Associations of ostracods in shallow lakes in the northeast of La Pampa province (Argentina)

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Abstract: Shallow lakes are common in the center of Argentina. Although many characteristics of its biota are known, information on the distribution and ecology of ostracods is scarce despite their importance as biological indicators in the studied lakes of northeastern Argentina (L. titicaca), the Buenos Aires province plain (H. similis, H. incongruens), and Patagonia (L. rionegroensis) allowed for affirming that the lakes of La Pampa are in a transition zone among different ostracods faunas.

Keywords: Non-marine ostracods, living ostracods, Limnocythere rionegroensis, Limnocythere titicaca.

Resumen: Asociaciones de ostrácodos de lagos someros del noreste de la provincia de La Pampa (Argentina). Los lagos someros son frecuentes en La Pampa. Aunque muchas características de su biota son conocidas, la información sobre la distribución y ecología de los ostrácodos es escasa, a pesar de su importancia como indicadores biológicos y en actuopalaeontología. El objetivo de este estudio es conocer la composición taxonómica, la densidad de ostrácodos y sus relaciones con parámetros ambientales en lagos del noreste de La Pampa. Se estudiaron cinco lagos desde septiembre de 2016 hasta marzo de 2017. Se tomaron muestras de sedimentos superficiales e in situ: conductividad, temperatura y transparencia. Ten taxa fueron registradas, algunas previamente encontradas en la provincia de Buenos Aires (Heterocypris similis, H. incongruens, Cypridopsis vidua, y Chlamydotheca incisa), el Llancanelo (H. incongruens y C. vidua), y lagos del norte de Patagonia (C. incisa, C. vidua, Potamocypris unicaudata, H. incongruens, y Amphicypris argentinensis). El efecto de salinidad fue verificado porque algunas especies (A. argentinensis, Limnocythere rionegroensis, y Limnocythere titicaca) fueron encontradas sólo en los lagos mas salinos. La existencia en La Pampa de tres diferentes ecorregiones (Pampean Plains, Espinal, y Patagonian Steppe) y la presencia de ostrácodos en los lagos del noreste argentino (L. titicaca), el Buenos Aires province plain (H. similis, H. incongruens), y la cuenca de Llancanelo (L. rionegroensis) permitiría afirmar que los lagos de La Pampa están en una zona de transición entre faunas diferentes.

Palabras clave: Ostrácodos no marinos, ostrácodos vivientes, Limnocythere rionegroensis, Limnocythere titicaca.

INTRODUCTION

Most aquatic ecosystems of La Pampa Province are shallow lakes. Additionally, most of these ecosystems are saline lakes (TDS > 3 g/L (Hammer, 1986), in which Cl⁻ and Na⁺ are the dominant ions. However, in the province there are some subsaline lakes, usually located in dune areas with HCO₃⁻ and Na⁺ or Ca²⁺ dominance (Echaniz & Vignatti, 2019).
Many physical-chemical and biological characteristics of the lakes in La Pampa Province have been studied, but of the latter, the most attention has been given to phytoplanktonic and zooplanktonic communities (Echaniz & Vignatti, 2017; 2019; Echaniz et al., 2006; 2012; Vignatti et al., 2007).

As the benthic community can be a useful tool to evaluate the characteristics of lakes, the study of ostracods has taxonomic, biogeographic, and ecological importance. In addition, determining the response of its community to different environmental parameters has attracted considerable interest because ostracods are good indicator organisms (Ruiz et al., 2013; Echeverría Galindo et al., 2019). Furthermore, knowledge about living ostracods can be used in actuopalaeontology studies to examine the evolution of lakes in the recent past (Laprida et al., 2006; D´Ambrosio et al., 2017), especially considering the current scenarios of climate change (Barros et al., 2014).

Ostracods are small crustaceans with a chitin-calcareous bivalve shell, which are able to inhabit a wide range of aquatic ecosystems. Ostracods are free-living and widely distributed in both marine and non-marine environments. Among the latter, ostracods will inhabit permanent or temporary environments with fresh or saline water, from small ponds to large lakes or humid, semi-terrestrial environments such as the soils of tropical forests (Shornikov, 1980; Pinto et al., 2005; Perçin-Paçal, 2011). Ostracods are usually benthic (Pieri et al., 2009), and also could be associated with algae or aquatic vegetation (D´Ambrosio et al., 2017). In other words, these organisms may crawl on the bottom of a waterbody, burrow in sediments, or swim amongst macrophytes. There are no truly planktonic non-marine ostracod species, but the early juvenile stages of some species are free-swimming and act as dispersal stages (Martens & Horne, 2016).

In continental waters, ostracod species distribution is controlled primarily by salinity or conductivity (Martínez-García et al., 2015; Cárdenas et al., 2015; D´Ambrosio et al., 2017), temperature, oxygen availability and substrate type, drought, water chemistry, acidification, turbidity, eutrophication, or the amount of organic matter (Pérez et al., 2010; Van der Meeren et al., 2010; Perçin-Paçal, 2011). In addition, the same environmental parameters influence the structures of ostracod assemblages (Ruiz et al., 2013; Coviaga et al., 2015). Further, these microcrustaceans show high sensitivity to pesticides, herbicides, heavy metal pollution, and oil inputs, so they may be included within the most promising sentinel groups in freshwater areas (Ruiz et al., 2013). The study of the ecology of non-marine ostracods is of value to water quality monitoring and management because different species respond in different ways to organic pollution and thus have potential as indicators of habitat disturbance (Mezquita et al., 1999).

In the Neotropical bioregion, studies on the ecology and biogeography of non-marine ostracods are relatively scarce, despite the importance of this field of study in paleoclimate and paleoecological reconstructions (D´Ambrosio et al., 2017). In Argentina, there have been some studies on ostracod assemblages in Patagonian lakes (Schwalb et al., 2002; Cusminsky et al., 2005; 2011; Ballent & Díaz, 2012; Ramón Mercau et al., 2012; Coviaga et al., 2015; 2018), the Altiplano of Northern Argentina (Laprida, 2006; Díaz & Lopretto, 2011; Palacios-Fest et al., 2016; D´Ambrosio et al., 2020), the Pampean region (César et al., 2001; Laprida, 2006; Liberto et al., 2012; Ramón Mercau et al., 2012), and the Payunia region, in the south of Mendoza province (D´Ambrosio et al., 2017).

In La Pampa Province, located in the center of Argentina, studies on the taxonomy, distribution, and ecology of ostracods are very scarce, existing only those of Khin & Pall (2013); Kihn et al. (2017) and Coviaga et al. (2018). Therefore, the objective of the present study is to determine the taxonomic composition, the density of ostracods, and their relationships with the main limnological parameters in shallow and relatively small lakes with different characteristics in the northeast of La Pampa province.

MATERIALS AND METHODS

Study area

Ostracods from the following five aquatic ecosystems located in northeastern La Pampa were studied: La Tradicion East (LTE) (35° 17' 57" S; 63° 37' 36" W), La Tradicion West (LTW) (35° 17' 43" S; 63° 37' 52" W), Los Molinos (DMO) (35° 22' 20" S; 63° 36' 19" W), Ustarroz (Ust) (35° 22' 30"S; 63° 34' 45" W) and El Bellaco (EBe) (35° 27' 08" S; 63° 36' 18" W) (Fig. 1). All are located at 120 - 121 m above mean sea level. LTE and LTW are located very close to each other but are not superficially connected. LTE and DMO are relatively small, less than 1 ha, have variable vegetation cover (especially Schoenoplectus californicus (C.A. Mey.) Sojak), whereas the other ecosystems range from 22 ha (EBe) to 200 ha (Ust) and lack aquatic vegetation.
All of these ecosystems are located at the western end of the Pampa ecoregion, in the Pampa Arenosa Anegable Complex, a region characterized by a humid temperate climate with an average annual rainfall close to 800 mm and an average temperature of 15 °C (Morello et al., 2012). This region is also characterized by dune fields that hinder drainage and by a predominance of livestock and agriculture; therefore, only small patches of natural vegetation (psammophylic grasslands) remain in this area (Morello et al., 2012).

Field and laboratory work

Samples were obtained in September and November of 2016 and January and March of 2017. A total of 60 sediment samples were collected. From each lake, three samples of the two superficial centimeters of sediment were collected with a metallic ring (10 cm in diameter) in transects from the shore to the interior of the lake, with a distance of 20 cm between samples. The maximum depths of LTE and DMo were very close to the coast, so the samples from these lakes were collected along a line parallel to the coastline, with a distance of 2 m between samples.

In situ conductivity and temperature were measured with an Oakton DO6+ multiparameter probe, dissolved oxygen concentration with a Lutron OD 5510 oximeter, and water transparency was determined with a 20 cm diameter Secchi disk. On all occasions, water samples were collected to determine salinity (as solid residue by drying at 104 °C) and pH (with a Corning PS 15 pH meter). In January 2017, one water sample was collected from each lake to determine the ionic composition according to standardized routines: \( \text{Na}^+ \) (selective ion electrode); \( \text{K}^+ \) (determination of the intensity of the turbidity by the combination of potassium with sodium tetraphenylborate); \( \text{Ca}^{2+} \) (EDTA digital titrimetric method or spectrophotometric method for very low calcium levels); \( \text{Mg}^{2+} \) (digital titrimetric method or spectrophotometric method for very low magnesium levels); \( \text{Cl}^- \) (argentometric method - digital titration with silver nitrate solution in the presence of potassium chromate - or the spectrophotometric method for very low concentrations); \( \text{SO}_4^{2-} \) (spectrophotometric determination of the intensity of the turbidity formed during the reaction of the sulfate with barium); and \( \text{HCO}_3^- \) and \( \text{CO}_3^{2-} \) (alkalinity method of phenolphthalein and digital titration) (APHA, 1992).

Dry sediment was processed and disaggregated using tap water. Then, samples were washed through a 63 mm mesh sieve and dried at room temperature. From the residue, 25 g of material was extracted and entire specimens were picked out and studied under a binocular micros-
cope. The adult and juvenile specimens from all the samples were counted, and its density was expressed as individuals/100 g of sediment (indiv./100 g sed.).

Systematic determinations were based mainly on studies by Moore (1961), Bertels & Martínez (1990), Cusminsky & Whatley (1996), Cusminsky et al. (2005), Ferrero (2006), Laprida (2006), Meisch (2000), and Karanovic (2012). Only live specimens were considered and to differentiate live specimens from dead ones at the time of sampling, the presence of soft parts and appendages was observed.

To study differences between the environmental variables of the lakes and ostracod population parameters, a non-parametric Kruskal-Wallis test was performed (Sokal & Rohlf, 1995). To group the lakes based on their limnological and chemical characteristics, a single linkage and Euclidean distance cluster analysis was performed. For this analysis, only conductivity (and not salinity) was used, given the strong correlation between these two variables.

To analyze the relationship between the abundances of the different taxa and their frequencies of occurrence, an Olmstead-Tukey non-parametric test with graphs of quadrants (Sokal & Rohlf, 1995) was applied. In this test, the density of each species (indiv./100 g sed.) was plotted on the ordinates versus the frequency of occurrence of each species (as percentages) in the abscissa. This allowed for the identification of four categories: frequent and abundant species (dominant species, quadrant I); abundant and infrequent species (occasional species, quadrant II); infrequent and scarce species (rare species, quadrant III); and frequent but scarce species (common species, quadrant IV; D’Ambrosio et al., 2016).

To determine the association between ostracods species in the lakes, a Bray-Curtis paired-group cluster analysis was performed.

A canonical correspondence analysis (CCA) was performed to investigate the relationship between the ostracod communities and the environmental variables because this test was created to understand how various taxa respond simultaneously to external factors (Ter Braak & Verdonk, 1995). The densities of the different taxa were used as a biological variable, and the environmental variables were: lake depth, conductivity, temperature, oxygen, transparency, and pH. Only conductivity (not salinity) was used given the strong correlation between these two variables.

We used PAST software (Hammer et al., 2001).

RESULTS

Environmental parameters

All the studied water bodies were relatively shallow (Table 1). Although the depths of these lakes varied, they were deepest in November and fell sharply (halved in DMo, Ust, and EBe) in March.

Salinity and conductivity were different among lakes (H = 18.07; p<0.01 and H =17.51; p<0.01 respectively), much higher in LTW and Ust. Mean water temperature did not significantly differ among the lakes, although that of LTW was almost 2 to 4 °C higher than that of the others. Water temperature varied between a minimum of 14.8 °C, measured in September in EBe, and a maximum of 31 °C, registered in January in Ust. Average oxygen concentration was relatively high in all water bodies and did not significantly differ between lakes. Water transparency was different (H = 15.28; p < 0.01), since it was greater than 0.7 m in DMo and LTE and more reduced in the rest of the lakes (Table 1).

The ionic composition of the water was heterogeneous, as EBe was bicarbonated-sodic, DMo and LTE were bicarbonated-calcic, LTW was chlorinated-sulfated-sodic, and Ust was chlorinated-sodic (Table 2). The F values were variable and highest in the larger water bodies (EBe, LTW, and Ust).

A cluster analysis based on the environmental variables and chemical compositions of the water identified two groups of lakes separated by the greatest distance. On the one hand, one group was integrated only by LTW due to its relatively high salinity, ion concentrations, and very low transparency and the second group consisted of lower, although variable, salinity and transparency lakes. In this group, Ust was separated because it has intermediate salinity and transparency, and the narrowest grouping was between DMo and LTE because both had the lowest salinities, the greatest water transparencies, and a shared ionic composition (Figure 2).

Ostracods

Ten ostracod taxa were registered. The highest richness was recorded in LTE and LTW (6 taxa), although these lakes shared only two species. Conversely, the lowest ostracod richness was recorded in Ust (3 taxa) (Table 3).

Heterocypris similis and Heterocypris incongruens were the dominant species, as they were registered in all lakes and the former was the
Table 1. Limnological parameters (mean and standard deviation) of the five studied water bodies. *Differed significantly among lakes

<table>
<thead>
<tr>
<th></th>
<th>EBe</th>
<th>DMo</th>
<th>LTE</th>
<th>LTW</th>
<th>Ust</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. depth (m)</td>
<td>0.80 ± 0.17</td>
<td>1.02 ± 0.29</td>
<td>1.28 ± 0.15</td>
<td>0.78 ± 0.21</td>
<td>0.85 ± 0.20</td>
</tr>
<tr>
<td>Salinity* (g/L)</td>
<td>1.50 ± 0.23</td>
<td>0.47 ± 0.05</td>
<td>1.14 ± 0.31</td>
<td>8.02 ± 1.62</td>
<td>3.72 ± 0.72</td>
</tr>
<tr>
<td>Conductivity* (mS/cm)</td>
<td>1.99 ± 0.33</td>
<td>0.71 ± 0.07</td>
<td>1.69 ± 0.47</td>
<td>10.53 ± 1.87</td>
<td>5.39 ± 1.07</td>
</tr>
<tr>
<td>Water temperature (°C)</td>
<td>20.18 ± 4.82</td>
<td>21.63 ± 4.12</td>
<td>22.38 ± 4.35</td>
<td>24.0 ± 5.03</td>
<td>22.05 ± 6.42</td>
</tr>
<tr>
<td>Dissolved oxygen (mg/L)</td>
<td>8.58 ± 0.97</td>
<td>8.65 ± 0.92</td>
<td>8.48 ± 0.76</td>
<td>8.10 ± 0.73</td>
<td>8.58 ± 0.96</td>
</tr>
<tr>
<td>Transparency* (m)</td>
<td>0.22 ± 0.08</td>
<td>0.74 ± 0.23</td>
<td>0.93 ± 0.44</td>
<td>0.09 ± 0.06</td>
<td>0.18 ± 0.08</td>
</tr>
<tr>
<td>pH</td>
<td>7.85 ± 0.44</td>
<td>7.70 ± 0.45</td>
<td>8.25 ± 0.51</td>
<td>8.78 ± 0.43</td>
<td>8.38 ± 0.39</td>
</tr>
</tbody>
</table>

Table 2. Ionic water compositions of the ecosystems studied

<table>
<thead>
<tr>
<th></th>
<th>EBe</th>
<th>DMo</th>
<th>LTE</th>
<th>LTW</th>
<th>Ust</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO$_3^{2-}$</td>
<td>643.4</td>
<td>0</td>
<td>321.8</td>
<td>1206.6</td>
<td>563.1</td>
</tr>
<tr>
<td>HCO$_3$^-</td>
<td>1326.6</td>
<td>683.7</td>
<td>522.8</td>
<td>508.2</td>
<td>890.4</td>
</tr>
<tr>
<td>Cl^-</td>
<td>204.5</td>
<td>102.2</td>
<td>344.5</td>
<td>1874.4</td>
<td>954.2</td>
</tr>
<tr>
<td>SO$_4^{2-}$</td>
<td>70.2</td>
<td>5.3</td>
<td>3.1</td>
<td>1750.6</td>
<td>525.2</td>
</tr>
<tr>
<td>Ca$^{2+}$</td>
<td>114.4</td>
<td>140.2</td>
<td>248.3</td>
<td>108.1</td>
<td>129.4</td>
</tr>
<tr>
<td>Mg$^{2+}$</td>
<td>41.6</td>
<td>51.2</td>
<td>90.3</td>
<td>39.3</td>
<td>43.6</td>
</tr>
<tr>
<td>K^+</td>
<td>66.2</td>
<td>7.6</td>
<td>96.2</td>
<td>78.8</td>
<td>71.3</td>
</tr>
<tr>
<td>Na^+</td>
<td>670.2</td>
<td>70.5</td>
<td>32.5</td>
<td>3060.7</td>
<td>1540.3</td>
</tr>
<tr>
<td>F</td>
<td>3.13</td>
<td>0.2</td>
<td>1.26</td>
<td>3.35</td>
<td>3.25</td>
</tr>
</tbody>
</table>

Table 3. Ostracods registered in the five studied lakes and their densities (means and standard deviations), expressed as individuals/100 g of sediment

<table>
<thead>
<tr>
<th>Ostracods registered</th>
<th>EBe</th>
<th>DMo</th>
<th>LTE</th>
<th>LTW</th>
<th>Ust</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Heterocypris similis</em> (Wierzejski, 1967)</td>
<td>140.30 ± 134.12</td>
<td>30.00 ± 60.00</td>
<td>543.75 ± 263.09</td>
<td>233.50 ± 263.70</td>
<td>290.00 ± 402.94</td>
</tr>
<tr>
<td><em>Heterocypris incongruens</em> (Ramdohr, 1808)</td>
<td>101.63 ± 129.89</td>
<td>16.25 ± 32.50</td>
<td>34.75 ± 69.50</td>
<td>175.00 ± 163.25</td>
<td></td>
</tr>
<tr>
<td><em>Candona</em> sp.</td>
<td>9.94 ± 9.17</td>
<td>12.50 ± 12.50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Cypridopsis vidua</em> (O.F. Müller, 1776)</td>
<td>0.81 ± 1.61</td>
<td>142.80 ± 138.16</td>
<td>431.25 ± 468.43</td>
<td></td>
<td>1.00 ± 2.00</td>
</tr>
<tr>
<td><em>Chlamydotheca incisa</em> (Claus, 1893)</td>
<td>1.61 ± 3.23</td>
<td>89.64 ± 86.65</td>
<td>65.63 ± 71.72</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Potamocypris unicaudata</em> Schäffer, 1943</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>50.00 ± 70.71</td>
</tr>
<tr>
<td><em>Amphycipris argentinensis</em> Fontana &amp; Ballent, 2005</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6.50 ± 13.00</td>
</tr>
<tr>
<td><em>Limnocythere rionegrensis</em> Cusminsksy &amp; Whatley, 1996</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>121.75 ± 172.06</td>
</tr>
<tr>
<td><em>Limnocythere titicaca</em> Lerner-Seggev, 1973</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>126.00 ± 145.49</td>
</tr>
<tr>
<td><em>Limnocythere</em> sp.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6.50 ± 13.00</td>
</tr>
<tr>
<td>No determined juvenil specimens</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>12.50 ± 25.00</td>
</tr>
</tbody>
</table>
most abundant species, exceeding 500 ind./100 g sed. in LTE (Table 3 and Figure 3). They were followed by *Cypridopsis vidua* and *Candona* sp., given their lower frequencies of appearance. Other taxa, such as *Limnocythere* sp., *Potamocypris unicaudata*, and *Amphicypris argentiniensis*, were classified as rare species since they presented at low frequencies (registered in only one lake) and low densities (Figure 3).

The cluster analysis revealed two groups of species that showed very low similarity. The Group I, composed by species found only in the highest salinity lake (LTW), was integrated by *A. argentinensis*, *Limnocythere titicaca*, *Limnocythere rionegroensis*, and *Limnocythere* sp. (Figure 4). In group II, two subgroups with low similarity were distinguished: IIa, composed by *C. vidua*, *H. incongruens* and *H. similis*, the species that had a wider distribution, since they were found in almost all environments; and IIb, integrated by *Candona* sp., *Chlamydotheca incisa* and *P. unicaudata*, the species registered only in the low-salinity high-transparency lakes (EBE, DMo, and LTE) (Figure 4).

According to the CCA, the first axis, with an eigenvalue of 0.4989, and the second axis, with 0.2814, explained more than 93% of the variance. The first axis showed a strong correlation with the conductivity (-0.9320) and transparency of the water (0.7734). This analysis showed that the environmental variable that has the greatest influence on the distribution of ostracods is water electrical conductivity (as an indirect measure of salinity) because it showed the same groups that had been formed in the previous cluster analysis. The first group was composed of species that showed a positive correlation with conductivity (Group I in the cluster analysis: *A. argentinensis*, *L. titicaca*, *L. rionegroensis*, and *Limnocythere* sp.). The CCA also revealed that *H. incongruens* and *H. similis* are more tolerant and only slightly influenced by conductivity or other environmental parameters. Therefore, they were found in almost all environments, while *C. incisa*, *Candona* sp., and *P. unicaudata* (Group IIb in the cluster analysis) had a negative correlation with conductivity but were positively associated with water transparency and oxygen concentration (Figure 5).

Although the mean total ostracods density of LTE (1306 ind./100 g sed.) was almost five times higher than those of EBE and DMo (244 and 288 ind./100 g sed., respectively), this difference was not significant (Figure 6).

Regarding temporal variations in density, we did not detect a homogenous pattern of temporal variation. The densities of LTE, LTW, and DMO were higher in January (2375, 982, and 670 indiv./100 g sed., respectively). However, the abundance in EBE was higher in March (603 indiv./100 g sed.) and that in Ust was highest in September (1268 indiv./100 g sed.) (Figure 7).

Considering the lake communities separately, in EBE *H. similis* and *H. incongruens*, were the most abundant species and reached the maximum density in March (313 and 290 indiv./100 g sed., respectively). The other two species, *C. vidua* and *C. incisa*, were found only once, in relatively low densities (3.22 and 6.4 indiv./100 g sed., respectively) (Figure 8).

In DMO, *C. vidua* was the most abundant species and reached its maximum density in November (330 indiv./100 g sed.). Was followed by *C. incisa*, which was more abundant in September.
Fig. 4. Groupings of the ostracod taxa registered in the five studied lakes.

Fig. 5. Results of the canonical correspondence analysis (185 indiv./100 g sed.). *Heterocypris similis* and *H. incongruens* were found only in January, albeit with relatively high densities (120 and 65 indiv./100 g sed., respectively) (Figure 8).

In LTE, *H. similis* and *C. vidua* were the most abundant species and reaches their maximum density in January (812.5 and 925 indiv./100 g sed., respectively), followed by *H. incongruens* which reach 412.5 indiv./100 g sed., also in January respectively) (Figure 8).

In LTW, *H. similis* was the most abundant species, with a maximum density in September (812.5 and 925 indiv./100 g sed., also in January respectively) (Figure 8).

In Ust, *H. similis* was the most abundant species followed by *H. incongruens*. They registered their maximum densities in September (872 indiv./100 g sed.) and November (180 indiv./100 g sed.). *Cypridopsis vidua* was found only in September at a low density (4 indiv./100 g sed.). No ostracods were found in January (Figure 8).

**DISCUSSION**

Despite the short distance among them, the set of ecosystems studied was highly heterogeneous, and the characteristics were relatively different in terms of size, water transparency, and salinity. Although two ecosystems (Ust and LTW) could be considered saline lakes (Hammer, 1986), with a predominance of Cl⁻, the analysis showed that LTW was relatively different because its salinity was much higher, which was reflected by the association of the species. On the other hand, EBe, DMo, and LTE are subsaline lakes (Hammer, 1986) with a predominance of bicarbonate, but the first differs slightly because...
it is more extensive and its transparency is much lower. The greater transparency that characterizes DMo and LTE is related to a greater vegetation cover that inhibits the growth of phytoplankton and decreases the removal of sediments by the wind (Echaniz & Vignatti, 2019).

Considering that the sampled lakes are located in a relatively small area, the total richness of ostracods was relatively high, probably due to the physical-chemical differences between the ecosystems, especially in conductivity (as an indirect measure of salinity). The richness found in this study was similar to that recorded by D’Ambrosio et al. (2017) (eleven taxa) in a heterogeneous set of aquatic ecosystems (lentic and lotic) in the Llancanelo Lake basin (Mendoza Province). The richness of ostracods in Northern Pampa was relatively high compared to that found in a transect of more than 700 km covering the regions of the Espinal (La Pampa Province), the Patagonian Steppe (Río Negro Province), and the Andean forest in Northern Patagonia (Neuquén and Río Negro Provinces) (Coviaga et al., 2018) or than that recorded in temporary fishless ponds near San Carlos de Bariloche (Río Negro Province) (Coviaga et al., 2015). However, the species number was lower compared to the twenty taxa registered by Laprida (2006) in the Depressed Pampa plain (Buenos Aires province), an extensive region with a high abundance of aquatic ecosystems.

The ostracod fauna found in this study was similar to that registered in temporary and permanent water bodies in Buenos Aires.
Province, characterized by *H*. *similis*, *H*. *incongruens*, *Candonia sp.*, *C. vidua*, *C. incisa*, and *Limnocythere* sp. (Laprida, 2006); this was expected because both the aquatic ecosystems studied by Laprida (2006) and those in the northeast of La Pampa, are located in the Pampa ecoregion (Morello et al., 2012). On the other hand, the Pampean sampled lakes share only two taxa (*H*. *incongruens* and *C. vidua*) with the fauna found in the Llancanelo Lake basin (D’Ambrosio et al., 2017), located in the Patagonian Steppe ecoregion (Payunia subregion) (Morello et al., 2012). Additionally, the Pampean studied lakes share five taxa (*C. incisa*, *C. vidua*, *P. unicaudata*, *H*. *incongruens*, and *A. argentinensis*) with those found by Covíaga et al. (2018) in the aforementioned transect of Northern Patagonia.

The importance of salinity as a structuring factor for communities (Ruiz et al., 2013; Martínez-García et al., 2015; Covíaga et al., 2015) shown by the CCA was also verified in the present study. A group of species composed of *A. argentinensis*, *L. rionegroensis*, *L. titicaca*, and *Limnocythere* sp. showed preference for saline lakes because they were found only in the saline LTW. Conversely, species such as *C. incisa*, *Candonia sp.*, and *P. unicaudata* were restricted to very low salinity ecosystems, while *H*. *incongruens* and *H*. *similis* thrived over a wider range of salinity levels.

Considering the clustering of taxa registered in this study, *H*. *similis* and *H*. *incongruens*, previously found in La Pampa (Kihn & Pall, 2013; Kihn et al., 2017), can tolerate a wide range of salinity and are widely distributed in South America (Ramírez, 1967; Martens & Behen, 1994; César et al., 2001; Laprida, 2006). *Heterocypris incongruens* is a cosmopolitan species (Külköylüoğlu, 2013; D’Ambrosio, 2014) registered in Buenos Aires Province (Laprida, 2006; Libertó et al., 2012) and Mendoza Province (D’Ambrosio et al., 2017). Although Roca et al. (1993) mentioned that *C. vidua* prefers periphyton growing on *Chara fragilis*, in La Pampa it was recorded in the benthos, even in Ust, a lake that lacks aquatic vegetation. In Pampean lakes, *C. vidua* reach relatively high densities (only surpassed by those of *H. similis*), which is consistent with that found in other studies (Fernandes-Martins et al., 2010; Martínez-García, 2015).

Considering the species found in the lakes with the highest salinity, although it has been indicated that species of the genus *Anphicyopus* mostly inhabit freshwater lakes (Fontana & Ballent, 2005), *A. argentinensis* was found in La Pampa at a salinity of 9.32 g/L. *Limnocythere rionegroensis*, present in recent environments of Patagonia is an indicator of environments with high saline concentrations (Cusminsky et al., 2005) resulting from high evaporation and chemical compositions rich in chlorides or sulfates (Ramón Mercau et al., 2012, what can explain its presence only in LTW. *Limnocythere titicaca*, which has also been registered in Runtuyoc Lake (northwest of Argentina) (D’Ambrosio et al., 2020), prefers permanent lakes (Palacios-Fest et al., 2016). However, in La Pampa, this species was registered in LTW, which can dry up occasionally.

The total mean density of the lakes was not different despite the fact that the density recorded for LTE was higher. This may be due to the high variability in the density because there was a time when no ostracods were recorded, such as in Ust in January or on occasions when the density exceeded 2000 ind./100 g sed. as in LTE during January and March. Although in three lakes the density was higher in January, a seasonal pattern of variation was not found.

La Pampa province is a transition zone characterized by a rainfall gradient from a mean of 800 mm/year in the northeast to 300 mm/year towards the southwest (Morello et al., 2012). This means that different ecoregions are represented in its territory from the fertile Pampa Plains in the wetter northeast to the arid Patagonian steppe in the southwest (Morello et al., 2012). These conditions affect the characteristics of their wa-
ter bodies, which show considerable heterogeneity, sometimes in small geographic areas (Echaniz & Vignatti, 2019), such as those included in this study.

This study shows the presence in La Pampa of ostracods previously registered in northwestern Argentina as *L. ticitaca*, others frequent in the center of the country (*H. similis*) but not found in northern Patagonia (Coviaga et al., 2018) or south of Mendoza Province (D’Ambrosio et al. 2017) and, conversely, the presence in pampenan lakes of *L. rionegroensis*, typical of Patagonia (Cusminsky et al., 2005, Cusminsky et al., 2011, Ramón Mercau et al., 2012). This co-occurrence in addition to its geographical location and climatic characteristics could indicate that the lakes of La Pampa are in a transition zone among the faunas of the north, center, and south of Argentina.

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