Sustainability, Agri, Food and Environmental Research, (ISSN: 0719-3726), 7(3), 2019: 261-280
DOI: http://dx.doi.org/10.7770/safer-V0N0-art1656

# Zooplankton and limnological parameters dynamics in a mesosaline lake of a protected area in the semi-arid Pampa of Argentina

# Dinámica del zooplancton y de los parámetros limnológicos de un lago mesosalino de un área protegida en la Pampa semiárida de Argentina

Santiago Andrés Echaniz, Alicia María Vignatti, Gabriela Cecilia Cabrera, and Florencia Lorena Torres[1]

Facultad de Ciencias Exactas y Naturales, Universidad Nacional de La Pampa. Avenida Uruguay 151. 6300. Santa Rosa, La Pampa. Argentina.

Santiago Andrés Echaniz: santiagoechaniz@cpenet.com.ar; santiagoechaniz@exactas.unlpam.edu.ar

Alicia María Vignatti: aliciavignatti@cpenet.com.ar; aliciavignatti@exactas.unlpam.edu.ar

Gabriela Cecilia Cabrera: gabrielacabrera@exactas.unlpam.edu.ar

Florencia Lorena Torres: florencia_vander@hotmail.com

ABSTRACT

Most of the mesosaline lakes in the semiarid central Pampas have a high anthropogenic influence. The aim was to determine the variation in limnological and zooplankton parameters of a mesosaline lake with little human impact, the West Lake of the Parque Luro Reserve during a year. Monthly samples were taken between 2014 and 2015. The mean depth and salinity were 0.66 m and 29.33 g/L, respectively. The transparency was total; the light reached the bottom and favored the growth of the macrophyte *Ruppia cirrhosa*. Two cladocerans, three copepods, and eight rotifers were registered. Among crustaceans, autochthonous halophilic species were found (*Daphnia menucoensis* and *Boeckella poopoensis*). Zooplankton density was 20 to 100 times lower than that of other Pampean lakes, probably due to the presence of the macrophyte, which distinguishes this lake from others in the region.

Key words: Saline lake, Reserve, crustaceans, *Ruppia cirrhosa*, Argentina.

RESUMEN

La mayoría de los lagos mesosalinos en la Pampa central semiárida sufren alta influencia antrópica. El objetivo fue determinar la variación de los parámetros limnológicos y del zooplancton de un lago mesosalino con poco impacto humano, el lago Oeste de la Reserva Parque Luro a lo largo de un año. Se tomaron muestras mensuales (2014 - 2015). La profundidad y salinidad media fueron 0,66 m y 29.33 g/L. La transparencia fue total, la luz llegó al fondo y favoreció el crecimiento de la macrófita *Ruppia cirrhosa.* Se registraron dos cladóceros, tres copépodos y ocho rotíferos. Entre los crustáceos se hallaron especies halófilas autóctonas (*Daphnia menucoensis* y *Boeckella poopoensis*). La densidad del zooplancton fue 20 a 100 veces menor que la de otros lagos pampeanos parecidos, probablemente debido a la presencia de la macrófita, lo que es un rasgo que distingue a este lago de otros de la región.

Palabras clave: Lago salino, Reserva, crustáceos, *Ruppia cirrhosa*, Argentina.

## INTRODUCTION

The dry Pampas region is located in the center of the arid and semiarid diagonal that crosses Argentina in a north-south direction (Ruggiero & Ezcurra 2003; D'Ambrosio *et al*. 2016). The central Pampa has a precipitation gradient ranging from about 800 mm/yr to the east to about 300 mm/yr to the west (Casagrande *et al*. 2006), which determines marked phytogeographical differences (Cabrera 1976) and therefore differences in the human activities that develop along that gradient.

The region contains many lakes, most of which are shallow and temporary. The majority of them are saline, since they have total dissolved solids concentrations greater than 3 g/L (Hammer 1986). These lakes can remain dry for variable periods, from a few months to several years. Most of them are located in arheic basins, fed by precipitation and groundwater inputs; as a result, their filling and drying are strongly related to the short-term precipitation-drought cycles determined by El Niño and La Niña events (Viglizzo 2010). The loss of water by evaporation and the abrupt inflow from rainfall mean that these lakes suffer pronounced changes in the water level during their hydroperiods, which produces marked fluctuations in salinity (Echaniz *et al*. 2006; Vignatti *et al*. 2012a; 2017).

During hydroperiods, the temporary lakes are inhabited by organisms that developed adaptations allowing them to withstand dry phases, which usually involve dormant or diapause structures (Bruno *et al.* 2001; Bayly 2001; Wallace *et al*. 2005), such as the production of resting eggs (Fryer 1996; Mura & Brecciaroli 2003; Alekseev & Ravera 2004; Schröder 2005), the burial of quiescence individuals in sediments (Hairston & Bohonak 1998; Santer & Hansen 2006), or coming from other lakes (Incagnone *et al*. 2015).

Studies have been carried out on the dynamics of several saline lakes in the region to compare the physical and chemical conditions recorded at different periods and shows the predominance of $Cl^-$ and $Na^+$, low total zooplankton density and the predominance of crustaceans, especially endemic Neotropical species as *Boeckella poopoensis* Marsh, 1906, *Moina eugeniae* Olivier, 1954, and *Daphnia menucoensis* Paggi,1996 (Echaniz & Vignatti 2011; 2013; Echaniz *et al*. 2006; 2008; 2009; 2012; 2013a, b; Vignatti *et al*. 2007; 2012 a, b). In some studied lakes, a significant coverage of the macrophyte *Ruppia cirrhosa* (Petagna, Grande), a rhizomatous, submerged herbaceous species, characteristic of saline environments (Obrador *et al*. 2007) and capable of tolerating temporary water fluctuations and large changes in temperature and salinity (Menéndez *et al*. 2003) was observed. In these lakes, water transparency was higher and phytoplankton chlorophyll-*a* concentrations were lower than in other lakes of similar salinity where the macrophyte was not registered (Echaniz *et al*. 2015; 2016).

Most of the studied ecosystems are subjected to strong anthropic influence because they are located in fields dedicated to farming. The existence of a temporary saline lake in a protected area (Parque Luro Provincial Reserve), where the current anthropogenic influence is relatively low, provides the opportunity to make comparisons with the most impacted lakes previously studied and to assess the magnitude of human influence. Several aspects of the ecology of the terrestrial flora and fauna of the reserve have been studied (Cano 1980; Maceda *et al*. 2001; Sosa *et al*. 2010; González-Roglich *et al*. 2012; Zanón-Martínez *et al*. 2016), and most of this information has been applied in its management (Subsecretaría de Ecología 2004). However, it is not the case for its aquatic ecosystems, on which only some hydrological information exists. Therefore, obtaining information on the limnological and biological variables of this lake can be useful for government agencies responsible for the management of the reserve. The objective of this work was to determine the main physical-chemical and zooplankton parameters of a shallow, temporary, and saline lake environment located in a protected area during a year.

## MATERIALS AND METHODS

Study area: West Lake (36° 55′ S, 64° 16′ W) (Fig. 1) is located in the Parque Luro Provincial Reserve. The reserve was created by the government of the province of La Pampa in 1967 to preserve a sector of 7,600 hectares of "caldén" (*Prosopis caldenia* Burkart) native forest. It is crossed from east to west by an extensive valley that contains a notable lake near the western limit of the reserve. As with most lakes located in the transverse valleys of the region, West Lake is located in an arheic basin, it is shallow, temporary, and fed mainly by rainfall (Cano 1980). The main water losses are due to evaporation during dry periods. In years before this study, the lake dried out completely (Echaniz & Vignatti pers. obs.). Its temporality and high salinity have prevented the development of fish fauna. During the study period, it was completely covered by the macrophyte *Ruppia cirrhosa*.

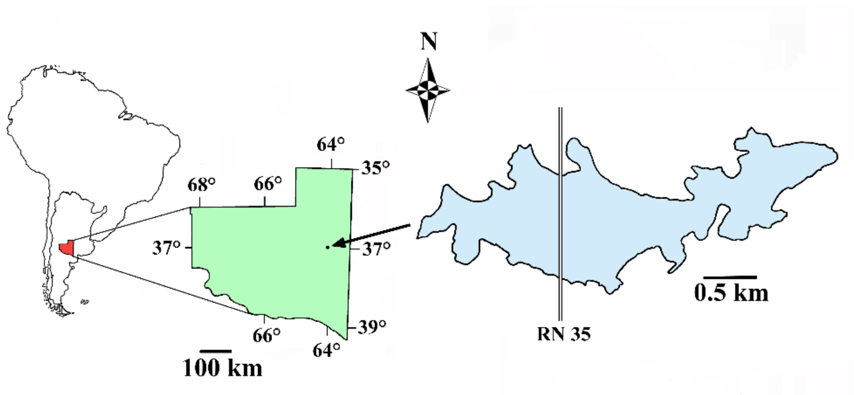


Figure 1. Geographic location of Parque Luro West Lake. RN 35: National route n° 35**.**

Field and laboratory work: Monthly samples of water and zooplankton were collected between October 2014 and September 2015, at two sites located along the main axis of the lake. *In situ* water temperature and dissolved oxygen concentration (Lutron® OD 5510 oximeter), water transparency (Secchi disk), and pH (Corning® PS 15 digital pHmeter) were determined, and water samples were taken and refrigerated until laboratory analysis.

At each site, two quantitative 20 L samples of zooplankton were taken and filtered through a 0.04 mm mesh net. Due to the presence of aquatic vegetation, they were obtained with a 10 L pail. A qualitative sample was also taken, with a similar net. All samples were anesthetized with $CO_2$ and kept refrigerated until fixation with 4% formalin.

Salinity was determined by the gravimetric method with drying at 104 °C, the concentration of chlorophyll-*a* (Chl-*a*) by extraction with aqueous acetone and spectrophotometry (APHA 1992; Arar 1997), and the content of suspended solids by water filtering through glass-fiber filters (Microclar FFG047WPH), drying at 103–105 °C until constant weight, and subsequent calcining at 550 °C (EPA 1993). The ionic content of the water was determined according to standardized routines: $Na^+$ (selective ion electrode); $K^+$ (determination of the intensity of the turbidity by the combination of potassium with sodium

Sustainability, Agri, Food and Environmental Research, (ISSN: 0719-3726), 7(3), 2019: 261-280
DOI: http://dx.doi.org/10.7770/safer-V0N0-art1656

tetraphenylborate); $Ca^{2+}$ (EDTA digital titulometric method or, for very low calcium levels, spectrophotometric method); $Mg^{2+}$ (digital titrimetric method or, for very low magnesium levels, spectrophotometric method); $Cl^-$ (argentometric method [digital titration with silver nitrate solution in the presence of potassium chromate] or, when the concentration was very low, the spectrophotometric method); $SO_4^{2-}$ (spectrophotometric determination of the intensity of the turbidity formed during the reaction of the sulfate with barium); and $HCO^-_3$ and $CO_3^{2-}$ (alkalinity method of phenolphthalein and digital titration) (APHA 1992).

The macro- and microzooplankton (Kalff 2002) were counted under compound and stereoscopic microscopes, in Bogorov and Sedgwick-Rafter chambers, respectively. To determine the biomass, 30 specimens of each species were measured with a 10X Arcano micrometric eyepiece; formulas that relate the total length to the dry weight were used for crustaceans (Dumont *et al*. 1975; McCauley 1984) and the relationship with geometric shapes for rotifers (Ruttner Kolisko 1977).

Data analysis: The lake was characterized using the salinity classification system proposed by Hammer (1986). The relationships between the different environmental factors and the zooplankton attributes were analyzed using Spearman's nonparametric correlation coefficients, after confirming the lack of normality of the data (Sokal & Rohlf 1995; Zar 1996) and principal component analysis (PCA) was performed (Pérez 2004). The nonparametric Olmstead and Tukey graphic test (Sokal & Rohlf 1995) was applied to analyze the relationship between the density and the frequency of appearance of the different taxa. This allowed us to distinguish four categories: frequent and abundant (dominant species, quadrant I); abundant and infrequent (occasional species, quadrant II); infrequent and scarce (rare species, quadrant III) and frequent but scarce (common species, quadrant IV) (D'Ambrosio *et al*. 2016).

We used Past (Hammer *et al*. 2001) and Infostat (Di Rienzo *et al*. 2010) software.

## RESULTS

Environmental parameters: In the water ionic composition, $Cl^-$ (13,844.2 mg/L) followed by $SO_4^{2-}$ (4500 mg/L) predominated among anions and $Na^+$ (8483.5 mg/L) and $Ca^{2+}$ (1590.8 mg/L) among cations. The amounts of $Mg^{2+}$ and $K^+$ were lower than the other cations (578.9 and 105.1 mg/L respectively). The M/D ratio (monovalent/bivalent cations) was 3.96, indicating the strong predominance of $Na^+ + K^+$ over $Ca^{2+} + Mg^{2+}$. The total water hardness was 3,973 mg/L. Due to the strong predominance of $Cl^-$ in the anions, the total alkalinity ($CO_3H^- + CO_3^{2-}$) was relatively reduced (212.2 mg/L). The pH remained relatively constant during the analyzed period, with a mean value of 9.12 (± 0.35).

The average lake depth was 0.66 m. It fluctuated between a maximum of 1.1 m in October 2014 and a minimum of 0.4 m in March 2015 (Fig. 2 A). The mean salinity was 29.33 ± 10.71 g/L and varied widely; the minimum value was recorded in October (13.6 g/L) and the maximum was found in March and September (44.2 g/L and 43.6 g/L, respectively) (Fig. 2 A). Significant correlation between both variables ($r_s$ = -0.89; p < 0.0001) was found.

The water temperature followed a seasonal pattern (Fig. 2 B) and ranged from a minimum of 7.7 °C in June to a maximum of 24.1 °C in October. The mean concentration of dissolved oxygen was 9.31 mg/L ± 0.98 and also showed a seasonal pattern, ranging from a minimum of 7.9 mg/L in October to a maximum of 11.2 mg/L in June (Fig. 2 B). There was a significant correlation between both variables ($r_s$ = -0.92; p < 0.0001).

The average phytoplankton Chl-*a* concentration was 1.85 mg/m$^3$ ± 3.28. A minimum value of 0.11 mg/m$^3$ was recorded in May and a maximum of 11.75 mg/m$^3$ in September (Fig. 2 C). The water transparency was total throughout all the samplings carried out (Fig. 2 C), coinciding with the depth of the lake. No correlation was found between Chl-*a* and water transparency.

The average concentration of total suspended solids was 12.06 ± 17.07 mg/L and presented two peaks, one in February (47.91 mg/L) and another in August (48.37 mg/L); the lower values were recorded in October (0.87 mg/L) and December (1.21 mg/L) (Fig. 2 D). Considering both fractions separately, suspended solids of inorganic origin (ISS) predominated and had an average concentration of 8.34 mg/L (± 13.27), and organic suspended solids (OSS) had a mean concentration of 3.71 mg/L (± 4.12). ISS predominated in eight occasions and OSS in four (Fig. 2 D). A correlation was found between the concentrations of both fractions ($r_s$ = 0.68, p = 0.0245) but not between those of Chl-*a* and OSS.

Zooplankton: Thirteen taxa were recorded: two cladocerans, three copepods, and eight rotifers (Table 1). A correlation was found between rotifers richness and total richness ($r_s$ = 0.81, p = 0.0014). The highest richness (five or more taxa), especially due to rotifers, was registered in the months of highest temperature (December to March) (Fig. 3 A).

The most frequent and abundant species was *Boeckella poopoensis*, present throughout the studied period (Table 1). It was followed by *Cletocamptus deitersi* (Richard, 1897) and *Daphnia menucoensis* Paggi, 1996, registered in 83% and 50% of the sampling occasions, respectively (Table 1 and Fig. 4 A). The remaining crustaceans, *Leberis davidi* (Richard, 1895) and *Metacyclops mendocinus* (Wierzejski, 1892), can be considered occasional species, given that they were rarely recorded and with low densities (Table 1 and Fig. 4 A). No correlations were found between the number of cladoceran´s and copepod´s

Sustainability, Agri, Food and Environmental Research, (ISSN: 0719-3726), 7(3), 2019: 261-280
DOI: http://dx.doi.org/10.7770/safer-V0N0-art1656

species of and environmental parameters, although the PCA showed some positive influence of salinity on the richness of the latter species (Fig. 4 B).

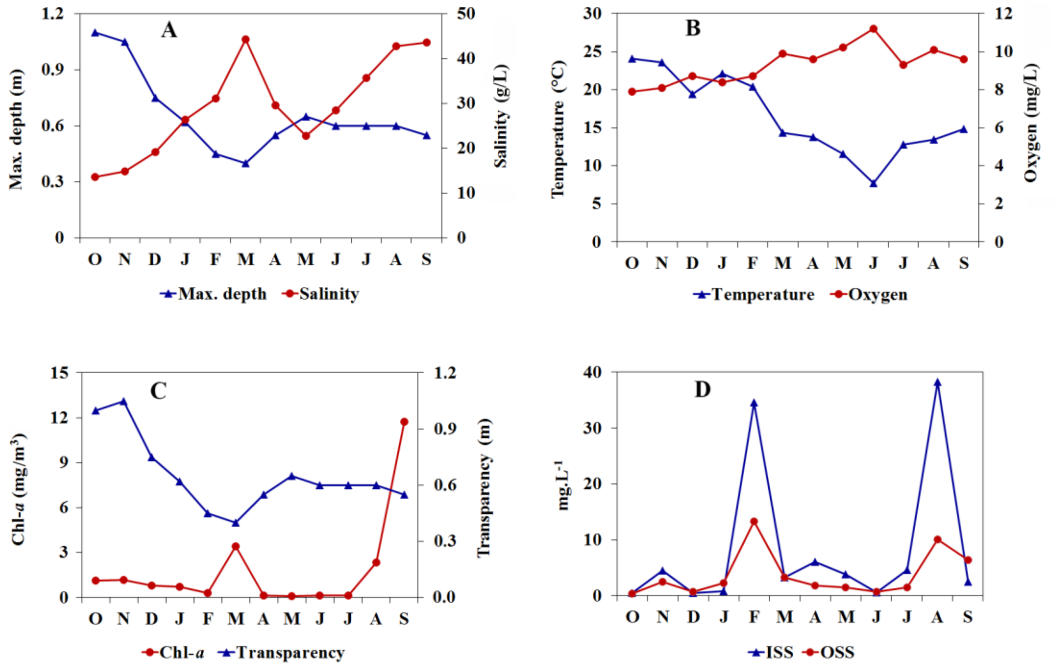


Figure 2. Monthly variation of: A: maximum depth and salinity; B: water temperature and dissolved oxygen concentration; C: water transparency and phytoplankton chlorophyll-*a* concentration and D: suspended organic solids (OSS) and inorganic suspended solids (ISS) of West Lake.

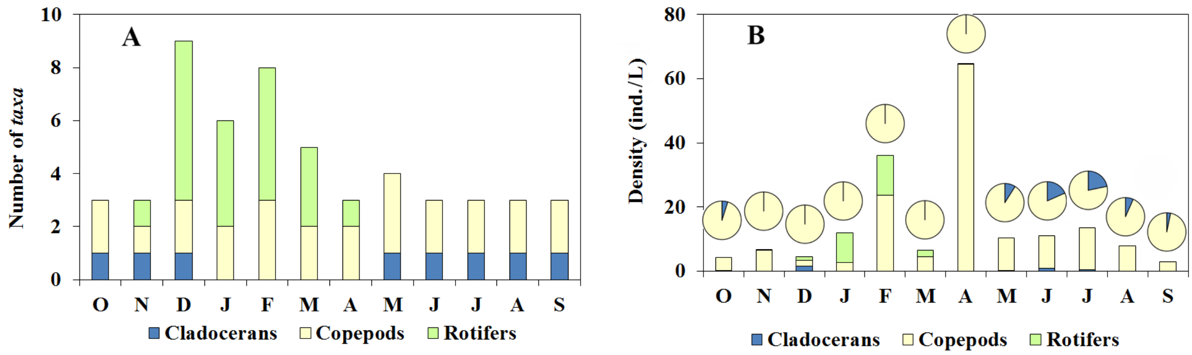


Figure 3. Monthly variation of: A: richness by zooplankton taxonomic group and B: density (bars, expressed in individuals per liter) and biomass (circles, expressed as a percentage of total biomass) of zooplankton, by taxonomic group, in West Lake.

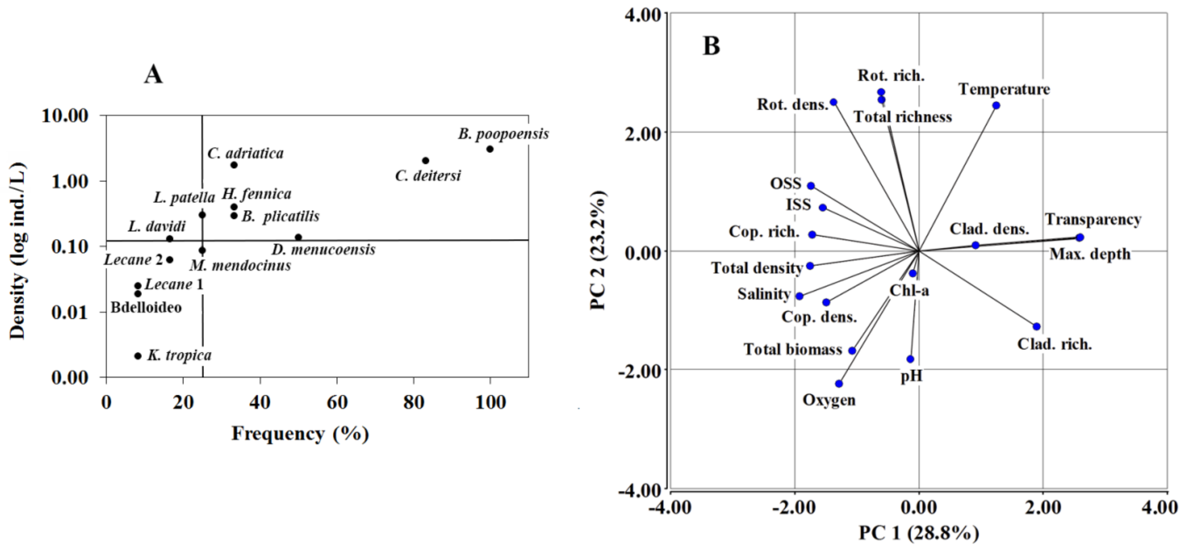


Figure 4. A: Olmstead & Tukey test of all *taxa* registered in the zooplankton of West Lake; B: Biplot of the principal component analysis of the limnological and biological parameters of zooplankton determined in West Lake.

Table 1. Zooplankton *taxa* and months of occurrence in the West Lake of Parque Luro Provincial Reserve.

| | O | N | D | J | F | M | A | M | J | J | A | S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cladocerans** | | | | | | | | | | | | |
| *Daphnia menucoensis* Paggi, 1996 | ■ | | | | | | | ■ | ■ | ■ | ■ | ■ |
| *Leberis davidi* (Richard, 1895) | | ■ | ■ | | | | | | | | | |
| **Copepods** | | | | | | | | | | | | |
| *Boeckella poopoensis* Marsh, 1906 | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| *Cletocamptus deitersi* (Richard, 1897) | ■ | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| *Metacyclops mendocinus* (Wierzejski, 1892) | | | ■ | | ■ | | | ■ | | | | |
| **Rotifers** | | | | | | | | | | | | |
| *Lecane 1* | | | | | ■ | | | | | | | |
| *Lecane 2* | | | ■ | ■ | | | | | | | | |
| *Lepadella patella* (Müller, 1786) | | | ■ | ■ | ■ | | | | | | | |
| *Hexarthra fennica* (Levander, 1892) | | | ■ | ■ | ■ | ■ | | | | | | |
| *Keratella tropica* (Apstein, 1907) | | | ■ | | | | | | | | | |
| *Brachionus plicatilis* Müller, 1786 | | ■ | | | ■ | ■ | ■ | | | | | |
| Bdelloideo no id. | | | ■ | | | | | | | | | |

The frequency of rotifers in the samples was low (Table 1 and Fig. 4 A). The most frequent species, although not very abundant, were *Hexarthra fennica* (Levander, 1892), *Brachionus plicatilis* Müller, 1786, and *Colurella adriatica* (Ehrenberg, 1831), which were found in 33% of the sampling occasions, followed by *Lepadella patella* (Müller, 1773), which was in 25% of the samples (Table 1 and Fig. 4 A). The rest of the rotifers can be considered rare species, because they were only found once or twice (Table 1 and Fig. 4 A). Although no correlation was found between the rotifer richness and water temperature, the PCA showed a certain influence of this parameter on the number of rotifer species (Fig. 4 B), since, as indicated, these organisms were recorded at the end of spring and summer (Fig 3 A).

The total density and biomass were 15.00 ind./L ± 17.92 and 40.08 µg/L ± 52.70 respectively and showed a strong peak in late summer-early autumn (April) (Fig. 3 B). No correlations were found between either biological parameter and the environmental variables.

Throughout the study, the highest density and biomass was contributed by the copepods, which, with averages of 12.66 ind./L (± 17.42) and 37.69 µg/L (± 52.24), represented 98% of the density and 94% of the total biomass of the zooplankton community, respectively (Fig. 3 B). Thus, correlations between the density and biomass of this group and the total density ($r_s$ = 0.76, p = 0.0115) and total biomass ($r_s$ = 0.85, p = 0.005) were found. The PCA also indicated the positive influence of salinity on both parameters (Fig. 4 B).

Copepods were the dominant organisms in winter and spring, when they greatly exceeded 90% of the community´s density (Fig. 3 B). Among this group, the species with the highest contribution to mean density and biomass were *Boeckella poopoensis* and *Cletocamptus deitersi,* which reached average densities of 3.02 (± 3.69) and 2.03 (± 4.23) ind./L and biomasses of 28.47 (± 40.96) and 3.92 (± 6.97) µg/L, respectively. The density and biomass of *B. poopoensis* showed a minimum in January (0.12 ind./L and 0.001 µg/L) and a maximum in April (13.04 ind./L and 143.3 µg/L), while *C. deitersi* reached its maximum density and biomass in February (11.66 ind./L and 17.52 µg/L).

Cladocerans reached a mean density of 0.27 ind./L (± 0.46) and a mean biomass of 2.39 µg/L (± 3.78), with a small peak in December (Fig. 3 B). PCA showed the negative influence exerted by salinity on the density of this group (Fig. 4 B). Among cladocerans, *Daphnia menucoensis* contributed to the highest density and biomass. Its mean density and biomass were 0.14 ind./L (± 0.25) and 2.39 µg/L (± 3.78), respectively. Correlations were found between *D. menucoensis* density and water transparency ($r_s$ = 0.59, p = 0.0448) and OSS concentration ($r_s$ = 0.59, p = 0.0448).

The rotifers reached a mean density of 2.08 ± 4.19 ind./L, and their contribution to the biomass was insignificant (Fig. 3 B). The PCA also showed the positive influence of water temperature on the density of this group (Fig. 4 B), since they were only abundant in summer, especially in January, when they accounted for 77.5% of the total density (Fig. 3 B). Among the rotifers, the species that reached the highest density was *Colurella adriatica*, which had a maximum peak of 9.30 ind./L in February. Despite being among the most frequent rotifers, *H. fennica* and *B. plicatilis* showed extremely reduced densities and both reached their maximum densities (3.2 and 3.1 ind./L, respectively) in February.

## DISCUSSION

Between 2009 and 2013, West Lake of Parque Luro was completely dry (Echaniz & Vignatti pers. obs.). After its filling and during the study, it showed a marked decrease in level that meant that, by the end of summer, in March 2015, the depth was almost one third of the initial level. After a small increase in early autumn, a period of high historical precipitation (Cano 1980), depth remained relatively stable until the end of the study. During the first three months (October to December), West Lake behaved like a hyposaline lake, but it changed to the mesosaline category (Hammer 1998) in January 2015, where it remained until the end of the study (September). These large variations in level and extent, which mainly affect changes in the concentration of total dissolved solids, are a common situation in lakes in the region (Vignatti et al. 2012 a; b; 2017; Del Ponti et al. 2015; Echaniz et al. 2013 a; b; 2016). This trend has been observed in the El Carancho and El Destino lakes, which went from respective salinities of 39.9 and 21.9 g/L in February 2001 to 12.1 and 9.34 g/L in November of the same year. Similarly, in another Pampean temporary lake, La Laura, salinity changes from 40 g/L in February 2001 to 9.2 g/L just one month later (Echaniz *et al*. 2006).

The chemical composition of the water, with the predominance of $Na^+$ among the cations and $Cl^-$ among the anions, is a feature of West Lake that resembles most of the shallow lakes studied in the semiarid central Pampa (Echaniz & Vignatti 2017), and indicates that the mechanisms that control the water chemistry of West Lake involve evaporation and crystallization, typical processes in arid or semiarid regions, with higher evapotranspiration rates than precipitation (Gibbs 1970, Wetzel 2001, Kalff 2002). This situation is shared with many of the environments of the Chaco Pampa plains (Drago & Quirós 1996).

The concentrations of suspended solids were very small, much lower than those found in other lakes in the region (Echaniz *et al*. 2015; 2016), what can be attributed to the presence of *Ruppia cirrhosa*. The low concentration of ISS could be because the plant reduced sediment resuspension from the bottom due to the wind (Borell Lövstedt & Bengtsson 2008; Markensten & Pierson 2003), similar to what was recorded in Utracán, where the plant was also registered and ISS were very reduced (Echaniz *et al*. 2015). On the other hand, low concentrations of OSS, not related to phytoplankton Chl-*a* concentration, could indicate a poor phytoplankton development and would suggest that OSS was mainly related to particles detached from the plants or periphythic biofilm.

The transparency of the water of West Lake was always high, so that the light reached the bottom in all the occasions in which the water was sampled, which would have favored the development of the dense cover of *R. cirrhosa*. This is a characteristic that West Lake shares with other semiarid central Pampa saline lakes that are especially influenced by cattle breeding, such as Utracán (Echaniz *et al*. 2015) and El Carancho (Vignatti *et al*. 2012b). However, this characteristic distinguishes West Lake from shallow lakes in the northern region (Chadilauquen, Estancia Pey-Ma, and San José), where cereal, oilseed, and soybean crops predominate (Echaniz & Vignatti 2011; Echaniz *et al*. 2013 a, b; 2016). The existence of *R. cirrhosa* in the Pampean lakes with relatively low anthropic influence could have favored the high water transparency in two ways. First, as it is a species rooted in the bottom, where it produces rhizomes, it would have fixed the sediments, avoiding their resuspension by the wind. Second, there could be both an allelopathic effect due to the release of substances by *R. cirrhosa* and a limitation of the amount of light, with a consequent limitation on the growth of algal populations in phytoplankton (Dembowska 2015). This would also explain the reduced concentration of Chl-*a*, although these are mechanisms that, at present, have not been studied in these lakes.

The water had high concentrations of dissolved oxygen, even in the months of higher temperatures when the water's capacity to dissolve gases is lower (Wetzel 2001; Kalff 2002). The same was observed in Utracán, the lake with coverage of *R. cirrhosa* (Echaniz *et al*. 2015) (Table 2) which would allow to affirm that oxygen would come from the plants' photosynthesis, since the low concentrations of Chl-*a* that were registered in both lakes indicate a poor phytoplankton development.

The zooplankton of subsaline ecosystems in the semiarid central Pampa that do not exceed 2 g/L can have more than 20 taxa of crustaceans and rotifers (Echaniz *et al*. 2008; 2012; Echaniz & Vignatti 2017). In the hypo- and mesosaline lakes, where salinity is a relevant factor in the structuring of the community (Herbst 2001; Ivanova & Kazantseva 2006), richness is lower (Echaniz & Vignatti 2011; Echaniz *et al*. 2013a, b; 2016; Vignatti 2011; Vignatti *et al*. 2007; 2012b) (Table 2). This last situation was verified in West Lake and an association typical of the pampean mesosaline lakes was found, characterized by such autochthonous halophilic crustaceans as *Daphnia menucoensis* and *Boeckella poopoensis*. Both are very common species in saline ecosystems of northern Patagonia and the center of the country, although *B. poopoensis* has a much wider geographical distribution, from the north of the Patagonian plateau to the south of Peru (Menu-Marque *et al*. 2000). The record of *D. menucoensis* in salinities close to 43 g/L is relevant, since it was previously believed that its tolerance range was not so broad.

Sustainability, Agri, Food and Environmental Research, (ISSN: 0719-3726), 7(3), 2019: 261-280
DOI: http://dx.doi.org/10.7770/safer-V0N0-art1656

Table 2. Comparison of physical, chemical, and biological parameters (averages ± standard deviation) of mesosaline lakes studied in the province of La Pampa. The density and biomass are the average of the entire zooplankton community. The specific richness indicates the total number of zooplankton species registered in the five lakes.

| | Utracán (2007)* | Chadilauquen (2007)** | Estancia Pey-Ma (2006)*** | Estancia San José (2006)**** | Parque Luro Oeste |
|---|---|---|---|---|---|
| Water temperature (°C) | 16.08 ± 7.18 | 16.58 ± 7.05 | 17.78 ± 6.91 | 17.23 ± 7.24 | 13.60 ± 5.02 |
| Transparency (m) | 1.15 ± 0.29 | 0.76 ± 0.26 | 0.17 ± 0.06 | 0.45 ± 0.19 | 0.55 ± 0.56 |
| Salinity (g/L) | 32.90 ± 2.70 | 26.16 ± 2.13 | 25.34 ± 6.15 | 22.22 ± 5.24 | 34.75 ± 10.25 |
| pH | 9.58 ± 0.13 | 9.40 ± 0.13 | 9.01 ± 0.17 | 9.13 ± 0.19 | 9.23 ± 0.34 |
| Dissolved oxygen (mg/L) | 10.07 ± 2.07 | 8.46 ± 1.10 | 6.29 ± 2.68 | 8.95 ± 2.22 | 9.83 ± 9.97 |
| Chlorophyll-*a* (mg/m$^3$) | 1.22 ± 0.92 | 1.73 ± 1.25 | 30.79 ± 27.01 | 20.16 ± 27.45 | 2.30 ± 3.14 |
| ISS (mg/L) | 4.30 ± 3.77 | 18.27 ± 24.23 | 38.03 ± 21.07 | 15.99 ± 19.22 | 11.72 ± 12.70 |
| OSS (mg/L) | 5.00 ± 1.89 | 6.72 ± 4.95 | 37.52 ± 17.27 | 17.96 ± 10.72 | 4.84 ± 3.94 |
| Max. depth (m) | 2.00 ± 0.15 | 2.12 ± 0.09 | 1.28 ± 0.20 | 2.71 ± 0.30 | 0.55 ± 0.20 |
| Rooted vegetation | Yes | No | No | No | Yes |
| Activity dominant in the basin | Cattle breeding | Cereals, oilseeds, and soybeans crops | Cereals, oilseeds, and soybeans crops | Cereals, oilseeds, and soybeans crops | None |
| Zooplankton density (ind./L) | 416.48 ± 379.58 | 201.41 ± 77.52 | 3023.47 ± 4772.42 | 1532.11 ± 1747.59 | 15.01 ± 17.92 |
| Zooplankton biomass (µg/L ) | 1728.00 ± 957.92 | 1621.91 ± 739.01 | 6614.06 ± 4336.94 | 4659.08 ± 3417.30 | 40.08 ± 52.70 |
| Richness | 6 | 6 | 6 | 8 | 13 |

*Echaniz *et al*. 2015; ** Echaniz *et al*. 2016; *** Echaniz *et al*. 2013a; **** Echaniz *et al*. 2013b

A particular feature of West Lake was the low density of zooplankton compared to other Pampean saline lakes (Table 2). *B. poopoensis* was between 20 and 100 times lower than in the Utracán, Chadilauquen, Estancia Pey-Ma, and Estancia San José Lakes (Echaniz *et* *al*. 2013a, b; 2015; 2016) (Table 2). This could be due to the limited food availability caused by scarce phytoplankton biomass. The phytoplankton growth can be negatively influenced by the presence of macrophytes since a large proportion of submerged macrophytes release allelopathic substances (Benítez & Claps 2012) or remove nutrients from the water column (Celewicz-Goldyn & Kuczynska-Kippen 2017). In addition, there could also be an allelopathic effect of plants on crustaceans, although this is an aspect that has not yet been studied.

The rotifers were recorded during the months of higher temperature; this is common in this group, which usually goes through winter periods in a state of resistance (Bērzinš & Pejler 1989; Agnieszka & Wilk-Woźniak 2007). Among these, the presence of such euryhaline species as *Brachionus plicatilis* and *Hexarthra fennica* is a feature that West Lake has in common with other similar lakes in the semiarid central Pampa (Echaniz & Vignatti 2011; Echaniz *et al*. 2013a, b; 2016; Vignatti 2011; Vignatti *et al*. 2007; 2012a, b), although they are species that are not typical of the region because of their cosmopolitan distribution (Fontaneto *et al*. 2006). However, the density of all rotifers was very low, even species such as *Keratella tropica* (Apstein 1907), which in other Pampean lakes has reached densities of several thousand individuals per liter, or *B. plicatilis*, which frequently reaches several hundred individuals per liter.

The low density and biomass, of both crustaceans and rotifers, distinguishes West Lake from other saline lakes studied in La Pampa (Table 2). As mentioned, this could be due to the different effects produced by the presence of *R. cirrhosa*, so it is an aspect that deserves to be studied in depth in order to better understand the functioning of this type of lake.

As conclusion, from October to December, the West Lake of Parque Luro Reserve was hyposaline, but after that, it changed to mesosaline (January to September). The water in West Lake is sodium chloride. The composition dominated by $Na^+$ and $Cl^-$ is similar to the other saline lakes of the semiarid central Pampa and indicates that the control of water chemistry predominates evaporation and crystallization processes. Water transparency was high and the light reached the bottom throughout the study, favoring the growth of the macrophyte *Ruppia cirrhosa*. This is a common feature with semiarid central Pampa lakes whose basins host cattle breeding rather than cereal and soybean agriculture. The presence of *R. cirrhosa* could have favored the increase of water transparency in two ways. As it is a species rooted in the bottom, it could 1) avoid sediment resuspension by the wind and 2) prevent the growth of phytoplankton algae (indicated by the low concentrations of phytoplankton Chl-*a* recorded) by light limitation or an allelopathic effect (not investigated here). The zooplankton was characterized by the presence of autochthonous halophilic crustaceans, such as *Daphnia menucoensis* and *Boeckella poopoensis*. Unlike other semiarid central Pampa saline lakes, in Parque Luro West Lake, the zooplankton density was low. *B.*

*poopoensis* in particular had densities between 20 and 100 times lower than in other pampean lakes. This may be due to the negative influence of the macrophyte, while *Leberis davidi*, a rare species in the region, could have been favored by the development of *R. cirrhosa.*

The low density and biomass, both of crustaceans and rotifers, distinguishes West Lake from other mesosaline lakes studied in La Pampa.

## ACKNOWLEDGEMENTS

We thank Lic. Fabián Tittarelli, Subsecretary of Ecology and the Subsecretary of Ecology of the Government of the Province of La Pampa, for allowing the access to the West Lake of Parque Luro Provincial Reserve and the FCEyN- UNLPam for the partial financing of this project and to a the reviewers whose work improved this article.

## REFERENCES

Agnieszka, P. and Wilk-Woźniak, E. (2007). Effect of environmental conditions on rotifers and selected phytoplankton species in three submountane dam reservoirs (Southern Poland, Central Europe). Ekológia (Bratislava) 26 (2): 132-142.

Alekseev, V., and Ravera, O., (2004). Introductory notes to the workshop: Diapause in Invertebrates. Journal of Limnology 63 (Suppl.1): iii-v.

APHA. (1992). Standard Methods for the Examination of Water and Wastewater. American Public Health Association (APHA), American Water Works Association (AWWA) and Water Pollution Control Federation (WPCF), 18th edition. Washington, DC.

Arar, E. (1997). In Vitro Determination of Chlorophylls a, b, c + c and Pheopigments in Marine and Freshwater Algae by Visible Spectrophotometry. Method 446.0. U.S. Environmental Protection Agency. Available at http://monitoringprotocols.pbworks.com/f/EPA446_0.pdf. (accessed 7-V-2018).

Bayly, I.A.E., (2001). Invertebrate ocurrence and succesion after episodic flooding of a central Australian rock hole. Journal of Research Society Western Australian 84: 29-32.

Benítez, H., and Claps, M.C., (2012). Estudio de migraciones del zooplancton en un lago somero: desarrollo de una nueva metodología a campo. Biología Acuática 27: 29-41.

Bērzinš, B., and Pejler, B., (1989). Rotifer occurrence in relation to temperature. Hydrobiologia 175: 223-231.

Borell Lövstedt, C., and Bengtson, L., (2008). The role of non-prevailing wind direction on resuspension and redistribution of sediments in a shallow lake. Aquatic Sciences 70: 304-313.

Bruno, M., Loftus, W., Reid, J., & Perry, S., (2001). Diapause in copepods (Crustacea) from ephemeral habitats with different hydroperiods in Everglades National Park (Florida, U.S.A.). Hydrobiologia 453-454: 295-308.

Cabrera, A., (1976). Regiones fitogeográficas argentinas. In: Kugler WF (Ed) Enciclopedia argentina de agricultura y jardinería. Tomo 2. 2º edición. Acme. Buenos Aires, Argentina. Fascículo 1, pp. 1-85.

Cano, E., (1980). Inventario Integrado de los Recursos Naturales de la provincia de La Pampa. Ed. Instituto Nacional de Tecnología Agropecuaria (INTA), Provincia de La Pampa y Universidad Nacional de La Pampa, Buenos Aires.

Casagrande, G., Vergara, G., and Bellini, Y., (2006). Cartas agroclimáticas actuales de temperaturas, heladas y lluvias de la provincia de La Pampa (Argentina). Revista de la Facultad de Agronomía, UNLPam 17: 15-22.

Celewicz-Goldyn, S., and Kuczynska-Kippen, N., (2017). Ecological value of macrophyte cover in creating habitat for microalgae (diatoms) and zooplankton (rotifers and crustaceans) in small field and forest water bodies. PLoS ONE 12: e0177317.

D'Ambrosio, S., Claps, M., and García, A., (2016). Zooplankton diversity of a protected and vulnerable wetland system in southern South America (Llancanelo area, Argentina). International Aquatic Research 8: 65-80.

Del Ponti, O.D., Cabrera, G.C., Vignatti, A.M., and Echaniz, S.A., (2015). Dynamics of the limnological parameters and zooplankton of La Brava, a shallow lake of the Atuel-Salado-Chadileuvú-Curacó rivers system (La Pampa, Argentina). Applied Ecology and Environmental Sciences 3: 193-199.

Dembowska, E., (2015). Seasonal variation in phytoplankton and aquatic plants in floodplain lakes (lower Vistula River, Poland). Wetlands Ecology and Management 23: 535-549.

Di Rienzo, J., Casanoves, F., Balzarini, M., González, L., Tablada, M., and Robledo, W., (2010). InfoStat (versión 2010), Grupo InfoStat, FCA, Universidad Nacional de Córdoba, Argentina.

Drago, E., and Quirós, R., (1996). The hydrochemistry of inland waters of Argentina; a review. International Journal of Salt Lake Research 4: 315-325.

Dumont, H., van de Velde, I., and Dumont, S., (1975). The dry weight estimate of biomass in a selection of Cladocera, Copepoda and Rotifera from the plankton, periphyton and benthos of continental waters. Oecologia 19: 75-97.

Echaniz, S. and A., Vignatti, A., (2011). Seasonal variation and influence of turbidity and salinity on the zooplankton of a saline lake in central Argentina. Latin American Journal of Aquatic Research 39: 306-315.

Echaniz, S. and Vignatti, A., (2013). Trophic status of shallow lakes of La Pampa (Argentina) and its relation with the land use in the basin and nutrient internal load. Journal of Environmental Protection (Special Issue on Eutrophication) 4 (11A): 51-60.

Echaniz, S. and Vignatti, A., (2017). The zooplankton of the shallow lakes of the semi-arid region of southern South America. Annales de Limnologie - International Journal of Limnology 53: 345-360.

Echaniz, S., Vignatti, A., José de Paggi, S., Paggi, J., and Pilati, A., (2006). Zooplankton seasonal abundance of South American saline shallow lakes. International Review of Hydrobiology 91: 86-100.

Echaniz, S., Vignatti, A., and Bunino, P., (2008). El zooplancton de un lago somero hipereutrófico de la región central de Argentina. Cambios después de una década. Biota Neotropica 8 (4): 63-71.

Echaniz, S., Vignatti, A., and Cabrera, G., (2009). Características limnológicas de una laguna turbia orgánica de la provincia de La Pampa y variación estacional del zooplancton. Biología Acuática 26: 71-82.

Echaniz, S., Vignatti, A., Cabrera, G., and José de Paggi, S., (2012). Zooplankton richness, abundance and biomass of two hypertrophic shallow lakes with different salinity. Biota Neotropica 12: 37-44.

Echaniz, S., Cabrera, G., Rodríguez, C., and Vignatti, A., (2013a). Do temporary lakes vary from year to year? A comparison of limnological parameters and zooplankton from two consecutive annual cycles in an Argentine temporary saline lake. International Journal of Aquatic Science 4: 44-61.

Echaniz, S., Cabrera, G., Aliaga, P., and Vignatti, A., (2013b). Variations in zooplankton and limnological parameters in a saline lake of La Pampa, central Argentina, during an annual cycle. International Journal of Ecosystem 3: 72-81.

Echaniz, S., Cabrera, G., and Vignatti, A., (2015). The ecology of the saline lakes in the semiarid Pampa central (Argentina): limnological characterization and zooplankton of Utracán, Advances in Life Sciences 5: 64-72.

Echaniz, S., Vignatti, A., Cabrera, G., Capecce, C., and Treffinger Cienfuegos, M., (2016). Comparación de los parámetros limnológicos y el zooplancton de un lago somero salino de La Pampa (Argentina) durante dos ciclos anuales de condiciones diferentes. Biología Acuática 31: 28-39.

EPA. (1993). ESS Method 340.2: Total Suspended Solids, Mass Balance (Dried at 103-105°C) Volatile Suspended Solids (Ignited at 550°C). Environmental Protection Agency (EPA). Available at http://www.epa.gov/glnpo/lmmb/methods/methd340.pdf. (accessed 7-V-2018).

Fontaneto, D., De Smet, W., and Ricci, C., (2006). Rotifers in saltwaters, re-evaluation of an inconspicuos taxon. Journal of the Marine Biological Association of the United Kingdom 86: 623-656.

Fryer, G. (1996). Diapause, a potent force in the evolution of freshwater crustaceans. Hydrobiologia 320: 1-14.

Gibbs, R. (1970). Mechanisms controlling world water chemistry. Science 170: 1088-1090.

González-Roglich, M., Villarreal, D., and Castro, M.G., (2012). Evaluación de la efectividad de la Reserva Parque Luro como herramienta de conservación del Caldenal pampeano: cambios en la cobertura vegetal a nivel de paisaje entre 1960 y 2004. Ecología Austral 22: 11-21.

Hairston, N., and Bohonak, A., (1998). Copepod reproductive strategies: life- history theory, phylogenetic pattern and invasion of inland waters. Journal of Marine Systems 15: 23-34.

Hammer, Ø., Harper, D., and Ryan, P., (2001). PAST: Paleontological Statistics Software Package for Education and Data Analysis. Palaeontologia Electronica 4: 1-9.

Hammer, U., (1986). Saline Lake Ecosystems of the World. Monographiae Biologicae 59. Dordrecht: Dr. W. Junk Publishers.

Herbst, D., (2001). Gradients of salinity stress, environmental stability and water chemistry as a templet for defining habitat types and physiological strategies in inland salt waters. Hydrobiologia 466: 209-219.

Incagnone, G., Marrone, F., Barone, R., Robba, L., and Naselli-Flores, L., (2015). How do freshwater organisms cross the ‘‘dry ocean’’? A review on passive dispersal and colonization processes with a special focus on temporary ponds. Hydrobiologia 750: 103-123.

Ivanova, M., and Kazantseva, T., (2006). Effect of Water pH and Total Dissolved Solids on the Species Diversity of Pelagic Zooplankton in Lakes: A Statistical Analysis. Russian Journal of Aquatic Ecology 37: 264-270.

Kalff, J. (2002). Limnology. Inland Water System*.* Prentice Hall, New Jersey.

Maceda J.J., Mero, M., Riesco, H., and Dolsan, M., (2001). Lista de las aves de la reserva Parque Luro, La Pampa. Rev.Fac. Agronomía - UNLPam 2: 47-59.

Markensten, H., and Pierson, D., (2003). A dynamic model for flow and wind driven sediment resuspension in a shallow basin. Hydrobiologia 494: 305-311.

McCauley, E., (1984). The estimation of the abundance and biomass of zooplankton in samples. In: Downing, J. & F. Rigler (eds.). A manual on methods for the assessment of secondary productivity in freshwaters. 2ª ed. Blackwell Scientific Publishing Oxford, pp 228-265.

Menéndez, M., Carlucci, D., Pinna, M., Comin, F., and Basset, A., (2003). Effect of nutrients on decomposition of *Ruppia cirrhosa* in a shallow coastal lagoon. Hydrobiologia 506/509: 729-735.

Menu-Marque, S., Morrone, J., and Locascio de Mitrovich, (2000). Distributional patterns of the south american species of *Boeckella* (Copepoda: Centropagidae): a track analysis. Journal of Crustacean Biology 20: 262-272.

Mura, G., and Brecciaroli, B., (2003). The zooplankton crustacean of the temporary waterbodies of the Oasis of Palo (Rome, central Italy). Hydrobiologia*,* 495: 93-102.

Obrador, B., Pretus, J., and Menéndez, M., (2007). Spatial distribution and biomass of aquatic rooted macrophytes and their relevance in the metabolism of a Mediterranean coastal lagoon. Scientia Marina 71 (1): 57-64.

Pérez, C., (2004). Técnicas de análisis multivariante de datos. Pearson Educación, Madrid.

Ruggiero, A. and Ezcurra, C., (2003). Regiones y transiciones biogeográficas. In Morrone, J. & J. Llórente (eds.), Biogeografía en Latinoamérica 2. Facultad de Ciencias IMAM, México, pp. 141-154.

Ruttner-Kolisko, A., (1977). Suggestions for biomass calculation of plankton rotifers. Archiv für Hydrobiologie–Beiheft Ergebnisse der Limnologie (8): 71-76.

Santer, B., and Hansen. A.M., (2006). Diapause of *Cyclops vicinus* (Uljanin) in Lake Søbygård: indication of a risk-spreading strategy. Hydrobiologia 560: 217-226.

Schröder, T., (2005). Diapuse in monogonont rotifers. Hydrobiologia 546: 291-306.

Sokal, R. and Rohlf, F., (1995). Biometría. Principios y métodos estadísticos en la investigación biológica. Ed. Blume, Barcelona.

Sosa, R.A., Benz, V.A., Galea, J.M., and Poggio Herrero, V., (2010). Efecto del grado de disturbio sobre el ensamble de aves en la Reserva provincial Parque Luro, La Pampa, Argentina. RASADEP 1: 101-110.

Subsecretaría de Ecología, (2004). Reserva Provincial "Parque Luro" Plan de Manejo. https://ambiente.lapampa.gob.ar/images/stories/Imagenes/Archivos/Plan_de_Manejo_Reserva_Provincial_Parque_Luro.pdf.

Viglizzo, E., (2010). El agro, el clima y el agua en La Pampa semiárida: revisando paradigmas, Anales de la Academia Nacional de Agronomía y Veterinaria (ANAV) LXIV 251-267. Available at http://sedici.unlp.edu.ar/bitstream/handle/10915/27600/Documento_completo.pdf?sequence=1. (accessed 7-V-2018).

Vignatti, A., (2011). Biomasa del zooplancton en lagunas salinas y su relación con la concentración de sales en ausencia de peces. Tesis Doctoral. Universidad Nacional de Río Cuarto Facultad de Ciencias Exactas, Físico-Químicas y Naturales.

Vignatti, A., Echaniz, S., and Martín, M., (2007). El zooplancton de lagos someros de diferente salinidad y estado trófico en la región semiárida pampeana (La Pampa, Argentina). Gayana 71: 38-48.

Vignatti, A., Cabrera, G., and Echaniz, S., (2012a) Changes in the zooplankton and limnological variables of a temporary hypo-mesosaline wetland of the central region of Argentina during the drying. Pan American Journal of Aquatic Sciences 7: 93-106.

Vignatti, A., Paggi, J., Cabrera, G., and Echaniz, S., (2012b). Zooplankton diversity and its relationship with environmental changes after the filling of a temporary saline lake in the semi-arid region of La Pampa (Argentina). Latin American Journal of Aquatic Research 40: 1005-1016.

Vignatti, A., Canosa, M., Cabrera, G., and Echaniz, S., (2017). The ecology of saline lakes in central Argentina: Environmental and zooplankton changes during the drying of a temporary shallow ecosystem. Universitas Scientiarum (Pontificia Universidad Javeriana de Bogotá) 22: 177-200.

Wallace, R., Walsh, E., Arroyo, M., and Starkweather, P., (2005). Life on the edge: rotifers from springs and ephemeral waters in the Chihuahuan Desert, Big Bend National Park (Texas, USA). Hydrobiologia 546: 147-157.

Wetzel, R., (2001). Limnology. Lake and river ecosystems. Academic Press, Elsevier, San Diego.

Zanón-Martínez, J., Kelly, M., Mesa-Cruz, J.B., Sarasola, J., DeHart, C., and Travaini, A., (2016). Density and activity patterns of pumas in hunted and non-hunted areas in central Argentina. Wildlife Research 43: 449-460.

Zar, J. (1996). Biostatistical analysis. 3º Ed. Prentice Hall. 988. New Jersey.

Reception date : 28th June 2018; Acceptation date: 21th March 2019.