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Investigation of zooplankton fauna in water wells of Yayladağı District (Hatay, Turkey)

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Abstract: In this study, water quality parameters and zooplankton fauna were investigated from 14 different water wells in Yayladağı District of Hatay Province. The study was conducted seasonally between October 2015 and July 2016. A total of 51 species were identified, including 30 species of rotifers, 9 species of cladocerans, and 12 species of copepods. The most abundant species, *Keratella cochlearis*, *Bosmina longirostris*, and *Tropocyclops prasinus*, were found in 11, 13, and 12 wells, respectively. However, species such as *Cephalodella catellina*, *Cephalodella ventripes*, *Filinia longiseta*, *Lecane lunaris*, *L. pumila*, *Lophocharis salpina*, *Mytilina unguipes*, *Platyias quadricornis*, *Trichocerca tigris*, *Ceriodaphnia pulchella*, *Diaphanosoma birgei*, *Alona guttata*, *Leydigia acanthocercoides*, *Simocephalus vetulus*, *Cyclops vicinus*, *Bryocamptus zschokkei*, *Diacyclops bicuspidatus*, *Canthocamptus microstaphylinus*, and *Nitocra hibernica* were each observed in only one well. The highest abundance of species was found in Well 1 with 22 species, followed by Well 14 with 19 species and Well 4 with 18 species. Only 4 species were found in Well 10. At the end of this study, the most abundant species, *Synchaeta stylata*, *Keratella quadrata*, *Bosmina longirostris*, *Tropocyclops prasinus*, and *Eudiaptomus drieschi*, were observed in Wells 1–3, 1, 4, 3–10, and 1–4, respectively. The monogonont rotifer *Lecane pumila*, collected from Well 4 (Yayladağı, Hatay), was reported for the first time from Turkish inland waters.

Key words: Rotifera, Cladocera, Copepoda, water well

1. Introduction

The primary source of freshwater in the hydrological cycle is groundwater. Groundwater is an important natural resource, providing water for human consumption and many groundwater-dependent ecosystems. In addition, groundwater and dependent ecosystems contain various organisms dominated by freshwater zooplankton, including rotifers, cladocerans, and copepods (Galassi et al., 2009; Brancelj et al., 2013). Zooplankton are important in freshwater ecosystems, as they serve as a link between primary producers and higher-level consumers. In addition, zooplankton are good bioindicators (Papa et al., 2012; Papa and Briones, 2014) due to their sensitivity to their habitat, making them suitable indicators for environmental changes, which may be utilized in determining the current environmental health status of most freshwater ecosystems.

Groundwater fauna from fractures and intergranular aquifers have been investigated for more than 250 years (Botosaneanu, 1986). More than 6700 stygobites have been described so far worldwide (Galassi, 2001; Galassi et al., 2009). In Europe, there are approximately 1800 known stygobitic species (Botosaneanu, 1986; Gibert and Culver, 2009), of which 1570 are Crustacea (Zagmajster et al., 2014). Ecological studies of groundwater ecosystems, especially in intergranular aquifers, became much more numerous in the 1990s (Gibert et al., 1990; Danielopol et al., 2001; Gibert, 2001; Gibert and Deharveng, 2002; Hancock et al., 2005; Danielopol and Griebler, 2008). The hyporheic zone continues to be intensively studied (Danielopol and Rouch, 1991; Rouch, 1992; Boulton et al., 2003; Di Lorenzo et al., 2013). In contrast, the deeper aquifer zones, like the phreatic zone, have received comparatively little attention and still constitute a research frontier for freshwater ecology (Larned, 2012). The few faunistic and ecological studies carried out to date have revealed that the deeper areas of the phreatic zone are habitats with very specific fauna (Marmonier et al., 1993; Stoch et al., 2009; Di Lorenzo et al., 2013), but detailed information is still lacking.

Well water, although a source of drinking water, is also used for most irrigation, especially for the majority of the rural population in Turkey. Therefore, villagers use well water as a water source for all their needs. These wells have been installed in sampling areas at various depths, depending on the availability and the level of groundwater.

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Freshwater zooplankton research in Turkey is mainly limited to surface waters such as rivers and lakes, mostly disregarding groundwater and groundwater-dependent ecosystems including caves, open wells, springs, and piped groundwater pumps. It has been said that the diversification of freshwater zooplankton in surface waters is parallel to that found in groundwater ecosystems, especially in copepods (Galassi et al., 2009). Groundwater diversity studies, such as those for surface water, may also contribute information needed to maintain a sustainable biodiversity for this type of ecosystem, as well as to provide useful biological indicators of subsurface–surface water connectivity.

In this study, considering the research shortcomings described above and in order to contribute to the determination of the groundwater zooplankton fauna in Turkey, some water quality parameters (dissolved oxygen, pH, water temperature, Secchi depth) and zooplankton fauna were investigated in 14 water wells located in the Yayladağı District of Hatay Province.

2. Materials and methods

Zooplankton samples were collected by vertical hauls of a standard net (60 µm mesh size) on 21 October 2015, as well as on 14 February, 23 April, and 16 July 2016, during routine surveys in 14 different water wells located within the boundaries of Yayladağı District of Hatay Province. First, 0.5 kg of metal weight was attached to the collector, and the net was then lowered to the bottom of the well and the water was mixed by shaking. Thus, the water became turbid and zooplankton in the benthic layers were mixed with water. The net was then pulled up; 8–10 replicates were performed for each well. The sampling coordinates and localities are given in Table 1 and the Figure.

The depth of the wells from the surface to the bottom, the depth of water at the sampling time, and the widths of the wells are given in Table 1.

After sampling, zooplankton were fixed and preserved in 4% formaldehyde. Zooplankton samples were examined in a distilled water and glycerol mixture.

Some water quality parameters such as dissolved oxygen (mg L^{-1}) and temperature (°C) were measured in the field with a YSI-52 model oxygen meter, pH with a YSI 600 model pH meter, and conductivity (µS cm^{-1}) with a YSI-30 model salinometer. The quantitative analysis of zooplankton was evaluated not by the counting method but by the general abundance. The evaluation was made as follows: absent (-), very few (┴), few (+), abundant (++), and very abundant (+++).

The zooplankton species were examined under an inverted microscope and identified by using a binocular (Olympus CH40) microscope. 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) were used to identify and review the specimens.

3. Results

Leakage of rainwater and groundwater was detected in 14 wells, and some water quality parameters were also investigated.

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

Sampling stations	Latitude	Longitude	Well depth (m)	Water depth (m)	Well width (m)
Well 1	35°54′31.17″N	36°03′09.68″E	9.4	3.2	0.57
Well 2	35°54′22.89″N	36°02′45.71″E	10.7	4.6	1.62
Well 3	35°54′35.37″N	36°02′51.27″E	5.2	2.1	0.62
Well 4	35°54′36.17″N	36°02′49.61″E	7.8	3.7	1.25
Well 5	35°54′36.51″N	36°02′48.79″E	4.7	1.9	0.77
Well 6	35°54′33.54″N	36°03′08.25″E	11.1	6.3	2.5
Well 7	35°55′00.72″N	36°02′36.73″E	3.9	2.1	0.94
Well 8	35°55′00.35″N	36°02′39.30″E	8.6	3.8	0.81
Well 9	35°54′39.98″N	36°02′56.05″E	6.8	3.6	0.65
Well 10	35°54′40.58″N	36°02′53.87″E	4.4	2.5	1.05
Well 11	35°54′23.01″N	36°02′45.38″E	3.7	1.7	0.74
Well 12	35°54′28.72″N	36°03′06.79″E	2.8	1.2	0.84
Well 13	35°54′08.36″N	36°02′45.61″E	12.3	5.8	1.92
Well 14	35°54′37.37″N	36°02′47.89″E	4.2	1.3	2.02

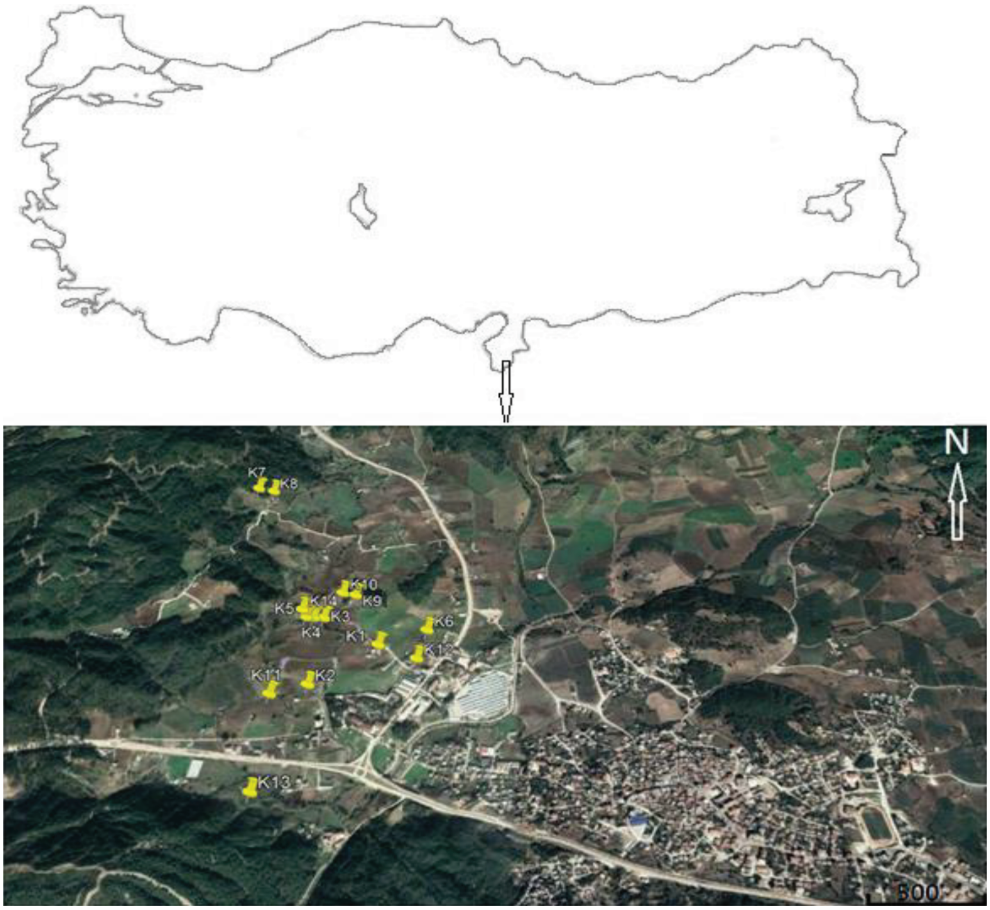

Figure. Study area and wells.

Water temperature varied between 10.2 °C (winter) and 23.3 °C (summer), with a mean of 17.78 ± 3.56 °C. The seasonal average temperature in all water wells was the highest in summer (20.93 ± 1.05 °C), followed by autumn (19.16 ± 0.94 °C), spring (18.54 ± 2.51 °C), and winter (12.48 ± 1.33 °C) (Table 2).

The conductivity value ranged from 272 µS cm^{-1} to 990 µS cm^{-1} with a mean value of 590 ± 165 µS cm^{-1}. Annual average conductivity in spring was 632.28 ± 164.37 µS cm^{-1}, followed by summer (606.86 ± 172.28 µS cm^{-1}), autumn (601.93 ± 159.88 µS cm^{-1}), and winter (520.21 ± 159.16 µS cm^{-1}) (Table 2).

Dissolved oxygen reached a maximum concentration of 8.10 mg L^{-1} (summer, fall) and minimum concentration of 6.15 mg L^{-1} (winter), with a mean value of 7.51 ± 0.38 mg L^{-1}. Seasonal mean dissolved oxygen was the highest in fall (7.62 ± 0.26 mg L^{-1}), followed by spring (7.53 ± 0.28 mg L^{-1}), summer (7.52 ± 0.36 mg L^{-1}), and winter (7.34 ± 0.53 mg L^{-1}) (Table 2).

pH value did not change much among the wells. The maximum, minimum, and mean pH values were 7.25 (winter), 8.93 (spring), and 8.28 ± 0.37, respectively. The seasonal average pH was 8.51 ± 0.28 in spring, 8.35 ± 0.29 in summer, 8.24 ± 0.33 in autumn, and 8.03 ± 0.41 in winter (Table 2).

In this study, 30 species of Rotifera (58.82%), 12 species of Copepoda (23.53%), and 9 species of Cladocera (17.65%) were identified in the wells (Table 3).

A total of 13 families were detected from Rotifera. Lecanidae was the richest family with 7 species of Rotifera, followed by Lepadellidae and Brachionidae with 4 species each. While Notommatidae was represented by 3 species, Mytilinidae, Testudinellidae, and Trichocercidae were represented by 2 species. Gastropodidae, Dicranophoridae, Euchlanidae, Filiniidae, Synchaetidae, and Trichotriidae were each represented by one species.

Four families were detected from Cladocera. Chydoridae was the richest family with 4 species, followed by Daphnidae with 3 species, and Bosminidae and Sididae with 1 species each. Among the 4 families of Copepoda, Cyclopoidae had 7 species, followed by 2 species of Canthocamptidae; Diaptomidae and Ameiridae each had 1 species (Table 3).

Table 2. Physicochemical parameters according to seasons.

Seasons	Summer				Autumn			
Wells	Temp (**°C**)	pH	DO (mg/L)	Con (**µ**Scm^{-1})	Temp (**°C**)	pH	DO (mg/L)	Con (**µ**S cm^{-1})
1	21.1	8.70	7.78	457	20.0	8.50	7.90	460
2	21.1	8.24	7.05	611	19.0	8.20	7.50	580
3	21.5	7.96	7.46	759	18.5	7.96	7.20	740
4	22.0	8.10	7.40	661	20.0	8.10	7.60	660
5	19.7	8.13	7.20	577	18.2	7.90	7.30	585
6	20.3	8.28	7.20	780	19.0	8.15	7.75	750
7	21.0	8.65	7.35	845	20.3	8.80	7.35	845
8	21.2	8.76	7.03	923	20.5	8.30	7.40	910
9	23.3	8.64	7.88	473	19.3	7.85	8.00	480
10	20.9	8.15	7.27	348	20.0	8.15	7.60	420
11	21.5	8.65	7.70	385	18.4	8.65	7.75	390
12	20.0	8.50	8.00	565	19.5	8.80	7.60	562
13	20.4	7.90	8.10	490	18.0	7.90	8.10	468
14	19.0	8.20	7.90	622	17.5	8.13	7.65	577
Medium	20.93 ± 1.05	8.35 ± 0.29	7.52 ± **0.36**	606.86 ± 172.28	19.16± **0.94**	8.24 ± 0.33	7.62 ± **0.26**	601.93 ± **159.88**
Seasons	Winter				Spring			
Wells	Temp	pH	DO	Con	Temp	pH	DO	Con
1	10.2	8.48	6.60	323	20.3	8.93	7.09	502
2	12.5	7.75	7.57	920	16.4	8.62	7.79	785
3	12.6	7.95	7.80	593	16.8	8.36	7.40	647
4	12.5	8.37	7.35	408	21.8	8.90	7.26	667
5	12.9	8.42	6.98	425	22.2	8.75	7.39	587
6	15.8	7.85	7.67	607	17.8	8.70	7.82	792
7	12.5	7.40	7.85	435	23.8	8.48	7.56	722
8	11.0	7.25	7.60	455	17.7	8.31	7.60	990
9	11.8	8.55	7.50	272	17.4	8.52	7.46	490
10	13.0	8.20	6.70	615	16.7	8.30	7.12	308
11	12.4	7.90	7.90	575	15.2	8.55	7.46	652
12	13.5	8.00	6.15	540	18.0	8.70	7.65	587
13	11.0	7.80	7.75	495	17.0	8.20	7.90	625
14	13.0	8.50	7.40	620	18.5	7.90	8.00	498
Medium	12.48 ± 1.33	8.03 ± 0.41	7.34 ± **0.53**	520.21 ± 159.16	18.54± **2.51**	8.51 ± 0.28	7.53 ± **0.28**	632.28 ± **164.37**

According to Table 4, the rotifer species with the largest distribution areas were *Keratella cochlearis* (found in 12 wells), *Trichocerca similis* (11 wells), and *Cephalodella gibba* (6 wells). Of Cladocera, *Bosmina longirostris* was found in 13 wells and had the largest distribution area, followed by *Ceriodaphnia reticulata* and *Pleuroxus aduncus* (6 wells each). *Tropocyclops prasinus* had the widest distribution area (found in 12 wells), followed by *Eudiaptomus drieschi* (6 wells), and *Acanthocyclops robustus* and *Diacyclops languidus* (5 wells). Some zooplankton species in the study showed limited distribution and were selective, being found in very few wells. *Cephalodella catellina* and *Cephalodella ventripes* from Rotifera; *Ceriodaphnia pulchella*, *Simocephalus vetulus*, *Diaphanosoma birgei*, *Alona guttata*, and *Leydigia acanthocercoides* from Cladocera; and *Cyclops vicinus*, *Diacyclops bicuspidatus*,

Table 3. Identified zooplankton species.

Rotifera	
Gastropodidae	*Ascomorpha ovalis* (Bergendahl, 1892)
Notommatidae	*Cephalodella catellina* (Müller, 1786) *Cephalodella gibba* (Ehrenberg, 1830) *Cephalodella ventripes* (Dixon-Nuttall, 1901)
Lepadellidae	*Colurella adriatica* Ehrenberg, 1831 *Colurella uncinata* (Müller, 1773) *Lepadella acuminata* (Ehrenberg, 1834) *Lepadella patella* (Müller, 1773)
Dicranophoridae	*Dicranophorus epicharis* Harring & Myers, 1928
Euchlanidae	*Euchlanis dilatata* Ehrenberg, 1832
Filiniidae	*Filinia longiseta* (Ehrenberg, 1834)
Brachionidae	*Keratella cochlearis* (Gosse, 1851) *Keratella tropica* (Apstein, 1907) *Keratella quadrata* (Müller, 1786) *Platyias quadricornis* (Ehrenberg, 1832)
Lecanidae	*Lecane bulla* (Gosse, 1851) *Lecane closterocerca* (Schmarda, 1859) *Lecane flexilis* (Gosse, 1886) *Lecane hamata* (Stokes, 1896) *Lecane lunaris* (Ehrenberg, 1832) *Lecane pumila* (Rousselet, 1906) *Lecane tenuiseta* Harring, 1914
Mytilinidae	*Lophocharis salpina* (Ehrenberg, 1834) *Mytilina unguipes* (Lucks, 1912)
Synchaetidae	*Synchaeta stylata* Wierzejski, 1893
Testudinellidae	*Testudinella elliptica* (Ehrenberg, 1834) *Testudinella patina* (Hermann, 1783)
Trichocercidae	*Trichocerca similis* (Wierzejski, 1893) *Trichocerca tigris* (Müller, 1786)
Trichotriidae	*Trichotria tetractis* (Ehrenberg, 1830)
Cladocera	
Bosminidae	*Bosmina longirostris* (Müller, 1785)
Daphniidae	*Ceriodaphnia pulchella* Sars, 1862 *Ceriodaphnia reticulata* (Jurine, 1820) *Simocephalus vetulus* (Müller, 1776)
Sididae	*Diaphanosoma birgei* Korinek, 1981
Chydoridae	*Alona guttata* Sars, 1862 *Chydorus sphaericus* (M**ü**ller 1776) *Leydigia acanthocercoides* (Fischer, 1854) *Pleuroxus aduncus* (Jurine, 1820)
Copepoda	
Cyclopidae	*Acanthocyclops robustus* (Sars, 1863) *Cyclops vicinus* Uljanin, 1875 *Diacyclops bicuspidatus* (Claus, 1857) *Diacyclops languidus* (Sars, 1863) *Macrocyclops albidus* (Jurine, 1820) *Megacyclops viridis* (Jurine, 1820) *Tropocyclops prasinus* (Fischer, 1860)
Diaptomidae	*Eudiaptomus drieschi* (Poppe and Mrazek, 1895)
Canthocamptidae	*Attheyella crassa* (Sars, 1863) *Bryocamptus zschokkei* (Schmeil, 1893) *Canthocamptus microstaphylinus* Wolf 1905
Ameiridae	*Nitocra hibernica* (Brady, 1880)

Table 4. Determined zooplankton species in different water wells.

Species Wells	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Rotifera														
Ascomorpha ovalis	×	-	-	-	-	-	-	-	-	-	×	×	-	-
Cephalodella catellina	-	-	-	×	-	-	-	-	-	-	-	-	-	-
Cephalodella gibba	×	×	-	-	×	-	-	-	×	-	×	×	-	-
Cephalodella ventripes	-	-	-	-	-	-	-	-	-	-	-	-	-	×
Colurella adriatica	-	×	-	-	-	-	-	×	-	-	-	×	-	-
Colurella uncinata	-	-	-	×	×	-	×	-	-	-	-	-	-	-
Dicranophorus epicharis	×	-	-	-	-	-	×	-	-	-	-	-	-	-
Euchlanis dilatata	×	-	-	-	-	-	-	-	×	-	-	-	-	-
Filinia longiseta	-	-	-	-	-	-	-	-	-	-	-	-	×	-
Keratella cochlearis	×	×	-	×	×	×	×	×	-	×	×	×	×	×
Keratella tropica	-	-	-	-	-	×	-	-	-	-	-	-	-	×
Keratella quadrata	×	-	-	-	-	×	-	-	-	-	-	-	-	×
Lecane bulla	×	-	-	-	×	-	-	-	-	-	×	-	-	-
Lecane closterocerca	×	×	-	×	×	-	-	-	-	-	×	-	-	-
Lecane flexilis	-	×	-	×	×	-	-	×	×	-	-	-	-	-
Lecane hamata	×	-	-	×	×	-	-	×	-	-	-	-	×	-
Lecane lunaris	-	-	-	-	-	-	×	-	-	-	-	-	-	-
Lecane pumila	-	-	-	×	-	-	-	-	-	-	-	-	-	-
Lecane tenuiseta	×	×	×	-	-	-	-	×	-	-	-	×	-	-
Lepadella acuminata	-	-	-	×	×	-	-	-	-	-	-	-	-	-
Lepadella patella	-	-	-	×	×	-	-	-	-	-	-	-	-	-
Lophocharis salpina	×	-	-	-	-	-	-	-	-	-	-	-	-	-
Mytilina unguipes	-	×	-	-	-	-	-	-	-	-	-	-	-	-
Platyias quadricornis	-	-	-	-	-	-	×	-	-	-	-	-	-	-
Synchaeta stylata	×	-	×	-	-	×	-	×	-	-	-	-	-	×
Testudinella elliptica	-	-	-	-	-	-	-	×	-	-	×	-	-	-
Testudinella patina	×	-	-	-	×	-	×	×	-	×	-	-	-	-
Trichocerca similis	×	-	-	×	×	×	×	×	×	×	×	×	-	×
Trichocerca tigris	-	-	-	-	-	-	-	-	-	-	-	-	-	×
Trichotria tetractis	×	-	-	-	-	-	×	-	-	-	-	×	-	-
Number of rotifer species	15	7	2	10	11	5	8	9	4	3	7	7	3	7
Cladocera														
Bosmina longirostris	×	×	×	×	×	×	×	×	×	-	×	×	×	×
Ceriodaphnia pulchella	-	-	-	-	-	-	×	-	-	-	-	-	-	-
Ceriodaphnia reticulata	-	-	-	×	×	-	-	×	-	-	×	×	-	×
Diaphanosoma birgei	-	-	-	-	-	-	-	×	-	-	-	-	-	-
Alona guttata	-	-	-	-	-	-	-	-	-	-	-	-	-	×
Chydorus sphaericus	×	-	-	-	×	×	-	-	-	-	×	-	-	×
Leydigia acanthocercoides	-	-	-	-	-	-	×	-	-	-	-	-	-	-
Pleuroxus aduncus	×	-	-	×	-	×	-	×	-	-	-	-	×	×
Simocephalus vetulus	-	-	-	-	-	-	-	-	-	-	-	-	-	×

Number of cladoceran species	3	1	1	3	3	3	3	4	1	0	3	2	2	6
Copepoda														
Acanthocyclops robustus	×	-	-	×	-	-	-	-	-	-	-	×	×	×
Cyclops vicinus	-	-	-	-	-	-	-	-	-	-	-	-	×	-
Diacyclops bicuspidatus	-	-	-	-	-	-	-	×	-	-	-	-	-	-
Diacyclops languidus	-	-	-	×	-	×	×	-	×	-	-	-	-	×
Macrocyclops albidus	×	-	-	-	×	-	-	-	-	-	-	-	×	×
Megacyclops viridis	-	×	-	×	-	-	-	-	×	-	-	-	-	-
Tropocyclops prasinus	×	×	×	×	×	-	×	×	×	×	×	×	-	×
Eudiaptomus drieschi	×	-	-	×	×	×	-	-	×	-	-	-	-	×
Attheyella crassa	-	-	-	-	-	-	-	-	-	-	-	-	×	×
Bryocamptus zschokkei	-	-	-	-	-	-	-	×	-	-	-	-	-	-
Canthocamptus microstaphylinus	-	-	-	-	-	-	-	-	-	-	-	-	×	-
Nitocra hibernica	-	-	×	-	-	-	-	-	-	-	-	-	-	-
Number of copepod species	4	2	2	5	3	2	2	3	4	1	1	2	5	6
Number of total species	22	10	5	18	17	10	13	16	9	4	11	11	10	19

×: Available, -: absent.

Bryocamptus zschokkei, *Canthocamptus microstaphylinus*, and *Nitocra hibernica* from Copepoda were found in one well each (Table 4).

The most species (15 species) from Rotifera were found in Well 1, followed by Well 5 with 11 species and Well 4 with 10 species. The most species from Cladocera were found in Well 14 (6 species), followed by Well 8 with 4 species and Wells 1, 4, 5, 6, 7, and 11 with 3 species each. The most species from Copepoda were found in Well 14 (6 species), followed by 5 species in Wells 4 and 13, and 4 species in Wells 1 and 9 (Table 4).

In terms of total zooplankton species, it was determined that Well 1 was the richest with 22 species, followed by Well 14 with 19 species and Well 4 with 18 species (Table 4). While the wells were rich in the variety of species of rotifers and copepods, they were very poor in terms of zooplankton.

Seven of 30 species from Rotifera, 3 of 9 species from Cladocera, and 6 of 12 species from Copepoda were found to be abundant in different seasons and wells. In spring, *Bosmina longirostris* and *Pleuroxus aduncus* from Cladocera in Well 4 and *Tropocyclops prasinus* and *Eudiaptomus drieschi* from Copepoda in Wells 7 and 4 were abundant (++), whereas *Synchaeta stylata* from Rotifera in Well 1 was very abundant (+++) (Table 5).

In summer, it was determined that *Synchaeta stylata* from Rotifera in Well 3, *Ceriodaphnia reticulata* from Cladocera in Well 5, *Tropocyclops pracinus* in Wells 3 and 10, and *Eudiaptomus drieschi* from Copepoda in Well 1 were very abundant. In the same season, the rotifer *Trichocerca similis* in Wells 8 and 9; cladocerans *Ceriodaphnia reticulata* in Well 11, *Diacyclops bicuspidatus* in Well 8, and *Diacyclops languidus* in Well 6; and copepod *Tropocyclops pracinus* in Well 7 were found to be abundant (Table 5).

In autumn, *Keratella quadrata* from Rotifera was very abundant (+++) in Well 1, but *K. quadrata* and *Lecane hamata* were abundant (++) in Wells 14 and 5, respectively. From Copepoda, *Eudiaptomus drieschi* in Well 14 and *Tropocyclops prasinus* in Well 1 were abundant, whereas *E. drieschi* in Well 1 was quite abundant (Table 5).

In winter, from Rotifera *Lecane pumila* (Well 4), *Lecane tenuiseta* (Well 8), *Testudinella patina* (Well l7), and *Attheyella crassa* and *Canthocamptus microstaphylinus* (Well 14) were abundant, while *Bosmina longirostris* and *Eudiaptomus drieschi* in Well 4 were quite abundant (Table 5).

New record *Lecane pumila*: relatively large, wider than long, soft lorica and short, curved toes bearing pseudoclaws distinguish the species from all other soft-bodied *Lecane*. Lorica flexible, although form constant; lateral sulci absent; toes extremely short; claw points curved backwards. Total length (7 specimens) 105–150 µm; toes 4–6 µm.

4. Discussion

Temperature is one of the most important environmental parameters controlling biological and chemical events; it also affects zooplankton species diversity and density

Table 5. Zooplankton in the water wells by seasons.

Wells	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Rotifera				Spring										
Synchaeta stylata	+++	-	-	-	-	-	-	⊥	-	-	-	-	-	-
Cladocera														
Bosmina longirostris	+	⊥	⊥	++	+	⊥	-	-	+	-	+	-	+	-
Pleuroxus aduncus	-	-	-	++	-	⊥	-	⊥	-	-	-	-	+	+
Copepoda														
Tropocyclops prasinus	⊥	-	⊥	⊥	-	-	+ +	+	-	+	-	⊥	-	+
Eudiaptomus drieschi	-	-	-	++	+	-	-	-	-	-	-	-	-	-
Rotifera				Summer										
Synchaeta stylata	-	-	+++	-	-	-	-	-	-	-	-	-	-	-
Trichocerca similis	⊥	-	-	+	⊥	+	+	++	++	+	⊥	+	-	+
Cladocera														
Ceriodaphnia reticulata	-	-	-	+	+++	-	-	-	-	-	++	-	-	+
Copepoda														
Diacyclops bicuspidatus	-	-	-	-	-	-	-	++	-	-	-	-	-	-
Diacyclops languidus	-	-	-	+	-	++	-	-	-	-	-	-	-	-
Tropocyclops prasinus	+	+	+++	⊥	⊥	-	++	+	⊥	+++	⊥	-	-	⊥
Eudiaptomus drieschi	+++	-	-	⊥	-	+	-	-	+	-	-	-	-	-
Rotifera				Autumn										
Keratella quadrata	+++	-	-	-	-	-	-	-	-	-	-	-	-	++
Lecane hamata	+	-	-	⊥	++	-	-	+	-	-	-	-	+	-
Copepoda														
Tropocyclops prasinus	++	-	-	-	+	-	-	-	-	-	+	-	-	⊥
Eudiaptomus drieschi	+++	-	-	-	+	-	-	-	-	-	-	-	-	++
Rotifera				Winter										
Lecane pumila	-	-	-	++	-	-	-	-	-	-	-	-	-	-
Lecane tenuiseta	⊥	-	⊥	-	-	-	-	++	-	-	-	⊥	-	-
Testudinella patina	-	-	-	-	-	-	++	-	-	-	-	-	-	-
Cladocera														
Bosmina longirostris	-	-	+	+++	+	-	-	-	-	⊥	-	-	+	-
Copepoda														
Eudiaptomus drieschi	-	-	-	+++	+	-	-	-	-	-	-	-	-	-
Attheyella crassa	-	-		-	-	-	-	-	-	-	-	-	++	-
Canthocamptus microstaphylinus	-	-	-	-	-	-	-	-	-	-	-	-	++	-

-: Absent, ⊥: very few, +: few, ++: abundant, +++: very abundant.

in aquatic ecosystems (Herzig, 1987). Biological activity in the aquatic environment increases with increasing temperature, and biochemical reactions accelerate to affect the reproduction, nutrition, and metabolic activities of aquatic organisms (Taş et al., 2010). As a result, when the temperature suddenly increases in spring, phytoplankton explosions and consequently zooplankton density increase and ecosystem productivity increases. In this study, it was determined that the water temperature varied between 10.20 °C and 23.30 °C. The temperature varied according to the season; hence, there were differences in zooplankton quantities due to seasonal differences.

pH, representing the acidity or alkalinity of water, is an important factor affecting life in the water. Each living organism has tolerance to a specific pH range. Berzins and Pejler (1987) reported that the density of zooplankton significantly affected the pH and the alkali boundary (pH) was 8.5. In the study, pH values were determined to be slightly alkaline, in the range of 7.25–8.98 in all sampling wells. According to EPA (1979) data, the optimum pH value for freshwater was between 6.5 and 9.0. The values we determined were consistent with the EPA values.

Although electrical conductivity values in freshwaters vary between 10 and 1000 µS cm^{-1}, it is between 150 and 500 µS cm^{-1} according to the protocol on water products standards and the protection of surface water sources against pollution (Uslu and Turkman, 1987). In this study, the conductivity was between 272 µS cm^{-1} and 990 µS cm^{-1}. Although the conductivity was close to the standards, it was high in many wells and several seasons.

The amount of dissolved oxygen is one of the most important parameters.–Solubility depends on the temperature of the water, the partial pressure of the atmosphere, biological phenomena, and the concentration of dissolved salt in the water (Tanyolaç, 2009). The amount of dissolved oxygen in our study was within the normal range of 6.15–8.10 mg L^{-1}.

The wells from which the samples were taken were open wells for irrigation water supply. The depths of these wells vary between 3.7 and 12.3 m and their width was 0.57–2.02 m. The water sources for the wells are rain and underground water. Therefore, the access of planktonic organisms to the well water may be caused by rainwater and underground leakage. The number of zooplankton species in the groundwater is reported to be around 120 species (Brancelj and Dumont, 2007).

A total of 51 species were identified including 30 species of rotifers, 9 species of cladocerans, and 12 species of copepods. When the species diversity of the zooplankton was examined, Rotifera was represented by the most abundant species, followed by Copepoda and Cladocera. Until now, only one study has been done on zooplankton related to groundwater and water wells of Turkey (Bozkurt, 2019). In that study, 13 species of rotifers, 9 species of copepods, and 2 species of cladocerans were reported from 8 different wells. A similar zooplankton species distribution was found in our study as well. Generally, the distribution of zooplankton in the lake and stream studies showed that Rotifera, Cladocera, and Copepoda, respectively, were the most represented.

Many of the species (*Ascomorpha ovalis*, *Cephalodella gibba*, *C. catellina*, *Colurella adriatica*, *C. uncinata*, *Dicranophorus epicharis*, *Euchlanis dilatata*, *Lecane closterocerca*, *L. tenuiseta*, *L. hamata*, *L. bulla*, *L. lunaris*, *L. pumila*, *Lepadella patella*, *L. acuminata*, *Keratella cochlearis, K. tropica*, *K. quadrata*, *F. longiseta*, *Synchaeta stylata*, *Testudinella patina*, *Trichotria tetractis*, *Trichocerca similis*, *Platyias quadricornis*, *Bosmina longirostris*, *Ceriodaphnia pulchella*, *Diaphanasoma birgei*, *Simocephalus vetulus*, *Chydorus sphaericus*, *Pleuroxus aduncus*, *Alona guttata*, *Leydigia acanthocercoides*, *Acanthocyclops robustus*, *Cyclops vicinus*, *Megacyclops viridis*, *Bryocamptus zschokkei*, *Nitocra hibernica*) in this study have been reported to be widespread species and tolerant to a wide range of environmental changes in many aquatic environments (Einsle, 1965; Monchenko, 1974; Ruttner-Kolisko, 1974; Braioni and Gelmini, 1983; Dussart and Defaye, 1985; Koste and Shiel, 1987; De Smet, 1996; De Manuel Barrabin, 2000; Stoch and Pospisil, 2000; Rybak and Bledzki, 2010). On the other hand, several species (*L. flexilis*, *L. bulla*, *Lophocharis salpina*, and *Trichotria tetractis*) in the study prefer alkali water and are also tolerant of wide pH changes (Koste, 1978; Berzins and Pejler, 1987; Koste and Shiel, 1989). The well waters in this study show alkaline properties.

Although copepod species are poor in terms of species richness and abundance in groundwater, they constitute an important community of these waters (Galassi, 2001). In addition, the pioneers of planktonic organisms in groundwater belong to the genera of *Diacyclops* and *Elaphoidella* (Brancelj and Dumont, 2007). Although many of them are found in inland waters, *Diacyclops bicuspidatus*, *D. languidus*, *Macrocyclops albidus*, and *Tropocyclops prasinus* are common species in caves, spring waters, and leakage groundwater (Marten et al., 1994; Lee and Chang, 2007).

Lecane pumila, a new record for Turkish inland waters, is distributed in Europe, Indonesia, and North America, in moss in standing and flowing water (Koste and Shiel, 1986).

In many studies conducted in our country, zooplankton species detected have been reported to be widespread in inland waters (Ustaoğlu, 2004, 2015; Ustaoğlu et al., 2012).

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