Chapter 5

Variations in the Zooplankton Species Structure of Eutrophic Lakes in Turkey

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Additional information is available at the end of the chapter

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Abstract

In freshwater ecosystems, zooplanktons provide an important food source for larval fish. Some species of zooplanktons are usually considered as useful indicators of water quality and trophic state, for example, *Filinia longiseta, Keratella cochlearis, Keratella quadrata, Brachionus angularis, etc*. The purpose of this study is to describe the recent zooplankton composition and monthly variations, to compare results with earlier studies, to determine the trophic level of the eutrophic lake and to show eutrophic lakes in Turkey.

Keywords: zooplankton (*Rotifera, Cladocera, Copepoda*), eutrophic, lake, Karamık, Turkey

1. Introduction

Zooplanktonic organisms form the second ring of the food chain in lake ecosystem after phytoplanktonic organism. Zooplanktonic organisms are one of the crucial study subjects in freshwater ecosystems. As forming the basic food chain between primary producers and other higher forms in the founded food chain, zooplankton has a great significance in aquatic ecosystems. Naturally, undergoing a change in number or variety of these organisms affects the living groups on the top of the food chain pyramid [1]. Zooplankton is significant for the nutrition of fish, fry, some invertebrates and birds and in the biodiversity structure of the ecosystem [2–5]. Besides, it is used as an indicator of trophic situation and the quality of water

in the lakes [6–10]. Zooplanktonic organisms, which are significant for inland fishery, with some species, are evaluated as indicators of contamination with their sensitivity to environmental changes and forming the great part of the aquatic organisms [11]. Zooplankton species are showed as bioindicator for determining the environmental contamination occurred due to environmental parameters [12, 13]. Among zooplanktonic organisms, *Rotifera* is the primary vertebrate group of freshwater. While *Rotifera* has an important role in many freshwater, *Cladocera* and *Copepoda* group are utilized in culture studies [14]. In eutrophication, distribution and intensity of especially *Copepoda* and *Rotifera* group of organisms among zooplanktonic organisms have been pointed out to be effective [15, 16]. Among zooplanktonic organisms, particularly small-sized *Cladocera*, the dominance of *Rotifera* species means eutrophic lakes; on the other hand, the dominance of *Copepoda* species points out oligotrophic lakes [17, 18]. In addition to this, *Cyclopoida* and *Harpacticoid Copepoda* groups have been used to determine the trophic situation [19, 20]. In the lakes where some dominant zooplankton species are located, the biodiversity of eutrophic lake has been observed as low. Also, zoobentos and *Rotifera* diversity are very low in the areas where eutrophication has been shown very high [21, 22]. *Copepoda*, which is intensely found in freshwater ecosystems, forms the main constituent of planktonic community. *Copepoda* group of organisms have been shown as the indicator species for determining the quality of water [23].

In the sediments of the lakes, the records of the change of the biological communities can be followed constantly, because while protecting the quality and the structure in aquatic ecosystems, it is benefited from the earlier formations. In fact, diatoms have been used in the content of functional implementations to evaluate the paleolimnological past of the trophic structure of the lakes. Besides, ecological communities in freshwater ecosystems have been primarily examined in taxonomically and morphologically. Lately, functional organizations, distribution of the species and different ecological roles have been stated as important features. *Cladocera* is important on the water quality and ecology of the lakes when appeared in the middle level of trophic degree [24]. Also, *Cladocera* has been defined as a good indicator of hydrological dynamism of the water floor and the heterogeneity of the habitat [25]. *Rotifera, Cladocera*, and *Copepoda* are the basic groups of zooplankton in freshwaters. Many *Rotifera* has great effect on the metabolism and rapid turnover of the lacustrine food chain [26, 27]. *Cladocera* group has viability feature in extreme conditions of freshwater [20]. It was observed that the contribution of Rotifer species in zooplankton community might raise the eutrophication [28]. Generally, zooplankton gives immediate reaction to climate change, but endangered populations can be too much insistent on main distribution areas for a long time [29]. Among the zooplankton community, Rotifers, having a high sensitiveness on the conditions of the environment where they live, have a particular importance being an indicator on determining the water quality, contamination, and eutrophication level of the water that contains some species [30]. To fulfill the food need of the people, freshwater fishery is gaining emphasis gradually because of the rising population of the world. Thus, the studies have been speeded up on zooplanktonic organisms, which are one of the main food sources of many fish species in larval stage and forms the basic chain of the food chain in transforming the phytonutrients to proteins in aquatic environment.

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2. Eutrophic lakes in Turkey

Eutrophic lakes in Turkey are listed in **Table 1**.

Lake name	Locality	Surface area	Trophic state	References
Beyşehir Lake	Konya, Isparta	650 km^2	Mesotrophic-eutrophic	[31, 32]
Eğirdir Lake	Eğirdir, Isparta	468 km^2	Mesotrophic-eutrophic	[33]
Marmara Lake	Salihli, Manisa	45 km^2	Eutrophic	[34]
Akşehir Lake	Konya	353 km^2	Mesotrophic-eutrophic	[35, 36]
Karagöl	Yamanlar, İzmir	2 ha	Eutrophic	[37]
Çavuşçu Lake	Ilgın, Konya	1000 ha	Mesotrophic-eutrophic	[38]
Gala Lake	Enez İpsala	5.6 km^2	Eutrophic	[39]
Mogan Lake	Gölbaşı, Ankara	561.2 ha	Mesotrophic-eutrophic	[40]
Karataş Lake	Burdur	11.9 km^2	Vulnerable to eutrophic	[5, 41]
Gölhisar Lake	Burdur	400 ha	Mesotrophic-eutrophic	[42]
Ladik Lake	Samsun	141.40 km^2	Eutrophic	[10]
Yenişehir Lake	Reyhanlı, Hatay	105.340 m^2	Eutrophic	[43]
Terkos Lake	İstanbul	25 km^2	Eutrophic	[44]
Çernek Lake	Samsun	589 ha	Eutrophic	[45]
Karamık Lake	Çay, Afyonkarahisar	38 km^2	Eutrophic	[1, 46, 47]
Liman Lake	Kızılırmak Delta	50.000 ha	Eutrophic	[48]
Gölcük Lake	Ödemiş, İzmir	125 ha	Eutrophic	[49]
Eber Lake	Bolvadin, Afyonkarahisar	12.500 ha	Eutrophic	[50]

Table 1. List of eutrophic lakes in Turkey.

3. Zooplankton indicators of eutrophic lake

Zooplanktonic organisms are studied from many researchers in terms of taxonomy and ecology. Species revealed in freshwater areas are used as an indicator to determine the water quality, contamination and eutrophication condition [51, 52]. *Rotifera* species are widely stated as an indicator of eutrophic water. *Brachionus calyciflorus, Trichotria tetractis*, and *Filinia longiseta* species are used as an indicator of eutrophication [53]. It is believed that *Rotifera* is dominant in eutrophic water. Because parthenogenetic reproduction and population length are very broad, lakes were seen as convenient for eutrophication for the species of *Sattal Keratella* sp, *Brachionus* sp, *F. longiseta*, and *T. tetractis* [54]. *Brachionus calyciflorus, B. angularis, Keratella quadrata, K. cochlearis, Polyarthra dolichoptera, Euchlanis dilatata, Lecane luna, Pompholyx*

sulcata, Filinia longiseta, Trichocerca species (*Rotifera*), *Bosmina longirostris, Chydorus sphaericus*, and *Daphnia cucullata* (*Cladocera*) are among the species characteristic of eutrophic water [55]. It was reported by Bozkurt and Akın [56] that species of *Brachionus quadridentatus, Notholca squamula, Lepadella patella, Lecane bulla, Bosmina longirostris, Alona rectangula, Acanthocyclops robustus*, and *Cyclops vicinus* were known as the indicator species of eutrophication and found mainly in hot zones. In Ballybeg, Crans and Morgan Lakes in Ireland *Bosmina longirostris, Daphnia longispina, D.pulex, Leydigia leydigi* and *Oxyurella tenuicaudis* species while showing a positive relationship with trophic condition variables at the same time are formed in high eutrophic areas [24]. Yet, in the study on the composition of zooplankton in Ladik Lake in 2015, the lake was identified as eutrophic for *Brachionus calyciflorus, B. angularis, Keratella quadrata, K. cochlearis, Bosmia longirostris, Cyclops vicinus*, and *Thermocyclops crassus* [10]. *Keratella cochlearis, Keratella qaudrata, Brachionus angularis* species, among the *Rotifera* group of organisms, are shown as the indicator of eutrophication by some researchers [2, 19, 27, 57]. Among the *Rotifera* group, *Brachionus calyciflorus, B. angularis, Keratella cochlearis, Keratella qaudrata, Conochilus dossuarius, Filinia longiseta, Trichocerca capucina, Trichocerca cylindrica* and *Bosmina longirostris, Graptoleberis testudinaria* among Cladocera group are stated as the most important indicators found in eutrophic conditions [19, 58–61].

While *Brachionus angularis* and *Keratella tropica* species form strongly in eutrophicated water [62], *Brachionus calyciflorus, Daphnia* sp. and *Ceriodaphnia* sp form in eutrophication conditions in Beira Lake [8]. Furthermore, *Cladocerans* and *Cyclopoid Copepods* adapted very well to eutrophic water [63]. In Sakarya River (Turkey) zooplankton, many species are shown as the indicator of eutrophication. As typical eutrophic species *Brachionus* spp., *E. dilatata, F. longiseta, K. cochlearis, K. quadrata, P. quadricornis, B. longirostris, C. sphaericus* and *C. vicinus* in Sakarya River [64]; *B. urceolaris, B. calyciflorus, K. quadrata, E. dilatata, B. longirostris, C. sphaericus, C. vicinus* and *E. serrulatus* in Gölcük Lake were found [48]. *Anuraeopsis fissa, Brachionus angularis. Keratella cochlearis f. tecta, Pompholyx sulcata* and *Filinia longiseta* species are important eutrophication indicators in the lakes of Poland [65].

4. Example of eutrophic lake: Lake Karamık (Çay, Afyonkarahisar, Turkey)

On the fishery of Lake Karamık, the size distribution of pike population, spawning period and nutrition were studied by Aksun [66, 67], and then in 2000s, the fishery of Lake Karamık and determining the biological properties of economical fish species were investigated by Çubuk et al [68]. Lake Karamık is located in 20 km southwest of Çay District in Afyon Province. Karakuş Mountains lie in the south part. The altitude is 1067 m, the acreage is 38 km^2 and the average deepness ranges between 2 and 3 m. Most of the lake is covered with plants living in water and on the surface of the water, and thus, the area for fishery is very limited. Lake Karamık is a very shallow lake showing eutrophic properties [1]. Snow and rain water, and Dipsiz, Aykırı and Kocabaş springs are the water sources of the lake and the outlets of the lake are evaporation and the sinkholes, named as Büyük subatan and Küçük subatan, in the south of the lake. The lake drains its water to Lake Hoyran via sinkholes. The wastewater of Afyon-

Çay SEKA paper mill was emptied to the lake in the past. After the year 2004, the mill was closed and the wastewater was prevented.

5. Study area

5.1. Sample collection and analysis

Monthly sampling was realized in Lake Karamık in three stations between the dates of March 2002 and March 2003. The coordinates of first station are 38° 26′ 10.16″ N, 30° 52′ 14.30″E, second station are 38° 27′ 13.33″N, 30° 51′ 20.05″E and third station are 38° 26′ 44.60″ N, 30° 50′ 36.47″E in Çay District in Afyon Province (**Figure 1**). Zooplankton samples were taken out of the lake via a 55 micron length of plankton mesh, and then, the samples were fixed in a %4 formaldehyde solution. Related sources were used in the sorting and identification of the species of zooplanktonic organisms [69–76]. Olympus model search technique and the invert and stereo model microscopes were used in species identification While making preparations for identification of the species, the samples were taken on the glycerine + formalin mixture dribbled on the slide, and then, the samples, covered with cover glass, were fixed with Canada balsam and taken into the collection In the identification process of the *Rotifera* species taking trophy with bleach, in the identification process of *Copepoda* and *Cladocera*, dissection process was realized. 0.10 and 0.60 mm numbered FST (fine science tools) stainless steel injections were

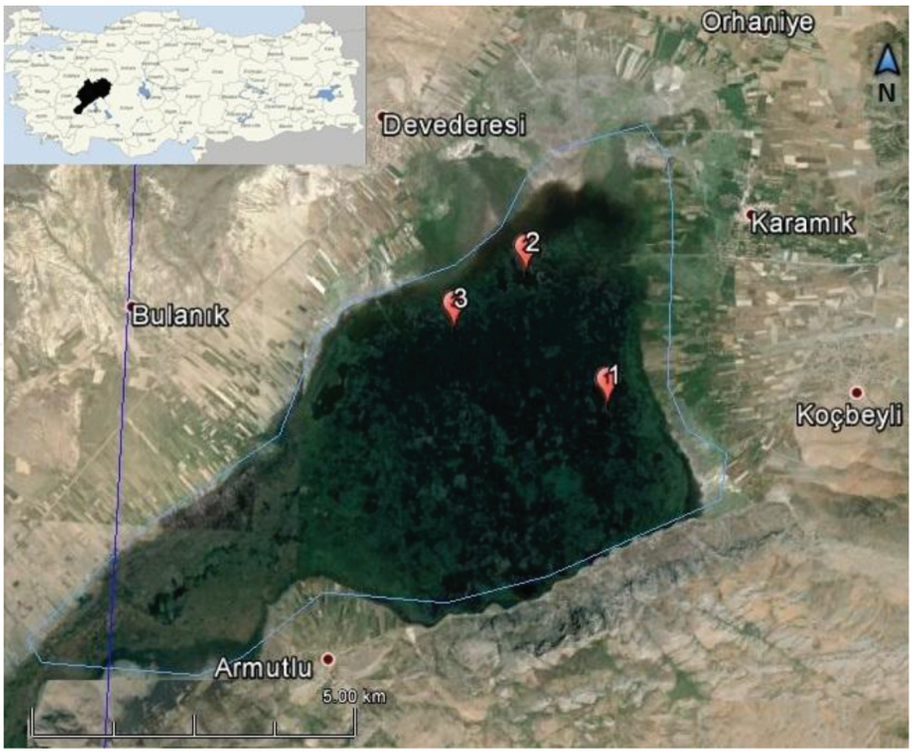

Figure 1. The study area and sampling stations in Lake Karamık.

used in the dissection process. Photographs of the organisms were taken by a microscope connected Nikon brand imaging device.

To determine the trophic index of the lake, *Brachionus*:*Trichocerca* (QB/T) [61] equality was used. According to Sládeček [61], while a quotient between one and two corresponds to mesotrophic conditions and a ratio of >2 is encountered in eutrophic lakes, a quotient of 1 indicates oligotrophic conditions. We used Soyer's [77] frequency index to define the frequency of species in the research area and constant ($F \geq 50\%$), common ($50\% > F \geq 25\%$), or rare ($F < 25\%$) estimated results were taken. $F = m/M \times 100$ is used in this index (F) to evaluate special species that m is the number of stations for the species and M is the number of all stations.

6. Results and discussion

In this study, totally 69 zooplankton species were identified. Thirty-seven of the species belong to *Rotifera* group (%54), 22 to *Cladocera* group (%32) and 10 to *Copepoda* group (%14) (**Figure 2**). The identified taxa were listed according to Ustaoğlu [78] and Ustaoğlu et al. [79].

6.1. Zooplankton composition of Lake Karamık (Çay, Afyonkarahisar, Turkey)

Platyias quadricornis (Ehrenberg, 1832), *Brachionus angularis* Gosse, 1851, *Brachionus quadridentatus* Hermann, 1783, *Brachionus rubens* Ehrenberg, 1838, *Keratella tecta* (Gosse, 1851), *Keratella quadrata* (Müller, 1786), *Notholca acuminata* (Ehrenberg, 1832), *Euchlanis incisa* Carlin, 1939, *Euchlanis meneta* Myers, 1930, *Mytilina mucronata* (Müller, 1773), *Mytilina ventralis* (Ehrenberg, 1830), *Trichotria pocillum* (Müller, 1776), *Trichotria tetractis* (Ehrenberg, 1830), *Macrochaetus collinsii* (Gosse, 1867), *Lepadella ehrenbergi* (Petry, 1850), *Lepadella ovalis* (Müller, 1786), *Lecane elsa* Hauer, 1931, *Lecane luna* (Müller, 1776), *Lecane ohioensis* (Herrick, 1885), (Herrick, 1885), *Lecane bulla* (Gosse, 1886), *Lecane clostrocerca* (Schmarda, 1859), *Lecane cornuta* (Müller, 1786), *Lecane lunaris* (Ehrenberg, 1832), *Lecane curvicornis* (Murray, 1913), *Lecane quadridentata* (Ehrenberg, 1830), *Trichocerca iernis* (Gosse, 1887), *Trichocerca similis* (Wierzeski, 1893), *Ascomorpha saltants* Bartsch, 1870, *Synchaeta pectinata* Ehrenberg, 1832, *Polyarthra dolichoptera* delson, 1925, *Dicranophorus grandis* (Ehrenberg, 1832), *Testudinella patina* (Hermann, 1783), *Conochilus unicornis* Rousselet, 1892, *Hexarthra mira* (Hudson, 1871), *Filinia longiseta* (Ehrenberg, 1834), *Filinia terminalis* (Plate, 1886), *Colletheca* sp, *Daphnia curvirostris* Eylmann, 1887, *Daphnia longispina* O.F. Müller, 1875, *Simocephalus exspinosus* (Koch, 1841), *Simocephalus vetulus* (O.F. Müller, 1776), *Ceriodaphnia quadrangula* (O.F. Müller, 1785), *Ceriodaphnia reticulata* (Jurine, 1820), *Scapholeberis kingi* Sars, 1903, *Bosmina longirostris* (O.F. Müller, 1785), *Eurycercus lamellatus* (O.F. Müller, 1785), *Pleuroxus aduncus* (Jurine, 1820), *Pleuroxus laevis* (Sars, 1862), *Alonella excisa* (Fischer, 1854), *Alonella nana* (Baird, 1850), *Chydorus sphaericus* (O.F. Müller, 1776), *Alona costata* Sars, 1862, *Alona guttata* Sars, 1862, *Alona rectangula* Sars, 1862, *Acroperus harpae* (Baird, 1835), *Graptoleberis testudinaria* (Fischer, 1848), *Biapertura affinis* (Leydig, 1860), *Tretocephala ambiqua* (Lilljeborg, 1900), *Oxyurella tenuicaudis* (Sars, 1862), *Acanthodiaptomus denticornis* (Wierzejski, 1887), *Macrocyclops albidus* (Jurine, 1820), *Eucyclops macruroides* (Lilljeborg, 1901), *Eucyclops macrurus* (G.O. Sars, 1863), *Eucyclops serrulatus* (Fischer, 1851), *Eucyclops speratus*

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(Lilljeborg, 1901), *Cyclops strenuus paternonis (Lindberg, 1956), Megacyclops viridis* (Jurine, 1820), *Megacyclops gigas* (Claus 1857), *Nitocra hibernica* (Brady, 1880).

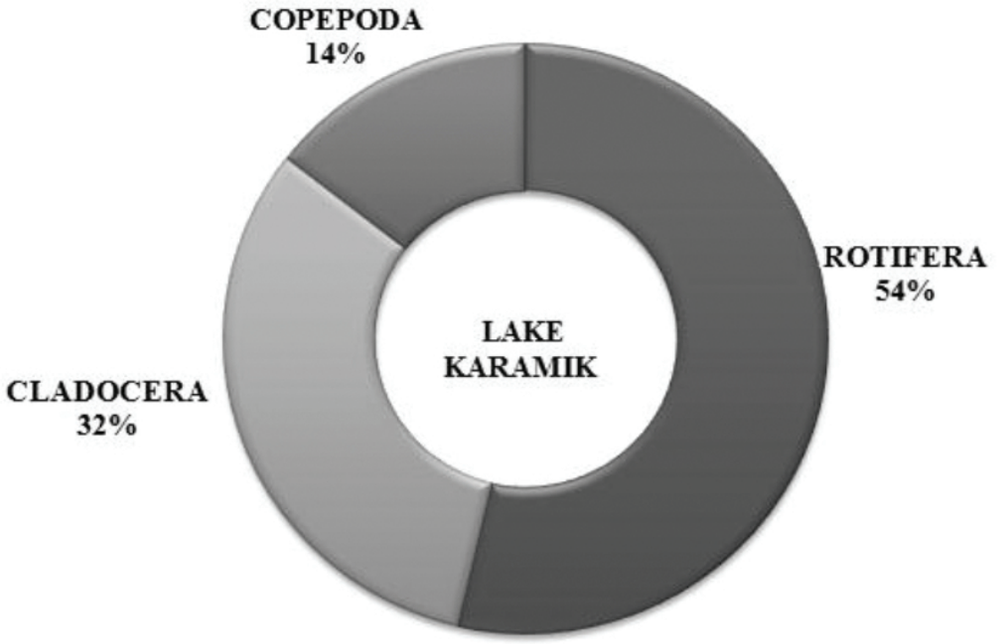

Figure 2. Composition of zooplankton in Lake Karamık.

Among the species identified in the lake, *K. quadrata, L. luna, L. bulla, T. patina, D. longispina, D. curvirostris, E. lamellatus, C. aphaericus, A. rectangula, P. aduncus, A. denticornis, E. macrurus* and *C. strenuus paternonis* were widely found, and *P. quadricornis, B. rubens, K. cochlearis tecta, N. acuminata, E. meneta, M. mucronata, T. tetractis, L. elsa, T. similis, D. grandis* and *A. guttata* were rarely found (**Table 2**). In this lake, 42 species by Gündüz [1], 86 species by Emir and Demirsoy [46], 18 species by Gündüz [80] and 9 species by Kazancı et al. [41] were reported. While 56 species were similarly found as in previous searches [1, 41, 46, 80], 64 species that were determined in previous were not appeared in this study (**Table 3**). First study on zooplankton in the lake started with Gündüz [1] (20 species of *Rotifera* and 22 species of *Cladocera*). Though in the study after 12 years, *Rotifera* group of organisms were widely studied [46] (86 species of *Rotifera*). Eighteen organisms only of *Cladocera* group were listed in the checklist presented in 1997 [80]. However, in the limnologic survey realized in the lake in 1999, a few zooplanktonic organisms were reported (totally nine species). The new species identified in this study (*K. cochlearis tecta, L. ehrenbergi, L. ovalis, L. cornuta, L. curvicornis, T. similis, D. grandis, Colletheca* sp., *B. longirostris, A. guttata, B. affinis, E. macruroides, E. serrulatus, M. gigas)* were indicated with asterisk and bold (**Table 3**). According to frequency index values, four species classified as constant ($F \geq 50$ %), 14 species as common (50 % > $F \geq 25$ %), 51 species as rare ($F < 25$ %). The constant species *K. qaudrata* was identified in all stations with the highest frequency value (74.29%). Of the group *Cladocera, C. sphaericus* (71.43%), *A. rectangula* (60 %), *P. aduncus* (54.29%) were other widespread species (**Table 2**).

Study period	2002																												2003									
Months	March			April			May			June			July			August			September			October			November			December		January			February			March			
Stations/Species	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	1	2	3	1	2	3	1	2	3	f %
ROTIFERA																																							
Platyias quadricornis	–	–	–	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2.86
Brachionus angularis	–	–	–	–	–	–	–	–	–	✧	–	–	❂	✧	❂	✧	–	★	✧	★	❂	–	✧	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	31.43
Brachionus quadridentatus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	✧	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5.71
Brachionus rubens	–	–	–	–	–	–	–	–	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2.86
Keratella tecta	–	–	–	–	–	–	–	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2.86
Keratella quadrata	❂	❂	★	❂	❂	–	❂	❂	✧	❂	❂	❂	★	✧	❂	✧	✧	★	★	★	★	✧	★	★	–	–	–	–	✧	–	–	–	–	✧	–	–	–	✧	74.29
Notholca acuminata	–	–	–	–	★	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2.86
Euchlanis incisa	–	–	–	–	–	–	–	–	–	–	★	✧	✧	–	✧	–	–	–	✧	–	–	✧	–	–	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	–	20
Euchlanis meneta																													✧	–	–	–	–	–	–	–	–	–	2.86
Mytilina mucronata	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2.86
Mytilina ventralis	–	–	–	–	–	–	–	–	–	–	–	–	✧	–	✧	–	–	–	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8.57
Trichotria pocillum	–	–	–	–	–	–	–	–	–	–	–	–	✧	✧	✧	–	–	–	–	✧	–	–	–	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14.29
Trichotria tetractis	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2.86
Macrochaetus collinsii	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	✧	–	–	–	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5.71
Lepadella ehrenbergi	–	–	–	–	–	–	–	–	–	–	–	–	–	✧	–	✧	–	–	✧	✧	–	–	✧	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	17.14
Lepadella ovalis	–	–	–	–	–	–	–	–	–	✧	–	–	–	–	–	–	–	–	✧	–	–	★	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	11.43
Lecane elsa	–	–	–	–	–	–	–	–	–	–	–	–	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2.86
Lecane luna	–	–	–	–	–	–	✧	–	–	✧	–	–	✧	★	★	★	✧	★	✧	★	✧	★	✧	★	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	40
Lecane ohioensis	–	–	–	–	–	–	–	–	–	–	–	–	–	✧	✧	★	–	✧	✧	✧	✧	✧	✧	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	28.57
Lecane bulla	–	✧	–	–	–	–	–	✧	–	✧	–	–	✧	★	★	✧	–	★	✧	★	★	❂	★	★	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	40
Lecane clostrocerca	–	–	–	✧	–	–	–	–	–	★	–	–	✧	✧	–	✧	–	–	✧	✧	–	✧	✧	✧	–	–	★	–	–	–	✧	–	–	–	–	–	–	–	–	34.26
Lecane cornuta	–	–	–	–	–	–	–	–	–	–	–	–	–	–	✧	–	–	✧	✧	–	✧	–	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14.29
Lecane lunaris	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	✧	–	–	–	✧	–	✧	✧	✧	–	–	★	–	–	–	–	–	–	–	–	–	–	–	–	17.14
Lecane curvicornis	–	–	–	–	–	–	–	–	–	–	–	–	–	✧	–	–	–	✧	✧	✧	✧	–	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	17.14
Lecane quadridentata	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	★	✧	✧	★	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	11.43
Trichocerca iernis	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	✧	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5.71
Trichocerca similis	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2.86
Ascomorpha saltants	–	–	–	–	–	–	–	–	–	★	–	–	–	–	✧	–	–	✧	✧	–	–	–	✧	✧	–	–	–	–	–	–	✧	–	–	–	–	–	–	–	–	–	20
Synchaeta pectinata	★	✧	–	–	✧	–	–	✧	–	–	–	–	–	–	–	–	–	–	✧	–	✧	✧	✧	✧	✧	–	–	–	✧	✧	–	–	–	–	–	–	–	–	–	34.29
Polyarthra dolichoptera	–	–	–	–	–	–	★	✧	✧	✧	–	–	✧	–	✧	–	–	–	–	–	–	–	–	–	–	–	–	✧	✧	✧	✧	–	–	–	–	–	–	–	–	28.57

Study period	2002																												2003									
Months	March			April			May			June			July			August			September			October			November			December		January			February			March			
Stations/Species	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	1	2	3	1	2	3	1	2	3	f %
Dicranophorus grandis	–	–	–	–	–	–	–	–	–	–	–	–	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2.86
Testudinella patina	–	–	–	✧	–	–	–	–	–	★	❂	★	★	✧	✧	–	–	✧	✧	★	✧	✧	✧	✧	–	–	–	✧	–	–	–	–	–	✧	–	–	–	–	45.71
Conochilus unicornis	–	–	–	–	–	–	–	–	–	❂	✧	✧	–	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	11.43
Hexarthra mira	–		–	–	–	–	–	✧	–	–	–	–	✧	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8.57
Filinia longiseta	–	–	–	–	–	–	–	–	–	–	–	–	–	✧	✧	–	–	–	–	✧	✧	–	–	–	–	–	–	–	–	✧	–	–	–	–	–	–	–	–	14.29
Filinia terminalis	–	–	✧	–	–	–	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5.71
Colletheca sp.	✧	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	✧	–	–	–	–	–	–	–	–	✧	✧	–	–	✧	–	–	–	17.14
CLADOCERA																																							
Daphnia curvirostris	–	–	–	–	–	–	–	❂	✧	✧	✧	–	–	–	–	–	–	–	–	✧	–	–	–	–	–	–	✧	–	–	❂	★	–	–	–	❂	–	–	25.71
Daphnia longispina	–	–	–	★	–	–	–	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	✧	–	✧	–	–	★	★	❂	–	❂	❂	25.71
Simocephalus exspinosus	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2.86
Simocephalus vetulus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	★	–	–	–	–	–	–	–	–	–	–	✧	✧	✧	11.43
Ceriodaphnia quadrangula	–	–	–	–	–	–	–	✧	–	–	–	–	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	–	✧	–	–	–	–	–	–	–	–	–	–	8.57
Ceriodaphnia reticulata	–	–	–	–	–	–	–	–	–	–	–	–	–	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	✧	–	–	–	–	–	–	–	5.71
Scapholeberis kingi	–	–	–	–	–	–	–	✧	–	✧	–	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	✧	–	–	–	–	–	–	–	–	–	11.43
Bosmina longirostris	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	✧	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5.71
Eurycercus lamellatus	–	–	–	–	–	–	–	★	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	❂	✧	–	–	✧	–	–	–	–	–	–	★	–	–	14.29
Pleuroxus aduncus	–	✧	–	✧	✧	–	–	★	–	–	✧	–	–	✧	✧	–	–	–	–	–	–	–	–	–	–	–	✧	★	❂	✧	★	★	❂	❂	★	★	★	❂	54.29
Pleuroxus laevis	–	–	–	–	–	–	–	★	–	–	–	–	✧	–	–	–	–	–	–	–	–	–	–	✧	–	✧	–	–	–	–	–	–	–	–	–	–	–	–	11.43
Alonella excisa	–	–	–	✧	✧	–	–	–	–	–	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8.57
Alonella nana	–	–	–	✧	–	–	–	–	–	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5.71
Chydorus sphaericus	✧	✧	✧	★	★	–	–	★	–	✧	✧	✧	–	–	–	–	–	–	–	–	–	✧	–	✧	❂	✧	✧	★	❂	✧	❂	❂	❂	❂	❂	❂	★	❂	71.43
Alona costata	–	–	–	–	–	–	–	–	–	✧	✧	–	–	–	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8.57
Alona guttata	–	–	–	–	–	–	–	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2.86
Alona rectangula	–	–	–	–	–	–	–	✧	–	★	–	✧	✧	✧	✧	–	–	–	✧	✧	✧	✧	✧	✧	–	✧	–	★	★	–	✧	✧	–	✧	✧	–	✧	✧	60
Acroperus harpae	–	–	–	✧	–	–	–	–	–	–	✧	–	–	–	✧	–	–	–	✧		✧	–	–	✧	✧	–	★	✧	★	–	✧	✧	–	–	–	–	–	–	34.29
Graptoleberis testudinaria	–	–	–	–	–	–	–	–	–	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	★	–	–	–	✧	–	–	–	–	–	–	–	8.57
Biapertura affinis	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	✧	–	2.86
Tretocephala ambiqua	–	–	–	–	–	–	–	–	✧	✧	–	–	–	–	–	–	–	✧	–	–	–	–	–	–	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	–	11.43
Oxyurella tenuicaudis	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	✧	–	–	–	–	–	–	✧	✧	–	✧	–	✧	✧	–	✧	–	–	✧	✧	25.71

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Study period	2002																											2003									
Months	March			April			May			June			July			August			September			October			November			December		January			February			March			
Stations/Species	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	1	2	3	1	2	3	1	2	3	f %
COPEPODA																																							
Acanthodiaptomus denticornis	–	–	–	–	–	–	✧	✭	✭	–	✭	–	–	–	–	–	–	–	–	–	–	–	–	–	✧	–	✭	✧	✧	✭	✭	✧	✭	✧	✭	✭	✧	45.71
Macrocyclops albidus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	✧	✧	–	✭	–	–	–	–	–	–	–	–	–	8.57
Eucyclops macruroides	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	✧	–	–	✭	✭	✧	–	✭	✧	17.14
Eucyclops macrurus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	✧	–	✧	✧	–	✭	–	–	✭	✧	–	–	–	17.14
Eucyclops serrulatus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	2.86
Eucyclops speratus	–	✧	–	–	–	–	–	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	✧	–	–	✧	–	–	–	–	–	–	–	–	–	–	11.43
Cyclops strenuus paternonis	–	–	–	–	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	✧	–	✭	–	–	✭	✧	✧	✭	✧	22.85
Megacyclops viridis	✧	–	–	–	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	✧	–	–	–	–	–	8.57
Megacyclops gigas	–	–	–	–	–	–	–	–	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	✧	–	–	–	–	–	–	8.71
Nitocra hibernica	–	–	–	–	–	–	–	–	–	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	✧	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5.71

Table 2. Distribution of zooplankton species found in the Lake Karamık according to months and stations (❁: abundant, ✭: some, ✧:scarce) .

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Species/authors	[1]	[46]	[80]	[41]	Present study
Rotaria neptunia		⬟			
Rotaria rotatoria		⬟			
Rotaria socialis		⬟			
Philodina megalotrocha		⬟			
Platyias quadricornis		⬟		⬟	⬟
Epiphanes senta	⬟				
Brachionus angularis		⬟			⬟
Brachionus calyciflorus	⬟	⬟			
Brachionus diversicornis		⬟			
Brachionus plicatilis		⬟			
Brachionus quadridentatus		⬟		⬟	⬟
Brachionus rubens		⬟			⬟
Brachionus urceolaris		⬟			
Keratella cochlearis	⬟	⬟			
Keratella tecta*					⬟
Keratella quadrata		⬟			⬟
Keratella tropica		⬟		⬟	
Notholca acuminata	⬟	⬟			⬟
Kellikottia longispina		⬟			
Anuraeopsis fissa		⬟			
Euchlanis dilatata		⬟			
Euchlanis incisa		⬟			⬟
Euchlanis meneta		⬟			⬟
Mytilina mucronata		⬟			⬟
Mytilina ventralis	⬟	⬟			⬟
Lophocharis rubens		⬟			
Lophocharis salpina		⬟			
Trichotria pocillum	⬟	⬟			⬟
Trichotria tetractis		⬟			⬟
Colurella adriatica		⬟			
Colurella colurus		⬟			

Species/authors	[1]	[46]	[80]	[41]	Present study
Colurella obtusa		⬟			
Colurella uncinata		⬟			
Colurella sp.	⬟				
Squatinella mutica		⬟			
Squatinella rostrum		⬟			
Squatinella sp.	⬟				
Lepadella ovalis		⬟			
Lepadella patella		⬟			
Macrochaetus collinsii		⬟			⬟
Lepadella ehrenbergi*					⬟
Lepadella ovalis*					⬟
Lepadella sp.	⬟				
Lecane elsa		⬟			⬟
Lecane inermis		⬟			
Lecane luna	⬟	⬟			⬟
Lecane nana		⬟			
Lecane ohioensis		⬟			⬟
Lecane stichaea		⬟			
Lecane furcata		⬟			
Lecane hamata		⬟			
Lecane lamellata		⬟			
Lecane bulla	⬟	⬟			⬟
Lecane clostrocerca		⬟			⬟
*Lecane cornuta**					⬟
Lecane lunaris		⬟			⬟
Lecane curvicornis*					⬟
Lecane quadridentata		⬟			⬟
Lindia truncata		⬟			
Scaridium longicaudum	⬟	⬟			
Monommata longiseta	⬟	⬟			
Eosphora najas		⬟			

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Species/authors	[1]	[46]	[80]	[41]	Present study
Notommata copeus		⬟			
Pleurotrocha petromyzon		⬟			
Cephalodella auriculata		⬟			
Cephalodella catellina		⬟			
Cephalodella gibba	⬟	⬟			
Cephalodella sterea		⬟			
Cephalodella ventripes		⬟			
Trichocerca cylindrica	⬟				
Trichocerca iernis		⬟			⬟
Trichocerca similis[*]					⬟
Trichocerca tenuior		⬟			
Trichocerca weberi		⬟			
Ascomorpha ovalis		⬟			
Ascomorpha saltants		⬟			⬟
Synchaeta oblonga		⬟			
Synchaeta pectinata	⬟	⬟			⬟
Polyarthra dolichoptera		⬟			⬟
Polyarthra vulgaris	⬟	⬟			
Asplanchna girodi		⬟			
Asplanchna priodonta	⬟	⬟			
Asplanchna sieboldi		⬟			
Asplanchna sp.				⬟	
Dicranophorus grandis[*]					⬟
Encentrum saundersiae		⬟			
Testudinella patina		⬟			⬟
Pompholyx complanata		⬟			
Floscularia ringens		⬟			
Ptygura beauchampi		⬟			
Conochilus dossuarius		⬟			
Conochilus natans		⬟			
Conochilus unicornis		⬟			⬟

Species/authors	[1]	[46]	[80]	[41]	Present study
Hexarthra fennica		⬟		⬟	
Hexarthra mira		⬟			⬟
Hexarthra sp.	⬟				
Filinia longiseta		⬟			⬟
Filinia pejleri		⬟			
Filinia terminalis	⬟	⬟			⬟
Colletheca ornata		⬟			
Colletheca sp.*					⬟
Diaphanosoma lacustris			⬟		
Daphnia curvirostris				⬟	⬟
Daphnia longispina	⬟		⬟	⬟	⬟
Simocephalus exspinosus			⬟		⬟
Simocephalus vetulus	⬟		⬟		⬟
Ceriodaphnia dubia			⬟		
Ceriodaphnia quadrangula	⬟				⬟
Ceriodaphnia reticulata			⬟		⬟
Scapholeberis kingi	⬟		⬟		⬟
Moina branchiata			⬟		
Macrothrix laticornis	⬟				
Macrothrix rosea			⬟		
Bosmina longirostris*					⬟
Eurycercus lamellatus	⬟		⬟		⬟
Pleuroxus aduncus	⬟		⬟		⬟
Pleuroxus laevis	⬟				⬟
Alonella excisa	⬟				⬟
Alonella nana	⬟				⬟
Chydorus sphaericus	⬟		⬟		⬟
Alona costata	⬟		⬟		⬟
Alona guttata*					⬟
Alona rectangula			⬟		⬟
Acroperus harpae	⬟		⬟		⬟

Species/authors	[1]	[46]	[80]	[41]	Present study
Graptoleberis testudinaria	⬟		⬟		⬟
Biapertura affinis*					⬟
Tretocephala ambiqua			⬟		⬟
Oxyurella tenuicaudis	⬟		⬟		⬟
Acanthodiaptomus denticornis	⬟				⬟
Macrocyclops albidus	⬟				⬟
Eucyclops macruroides*					⬟
Eucyclops macrurus	⬟				⬟
Eucyclops serrulatus*					⬟
Eucyclops speratus	⬟				⬟
Eucyclops sp.				⬟	
Cyclops strenuus paternonis	⬟				⬟
Cyclops sp.				⬟	
Megacyclops viridis	⬟				⬟
Megacyclops gigas*					⬟
Nitocra hibernica	⬟				⬟

Table 3. Checklist of zooplankton species studied during the present and earlier studies in Lake Karamık.

Among the species identified in the lake, *B. angularis, F. longiseta, Keratella quadrata* [19, 57], *B. longirostris* and *G. testudinaria* ([58–60] species grow in eutrophic conditions. According to QB/T *Rotifera* index, with the values of Karamık Lake with QB/T = 2.3 [46], Xochimilco Lake (Mexico) QB/T = 10 [81], Dojran Lake (Macedonia) QB/T = 1.6 [82], Beyşehir Lake (Beyşehir, Turkey) QB/T = 1.5–2 [30, 31], Gölcük Lake (Ödemiş, İzmir, Turkey) QB/T = 5 [48], Ladik Lake (Samsun, Turkey) QB/T = 5 [10], Abo Zaabal Lake (Cairo, Egypt) QB/T = 4 [83], Liman Lake (Kızılırmak delta, Turkey) QB/T = 2.5 [84] were shown as eutrophic. *Rotifera* species were used as indicator while identifying the trophic condition of the lake.

In this study, Karamık Lake was determined QB/T = 1.5. Finally, the lake showed mesotrophic property according to *Rotifera* index and eutrophic property in terms of *Rotifera* and *Cladocera* dominance. It is reported that the dominance of *Cladocera* and *Cyclopoid Copepoda* group of organisms in eutrophic waters [3], Cyclops strenuus *Cyclopoid* copepod dominance in freshwater widely in oligotrophic waters and rarely in shallow eutrophic waters in Japan [85]. *B. angularis, B. quadridentatus, K. qaudrata, P. dolichoptera, F. longiseta, C. qaudrangula, B. longirostris, C. sphaericus, Daphnia longispina* and *Cyclops strenuus paternonis* species identified in this study are the indicators of mesotrophic-eutrophic.

While *Keratella cochlearis, Keratella quadrata* and *Polyarthra vulgaris* species were reported as dominant species in the study made in the lake in 1984, the dominance of these little herbivorous zooplanktons (*Rotifera* and *Cladocera*) in the Lake Karamık was presented as the proof that this lake was eutrophic [1]. After the closure of the paper mill around Karamık Lake, becoming hypereutrophic of the lake was prevented. Existing quantitatively more of the zooplankton species than zooplankton groups depends on high level of food, breeding success of the *Rotifera* species and above all restrain of the increase in *Cladocera* and *Copepoda* by fish [46]. Consequently, the dominance of the number *Rotifera* and *Cladocera* species and also being in the large form of the *Cladocera* group of organisms show that the lake has turned into eutrophic condition. In this research, the shallow eutrophic lakes in Turkey were reported, and the zooplankton composition in shallow Lake Karamık was studied in detail, and zooplanktonic organisms of the eutrophic lakes were presented. Finally, this study will be useful contributions to the notice of zooplankton fauna of eutrophic lakes and of Turkey's biodiversity.

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