

Zooplankton variation in Fraijanes Lake (Costa Rica) during the course of one year

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Abstract: Zooplankton in small tropical lakes has been little studied and its variation during the year may respond to different factors. In this study, the zooplankton of a small neotropical lake was studied at different times during one year and compared with changes in the lake conditions and in phytoplankton composition. The lake stratifies from March until September, and mixes during the hemispherical winter, from October until February. Besides the lake show a seasonal fluctuation in water level according to the seasonality of rains. Zooplankton was composed of at least 13 species, four Cladocerans, three Copepods, four Rotifers and other groups such as an Ostracod and the larvae of *Chaoborus*. The most abundant were *Thermocyclops* sp., *Daphnia* sp. and *Keratella tropica*. Their abundance fluctuated along the year, probably in response to changes in lake level and changes in hydrological conditions, increasing during dry season when the main outlet of the lake dried up. Changes in phytoplankton composition do not seem to be as relevant for zooplankton variation in this small lake. Rev. Biol. Trop. 66(Suppl. 1): S123-S131. Epub 2018 April 01.

Key words: Zooplankton, Neotropics, small lake, seasonality.

Zooplankton is an important component of all water bodies, from small ponds to large lakes. Its seasonal variability has been described for temperate lakes and summarized in the model developed by the Plankton Ecology Group (PEG) (Sommer, Gliwicz, Lampert, & Duncan, 1986; Sommer et al., 2012). Their model explains planktonic seasonality as the result of a combination of factors associated with temperature, food availability and quality and predation pressure. According to this model, tropical conditions are similar to summer conditions of temperate regions that prevail all year round. In temperate lakes, summer time temperature increases, so a direct stratification occurs. Surface nutrients are consumed

rapidly and lake productivity decreases later in the season (Hutchinson & Löffler, 1956; Sommer et al., 1986; Roldán- Pérez & Ramírez-Restrepo, 2008). However, in tropical regions the driving role played by seasonal variation of temperature and light availability is reduced (Lewis, 1996). It means that species interactions of predation and competition are active all year round, without the starting point in plankton succession that is common to occur during spring at temperate lakes. The main driving force for seasonal changes in tropical ecosystems is usually the variability of precipitation associated to the migration of the Intertropical Convergence Zone (ITCZ) (Kricher, 2011; Haug, Hughen, Sigman, Peterson, &

Röhl, 2001; Waylen, Caviades, Poveda, Mesa, & Quesada, 1998; De Groot, 1998). Studies on seasonal changes of lacustrine zooplankton composition in tropical regions had yielded different results and vary depending on the system (Hart, 1985). In some cases, it has been observed an effect of hydroclimatic variability and associated changes in turbidity, with lower densities during the rainy season, this is due to the effect of dilution and turbidity (López-López & Serna-Hernández, 1999; Twombly, 1983; Hart, 1990; Arcifa, Gomez, & Meschiatti, 1992; Vásquez & Rey, 1992; Dejen, Vijverberg, Nagelkerke, & Sibbing, 2004; Nogueira, Reis-Oliveira, & Tenorio de Britto, 2008), but also from changes in stratification (Saunders & Lewis, 1988; Mengestou & Fernando, 1991; Panarelli, Nogueira, & Henry, 2000); or changes in temperature, which also seem to correlate with changes in predation from *Chaoborus* and fishes in some cases (Cardoso & Marques, 2009; Jiménez-Contreras, Sarma, Merino-Ibarra, & Nandini, 2009; Arcifa et al., 2015). In the present study, the temporal variation of zooplankton in a small neotropical lake, is examined in order to know if changes in zooplankton composition could be explained by the variation in the physical condition of the lake or by changes in phytoplankton composition.

MATERIALS AND METHODS

Study site and sampling: Fraijanes is a small lake located in the south west down slope of Poas Volcano, at 1 160 m above the sea level. It has 2.2 ha of surface area and a maximum depth of 6.2 m when at its maximum level. It is eutrophic, and Secchi readings vary between 0.3 and 1.38 m (Umaña, 2014). The lake changes in water level with the season, and its outlet was active only during the rainy season, with a delay as the level dropped or accumulated back again. It remained dry from March until August 2009. Weather data was provided by the Field Station of the University of Costa Rica at Fraijanes (Station Number 84030, 10°08'14.36" N - 84°11'36.58" W). There was a marked dry season from December to April next year, and a minor dry period in July and August. Air temperature varied between 15 and 20 °C, with minimum temperatures during January and February (Fig. 1).

Zooplankton was sampled at different times during a year period. It started in the middle of the rainy season in August, 2008 and extended into the rainy season in August, 2009. At the beginning sampling was weekly, but later it changed due to logistic reasons. Actual dates are shown in Table S1. A break in the sampling occurred between late December

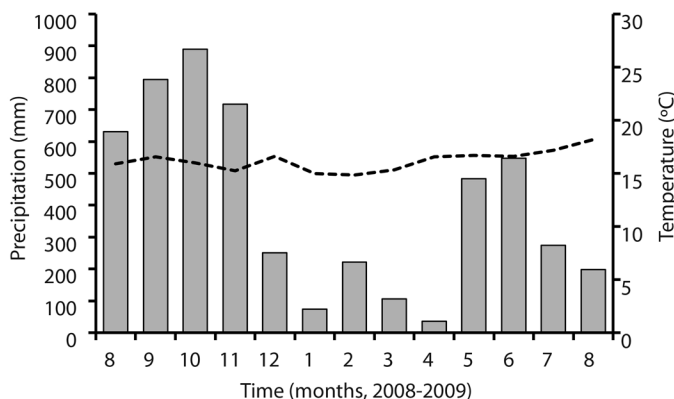


Fig. 1. Monthly variation of precipitation (mm) and air temperature at a station near Lake Fraijanes (Station Number 84030, 10°08'14.36" N - 84°11'36.58" W).

2008 and March 2009 due to the occurrence of an earthquake in January 2009, after which the recreational park where the lake is located, was closed to any visits as it was used as a temporal refuge. One sample was taken per visit, by a horizontal drag from a dock that reached into the middle of the lake, with a 64 μm plankton net mesh size. The trawl distance was used to determine the density of organisms per liter. Samples were preserved in 4 % formaldehyde, then the samples were washed with distilled water in the laboratory and preserved in 70 % ethanol.

Quantification and identification: Samples analysis was made taking five aliquots of 1 ml per sample in which organisms were counted and identified. Zooplankton identification was made following the identification guides of Fernando (2002), Kotov & Stifter (2006), Gutiérrez et al. (2008), Suárez-Morales, Reid, Iliffe & Fiers (1996) y Maas (1998).

Statistical analysis: A cluster analysis was performed to test if changes in composition followed a seasonal trend. A correspondence analysis was employed as a mean to confirm the groupings of sampling dates along the year. A Similarity Percentage test (SIMPER) was used to determine which species contributed

the most to the observed differences among periods of the year. An Analysis of Similarity (ANOSIM) was used to test whether the differences in composition among the periods of the year were significant. All analysis were performed using PAST software (Hammer, Harper, & Ryan, 2001). Phytoplankton data composition from a parallel study (Umaña, 2014) was employed to test the relationship between zooplankton and phytoplankton by means of the BioEnv (Best Subset of Environmental Variables with Maximum (Rank) Correlation with Community Dissimilarities) (Clarke & Ainsworth, 1993) of the library Vegan in R software. For this test phytoplankton data was considered as the environmental data that would explain zooplankton variation. Finally a Canonical Correspondence Analysis between both sets of data performed with PAST in order to visualize the relationships among the phytoplankton and zooplankton taxa.

RESULTS

A total of 59456 individuals were counted in all samples. From these, 12 taxa were identified, four of Cladocera, three of Copepoda, four of Rotifera and the larvae of *Chaoborus* (Table 1), however total diversity is higher

TABLE 1

List of species of zooplankton in Lake Fraijanes, with their accumulated total abundance and frequency of appearance. Groups marked with an asterisk are occasional occurrences of littoral dwellers

Taxonomic Group	Species	General Total	Frequency
Cladocera	<i>Daphnia</i> spp.	5 510.0	17
	<i>Ilyocryptus</i> sp*	289.1	2
Copepoda	<i>Paracyclops</i> sp.*	115.6	4
	<i>Thermocyclops</i> sp.	19 919.4	17
	Nauplio	38 722.9	17
Rotifera	<i>Brachionus</i> sp	333.0	3
	<i>Keratella cochleraris</i>	69.9	1
	<i>Keratella tropica</i>	6 251.2	16
	<i>Lecane</i> sp.	802.2	7
Diptera	<i>Chaoborus</i> sp.	75.7	2
	Other Diptera*	125.4	4
Ostracoda	Ostracoda*	465.0	9
Tardigrada	Tardigrada*	51.5	2

since other groups such as an Ostracod and another Diptera larvae were observed but it was not possible to identify them due to their low abundance. The cladoceran *Ilyocryptus*, the copepod *Paracyclops* and ostracod were occasional dwellers of the pelagial. The most abundant group were the Copepods of the genus *Thermocyclops* sp., followed by the cladoceran *Daphnia* sp.. Two species of *Daphnia* were observed: *Daphnia laevis*, which was the most abundant and *Daphnia gessneri*, with much lower density. Since it was not possible to identify each individual down to species level during sample enumeration, analysis of zooplankton variation was performed with the total *Daphnia* pooled together. Among the Rotifers, the most abundant species was *Keratella tropica*, followed by *Brachionus* sp. and *Lecane* sp.

Abundance of zooplankton changed along the year. During the rainy season 2008, when the outlet of the lake was active, abundance was low for most of the groups. During the dry season in 2009, density increased, especially due to an increase of *Thermocyclops* (Fig. 2).

The cluster analysis using Morisita Similarity Index, separated the sampling dates into three main groups, at the level of 0.81 similarity. A SIMPER analysis showed that 90 %

of the variation was explained by the relative dominance of *Thermocyclops* sp., *Daphnia* spp., and *K. tropica* (Fig. 3A). The first group included some of the samples from September to December 2008, and was characterized by the low abundance of all groups, and *Daphnia* was the second in importance. The second group included only the samples from March 2009, during the dry season with low water level, when the abundance of all groups was higher than the previous groups, and *K. tropica* was second in dominance over *Daphnia* sp. The third group included all other samples, some from 2008 and the samples of the rainy season of 2009, during which a high abundance of all groups, and *Daphnia* and *K. tropica* had similar abundances. An ANOSIM test yielded that the differences were highly significant different ($R = 0.8671$; $p = 0.0001$). However, a Correspondence Analysis did not show such a clear separation between the periods of sampling (Fig. 3B), and the first and third groups did not separate much from each other.

The result of the BioEnv exploratory analysis using the phytoplankton composition as explanatory variables of the zooplankton yielded the best fit model with six phytoplankton taxa: *Coelastrum proboscideum*, *Coelastrum reticulatum*, *Scenedesmus smithii*,

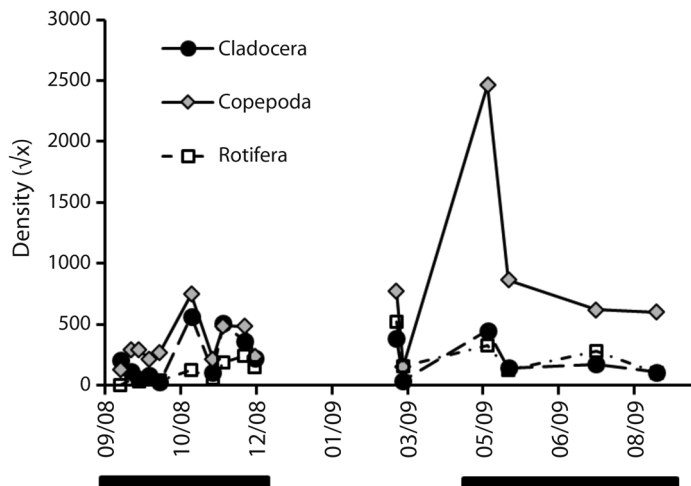


Fig. 2. Temporal variation of the main groups of the zooplankton assemblage in Lake Fraijanes 2008-2009. Densities are represented as the square root of actual values. Horizontal lines mark the extent of the rainy season.

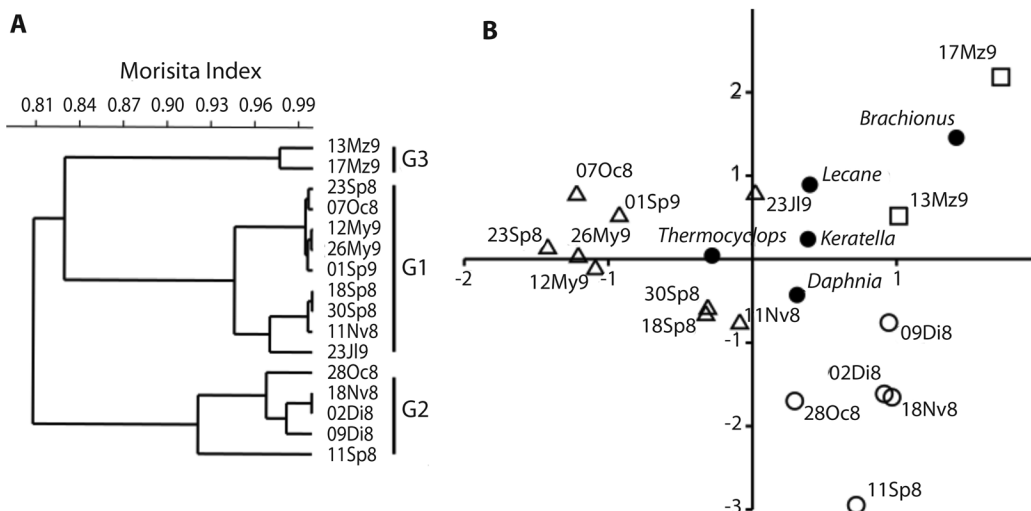


Fig. 3. A: Dendrogram of the sampling dates based on the abundance of the most common zooplankton taxa in Lake Fraijanes. Cophenetic correlation = 0.74; **B:** Correspondence analysis of zooplankton among sampling dates in Lake Fraijanes. It also shows the relation of the taxa with both axis, to aid in the interpretation. Eigen values were $\lambda_1 = 0.1073$ (it explains 51 % of the variation), $\lambda_2 = 0.0821$ (39 %).

Cryptomonas ovata, *Rhodomonas* sp. and *Cyclotella meneghiniana*, in spite of the Spearman correlation between both sets of data that was low ($r = 0.56$). The canonical correspondence analysis including only the six best fitting phytoplankton species, showed that only *Daphnia* was most related with *C. ovata* and *Rhodomonas*. Cyclopoids were close to the center of the diagram and *Keratella* appeared off to the upper right, with little correlation with any of the phytoplankton taxa (Fig. 4)

DISCUSSION

Zooplankton composition in Lake Fraijanes has low species richness, such as most neotropical lakes in Central America (Collado, Defaye, Dussart, & Fernando, 1984; Dussart, Fernando, Matsumura-Tundisi, & Shiel, 1984). In previous work at the lake, four species of copepods were recorded (Collado et al., 1984), of which only *Mesocyclops thermocycloipoides* was later observed (Haberyan, Umaña, Collado, & Horn, 1995). In this study a much richer fauna was recorded, including some Cladocera and Rotifera, and most abundant copepod species was *Thermocyclops* sp. Most species were

observed only once during the study, and with low abundance.

Although two *Daphnia* species were identified there is still some controversy about whether these two species of *Daphnia* are

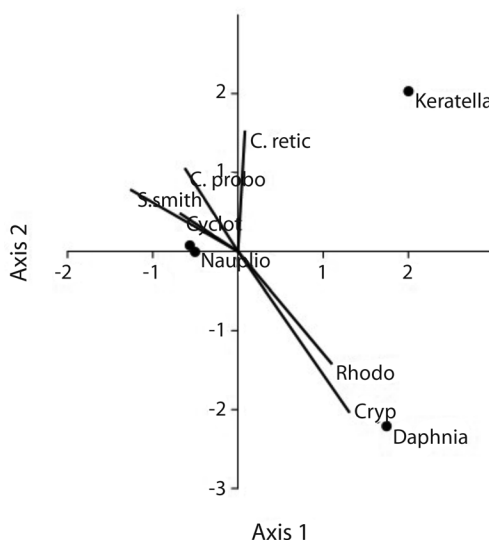


Fig. 4. Canonical correspondence analysis between selected phytoplankton species in Fraijanes lake and the most abundant zooplankton groups. Eigen values were $\lambda_1 = 0.2157$ (73.7 %) and $\lambda_2 = 0.0760$ (26.0 %).

actually different forms of the same species or not (Fernando, Paggi, & Rajapaksa, 1987; Taylor, Finston, & Hebert, 1998). It is generally accepted that the genus *Daphnia* is less diverse in the tropics than it is in north temperate regions (Fernando et al., 1987; Dussart, 1994). These two species seldom occur sympatrically, and their co-occurrence in this small lake is interesting. The lake has been stocked with Tilapia fish for some time now, and although they are not supposed to feed on zooplankton, their presence might be influencing the occurrence of both *D. laevis* and *D. gessneri*. In fact, Arcifa & Meschiatti (1996) report a case where *D. gessneri* was found in the diet of Tilapia in a Brazilian lake. A similar situation, where both species have been found together was reported from a Brazilian reservoir (Pinto-Coelho, Bezerra-Neto, & Morais Jr., 2005) and in Itapeva Lake (Cardoso & Marques, 2004).

The common genera of Rotifera (*Keratella*, *Brachionus* and *Lecane*) found in Fraijanes Lake are those typical of most shallow freshwater systems in the Neotropics (Miyashiro-Aoyagui & Costa-Bonecker, 2004). Rotifers are generally the most speciose group in zooplankton community, but most species occur near the littoral (Bonecker & Lansac-Tôha, 1996). Species richness of Rotifera is usually higher than the other zooplankton groups, as is the case in Fraijanes Lake, however the total number of taxa may be higher than was found in this small lake. In other lakes in Costa Rica, number of Rotifer species may be as high as 50, as was reported in Arenal Reservoir (Umaña & Collado, 1990). In other cases in Costa Rica, Rotifer diversity has been also low, similar to Fraijanes. For example in Lake Cote a total of 12 species of Rotifers (Umaña, 2016; in prep.), and in Lake Río Cuarto Ramírez, Tabash, & Charpentier (1990) reported the presence of five species of Rotifers.

Typically, eutrophic lakes are dominated by Rotifers, small sized Cladocera and Cyclopoid copepods (Pinto-Coelho et al., 2005; Merayo & González, 2010), just as was the case in Fraijanes lake. However, instead of small sized species such as bosminids there were the

two species of *Daphnia*, which seems off from what is expected from a small eutrophic lake. In other situations large Cladocera, mainly *Daphnia* are negatively affected by eutrophication due to interference with feeding apparatus caused by colonial and filamentous blue greens algae (Gliwicz, 2004). However in this lake, *Daphnia* species seem not to be affected by the composition of phytoplankton, given that it is dominated by green colonial and pico Cyanobacteria, and filamentous or big colonial phytoplankton species are scarce (Umaña, 2014). The lack of a close relationship between zooplankton and phytoplankton composition and abundance has also been observed in other cases, such as the Arenal Reservoir (Gavlas, 2012), and seems to support the hypothesis that the main food source for zooplankters are actually bacteria and suspended particulate organic matter (Pace, McManus, & Findlay, 1990), since most phytoplankton species are inedible for the zooplankton considered as herbivores (Burns, 1968; DeMott, 1982). The presence of larvae of *Chaoborus* sp. is another factor that may influence the results, as it may be preying on smaller species such as rotifers and small Cladocera, which favors *Daphnia*. This agrees with the hypothesis proposed by Brooks & Dodson (1965) about the effect of body size on the predation ecology of zooplankton.

The temporal variation followed a pattern of low abundance during the rainy season and high during the dry season. Although there was a gap in the sampling, it occurred during the transition from the rainy to the dry season, and as such, it was possible to compare the composition from both seasons. The difference between both seasons can be explained by the change in water level, since the outflow was active only during high level season. The outflow represents a source of mortality and wash out of plankton populations. This pattern of variation has been observed in other cases where the hydrological conditions change completely between dry and rainy season (Twombly, 1983; Hart, 1990; Arcifa et al., 1992; Vásquez & Rey 1992; Dejen et al., 2004, Merayo & González, 2010). But also changes

in stratification, such as occur in Lake Fraijanes between wet and dry season (Umaña, 2014) are an important factor (Saunders & Lewis, 1988; Mengestou & Fernando, 1991; Panarelli et al., 2000) as this condition is highly associated with changes in weather conditions, as was also the case in Clavellinos reservoir (Merayo & González, 2010).

In conclusion, composition and temporal variation of zooplankton community in Fraijanes lake, although is typical of a eutrophic lake, does not conform to the common view of trophic relationships between phytoplankton and zooplankton. The latter seems to respond more to variations in hydrological and environmental variables of the lake between wet and dry season; than to changes in phytoplankton composition.

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RESUMEN

El zooplancton de lagos pequeños tropicales ha sido poco estudiado y sus variaciones a lo largo del año pueden responder a diferentes factores. En el presente estudio se analizaron los cambios de la comunidad zooplanctónica de un pequeño lago Neotropical en diferentes momentos durante un año y se compararon con cambios en las condiciones del lago y en la composición del fitoplancton. El lago se estratifica de marzo a septiembre y se mezcla durante el invierno hemisférico, de octubre a febrero. Además el lago muestra una fluctuación en el nivel del agua de acuerdo a la estacionalidad de las lluvias. El zooplancton estuvo compuesto por al menos 13 especies, cuatro Cladocera, tres Copepoda, cuatro Rotifera y otros grupos como

Ostracoda y larvas de *Chaoborus*. Las más abundantes fueron *Thermocyclops* sp., *Daphnia* sp. y *Keratella tropica*. Su abundancia fluctuó a lo largo del año, posiblemente en respuesta a cambios en el nivel del lago y cambios en las condiciones hidráulicas, con una mayor abundancia en la época seca, periodo durante el cual el efluente principal se secó. Los cambios en la composición del fitoplancton no parecen ser relevantes para la variación del zooplancton en este pequeño lago.

Palabras clave: Zooplancton, Neotropical, lagunas, estacionalidad.

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