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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 and in actuopaleontology. The objective of this study was to determine the taxonomic composition, the density of ostracods, and their relationships with environmental parameters in lakes in the northeast of La Pampa. Five aquatic ecosystems were studied from September 2016 to March 2017. Samples of superficial sediments were collected, and conductivity, temperature, and transparency were measured *in situ*. Water samples were collected to determine salinity, pH, and ionic composition. The lakes differed in salinity, ionic composition, and transparency. Ten taxa were registered, some previously found in the province of Buenos Aires (*Heterocypris similis*, *Heterocypris incongruens*, *Cypridopsis vidua,* and *Chlamydotheca incisa*), the Llancanelo basin (*H. incongruens* and *C. vidua*), and North Patagonia lakes (*C. incisa*, *C. vidua*, *Potamocypris unicaudata*, *H. incongruens,* and *Amphicypris argentiniensis*). The influence of salinity was verified because some species (*A. argentinensis*, *Limnocythere rionegroensis,* and *Limnocythere titicaca*) were found only in the most saline lake. The existence in La Pampa of three different ecoregions (Pampean Plains, Espinal, and Patagonian Steppe) and the presence of ostracods in the studied lakes of northwestern 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 actuopaleontología. 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* se midieron: conductividad, temperatura y transparencia y se tomaron muestras para determinar salinidad, pH y composición iónica. Los lagos difirieron en su salinidad, composición iónica y transparencia. Se registraron diez taxa, algunos hallados previamente en la provincia de Buenos Aires (*Heterocypris similis*, *Heterocypris incongruens*, *Cypridopsis vidua y Chlamydotheca incisa*), la cuenca de Llancanelo (*H. incongruens* y *C. vidua*) y lagos del norte de Patagonia (*C. incisa*, *C. vidua*, *Potamocypris unicaudata*, *H. incongruens* y *Amphicypris argentiniensis*). Se comprobó la influencia de la salinidad ya que algunas especies (*A. argentinensis, Limnocythere rionegroensis* y *Limnocythere titicaca*) se encontraron sólo en el lago más salino. La existencia en La Pampa de tres ecorregiones diferentes (Llanura Pampeana, Espinal y Estepa Patagónica) y la presencia en los lagos estudiados de ostrácodos del noroeste argentino (*L. titicaca*), de la llanura bonaerense (*H. similis, H. incongruens*) y otras de Patagonia (*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 HCO_3^- and Na^+ or Ca^{2+} 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 actuopaleontology 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), Dos 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.) Soják), whereas the other ecosystems range from 22 ha (EBe) to 200 ha (Ust) and lack aquatic vegetation.

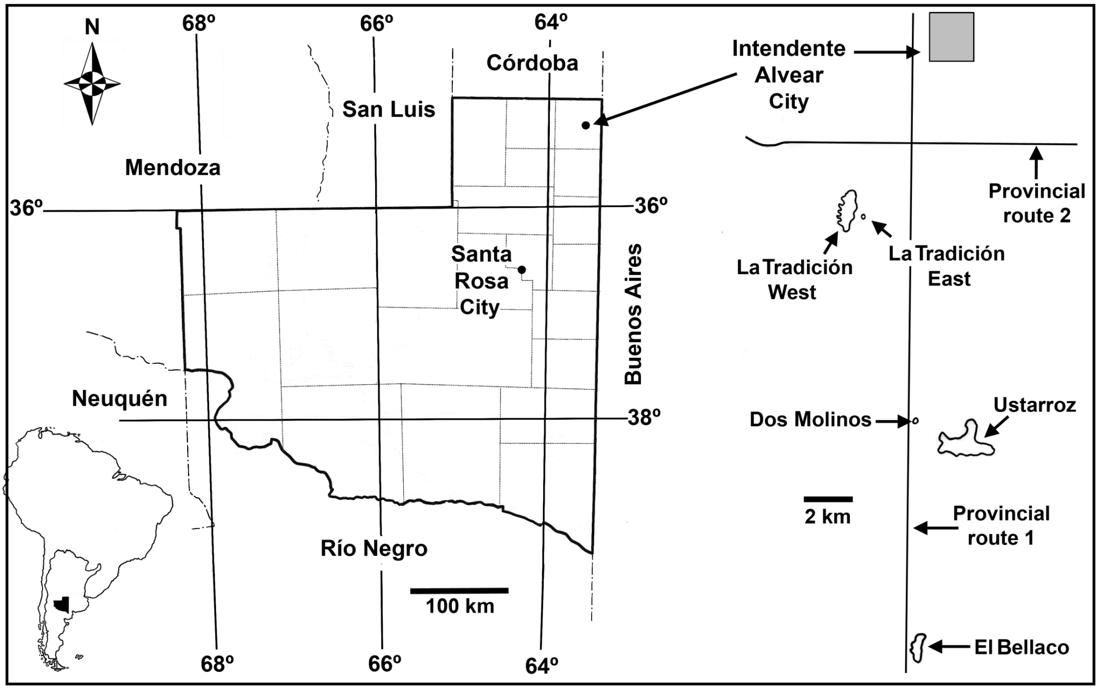

Fig. 1. Geographical locations of the five aquatic ecosystems studied in La Pampa province.

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 (psammophyllic 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 a 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: Na^+ (selective ion electrode); K^+ (determination of the intensity of the turbidity by the combination of potassium with sodium tetraphenylborate); Ca^{2+} (EDTA digital titulometric method or spectrophotometric method for very low calcium levels); Mg^{2+} (digital titrometric method or spectrophotometric method for very low magnesium levels); Cl^- (argentometric method - digital titration with silver nitrate solution in the presence of potassium chromate - or the spectrophotometric method for very low concentrations); 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).

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 microscope. 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 & Verdonshot, 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

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

Table 2. Ionic water compositions of the ecosystems studied

	EBe	DMo	LTE	LTW	Ust
CO_3^{2-}	643.4	0	321.8	1206.6	563.1
HCO_3^-	1326.6	683.7	522.8	508.2	890.4
Cl^-	204.5	102.2	344.5	1874.4	954.2
SO_4^{2-}	70.2	5.3	3.1	1750.6	525.2
Ca^{2+}	114.4	140.2	248.3	108.1	120.4
Mg^{2+}	41.6	51.2	90.3	39.3	43.6
K^+	66.2	7.6	96.2	78.8	71.3
Na^+	670.2	70.5	32.5	3060.7	1540.3
F^-	3.13	0.2	1.26	3.35	3.25

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

	EBe	DMo	LTE	LTW	Ust
Heterocypris similis (Wierzejski, 1967)	140.30 ± 134.12	30.00 ± 60.00	543.75 ± 263.09	233.50 ± 263.70	290.00 ± 402.94
Heterocypris incongruens (Ramdohr, 1808)	101.63 ± 129.89	16.25 ± 32.50	190.63 ± 221.59	34.75 ± 69.50	175.00 ± 163.25
Candona sp.		9.94 ± 9.17	12.50 ± 12.50		
Cypridopsis vidua (O.F. Müller, 1776)	0.81 ± 1.61	142.80 ± 138.16	431.25 ± 468.43		1.00 ± 2.00
Chlamydotheca incisa (Claus, 1893)	1.61 ± 3.23	89.64 ± 86.65	65.63 ± 71.72		
Potamocypris unicaudata Schäfer, 1943			50.00 ± 70.71		
Amphycipris argentinensis Fontana & Ballent, 2005				6.50 ± 13.00	
Limnocythere rionegroensis Cusminsky & Whatley, 1996				121.75 ± 172.06	
Limnocythere titicaca Lerner-Seggev, 1973				126.00 ± 145.49	
Limnocythere sp.				6.50 ± 13.00	
No determinated juvenil specimens			12.50 ± 25.00		

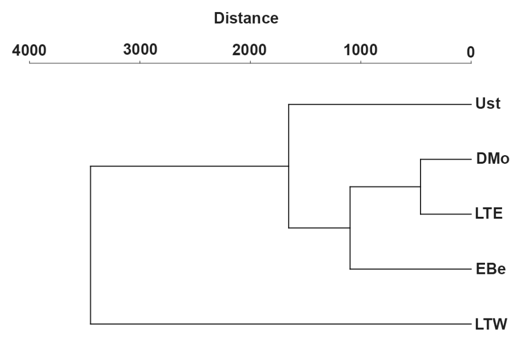

Fig. 2. Grouping of lakes based on the main limnological parameters and ionic compositions of their waters.

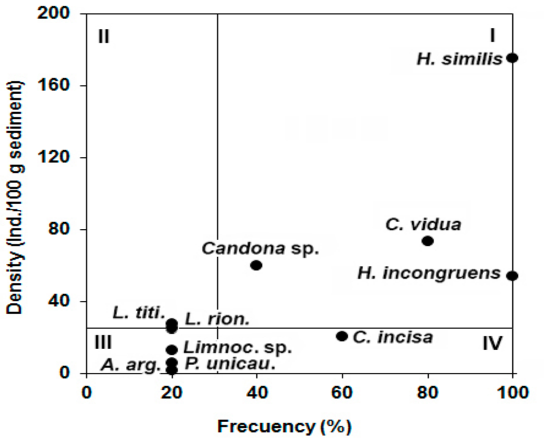

Fig. 3. Results of the Olmstead-Tukey test

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 (0.77341). 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 ind./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,* wich was more abundant in September

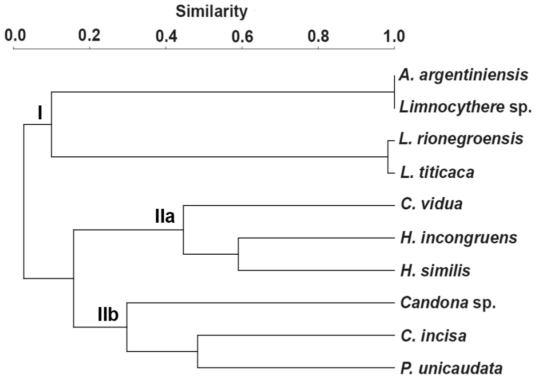

Fig. 4. Groupings of the ostracod taxa registered in the five studied lakes

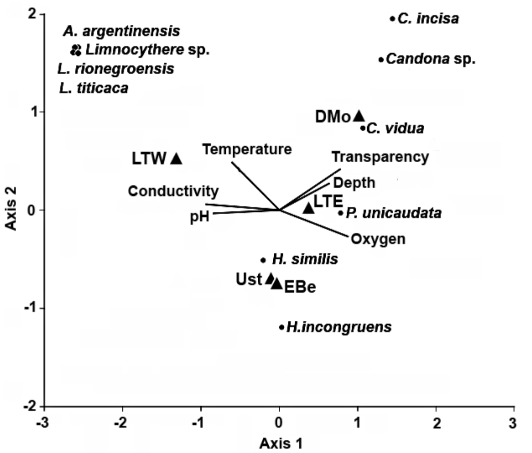

Fig. 5. Results of the canonical correspondence analysis

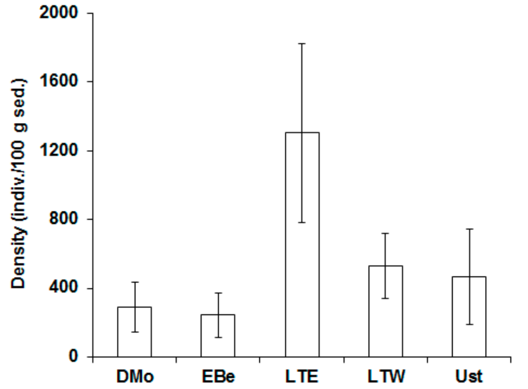

Fig. 6. Comparison of the total average densities recorded in the five studied bodies of water. The bars indicate standard deviations.

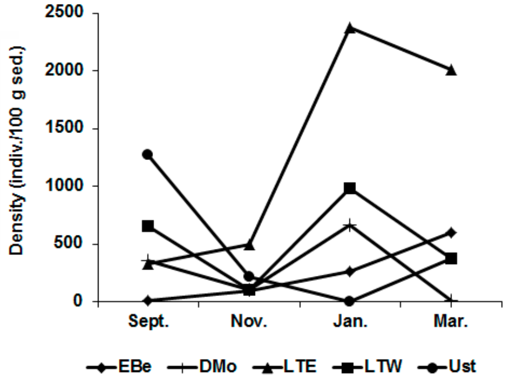

Fig. 7. Temporal variations in the densities of the ostracod taxa recorded in the five studied lakes.

(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 (604 indiv./100 g sed.), followed by *L. rionegroensis* and *L. titicaca*, which showed their maximum density in January (365 and 252 indiv./100 g sed. respectively). The rest of the species were found only once with much lower densities (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

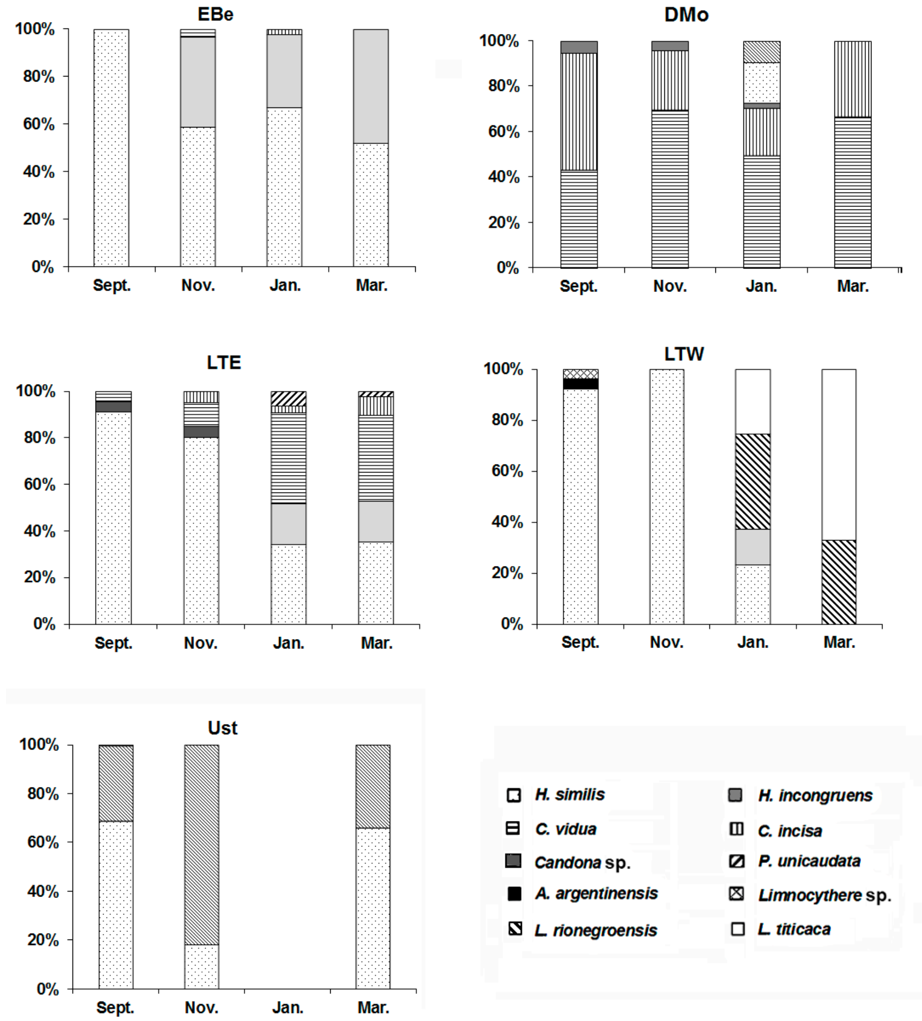

Fig. 8. Temporal variations in the densities (%) of the ostracod taxa recorded in the five studied lakes

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*, *Candona* 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. argentiniensis*) with those found by Coviaga *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; Coviaga *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, Candona* 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; Fernández *et al.*, 2016) frequently found in Buenos Aires Province (Ramírez, 1967; Laprida, 2006) and Patagonia (Schwalb *et al.*, 2002; Cusminsky *et al.*, 2005; 2011) that could be used as an indicator of water pollution (Van der Meeren *et al.*, 2010). The dominance of *H. incongruens* in Pampean lakes coincides with that found by D´Ambrosio *et al.* (2017) in Llancanelo and by Coviaga *et al.* (2018) in Northern Patagonia.

Among the taxa found in the lowest-salinity lakes, *C. incisa* is widely distributed in subsaline, shallow, vegetated, and chlorinated sodium lakes of South America and Argentina (Ramírez, 1967; Martens & Behen, 1994; César *et al.*, 2001; Laprida, 2006; Díaz & Lopretto, 2011; Kihn *et al.*, 2017). These conditions were found in DMo, and LTE, which have coverage of *Schoenoplectus californicus* in the Pampean lakes bicarbonate predominates.

Together with *C. incisa*, *C. vidua* was found. *Cypridopsis vidua* is a cosmopolitan species (Külköylüoğlu, 2013; D´Ambrosio, 2014) registered in Buenos Aires Province (Laprida, 2006; Liberto *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 *Amphicypris* 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 ocasionally.

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 water 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. titicaca*, 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 pampean 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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