species each (Table 3).

Among the 5 families of Copepoda, Cyclopoidae had 6 species, and the other four families (Diaptomidae, Parastenocarididae, Ameiridae and Phyllognathopodidae) were represented by one species each (Table 3).

According to Table 4, the rotifers with the largest distributions were Rotaria neptunia (recorded in 7 wells), Keratella quadrata (5 wells) and Synchaeta styllata (4 wells). For the Cladocera,

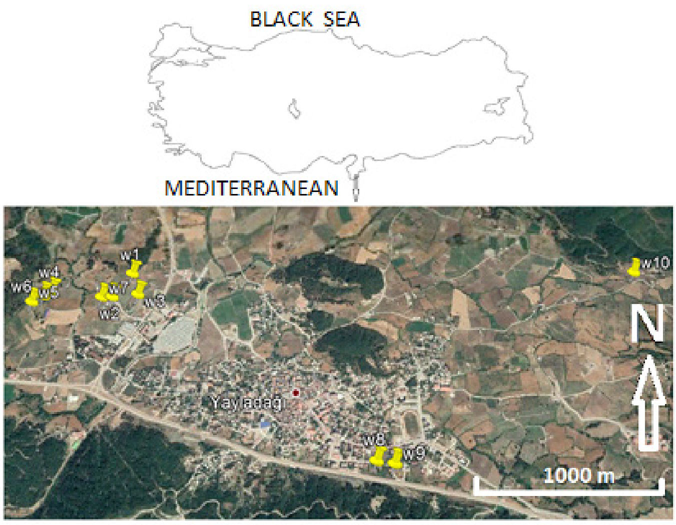

Figure 1. Study area and wells

Daphnia curvirostris, recorded in 8 wells, had the largest distribution range, followed by *Coronatella rectangula* (6 wells) and *Chydorus sphaericus* and Pleuroxus aduncus (5 wells each). On the other hand, *Megacyclops viridis* had the largest distribution range (8 wells), followed by *Tropocyclops prasinus* (6 wells) and *Macrocyclops albidus* (4 wells) among the copepods.

Some zooplankton species had limited distribution and were recorded in very few wells. *Ascomorpha ovalis, Cephalodella tenuiseta, C. uncinata, Keratella cochlearis, Kellicottia longispina, Lecane closterocerca* and *Hexarthra fennica* (Rotifera) and

Table 1. Coordinates, depth, width, and water depth of wells

Station	Latitude	Longitude	Well depth (m)	Water depth (m) 2019 30/06	2019 16/11	2020 22/02	2020 15/05	Well width (m)
Well 1	35° 54′48.78″N	36° 03′09.58″E	8.70	7.20	8.60	8.70	7.05	3.00
Well 2	35° 54′51.46″N	36° 03′09.56″E	9.00	7.80	6.70	9.00	9.00	4.00
Well 3	35° 54′53.27″N	36° 03′10.27″E	7.65	5.75	5.80	5.30	4.90	4.00
Well 4	35° 54′53.97″N	36° 02′76.81″E	5.10	2.30	1.75	3.90	3.15	3.00
Well 5	35° 54′49.58″N	36° 02′70.44″E	4.00	2.10	2.35	2.44	2.20	3.20
Well 6	35° 54′51.66″N	36° 02′70.44″E	3.40	2.60	2.65	2.85	2.65	2.40
Well 7	35° 54′46.99″N	36° 03′04.02″E	6.30	4.10	5.40	5.60	4.60	3.00
Well 8	35° 53′92.82″N	36° 04′04.11″E	8.00	2.10	1.60	3.70	2.05	2.40
Well 9	35° 53′91.99″N	36° 04′10.45″E	5.00	2.60	2.50	4.50	2.50	2.20
Well 10	35° 54′56.72″N	36° 05′07.13″E	5.40	4.15	1.80	0.50	2.70	3.00

Table 2. Summary of the seasonal variations of the physicochemical parameters

Seasons/ Parameters	Temp (°C)	pH	Ele. Cond. (µS cm^{-1})
Summer 2019	21.21±0.96	8.36±0.30	643.40±184.89
Fall 2019	19.48±0.79	8.19±0.29	643.00±166.79
Winter 2020	12.48±1.47	8.02±0.46	505.30±186.52
Spring 2020	19.09±2.69	8.59±0.23	649.00±190.87
Annual Mean	18.05±3.70	8.29±0.38	610.18±185.77

Paracyclops chiltoni, Kinnecaris xanthi, Nitocrella stammeri and *Phyllognathopus viguieri* (Copepoda) were recorded in one well each (Table 4).

Most species (7 species) of Rotifera were found in well 8, followed by wells 1 and 6 with 4 species. Most species of Cladocera were found in well 9 (5 species) followed by wells 3, 5, 7 with 4 species each. Most species of Copepoda were found in well 1, 3, 5, 7 and 8 (4 species) followed by 3 species in well 2 and 9 (Table 4). In terms of total number of zooplankton species, well 8 was the richest with 13 species followed by wells 3, 5, 7, 9 with 11 species and well 1 with 10 species (Table 4). Though the wells were rich in species of rotifers and copepods, they were poor in Cladocera. Six of the 14 Rotifera species and four of the six Cladocera species were plentiful in different seasons and wells, but none of the ten copepoda species reached the same degree of abundance as the rotifers and cladocerans (Table 5). In spring, *R. neptunia* (Rotifera) was abundant in well 5 and D. curvirostris (Cladocera) was abundant in well 3 (++), while *S. stylata* (Rotifera) was very abundant in well 5 (+++) (Table 5). In summer, *A. ovalis* and *K. quadrata* in well 6, *D. curvirostris* and *C. sphaericus* in well 7 were very abundant, but *S. stylata* in well 6, *D. curvirostris* in wells 5 and 10, *C. rectangula* in wells 4 and 9 and *P. aduncus* in well 5 were abundant (Table 5). In autumn, *H. fennica* and *R. neptunia* (Rotifera) were very abundant (+++) in wells 4 and 5, respectively, while *L. pyriformis* and *S. stylata* were very abundant (++) in wells 8 and 5, respectively. For the *Cladocera*, *D. curvirostris* were abundant in wells 3 and 7 (Table 5). In winter, *R. neptunia* (Rotifera) in well 5, of *D. curvirostris* (Cladocera) in well 3 were abundant (Table 5). The copepod species were recorded in very low and low abundance in all wells and seasons.

There was a significant positive correlation between the number of zooplankton species and temperature (R^2=0.61), pH (R^2=0.90), and conductivity (R^2=0.90) (Table 6). Similarly, a significant positive correlation was observed between the abundance of zooplankton and temperature (R^2=0.52), pH (R^2=0.83), and conductivity (R^2=0.89) (Table 6).

Discussion

Biological and chemical processes are among the most important environmental parameters controlled by temperature, and they also influence the species diversity and density of zooplankton in aquatic ecosystems (Herzig, 1987; Sharma et al., 2007). Biological activity in water increases with temperature and biochemical reactions accelerate in a way that affects the reproduction, feeding and metabolic activities of aquatic organisms (Taș et al., 2010). Seasonally changing temperature caused differences in zooplankton abundance (Rossetti et al., 2009). Water temperature varied between 12.48 and 21.21°C and a positive significant relationship between temperature and zooplankton was observed. Similarly Dorak (2013), reported that zooplankton composition and abundance are significantly influenced by environmental parameters, especially water temperature and nutrients, and generally, high zooplankton abundance is associated with high water temperature.

Table 3. The zooplankton species recorded in the wells

	Rotifera	*	**
Gastropodidae	*Ascomorpha ovalis* (Bergendahl, 1892)	-	+
Notommatidae	*Cephalodella tenuiseta* (Burn, 1890)	+	-
Lepadellidae	*Colurella uncinata* (Müller, 1773)	-	+
Lecanidae	*Lecane pyriformis* (Daday, 1905) *Lecane closterocerca* (Schmarda, 1859)	+ -	- +
Mytilinidae	*Mytilina bisulcata* (Lucks, 1912)	+	-
Synchaetidae	*Synchaeta stylata* (Wierzejski, 1893)	-	+
Testudinellidae	*Testudinella patina* (Hermann, 1783)	-	+
Hexarthridae	*Hexarthra fennica* (Levander, 1892)	+	-
Philodinidae	*Rotaria neptunia* (Ehrenberg, 1830)	+	-
	Cladocera		
Bosminidae	*Bosmina longirostris* (Müller, 1785)	-	+
Daphniidae	*Daphnia curvirostris* Eylman, 1887	+	-
Chydoridae	*Chydorus sphaericus* (Muller 1776) *Coronatella rectangula* (Sars, 1862) *Pleuroxus aduncus* (Jurine, 1820) *Leydigia acanthocercoides* (Fischer, 1854)	- + - -	+ - + +
Copepoda			
Cyclopidae	*Diacyclops languidus* (Sars, 1863) *Eucyclops serrulatus* (Fischer, 1851) *Macrocyclops albidus* (Jurine, 1820) *Megacyclops viridis* (Jurine, 1820) *Paracyclops chiltoni* (Thomson, 1883) *Tropocyclops prasinus* (Fischer, 1860)	- + - - + -	+ - + + - +
Diaptomidae	*Eudiaptomus drieschi* (Poppe and Mrazek, 1895)	-	+
Parastenocarididae	*Kinnecaris xanthi* (Bruno & Cottarelli, 2015)	+	-
Ameiridae	*Nitocrella stammeri* (Chappuis, 1938)	+	-
Phyllognathopodidae	*Phyllognathopus viguieri* (Maupas, 1892)	+	-

*: recorded only in this study; **: recorded in this study and Bozkurt and Bozça (2019). (+: present, -: absent)

Table 4. Zooplankton species in different water wells

Species wells	1	2	3	4	5	6	7	8	9	10
Rotifera										
Ascomorpha ovalis	-	-	-	-	-	+	-	-	-	-
Cephalodella tenuiseta	-	-	-	-	-	-	-	+	-	-
Colurella uncinata	-	-	-	-	-	-	-	+	-	-
Brachionus urceolaris	+	-	-	-	-	-	+	-	-	-
Keratella quadrata	-	-	+	-	-	+	+	+	-	+
Keratella cochlearis	-	-	-	-	-	-	-	-	+	-
Kellicottia longispina	-	-	-	-	-	-	-	+	-	-
Lecane closterocerca	-	-	-	-	+	-	-	-	-	-
Lecane pyriformis	+	-	-	-	-	-	-	+	+	-
Mytilina bisulcata	-	+	+	-	-	-	-	-	+	-
Synchaeta stylata	+	-	-	-	+	+	-	+	-	-
Testudinella patina	-	-	+	-	-	-	-	-	-	+
Hexarthra fennica	-	-	-	+	-	-	-	-	-	-
Rotaria neptunia	+	+	-	+	+	+	+	+	-	-
Number of rotifer species	**4**	**2**	**3**	**2**	**3**	**4**	**3**	**7**	**3**	**2**
Cladocera										
Bosmina longirostris	-	+	-	-	-	-	+	-	+	-
Daphnia curvirostris	+	+	+	+	+	-	+	+	-	+
Chydorus sphaericus	+	-	+	-	-	+	+	-	+	-
Coronatella rectangula	-	+	+	-	+	+	+	-	+	-
Pleuroxus aduncus	-	-	+	-	+	+	-	+	+	-
Leydigia acanthocercoides	-	-	-	-	+	-	-	-	+	-
Number of cladoceran species	**2**	**3**	**4**	**1**	**4**	**3**	**4**	**2**	**5**	**1**
Copepoda										
Diacyclops languidus	-	-	-	-	-	-	-	+	+	+
Eucyclops serrulatus	-	+	+	-	-	-	+	-	-	-
Macrocyclops albidus	-	-	+	-	+	+	-	-	+	-
Megacyclops viridis	+	+	+	+	+	+	+	+	-	-
Paracyclops chiltoni	+	-	-	-	-	-	-	-	-	-
Tropocyclops prasinus	+	+	+	+	+	-	+	-	-	-
Eudiaptomus drieschi	+	-	-	-	+	-	+	-	-	-
Kinnecaris xanthi	-	-	-	-	-	-	-	+	-	-
Nitocrella stammeri	-	-	-	-	-	-	-	+	-	-
Phyllognathopus viguieri	-	-	-	-	-	-	-	-	+	-
Number of copepod species	**4**	**3**	**4**	**2**	**4**	**2**	**4**	**4**	**3**	**1**
Total zooplankton species	**10**	**8**	**11**	**5**	**11**	**9**	**11**	**13**	**11**	**4**

One of the important factors that affect aquatic life is the pH, which is the acidity and alkalinity of water. The pH values recorded in the wells were slightly alkaline; ranging between 8.02 and 8.59. The Ministry of Forestry and Water Affairs of the Republic of Turkey (OSIB, 2015) set the optimum pH for freshwater to be between 6.5 and 8.5 in the regulation of Quality Criteria for Turkish Surface Water Resources. There are certain pH ranges that are tolerated by living organisms (Boyd, 1990). pH can affect zooplankton abundance; low pH causes decreased zooplankton abundance, biodiversity and the extinction of some species (Yamada and Ikeda, 1999; Ivanova and Kazantseva, 2006), whereas alkaline conditions associated with high primary production favor zooplankton growth and abundance (Bednarz et al., 2002; Mustapha, 2009).

Conductivity was between 505.30 and 649.00 µScm^{-1}. Although the electrical conductivity in freshwater varies between 400 and 3000 µS cm^{-1}. Zooplankton groups differ between high and low conductivity lakes, species diversity decreases with increasing conductivity (Tavsanoglu et al., 2015). Although the conductivity

Table 5. Checklist of Zooplankton in the water wells by seasons

Species wells	1	2	3	4	5	6	7	8	9	10
Rotifera					**Summer 2019**					
Ascomorpha ovalis	-	-	-	-	-	+++	-	-	-	-
Cephalodella tenuiseta	-	-	⊥	-	-	-	-	-	-	⊥
Colurella uncinata	-	-	-	-	-	-	-	⊥	-	-
Brachionus urceolaris	⊥	-	⊥	⊥	-	-	⊥	-	-	-
Keratella quadrata	-	-	-	-	-	+++	+	-	-	-
Keratella cochlearis	-	-	-	-	-	-	-	-	⊥	-
Lecane pyriformis	-	⊥	⊥	-	-	⊥	-	⊥	⊥	-
Mytilina bisulcata	-	-	-	-	-	-	-	-	-	⊥
Synchaeta stylata	-	-	-	-	-	++	-	-	-	-
Testudinella patina	-	-	-	⊥	-	-	-	-	-	-
Rotaria neptunia	-	-	-	-	-	⊥	-	⊥	-	-
Cladocera										
Bosmina longirostris	-	-	-	-	-	-	⊥	-	-	-
Daphnia curvirostris	-	⊥	+	-	++	⊥	+++	⊥	-	++
Chydorus sphaericus	⊥	⊥	-	-	-	-	+++	-	+	+
Coronatella rectangula	-	-	⊥	++	+	-	+	-	++	-
Pleuroxus aduncus	-	-	-	-	++	⊥	-	-	⊥	-
Leydigia acanthocercoides	-	-	-	-	-	-	-	-	⊥	-
Copepoda										
Diacyclops languidus	-	⊥	⊥	-	-	-	-	+	-	-
Macrocyclops albidus	-	-	-	-	⊥	-	-	-	-	-
Megacyclops viridis	⊥	-	⊥	-	-	⊥	⊥	-	-	-
Paracyclops chiltoni	-	⊥	-	-	-	-	-	-	-	-
Tropocyclops prasinus	⊥	-	-	⊥	⊥	-	+	-	-	⊥
Nitocrella stammeri	-	-	-	-	-	-	-	⊥	-	-
Phyllognathopus viguieri	-	-	-	-	-	-	-	-	⊥	-
Rotifera					**Fall 2019**					
Cephalodella tenuiseta	-	-	-	-	-	-	-	⊥	-	-
Keratella quadrata	-	-	⊥	-	-	⊥	-	-	-	⊥
Kellicottia longispina	-	-	-	-	-	-	-	⊥	-	-
Lecane pyriformis	-	-	-	-	+	-	-	++	⊥	-
Mytilina bisulcata	-	⊥	⊥	-	-	-	-	-	+	-
Synchaeta stylata	-	-	-	-	++	-	-	-	-	-
Testudinella patina	-	-	-	-	-	-	-	-	-	⊥
Hexarthra fennica	-	-	-	+++	-	-	-	-	-	-
Rotaria neptunia	-	-	-	-	+++	-	-	-	-	-
Cladocera										
Bosmina longirostris	-	⊥	-	-	-	-	-	-	⊥	-
Daphnia curvirostris	-	+	+++	+	-	-	+++	+	-	⊥
Chydorus sphaericus	-	-	⊥	-	-	⊥	⊥	-	+	-
Coronatella rectangula	-	⊥	+	-	-	⊥	-	-	-	-
Pleuroxus aduncus	-	-	⊥	-	-	-	-	⊥	⊥	-
Copepoda										
Diacyclops languidus	-	-	-	-	-	-	-	⊥	-	⊥
Eucyclops serrulatus	-	⊥	-	-	-	-	⊥	-	-	-
Macrocyclops albidus	-	-	-	-	-	⊥	-	-	+	-
Megacyclops viridis	-	⊥	⊥	-	⊥	-	⊥	-	-	-
Paracyclops chiltoni	-	-	-	-	⊥	-	-	-	-	-
Tropocyclops prasinus	-	⊥	+	+	-	-	+	-	-	-
Eudiaptomus drieschi	-	-	-	-	⊥	-	-	-	-	-
Kinnecaris xanthi	-	-	-	-	-	-	-	⊥	-	-
Nitocrella stammeri	-	-	-	-	-	-	-	⊥	-	-
Rotifera					**Winter 2020**					
Colurella uncinata	-	-	-	-	-	-	-	⊥	-	-
Mytilina bisulcata	-	-	-	-	-	-	-	-	+	-
Testudinella patina	-	-	⊥	-	-	-	-	-	-	-
Rotaria neptunia	-	-	-	-	++	⊥	-	-	-	-
Cladocera										
Daphnia curvirostris	⊥	⊥	++	-	-	-	⊥	-	-	⊥
Chydorus sphaericus	-	-	-	-	-	-	⊥	-	⊥	-
Pleuroxus aduncus	-	-	-	-	-	⊥	-	-	-	-
Leydigia acanthocercoides	-	-	-	-	+	-	-	-	-	-
Copepoda										
Diacyclops languidus	-	-	-	-	-	-	-	⊥	⊥	-
Eucyclops serrulatus	-	⊥	⊥	-	-	-	-	-	-	-
Macrocyclops albidus	-	-	-	-	-	⊥	-	-	-	-
Megacyclops viridis	-	-	-	-	+	-	⊥	-	-	-
Tropocyclops prasinus	-	-	-	⊥	-	-	⊥	-	-	-
Eudiaptomus drieschi	-	-	-	-	⊥	-	-	-	-	-
Nitocrella stammeri	-	-	-	-	-	-	-	⊥	-	-
Rotifera					**Spring 2020**					
Lecane closterocerca	-	-	-	-	⊥	-	-	-	-	-
Mytilina bisulcata	-	-	+	-	-	-	-	-	-	-
Synchaeta stylata	-	-	-	-	+++	⊥	-	-	-	-
Rotaria neptunia	-	-	-	-	++	-	-	-	-	-
Cladocera										
Daphnia curvirostris	-	⊥	++	-	-	-	+	-	-	-
Chydorus sphaericus	-	-	-	-	-	-	-	-	⊥	-
Pleuroxus aduncus	-	-	-	-	-	⊥	-	-	-	-
Leydigia acanthocercoides	-	-	-	-	⊥	-	-	-	-	-
Copepoda										
Diacyclops languidus	-	-	-	-	-	-	-	⊥	⊥	-
Eucyclops serrulatus	-	⊥	-	-	-	-	-	-	-	-
Macrocyclops albidus	-	-	⊥	-	-	-	-	-	-	-
Megacyclops viridis	-	-	-	⊥	⊥	⊥	⊥	-	-	-
Tropocyclops prasinus	-	-	-	⊥	-	-	⊥	-	-	-
Eudiaptomus drieschi	-	-	-	-	+	-	-	-	-	-

-: Absent, ⊥: very few (1-10 individuals in each petri), **+**: few (10-30 individuals in each petri), **++**: abundant (30-60 individuals in each petri), **+++**: very abundant (more than 60 individuals in a petri)

Table 6. The relationships between zooplankton and water quality parameters

	Zooplankton species number	Zooplankton abundance
Temp	$R^2 = 0.61$	$R^2 = 0.52$
pH	$R^2 = 0.90$	$R^2 = 0.83$
Con	$R^2 = 0.92$	$R^2 = 0.89$

is close to the standards (<400 µScm^{-1}-first class waters), it was found to be high in many wells and at certain times of the year. pH and conductivity are important water quality parameters that are significantly correlated with zooplankton abundance and distribution. Therefore, there was a positive correlation between zooplankton diversity, abundance and pH (Sarvala and Halsinaho, 1990), and zooplankton diversity, abundance and conductivity (Bos et al., 1996).

The depths of the sampling wells vary from 4.00 to 9.00 m, and their widths are 2.20-3.40 m. The water sources of the wells are mainly groundwater and little rainwater. For this reason, it is assumed that the presence of planktonic organisms in the well water was through rainwater, air flow and groundwater (Hessen et al., 2019). Rotifera was the most represented zooplankton group with 14 species, followed by 10 copepod species and 6 cladoceran species, and a total of 30 species were recorded. This trend was reported by Bozkurt (2019) and Bozkurt and Bozça (2019).

Some of the species recorded- *A. ovalis, C. uncinata, B. urceolaris, L. closterocerca, L. pyriformis, K. cochlearis, K. quadrata, K. longispina, S. stylata, R. neptunia, T. patina, B. longirostris, C. rectangula, C. sphaericus, L. acanthocercoides, P. aduncus, E. serrulatus, M. viridis, P. chiltoni,* and *P. viguieri* have been reported by various researchers to be cosmopolitan and widely distributed throughout the year (De Smet, 1996; Ramdani et al., 2001; Rybak and Bledzki, 2010) and they are very tolerant to changes in water quality parameters (Koste and Shiel, 1989; De Manuel Barrabin, 2000). According to Koste (1978), *B. urceolaris* is thermophilic and common in tropical and subtropical waters in summer. *B. urceolaris* and *C. uncinata* are benthic (Yalim, 2006).

Although the species richness and abundance of zooplankton in groundwater are low, they are an important assemblage in these waters (Galassi 2001). Furthermore, the genera Diacyclops and Elaphoidella are the forerunners of planktonic organisms in groundwater (Brancelj and Dumont, 2007). *D. languidus, M. albidus, M. viridis, T. prasinus, K. xanthi,* and *N. stammeri* are common species in caves, springs, seeps, and groundwater, despite the fact that many of them are found in inland waters (Lee and Chang, 2007; Bruno and Cottarelli, 2015).

K. longispina, K. cochlearis, S. stylata, T. patina, R. neptunia, E. serrulatus, M. albidus and *E. drieschi* are common species with high tolerance to environmental conditions (Segers, 2007). They can live in many aquatic environments, both pelagic and plant-based (Stankovic and Ternjej, 2007). Rotifer species with wide tolerance to different water properties have been reported (Jersabek and Bolortsetseg, 2010; Hamaidi-Chergui et al., 2013).

The species recorded could have been introduced from the groundwater feeding the wells, and on the zooplankton distribution patterns such as winds, water particles and insects (Hessen et al., 2019).

There are differences between the number of species recorded in this study and that of Bozkurt and Bozça (2019). The number of common species found in both studies was 16, while the number of species recorded in this study but not in Bozkurt and Bozça (2019) was 14 (Table 3).

The reason for these differences may be due to the different characteristics of the underground water resources, the different water properties and the fact that the groundwaters do not come into contact with each other. According to Winter et al. (1998), it is almost impossible to monitor the movement and behavior of groundwater. Groundwater moves both vertically and laterally within the underground system. The flow paths, which can be tens to hundreds of meters long, are in the form of a complex network system that begins at the water table, continues through the groundwater system, and ends in the well.

Conclusion

The zooplankton fauna of the wells, which were mostly fed by groundwater, consists of 14 rotifer, 10 copepod and 6 cladoceran species. A total of 10 rotifer families, three Cladocera families and 5 copepod families were recorded. The number of zooplankton species and abundance had significant positive correlation with temperature, pH and conductivity. *A. ovalis, H. fennica, K. quadrata, R. neptunia, S. stylata* (Rotifera), *C. sphaericus* and *D. curvirostris* (Cladocera) were very abundant in different seasons and wells, while copepod species were much less common in all wells and seasons. Most of the species recorded are cosmopolitan.

COMPLIANCE WITH ETHICAL STANDARDS

Conflict of Interest

The author declare that there is no conflict of interest.

Ethical Approval

For this type of study, formal consent is not required.

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