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Composition and Abundance of Zooplankton in a Natural Aquarium, Lake Balikligol (Sanliurfa, Turkey) and New Records

[1]Aysel Bekleyen and [2]Erdogan Ipek
[1]Department of Biology, Faculty of Science, Dicle University, Diyarbakir, Turkey
[2]Graduate School of Natural and Applied Sciences,
Suleyman Demirel University, Isparta, Turkey

Abstract: Balikligol Lake also known as the holy Halil-ür Rahman Lake is an important tourism centre in Turkey. Since its waters and fish are considered to be holy, the shallow lake has a dense fish population and can be considered a unique natural aquarium. In this natural aquarium, seasonal changes in the zooplankton community structure were evaluated in terms of species composition and abundance for the first time and a total of 34 taxa were identified, 29 of them belonging to Rotifera, 3 Cladocera and 2 Copepoda. Two of these rotifers *Lecane thienemanni* (Hauer, 1938) and *Notommata glyfura* Wulfert, 1935 are new records for Turkey. In addition, *L. thienemanni* is new for Western Asia. The species richness was high in summer. Total abundance ranged from 941-23.312 ind. m^{-3}, exhibiting a major peak in early spring and a minor one in early autumn. In terms of density, Rotifera dominated with 63%, followed by Copepoda with 33% and Cladocera with 4%. Predation pressure from fish, high temperatures and low oxygen values had significant impacts on zooplankton composition and abundance, especially for the crustacean community.

Key words: Rotifera, cladocera, copepoda, balikligol, Sanliurfa, Turkey

INTRODUCTION

Zooplankton constitutes the food source of organisms at higher trophic levels, especially fish in lake ecosystems. Since most are filter feeders, this serves to cleanse the water column of suspended matter and thus contributes significantly to the improvement of water quality. The composition and development of zooplankton are immediately influenced by changes in the physical and chemical conditions of the water. Therefore, zooplankton (especially rotifers) has been recognised as an indicator of the water quality and trophic status of lakes.

To date many studies of zooplankton have been carried out in artificial fish culture pools but Balikligol Lake differs from these pools in its natural dynamics, prohibition of fishing and the protection of its fish, which are considered to be holy. Fish cannot leave the lake due to a strainer at its exit and the lake therefore always has a dense fish population.

The zooplankton fauna of Turkey were listed by Ustaolu (2004) but the knowledge about the zooplankton fauna of the Southeast Anatolia region of Turkey is scarce. Therefore, the purposes of the present study were to examine the abundance and species composition of zooplankton groups and to investigate the effects of some physico-chemical characteristics and predation pressure on zooplankton structure in the dense fish population of Lake Balikligol.

MATERIALS AND METHODS

Site description: The shallow Lake Balikligol is located in the Sanliurfa city centre in south-eastern Turkey (N 37°08'51'', E 38°47'03'') at 514 m above sea level. Sanliurfa is one of the warmest cities of Turkey in the summer months (above 40°C) and has a continental climate. The lake consists of two big pools connected to each other by a large pipe (Fig. 1) and is fed by rainfall and underground water originating at the north side of the lake. The surface area and maximum depth of the lake are 4075 m^2 and 2.5 m, respectively. The amount of the groundwater changes according to seasons and precipitation. The excess water from Balikligol drains into Karakoyun stream through a canal. The entry of the canal has a strainer so that fish cannot move to the other side. Its bottom is covered by a thick layer of mud containing organic materials. The lake has the appearance of a natural aquarium, with fish swimming in its waters and the centuries-old plane and willow trees growing above. It is known that Balikligol contains five fish species, *Leuciscus cephalus orientalis*, *Capoeta capoeta umbla*,

Corresponding Author: Aysel Bekleyen, Department of Biology, Faculty of Science, Dicle University, Diyarbakir, Turkey

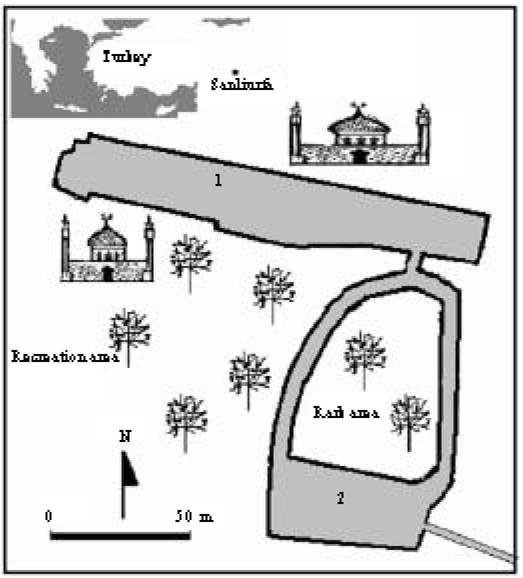

Fig. 1: Balikligöl and sampling stations

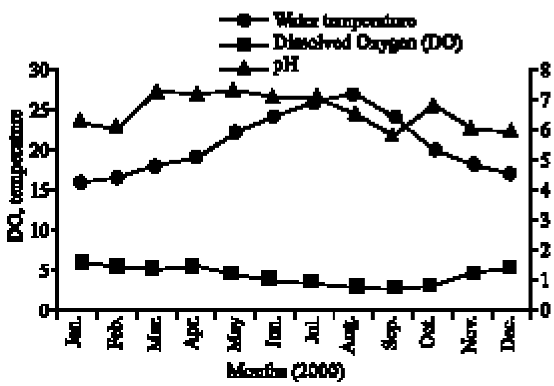

Fig. 2: Monthly variation in water temperature, DO and pH

Alburnus caeruleus, *Garra rufa obtusa* and *Carasobarbus luteus* (Unlu and Bilgin, 1987). According to legend, the lake is known as the spot where the Prophet Abraham fell when he was cast into the flames by Nimrod and therefore, its waters and fish are considered to be sacred and in no way edible by the people and are protected. Thus, the lake has a dense fish population. The lake and the historical monuments in its vicinity are visited by many tourists from all over the world, who unfortunately pollute the lake by feeding the fish.

Sampling and analysis of zooplankton: Zooplankton samples were collected monthly at two stations (pools) from January to December 2000 (Fig. 1). Because of the shallowness of the pools, qualitative and quantitative samples were taken by vertical hauls from the bottom to the surface to integrate vertical variations of abundance using a standard plankton net (55 µm mesh size, mouth diameter 25 cm). Rotifers, cladocerans and copepods were immediately preserved in 4% formaldehyde solution and later identified to the genus or species level. Identification was based on De Smet and Pourriot (1997), Dorner (1965), Harding and Smith (1974), Kiefer (1978), Ruttner-Kolisko (1974), Koste (1978), Negrea (1983), Nogrady *et al.* (1995), Rylov (1963), Scourfield and Harding (1966), Segers (1995) and Smirnov (1974). For quantitative analysis of zooplankton groups, subsamples made with Eppendorf pipettes of 1 and 5 mL were counted under a compound microscope and zooplankton densities, expressed as number per cubic meter were calculated by dividing the number of organisms estimated in each sample by the volume of water filtered in the field. The developmental stages of all copepod species were grouped together as copepodite and naupliar stages, while for cladocerans all stages were counted as one age class. The work includes original pictures taken by means of an Olympus DP71 digital camera.

Analysis of physico-chemical variables: Temperature, dissolved oxygen and pH values were measured in the field from the surface layer by YSI-O_2-meter and NEL 890 pH meter.

RESULTS AND DISCUSSION

Physical and chemical characteristics of water: The shallow lake is generally mixed by spring water and the swimming of large fish. The annual mean surface water temperature of Balikligol was around 20°C. The highest temperature of 27°C was reached in August and the lowest value of 15.5°C was recorded in January (Fig. 2). The pH was first neutral and later light acidic and measured between 5.7 (in September) and 7.5 (in March). pH values were relatively high in the spring months due to rainfall, spring water volume and primer productivity, but decreased toward the end of the year. Dissolved oxygen values were generally low during the study period and varied between 2.4 (in September) and 6.2 mg L^{-1} (in April). The minimum values (<5 mg L^{-1}) were measured between May and October. Dissolved oxygen can be rapidly reduced by intense microbial activity occurring at the sediment/water interface and can induce denitrification processes (Wetzel, 1983).

Seasonal changes in the zooplankton species composition and abundance: A total of 34 zooplankton taxa were identified: 29 rotifers, 3 cladocerans and 2 copepods (Table 1). Of these species, *Lecane thienemanni* (Hauer, 1938) and *Notommata glyfura* Wulfert, 1935 are new records for the Turkey. Also, *L. thienemanni* is new for Western Asia.

Table 1: List and monthly distribution of zooplanktonic taxa identified in Balikligöl

	Months (2000)											
Species	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Rotifera												
Aspelta labri (Harring and Myers, 1928)	-	-	-	-	-	-	+	-	-	-	-	-
Brachionus bidentatus (Anderson, 1889)	-	-	-	-	-	+	-	+	-	-	-	-
Brachionus calyciflorus (Pallas, 1766)	-	-	-	-	-	+	+	+	+	-	-	-
Brachionus quadridentatus (Hermann, 1783)	-	-	-	-	-	+	+	+	+	-	-	-
Cephalodella forficula (Ehrenberg, 1838)	-	-	-	-	+	-	-	+	-	-	-	-
Colurella uncinata (O.F.Müller 1773)	-	-	-	-	-	-	-	+	-	-	-	-
Dicranophorus epicaris (Harring and Myers, 1928)	-	-	-	-	+	-	+	+	-	-	--	
Euchlanis dilatata (Ehrenberg, 1832)	-	-	+	+	+	-	-	-	-	-	-	-
Euchlanis lyra (Hudson, 1886)	-	-	-	-	+	-	-	-	-	-	-	-
Floscularia ringens (Linnaeus, 1758)	-	-	-	-	+	-	+	+	-	-	-	-
Hexarthra fennica (Levander, 1892)	-	-	-	-	-	-	-	+	-	-	-	-
Keratella cochlearis (Gosse, 1851)	-	-	-	-	-	-	-	+	-	-	-	-
Lepadella acuminata (Ehrenberg, 1834)	+	+	-	+	-	+	+	+	-	-	-	-
Lepadella biloba (Hauer,1958)	+	-	-	-	-	-	-	-	+	+	+	+
Lecane luna (O.F.Müller 1776)	-	-	-	-	-	-	-	+	-	-	-	-
Lecane (M.) bulla (Gosse, 1886)	-	-	-	-	+	-	+	-	-	-	-	-
Lecane (M) closterocerca (Schmarda,1859)	-	-	-	-	-	-	-	+	+	-	+	-
Lecane (M.) hamata (Stokes, 1896)	-	-	+	+	+	+	-	+	+	+	+	-
**Lecane (M.) thienemanni* (Hauer,1938)	-	-	-	-	-	-	-	-	-	+	+	-
Mytilina bisulcata (Lucks, 1912)	-	-	-	-	-	-	-	-	+	-	-	-
**Notommata glyfura* (Wulfert, 1935)	-	+	-	-	-	-	-	+	-	-	-	-
Philodina megalotrocha (Ehrenberg, 1832)	-	-	-	+	+	+	+	-	-	-	-	+
Philodina roseola (Ehrenberg, 1832)	+	-	-	-	+	+	+	+	+	-	-	-
Pleurotrocha petromyzon (Ehrenberg, 1830)	-	+	-	-	-	-	-	-	-	-	-	-
Rotaria neptunia (Ehrenberg, 1832)	+	+	+	+	+	+	+	+	+	+	+	+
Rotaria rotatoria (Pallas, 1776)	-	+	+	+	+	+	+	+	-	-	+	+
Testudinella patina (Hermann, 1783)	+	-	-	+	-	-	-	-	+	-	-	-
Ptygura sp.	-	-	-	-	+	+	+	+	-	+	-	-
Sinantherina sp.	-	-	-	-	-	-	+	+	-	-	-	-
Cladocera												
Alona rectangula (Sars, 1862)	+	+	+	-	-	-	+	-	-	-	+	+
Ilyocryptus sordidus (Lievin, 1848)	-	-	+	+	+	+	+	-	-	-	-	-
Leydigia acanthocercoides (Fischer, 1854)	+	+	+	-	+	+	+	-	-	-	+	+
Copepoda												
Ergasilus sieboldi (Nordman, 1832)	+	+	+	+	+	-	-	-	+	+	+	+
Eucyclops serrulatus (Fischer, 1851)	+	+	+	+	+	+	+	+	-	-	+	+

*: New records

***Lecane thienemanni*:** Figure 3 resembles *L. hamata* but these species *can be* distinguished only by carefully comparing the shape of the head aperture (larger and sharper antero-lateral projections in *L. thienemanni* and narrower anterior margin of dorsal plate), the shape of the ventral plate (nearly parallel-sided, lateral margins nearly straight in *L. thienemanni*, curved in *L. hamata*) and the foot pseudosegment (mostly projecting in *L. thienemanni*).

This species is rare but has been recorded in several localities in tropical and subtropical regions of Africa, America, Asia and Australia (Segers, 1995).

In Asia, the pantropical *L. thienemanni* has so far been recorded in the northeast region of India (Sharma and Sharma, 1997; Sharma, 2005) and Southeast Asia (Sanoamuang and Savatenalinton, 1999) but there is no record of *L. thienemanni* living West of the Oriental region (Segers, 2007). At present, the Western boundary of its distribution has been expanded to the Southeast Anatolia region of Turkey.

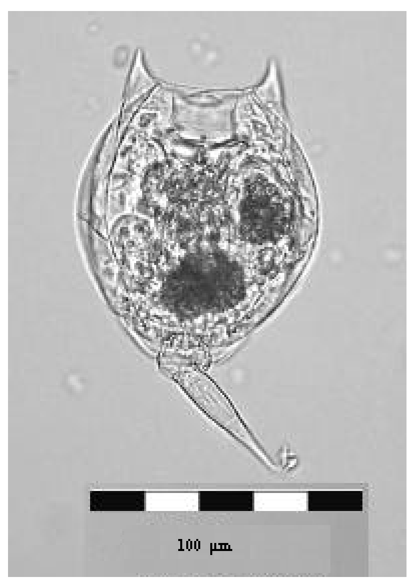

Fig. 3: Lecane thienemanni (Hauer, 1938)

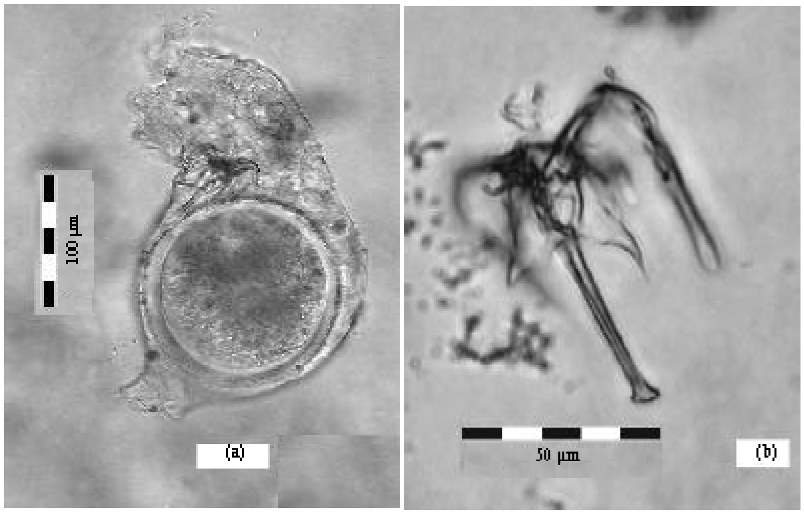

Fig. 4: *Notommata glyfura* Wulfert, 1935, (a) Female and (b) Trophi

Notommata glyfura: Wulfert, 1935 have short toes and are easily distinguished from that species by the RCO and the mastax (Fig. 4). The asymmetric trophus is robust, rami with teeth, the left alula is very large and dagger shaped (Nogrady *et al*., 1995). This species is eurytop and common (Koste and Terlutter, 2001). This species is new for Turkey.

All of the identified species were recorded for the first time in the lake. Lepadella biloba, *Mytilina bisulcata* and *Aspelta labri* Harring and Myers, 1928 were recorded for the second time for Turkish fauna. Previously, *L. biloba* and *M. bisulcata* were found in the central Anatolia region by Kaya and Altindag (2007, 2008) and *A. labri* was found in the Southeastern Anatolia region by Kaya *et al*. (2007). So, in the present study, *L. biloba* and *M. bisulcata* are first records for the Southeastern Anatolia region of Turkey.

The zooplankton communities of the two sampling stations of Lake Balikligol were completely similar in species composition but different in densities. During the study period, Rotifera was the dominant group in species composition followed by Cladocera and Copepoda. Zooplankton succession indicated large seasonal variations. Although, some species were found commonly throughout the year, some species were rare. The most frequently encountered species were *Rotaria neptunia*, R. *rotatoria*, *Lecane hamata* from rotifers and *Leydigia acanthocercoides*, *Alona rectangula*, *Eucyclops serrulatus*, *Ergasilus sieboldi* from cladocerans and copepods. However, *Aspelta labri*, *Colurella uncinata*, *Euchlanis lyra*, *Hexarthra fennica*, *Keratella cochlearis*, *Lecane luna*, *Mytilina bisulcata* and *Pleurotrocha petromyzon* were only found in one month (Table 1). Cladocerans, represented in small numbers, were not found in August, September and October. Furthermore, the parasitic copepod *Ergasilus sieboldi* (Nordman, 1832) commonly found in the lake was absent in summer plankton, whereas Brachionus species were found only in summer and early autumn plankton and occurred in higher numbers. A richer species composition was observed in summer than in the other seasons. Calanoid and harpacticoid copepods and large-sized cladocerans were totally absent.

Seasonal changes of zooplankton abundance are shown in Fig. 5. Total abundance ranged from 941-23.312 ind. m^{-3} (Fig. 5), exhibiting a major peak in early spring and a minor one in early autumn. In terms of density, Rotifera dominated with 63% and were followed by Copepoda with 33% and Cladocera with 4%. According to the average values, rotifers generally dominated in all seasons, whereas copepods were dominant in only June and January. Bdelloids, Brachionus and Lecane species of rotifers were the most abundant species during the sampling period. The total number of copepods varied between 108 ind. m^{-3} in October and 8128 ind. m^{-3} in March. The highest percentage (73.75%) occurred in January 2000 and the lowest (5.44%) in October. *Ergasilus sieboldi* and nauplii were the most abundant copepods. Although, the highest cladoceran abundance occurred in December with 1307 ind. m^{-3}, Cladocera densities in plankton were generally either rather low or absent in some months. *Leydigia acanthocercoides* was the most abundant cladoceran. The population densities of the two stations were different (Fig. 6). Station II had more abundant zooplankton species than station I, which had a high fish population and was exposed to direct sun.

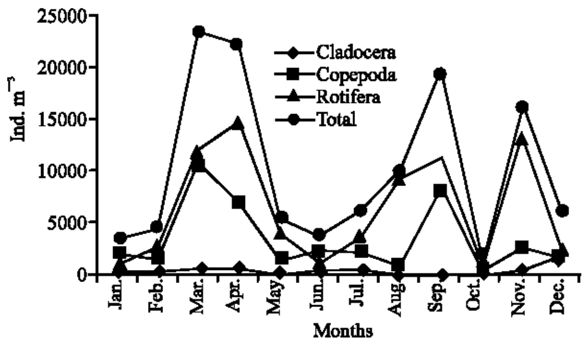

Fig. 5: The average values of zooplankton density of Balikligöl

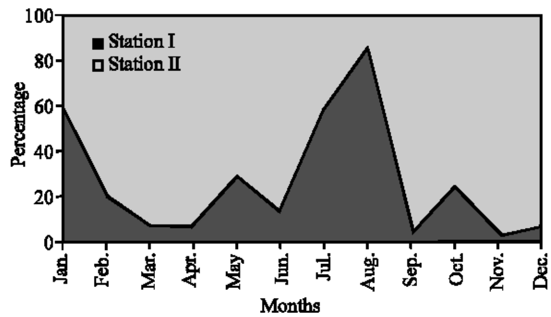

Fig. 6: Contributions of Station I and II to total zooplankton density

Physical and chemical parameters (e.g., temperature, dissolved oxygen, electrical conductivity) play an important role in the occurrence of zooplankton communities (Herzig, 1987). Especially, the influence of water temperature on the zooplankton community is a well-known phenomenon (Haberman, 1998). In Balikligol, the seasonal variability in total zooplankton abundance is clearly caused by water temperature and oxygen content. In the shallow and fast-warming Balikligol, the intensive development of zooplankton started in March at a temperature 18°C, probably because of a combination of high fecundity of the overwintering population and the hatching of resting eggs. Following this, there was a decline in total number, which is thought to have been reinforced by fish predation. The summer plankton were the most typical in the lake. The high temperature and the low dissolved oxygen values were unfavourable for the density of cladocerans and copepods but favourable for the considerably smaller-sized rotifers, which are tolerant of low oxygen levels. Rotifers are particularly sensitive to environmental conditions and respond quickly to environmental changes and therefore, have been considered good indicators of water quality (Gannon and Stemberger, 1978; Sladecek, 1983; Marneffe *et al.*, 1998). No ergasiliids were found in this period and the remaining species except Brachionus species and bdelloids occurred at low densities. Rotifera were represented mainly by *Brachionus calyciflorus*, *Br. quadridentatus* and bdelloids. According to Sladecek (1983), the genus Brachionus is in the index of eutrophic waters and its abundance is considered as a biological indicator of eutrophication. So, in the present study the abundance (83%) of Brachionus species in summer suggests that lake had reached the eutrophic stage. Besides, in summer the availability of food is more due to organic matter production and decomposition (Kudari *et al.*, 2005) and most rotifers feed predominantly on detritus and bacteria (Koste, 1978). The above factors may have contributed to the increased number of species present in the summer months. The highest species number was observed in August with 20 species, 19 of which were rotifers. After summer, while the numbers of ergasiliids rapidly increased in September, Brachionus species decreased and the lowest oxygen and pH values of the sampling period were recorded with 2.6 mg L^{-1} and 5.8, respectively. As a result, zooplankton abundance and composition changed drastically and naturally not only was total abundance suddenly decreased but also the diversity was rather low with six species in October. However, in November, zooplankton abundance rebounded because of changed ecological conditions. During early and mid-winter, crustaceans exhibited a specific succession pattern. The early winter population started with *Alona rectangula* and *Leydigia acanthocercoides* and cladocerans built up a maximum for the first time in December followed by copepods and rotifers. In the lake during the study period, cladocerans constituted a small part of zooplankton composition and abundance. Moreover, in some months, such as August, September and October no cladocerans were found. Their scarcity may be a result of predation pressure and environmental conditions.

As catches of fish in this lake are not permitted for religious reasons, the numbers of fish have enormously increased. The large fish population has negative effects on zooplankton composition and abundance because of predation pressure (Michaloudi *et al.*, 1997). Size-selective feeding by fish as well as a reduction of the fecundity of Cladocera has led to changes in the species structure of the crustacean community leading to an increase in the density and domination of small species. Thus, the effects of fish pressure and eutrophication on zooplankton are similar (Karabin *et al.*, 1997). In Balikligol, pressure from fish has a significant impact on zooplankton especially crustaceans. The lake is dominated mainly by small sized species (rotifers, small sized cladocerans and nauplii of copepods). On the other hand, the severe oxygen deficit that occurred throughout the sampling period is also one of the main problems for Balikligol and is the main factor in fish mortality. In particular, many dead fish were observed in the late summer and early autumn period. Deniz (1967) pointed out that oxygen deficiency was the main factor in sudden fish mortalities that occurred in mid-August 1967 and the water of Lake Balikligol has been highly contaminated with organic pollution for a long time. Also, Armagan *et al.* (2008) reported low COD values of Balikligol Lake in summer period.

Undoubtedly, foods like bread and maize thrown by visitors to feed the fish, dead fish and fish metabolism products have been causing organic pollution for a long time. During the study, high amounts of organic particles and low oxygen values were observed particularly from the summer months to mid-autumn supporting the presence of organic pollution. At the same time, high temperature was also a main factor in the oxygen deficit and also in the increasing of assimilation of organic matter in sediment. These findings show that most of the recorded species in Balikligol are specialised organisms tolerant of low oxygen levels and high temperatures and hence have survived in spite of predation pressure.

CONCLUSION

Balikligol Lake can be characterized quite rich as regard to in zooplankton structure in spite of predation pressure and negative environmental conditions. Foods like bread and maize thrown by visitors to feed the fish and intensive fish metabolism products have been causing pollution for a long time. Deterioration of water quality, especially in summer and autumn period has a negative impact on animal communities. Thus, lake needs to emergency precautions.

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