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# ZOOPLANKTON IN LAKE ZEMPOALA, LAGUNAS DE ZEMPOALA NATIONAL PARK, MORELOS, MEXICO

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**Abstract:** The zooplankton of Lake Zempoala play a key role in aquatic ecosystems, as they feed on microalgae and serve as a source and transfer of energy for juvenile fish. For this reason, the present study aims to provide recent information on the zooplankton richness of Lake Zempoala and its relationship with some physicochemical parameters of the water. Sampling was carried out in three months during the cold rainy and dry seasons. Three monitoring stations were located in the aquatic system and water samples were taken to determine the water quality and its relationship with the organisms. Twenty species of zooplankton were identified, distributed in two phyla: Rotifera and Arthropoda. Rotifers represented 65% of the species richness, with the Brachionidae family being the most diverse, cladocerans made up 25% and copepods 10%. The sampling stations (E1, E2 and E3) showed differences in richness, with September being the month with the highest number of species (18). *Asplanchna sieboldi* and *Brachionus havanaensis* were the common species in all stations. The physicochemical characteristics of the water revealed that the lake has alkaline conditions and moderate levels of conductivity and dissolved oxygen, with seasonal variations. The highest oxygen levels were recorded in February, while September showed the highest species richness. In general, these relatively stable environmental conditions favored zooplankton biodiversity during the study period. Lake Zempoala, with moderate zooplankton diversity and environmental stability, offers a suitable environment for the persistence of this community, despite seasonal fluctuations.

**Keywords:** Zooplankton, Lake Zempoala, Biodiversity, water quality, Rotifera, Biodiversity, water quality.

## INTRODUCTION

The microscopic fauna in water consists of a great diversity of organisms with representatives of almost all taxonomic groups (Wetzel, 2001). Zooplankton play a key role in aquatic ecosystems as they feed on microalgae and particulate organic matter; these organisms have a high ecological value because they serve as food for larvae, juveniles and small sizes of fish (Gallo-Sánchez *et al.*, 2009; Astiz and Álvarez, 2014). In addition, they play an important role in nutrient cycling and energy transfer (Sree and Shameem, 2017; Yang *et al.*, 2017); since their representatives are located at higher trophic levels and primary producers, these are sensitive to both nutrient control ("bottom-up") and predation ("top--down") effects (Caroni and Irvine, 2010).

The specific composition of zooplankton can be an excellent criterion to characterize the trophic state of aquatic ecosystems, as well as to deduce the structure of aquatic communities (Conde-Porcuna *et al.,* 2004; Gómez--Márquez *et al.*, 2013). Likewise, population changes as well as chemical perturbations within the ecosystem will affect community composition; however, the direct and indirect effects on these communities and other taxonomic groups will depend on the interaction that occurs between physical, chemical and biological factors (Astiz and Alvarez, 2014; Sree and Shameem, 2017).

The abundance of these groups varies according to the conditions presented by the aquatic ecosystems; copepods represent on average 35 to 50% of the zooplankton biomass (Granados, 1981; Suárez-Morales *et al.,* 1996; Granados and Álvarez del Ángel, 2007; Gómez-Márquez *et al.*, 2013). The participation of copepods in secondary production is relatively lower because their individual life span is on average longer. In biomass, cladocerans often compete extensively with rotifers because they sustain a similarity in the way they feed (Margalef, 1981; Merayo and González, 2010). Rotifers dominate in eutrophic conditions or also when crustacean development is inhibited by external agents (chemical wastes) (Margalef, 1983; Sarma and Nandini, 2017). The distribution of zooplankton shows changes in spatial and temporal abundance, and for the identification of these it is convenient the description of zooplankton communities that allow to know their role within the trophic dynamics of epicontinental aquatic ecosystems (Granados and Álvarez del Ángel, 2007; Merayo and González, 2010).

In the state of Morelos, Lake Zempoala is one of the few aquatic ecosystems of volcanic origin that harbor endemic organisms such as the salamander (*Ambystoma zempoalensis*); the acocil (*Cambarellus zempoalensis*) and a calanoid copepod (*Letpdiaptomus cuahutemoci*) (Trejo, 2012; Granados-Ramírez *et al.*, 2014; Trejo-Albarrán *et al.*, 2018; Trejo-Albarrán *et al.*, 2023). On the other hand, due to its geological and topographic formation, this lake provides a series of environmental services, including air purification, microclimate regulation, and groundwater recharge. Because it is a protected natural area, it is subject to different research on environmental issues that may favor the conservation of the aquatic and terrestrial ecosystem. Based on the above mentioned, the present study aims to provide recent information on the zooplankton richness of Lake Zempoala and, its relationship with some physicochemical parameters of the water.

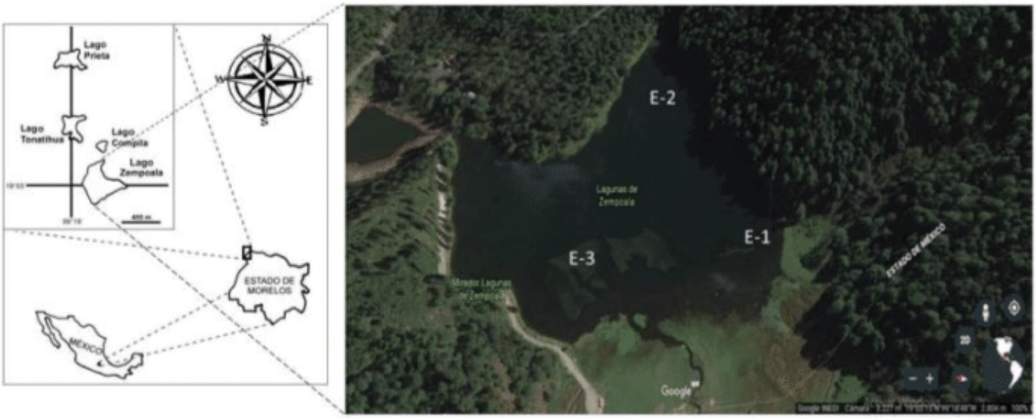


**Figure. 1.**- Location of the Study area of Lake Zempoala and location of the sampling stations (Taken from Google Earth, 2018)

| Filo | Class | Order | Family | Species |
|---|---|---|---|---|
| Rotifera | Eurotatoria | Ploima | Asplanchnidae | *Asplanchna sieboldii* De Guerne, 1888 |
| | Monogonta | | Brachionidae | *Brachionus havanaensis* Rousselet, 1913 |
| | | | Brachionidae | *Brachionus falcatus* Zacharias, 1898 |
| | | | | *Keratella cochlearis* Gosse, 1851 |
| | | | | *Keratella quadrata* Müller, 1786 |
| | | | | *Keratella valga* Apstein, 1907 |
| | | | | *Kellicottia bostoniensis* Rousseletet, 1908 |
| | | | Euchlanidae | *Euchanis dilata* Ehrenberg, 1832 |
| | | | Lecanidae | *Lecane luna* Müller, 1776 |
| | | | Lepadellidae | *Lepadella ovalis* De Müller, 1896 |
| | | Flosculariaceae | Filinidae | *Filinia longiseta* Ehrenberg, 1834 |
| | | | | *Filinia terminalis* Plate, 1886 |
| | | | Testudinellidae | *Testudinella patina* Hermann, 1783 |
| Arthropoda | Branchiopoda | Diplostraca | Chydoridae | *Alona setulosa* Megard, 1967 |
| | | | | *Alona guttata* Sars, 1862 |
| | | | | *Camptocercus* sp. Baird, 1843 |
| | | | Bosminidae | *Bosmina longirostris* Müller, 1776 |
| | | | Daphniidae | *Daphnia laevis* Birge, 1879 |
| | Maxillopoda | Calanoid | Diaptomidae | *Leptodiaptomus cuautemoci* Osorio-Tafall, 1941 |
| | | Cyclopoida | Cyclopoidae | *Tropocyclops prasinus* Fisher, 1860 |

**Table 1.** List of zooplankton species recorded in Lake Zempoala.

## STUDY AREA

Lagunas de Zempoala National Park is located 65 km south of Mexico City and 30 km north of Cuernavaca City between parallels 19° 01' 30" and 19° 06' 00" N and meridians 99° 16' 20" and 99° 21' 00" W (Bonilla-Barbosa and Novelo-Retana, 1995) (Figure 1). Lake Zempoala is the largest of the seven semi-permanent environments that make up the park's lakes, located at coordinates 19° 03' 00" N and 99° 18' 42" W, at 2800 m.a.s.l., at the foot of Zempoala hill (INEGI, 2000). It has an area of 10.564 ha, 508 m., maximum length in NNE--SSW direction and an average width of 207.9 m (García, 1988; Taboada *et al.*, 2009; Godínez-Ortega *et al.*, 2017).

## MATERIALS AND METHODS

For the present study, three sampling sites were established in Lake Zempoala, taking into account the visibility of submerged aquatic vegetation. Station one (E1) is located on the eastern shore, and is identified by having rooted macrophytes (*Egeria densa*) visibly protruding from the lake. Station two (E2) is located in the north of the lake, in this station the macrophytes are not so prominent so the stain generated by the itself is continuously removed by the people in charge of the park; however, species such as *Potamogeton crispus* and *Egeria densa* can be observed. Station three (E3) was considered to the west of the lake, where a patch of *Potamogenton illinoensis* was recorded. Three samplings were conducted at each study site, covering the two contrasting seasons of the year in this ecosystem: rains (September and October 2018) and cold low water (February 2019).

During each visit, the following parameters were determined: ambient and water temperature with the help of a ± 1°C thermometer, water transparency (m) by means of a Secchi disk. For the determination of dissolved oxygen, a HANNA model HI9146 oximeter was used. The pH, total dissolved solids and electrical conductivity were measured with a multiparameter pH/mV/Temperature meter xtech instruments. To evaluate water quality, water samples were collected at each site (in duplicate) to determine total hardness by the complexometric method and alkalinity by the indicator method (APHA, 2009). All water samples were stored and refrigerated at 4°C and in darkness until they were transferred to the laboratory.

For the zooplankton collection, 80 liters were filtered for each station with a 50 µm net, the samples were deposited in 250 ml bottles and fixed in 10% formalin for the preservation of the organisms. Observation of the samples taken was carried out in the Laboratory of Hydrobiology of the Los Belenes Professional Unit of the Centro de Investigaciones Biológicas (CIB), after which a list of the species found was drawn up and a taxonomic analysis was made. The separation of copepods and cladocerans was carried out with a dissection needle and in the case of rotifers with capillary tubes, with the aid of a stereoscopic microscope (Leica, EZ4E) and a compound microscope (Leica, DM500). For taxonomic identification, the works of Balwin and Chandler (1918), Ahlstrom (1940), Edmonson and Winberg (1971), Smirnov (1971), Pennak (1978), Koste (1978), Elías-Gutiérrez *et al.*, (1997), Elías--Gutiérrez *et al.*, (2008) and Thorp and Rogers (2015) were taken as sources in order to reach the lowest possible taxonomic level.

Quantitative analysis of zooplankton samples was performed using a one-milliliter Sedwick-Rafter chamber, with two replicates (Wetzel and Likens, 2000) and specific richness was analyzed (Moreno, 2001). The Shannon-Wiener index was used to determine the diversity of the lake and Simpson's index was used to determine dominance (Moreno, 2001). Finally, based on Ledesma *et al.* (2013), principal component analysis (PCA) was car-


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ried out using the STATGRAPHICS plus v. 5.1 statistical package, in order to reduce the dimensionality of the total parameters obtained during the study and determine the behavior of the system based on the parameters that most influence the organisms (Dallas, 2000).

## RESULTS

A total of 20 species were recorded, distributed in two phyla (Rotifera and Arthropoda), four classes (Eurotaria, Monogononta, Brachiopoda and Maxilopoda). five orders (Ploima, Floscularíaceae, Diplostraca, Calanoida and Ciclopoida) and 12 families (Asplachnidae, Brachionidae, Euchlanidae, Lecanidae, Lepadellidae, Fillinidae, Testudinellidae, Chydoridae, Bosminidae, Diaptomidae, Cyclopoidae). It was observed that the class Monogonta was the most represented in families (seven) and species (12) (Table 1).

It was observed that rotifers registered the highest percentages in terms of species richness (65.0%), followed by cladocerans with 25.0% and the minimum corresponded to copepods (10.0%) (Figure 2).

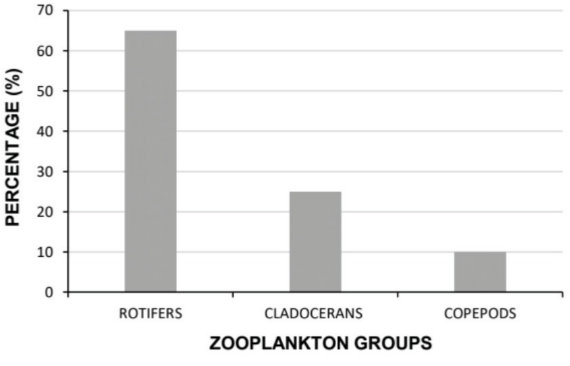


**Figure 2.** Total percentage of zooplankton groups recorded at three stations in Lake Zempoala, Morelos.

The family Brachionidae (Rotatoria; Ploimidia) presented the highest richness with seven species representing 35% of the total richness; the family Chydoridae (Arthropoda; Branchiopoda) with three species represented 15%; the families Lecanidae and Filinidae (Rotatoria; Ploimidia) with 2 species each accounted for 20% of the total richness. Finally, the families Asplanchnidae, Testudinellidae (Rotatoria; Ploimidia), Diaptomidae, Cyclopoidae (Arthropoda; Maxilopodae), Daphniidae and Bosminidae (Arthropoda; Branchiopoda) with one species each, together accounted for 30% of the total richness (Figure 3).

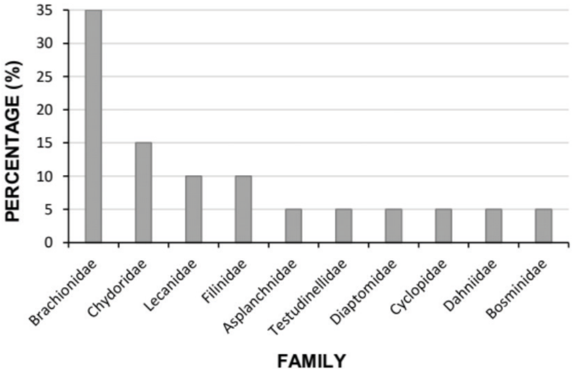


**Figure 3.** Total percentage of zooplankton species by family recorded in three stations in Lake Zempoala, Morelos, Mexico

### SPECIES RICHNESS BY SEASON

Stations 1 (E1) was recorded to have a total of 16 species, followed by the station 3 (E3) with 13 species, while station 2 (E2) exhibited a total of 11 species. It was observed that the rotifers *Asplachna sieboldi, Brachionus havanaensis, Kelicottia bostoniensis, Testudinela patina* and *Keratela valga*, as well as the cladoceran *Alona setulosa*, were recorded at all three sampling stations. Likewise, the rotifer *Lepadella ovalis* was observed only in E1, while the cladocerans *Alona gutatta* and *Bosminia longirostris* are exclusive to E2, the rest of the species were present in two stations (Table 2).

### ZOOPLANKTON RICHNESS BY MONTH

The species richness recorded in each of the sampling months in the three stations was 20 species, with a total of 18 species in September and 16 in October and February. *Asplanchna sieboldii, Brachionus havanaensis, Brachionus falcatus, Keratella quadrata, Leca-*

*ne luna, Filinia longiseta, Testudinella patina, Alona setulosa, Camptocercus* sp., *Daphnia laevis, Leptodiaptomus cuautemoci* and *Tropocyclops prasinus* were recorded in the three sampling months. The rotifer *Keratella valga* was only obtained in February and the cladoceran *Alona guttata* in September; the rest of the species were recorded in at least two sampling months (Table 3).

| Species | E1 | E2 | E3 |
|---|---|---|---|
| *Asplanchna* | 1 | 1 | 1 |
| *Brachionus* | 1 | 1 | 1 |
| *Brachionus* | 1 | 1 | 0 |
| *Keratella* | 1 | 0 | 1 |
| *Keratella* | 1 | 0 | 1 |
| *Keratella* | 1 | 1 | 1 |
| *Kellicottia* | 1 | 1 | 1 |
| *Euchanis* | 1 | 0 | 1 |
| *Lecane* | 1 | 0 | 1 |
| *Lepadella* | 1 | 0 | 0 |
| *Filinia* | 1 | 0 | 1 |
| *Filinia* | 1 | 0 | 1 |
| *Testudinella* | 1 | 1 | 1 |
| *Alona setulosa* | 1 | 1 | 1 |
| *Alona guttate* | 0 | 1 | 0 |
| *Camptocercus sp.* | 1 | 0 | 1 |
| *Bosmina longirostris* | 0 | 1 | 0 |
| *Daphnia laevis* | 1 | 0 | 1 |
| *Leptodiaptomus cuautemoci* | 0 | 1 | 1 |
| *Tropocyclops prasinus* | 0 | 1 | 1 |

**Table 2.** Absence (0) and presence (1) of zooplankton species recorded in the three localities of Lake Zempoala

## ZOOPLANKTON RICHNESS BY LOCALITY AND MONTHS

In the month of September at station 1, a total richness of eight species was obtained, while in October and February the total richness was ten species each. The species *A. sieboldi, L. luna, Camptocercus* sp and *D. laevis* were present in the three months sampled, while *B. havanaensis* and *F. longiseta and F. terminalis* were only present in September; likewise, *K. cochlearis* and *K. bostoniensis* were only observed in October; finally, *T. patina, E. dilata* and *K. valga* were only observed in February. The rest of the species were present in two months sampled (Table 4).

For station 2, September showed a richness of eight species, followed by February with six species and finally October with four species. In this station, only the rotifer *A. sieboldi* was recorded in the three months sampled. The species *B. falcatus*, *A. gutatta* and *A. setulosa* were recorded only in September, while *B. havanaensis* and *F. longiseta* were recorded only in October. Finally, *T. prasinus* was only observed in February, the rest of the species were found in two months sampled (Table 4).

| Species | Sept | Oct | Feb |
|---|---|---|---|
| *A. sieboldi* | 1 | 1 | 1 |
| *B. havanaensis* | 1 | 1 | 1 |
| *B. falcatus* | 1 | 1 | 1 |
| *K. cochlearis* | 1 | 1 | 0 |
| *K. quadrata* | 1 | 1 | 1 |
| *K. valga* | 0 | 0 | 1 |
| *K. bostoniensis* | 1 | 1 | 0 |
| *E. dilata* | 0 | 1 | 1 |
| *L. luna* | 1 | 1 | 1 |
| *L. ovalis* | 1 | 1 | 0 |
| *F. longiseta* | 1 | 1 | 1 |
| *F. terminalis* | 1 | 0 | 1 |
| *T. patina* | 1 | 1 | 1 |
| *A. setulosa* | 1 | 1 | 1 |
| *A. guttata* | 1 | 0 | 0 |
| *Camptocercus sp* | 1 | 1 | 1 |
| *B. longirostris* | 1 | 0 | 1 |
| *D. laevis* | 1 | 1 | 1 |
| *L. cuahutemoci* | 1 | 1 | 1 |
| *T. prasinus* | 1 | 1 | 1 |

**Table 3.** Monthly variation of zooplankton species recorded in three localities of Lake Zempoala.

In station 3, 13 species were recorded in September, followed by October with 11 species, while February presented the lowest richness with eight species. The species *A. sieboldi, B. havanaensis, F. longiseta, D. laevis, L. cuahutemoci* and *T. prasinus* were recorded in the three months sampled. *K. cochlearis,* *Camptocercus* sp and *A. setulosa* were recorded only in the month of September, while *F. terminalis* was exclusive to the month of February, the remaining species were recorded in two of the three sampling months (Table 4).

Based on the Shannon-Wiener diversity index, the system showed low diversity values in all sampling months with values of 1.1 for September, 0.8 in October and 1.0 in February. Evenness was 0.5 for September and February and 0.7 in October and tended to decrease towards the end of sampling, but the overall pattern remained with little fluctuation.

| | E1 | | | E2 | | | E3 | | |
|---|---|---|---|---|---|---|---|---|---|
| **Species** | **sept** | **Oct** | **feb** | **sept** | **oct** | **feb** | **sept** | **oct** | **feb** |
| A. sieboldi | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| B. havaensis | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 |
| B. falcatus | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| K. cochlearis | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| K. quadrata | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 |
| K. valga | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 |
| K. bostoniensis | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 |
| E. dilata | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| L. luna | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 |
| L. ovalis | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| F. longiseta | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 |
| F. terminalis | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| T. patina | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 |
| A. setulosa | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 |
| A. guttate | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| Camptocercus sp | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| B. longirostris | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| D. laevis | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 |
| L. cuahutemoci | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 |
| T. prasinus | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| Total species | **8** | **10** | **10** | **8** | **4** | **6** | **13** | **11** | **8** |

**Table 4.** Monthly variation by locality of zooplankton species recorded in three localities of Lake Zempoala

## PHYSICAL-CHEMICAL CHARACTERIZATION

Temperature ranged from 12.7ºC to 20ºC recorded in February at stations E1 and E2 and in September at station E1, respectively. Trends in ambient temperature were similar at the three stations, recording similar averages of 16.7±2.1ºC (E1); 16.8±2.1ºC (E2) and 16.8±1.8ºC (E3) (Table 5). Transparency recorded by Secchi disk exhibited two maximum values, both in the month of February at station E2 (4.5 m) and station E3 (3.5 m) and the minimum in September at all three stations (1.6 m). Station E1 exhibited an average of 2.0±0.3, E2 2.7±0.9 and E3 2.4±0.6 (Table 5).

Dissolved oxygen concentration recorded its lowest values in October at all three sampling stations with a minimum of 2.2 mg/L corresponding to station E1, while the highest values were exhibited in the month of February also at all three stations of 8.02 mg/L at station E3. Station E1 had an average of 4.9±1.8 mg/L; while stations E2 and E3 had similar means (5.3±1.5 mg/L and 5.0±1.6 mg/L respectively) (Table 5).

The variation in pH concentration indicates an alkaline state in the three sampling stations, with a range between 8.3 in the month of October to 10 in September, both values corresponding to station E2. An average of 9.0±0.9 was observed at the three stations (Table 5).

The highest conductivity recorded was at station E2 (102.0 µS/cm) in the month of October, while the minimum was 80.0 µS/cm and was observed in the months of September and October at station E3. The lowest average value was present at station E3 (83.0±3.0 µS/cm), while the maximum corresponded to station E2 91.3±5.8 µS/cm (Table 5). Total dissolved solids (TSD), showed a range between 40.0 ppm corresponding to the months of September and October at station E3, with an average of 41.7±1.7 ppm, to 51.0 ppm in October recorded at station E2 with an average of 45.7±2.9 ppm (Table 5).

The alkalinity levels recorded ranged from 28 mg/l $CaCO_3$ in September to 95.0 in February, both at station E3. Stations E1 and E2 exhibited similar average (58.7±15.0 mg/l $CaCO_3$ and 56.7±12.5 mg/l $CaCO_3$), while station E3 was 60.7±19.4 mg/l $CaCO_3$ (Table 5). As for the hardness recorded during the sampling period, station E2 exhibited the minimum and maximum values (32.0 mg/l $CaCO_3$, and 90.09 mg/l $CaCO_3$ respectively). As for the average values, station E2 showed the lowest values (59.4±16.9 mg/l $CaCO_3$), while stations E1 and E3 had relatively similar values (66.7±7.9 mg/l $CaCO_3$ and 68.1±6.1 mg/l $CaCO_3$) (Table 5).

## DISCUSSION

Based on the bibliographic review, a total of 117 species of zooplankton have been reported, which vary according to the years of study. Flores (1998) conducted an exclusive study of rotifers and recorded a total of 35 species for this ecosystem. Trejo (2012) conducted a study on the variation of zooplankton, in which he reports a total of 25 species belonging to the groups of copepods, cladocerans and rotifers. Muñoz (2014) reports the specific richness of rotifers (64 species) and Barragán (2016) reports a total of 57 species belonging to the groups of rotifers, copepods and cladocerans, while in the present study a total of 20 species were recorded. The difference in the number of species is possibly due to the techniques and time of collection and even, to the disturbance that over the years has been presenting the ecosystem and also possibly to the predation that may be causing the presence of the fish fauna in the aquatic system, mainly *Girardinichthys multiradiatus* (Trujillo-Jiménez & Espinosa de los Montero, 2006; Granados-Ramírez *et al.,* 2014), *Poecilia* sp. and *Oncorhynchus mykiss* (Granados-Ramírez *et al.*, 2014; Trejo-Albarrán *et al.*, 2022).

The aquatic ecosystem, even though it is located in a protected natural area, has been affected by various environmental problems, such as erosion, deforestation, loss of biodiversity, soil contamination, which indirectly affects the aquatic ecosystems, registering over time that the water quality has changed negatively. Flores (1998) reported that according to the Dinius water quality index, Lake Zempoala was an ecosystem of excellent quality for aquatic life, fishing and recreational use, acceptable for agriculture and slightly contaminated for use as drinking water, while according to the organic matter content index, it is an oligosaprobic ecosystem (corresponding to waters saturated with oxygen, with little nitrogen, clean and generally transparent). However, Quiroz (2011) reports that the conditions of Lake Zempoala show serious ecological deterioration, caused by several factors, such as: immoderate logging, extraction of forest land, overgrazing, contamination (by various means), mainly due to the inclusion of solid materials, organic matter, grease, detergents and its use as a recreational area. Also, by the extrac-

| | | T. water (\|C) | Transparency (cm) | pH | Conductivity (µS/cm) | TSD (ppm) | $O_2$ (mg/L) | Alkalinity (mg $CaCO_3$/L) | Hardness (mg $CaCO_3$/L) |
|---|---|---|---|---|---|---|---|---|---|
| | **Sep** | 20.0 | 1.6 | 9.8 | 83.0 | 42.0 | 4.2 | 32.0 | 56.1 |
| | **Oct** | 17.3 | 2.0 | 9.0 | 84.0 | 42.0 | 2.2 | 60.0 | 62.1 |
| **E1** | **Feb** | 12.7 | 2.5 | 8.6 | 89 | 45.0 | 8.2 | 84.0 | 82.1 |
| | $\dot{X}$ | 16.7 | 2.0 | 9.1 | 85.3 | 43.0 | 4.9 | 58.7 | 66.7 |
| | **e.g.** | 2.1 | 0.3 | 0.4 | 1.9 | 1.0 | 1.8 | 15.0 | 7.9 |
| | **Sep** | 19.4 | 1.7 | 10.0 | 82.0 | 41.0 | 4.8 | 32.0 | 32.0 |
| | **Oct** | 18.4 | 2.0 | 8.3 | 10.02 | 51.0 | 2.9 | 65.0 | 56.1 |
| **E2** | **Feb** | 12.7 | 4.5 | 8.8 | 90.0 | 45.0 | 8.2 | 73.0 | 90.1 |
| | $\dot{X}$ | 16.8 | 2.7 | 9.0 | 91.3 | 45.7 | 5.3 | 56.7 | 59.4 |
| | **e.g.** | 2.1 | 0.9 | 0.5 | 5.8 | 2.9 | 1.5 | 12.5 | 16.9 |
| | **Sep** | 19.3 | 1.7 | 8.7 | 80.0 | 40.0 | 4.2 | 28.0 | 56.1 |
| | **Oct** | 17.8 | 2.0 | 9.6 | 80.0 | 40.0 | 2.6 | 59.0 | 76.1 |
| **E3** | **Feb** | 13.4 | 3.5 | 8.6 | 89.0 | 45.0 | 8.0 | 95.0 | 72.1 |
| | $\dot{X}$ | 16.8 | 2.4 | 9.0 | 83.0 | 41.7 | 5.0 | 60.7 | 68.1 |
| | **e.g.** | 1.8 | 0.6 | 0.3 | 3.0 | 1.7 | 1.6 | 19.4 | 6.1 |

**Table 5.** Physical and chemical parameters by stations and periods of study of Lake Zempoala. $\dot{X}$, Mean; i.e., standard error.

tion of water, as well as the increase in sediment levels, caused by the continuous contribution of exogenous material (soil, trunks and leaves) and endogenous material (mainly due to the increase in aquatic vegetation). Likewise, this author reports that at the beginning of the 1980s there was a maximum depth level of 8 meters and at the end of the 1990s, 6 and even 7 meters were recorded. Muñoz (2014), reports that according to Sládeček's (1983) saprobitic index, this ecosystem is oligotrophic, while Molina-Astudillo *et al*., (2016) mention that according to Carlson's trophic state index, Lake Zempoala is considered a eutrophic system with a tendency towards hypereutrophy. Likewise, Godínez-Ortega *et al*., (2017) mention that, according to the algal flora found in this ecosystem, suggests that the lentic environments of Zempoala could be in a medium process of water pollution, most likely due to anthropogenic processes. The aforementioned could be the causes of the variability of the specific richness of Lake Zempoala.

Flores (1998), Trejo (2012), Muñoz (2014), Ramírez-Granados *et al*. (2014) and Barragán (2016), cite seven species that are recorded in the present study and have been maintained in this ecosystem (*Brachionus havaenensis, Kellicottia bostoniensis*, *Keratella cochlearis, Filinia longiseta, Filinia terminalis*, *Lepadella ovalis* and *Lecane luna*). According to Pejler (1977) and Roldán & Ramírez (2008), rotifers of the genera *Brachionus* and *Keratella* are typically dominant in water bodies. While *Kellicotia bostoniensis* has a capacity for high ecological plasticity, allowing it to colonize water bodies that differ in trophic status, water salinity, color and pH (Zhdanova *et al*., 2016). The genus *Filinia* contains species that possess mobile, elongated and flexible appendages that swing, making wide, arc-shaped movements and after detecting disturbances in their environment produced by a predator or a large suspension feeder, these species exhibit a series of rapid jumping movements that help them escape (Basińska, *et al.*, 2010).

In addition, Granados-Ramírez and Álvarez--Del Ángel (2003) report that *Filinia longiseta* is a thermophilic, epilimnetic species, of stratified environments, and is present in temporary or permanent systems, which are present in subtropical and tropical (24-28°C) zones. Yin *et al*., (2018) mention that species of the genera *Lepadella* and *Lecane,* have benthic and periphytic habits and find favorable living conditions and have no competition compared to planktonic species living in open areas of calm waters, which tend to be predated by *Asplanchna* and copepods and that, in addition, the number of emergent and submerged aquatic plants may be another important factor, as it provides an ideal habitat for rotifers. The above mentioned literature makes these species successful and that is why they have the ability to remain in aquatic ecosystems.

In the present study, a total of 20 species were recorded, of which 13 were rotifers, five were copepods and two were cladocerans. Trejo (2012) reports a total of 21 species of rotifers for this same ecosystem, followed by cladocerans with three species and finally copepods (two species). Likewise, Barragán (2016) reports a total of 46 species of rotifers, two of copepods and three of cladocerans, which coincides with the present study in that rotifers were the most representative and cladocerans and copepods very low representativeness. Merayo & González (2010) and Gómez-Márquez *et al.* (2013), report that the highest species richness was represented by rotifers (10 and 11 species, respectively). Unlike other studies (Suárez-Morales *et al*., 1993), in the present study rotifers were the most representative, Margalef (1976) confers that the diversity of rotifers is due to their high degree of population renewal, which allows them to use diverse material in suspension, confining them ecological preferences that places them as indicators of water quality. the specific richness obtained in this study is considered.

Although there is an inverse behavior between diversity and evenness, the variation throughout the study remained within a range. It is possible that the low diversity and density of zooplankton, was caused by human activities as happens in other aquatic systems in the state of Morelos, as well as the predatory activity of the existing ichthyofauna (*Oncorhynchus mikyss, Poecilia sp. and Girardinichthys multiradiatus*), reported by Granados-Ramírez *et al.* (2014).

In the present study, the genus *Keratella* was the most representative with three species, noting that the average temperature value was 16.8ºC, which according to Wetzel (2001), temperature is a key factor in determining the reproduction rates of rotifers, indicating that temperatures between 15 and 20ºC are optimal for rotifers reproduction. Gómez-Márquez *et al*., (2013) mention that on the Huitchila bordo in the state of Morelos, *Keratella cochlearis* and *K. quadrata* achieved high densities in a wide range of temperatures and that, according to field data, suggest that both species are truly thermal in the temperature ranges recorded and that variations in abundance were largely related to some other environmental factor, probably food availability.

Regarding the composition of cladocerans, Elías-Gutiérrez *et al.* (1999) cite that the large Mexican reservoirs are dominated by several species of the genera *Daphnia* and *Bosmina;* the first genus is characteristic of temperate and cold waters and the second of coastal conditions, with *Daphnia laevis* and *Bosmina longirostris* being recorded in the present study.

Within the group of rotifers, the Branchionidae family presented the greatest richness with seven species, representing 35% of the total richness; Sládecek (1983) mentions that they can be considered as highly tolerant to certain concentrations of contaminants, as well as to diverse ecological factors; Osorio (1942) mentions that brachionids are especially frequent in Mexican fresh and brackish waters.

The rotifers *Asplachna sieboldi, Brachionus havanaensis, Kelicottia bostoniensis, Testudinela patina* and *Keratela valga*, as well as the cladoceran *Alonna setulosa*, were recorded at all three sampling stations. Likewise, it was observed that the rotifer *Lepadella ovalis* was found only in E1, while the cladocerans *Chydorus sphaericus, Alona gutatta* and *bosminia longirostris* are exclusive to E2. The rotifers *Asplachna sieboldi, Brachionus havanaensis, Kelicottia bostoniensis, Testudinela patina* and *Keratela valga*, as well as the cladoceran *Alonna setulosa*, were present in all three sampling stations since they are reported by Granados (1990) as species associated with aquatic vegetation as well as being tolerant to contamination. Gómez-Márquez *et al.* (2013) mention that they are cosmopolitan species that were regularly found in alkaline environments.

Muñoz (2014), reports that the species did not always occur during the study period, which may be due to environmental conditions, as well as nutrient concentration and temperature. In the present study, 60% of the species were collected throughout the entire sampling period; however, the cladoceran *Alona guttata* was exclusive to the month of September, while the rotifer *Keratella valga* was only collected in the month of February, the rest of the species were obtained in at least two months of sampling. Likewise, Muñoz (2014), mentions that the influence of abiotic factors in neotropical or tropical lakes can be specific for each of the species, which can be observed in the present study.

Finally, Trejo *et al.* (2018), conducted a study about the copepod *Leptodiaptomus cuahutemoci* in Lake Zempoala, Morelos, in which he describes that the composition, abundance and spatial distribution has greater variation in terms of biological cycles, that affect the population dynamics and not by the effect of physical and chemical factors. It also mentions that the abundance and spatial distribution was higher during the rainy season because there is more organic matter and the depth and volume increase. It should be noted that *Leptodiaptomus cuahutemoci* is a species endemic to the state of Morelos, first described by Osorio (1941; cited in: Suarez-Morales *et al.*, 2000). This genus is widespread in North America.

## CONCLUSIONS

In the study of zooplankton from Lake Zempoala, Morelos, 20 species were recorded, distributed mainly in two phyla: Rotifera and Arthropoda. Rotifers were the dominant group, representing 65% of the total species richness, while cladocerans and copepods represented 25% and 10%, respectively. The Brachionidae family was the most diverse, contributing 35% of the species. The physical-chemical behavior of the water showed slight variations between seasons, relatively stable environmental conditions that favor the zooplanktonic biodiversity of the lake, which facilitates its persistence and seasonal distribution.

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