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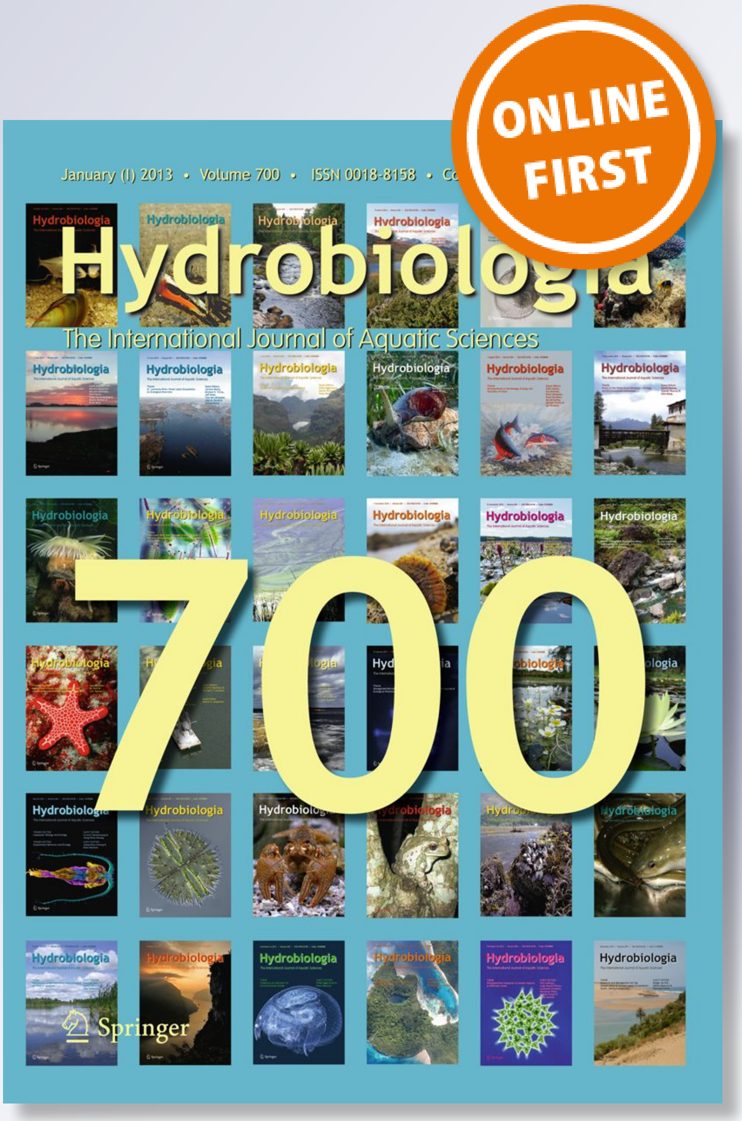

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PATAGONIAN LAKES

Ecology of freshwater ostracods from Northern Patagonia and their potential application in paleo-environmental reconstructions

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Abstract In order to generate a database of the auto-ecology and distribution of Argentinian North Patagonian ostracods (Argentina), a survey in 40 aquatic systems has been carried out. For this purpose, we report the ostracod diversity and assess the relationships between ostracod occurrence and abundance considering abiotic environmental variables. Twenty-two ostracod species have been found, three of which first record for Neotropical region and one for Argentina. Conductivity, temperature, and energy level have significantly explained ostracod distribution and abundance. Based on host waters features, three ostracod assemblages have been recognized: (1) temperate waters with moderate to high conductivity have presented in *Sarscypridopsis aculeata*, *Potamocypris unicaudata*, *Heterocypris hyalinus*, and *Cypridopsis vidua* as typical fauna; (2) environments with flowing waters were dominated by *Ilyocypris ramirezi* and *Heterocypris incongruens*, whereas (3) in cold and low conductivity environments, *Tonnacypris lutaria*, *Eucypris virens*, and *Bradleystrandesia fuscata* were the characteristic taxa. Our data indicate that Patagonian ostracods are largely influenced by host waters features, mainly conductivity and temperature. Likewise, due to the fact that eight of the twenty-two identified taxa in this survey were recovered in Holocene sequences from Patagonia, this study provides valuable information for future paleo-environmental reconstructions in North Patagonia.

Keywords Lacustrine Ostracoda · Biodiversity · Auto-ecology · Paleoproxies · Argentina · South America

Introduction

Ostracods are small crustaceans, present in almost every aquatic ecosystem, from oceans to temporary environments, streams, estuaries, and semi-terrestrial habitats (Horne et al., 2002; Mesquita-Joanes et al., 2012). Their carapace are made of low-magnesium calcite that fossilizes well in lake sediments, preserving information about the past lake environment (Griffiths & Holmes, 2000). The presence, absence, and relative abundance of continental ostracods are

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influenced by the physical and chemical features of aquatic environments they inhabit, as conductivity, temperature, energy level, ionic, and dissolved oxygen concentrations (Yassini & Jones, 1995; Holmes, 2001; Schwalb et al., 2002; Mezquita et al., 2005). Within this full spectrum of environmental variables, many species display specific preferences and tolerance ranges (Iglikowska & Namiotko, 2012). In this context, if ecological preferences and tolerance levels of individual species are known, the past and current habitat conditions can be estimated, making ostracods good proxies of environmental change (De Deckker & Forester, 1988; Curry, 1999; De Deckker, 2002; Dügel et al., 2008).

The correct usage of ostracods as biological proxies requires a deep knowledge of their taxonomy and ecology, a requisite usually not met in some remote areas as Patagonia (Ramón-Mercau et al., 2012). In this context, and although in the last years the study of Patagonian ostracods has increased (Cusminsky & Whatley, 1996; Schwalb et al., 2002; Cusminsky et al., 2005; Ramón-Mercau et al., 2012; Coviaga et al., 2015; Ramos et al., 2015, 2016), their ecological and taxonomical knowledge remains insufficient.

The aims of the present study were (1) to assess the composition and spatial distribution of modern ostracod assemblages along a North Patagonia transect and (2) to investigate relationships between the occurrence and abundance of the different taxa identified and abiotic environmental parameters, characterizing their ecological preferences and tolerance levels. Results of the present study will increase the taxonomical and ecological knowledge on non-marine ostracods in Patagonia, contributing to the use of ostracods as biological proxies of environmental change and allowing for the future development of quantitative ostracod-based environmental reconstructions in the Patagonian region.

Materials and methods

Study area

Sampling was carried out in 40 aquatic systems in Northern Patagonia, located along a 670-km-long west–east transect (39°00′–41°38′S; 63°46′–71°27′W; Table 1; Fig. 1). North Patagonia presents a large longitudinal extension, which guarantees a wide range of climatic conditions and a broad environmental heterogeneity. In this context, sampled sites were located in four ecoregions: *Andean-Patagonian forest, Patagonian steppe*, *Monte*, and *Espinal* (Burkart et al., 1999). The ecoregion of *Andean-Patagonian forest* is characterized by a climate temperate–humid (5.4–9.5°C average annual temperature, 800–3,500 mm/year) with moderate to high winds speed and soils rich in organic matter. This ecoregion is defined by the presence of the Andean Mountains, which act as a barrier to western wind flow, causing abundant precipitations in these temperate forests. As a result of this barrier effect, a strong precipitation gradient is generated ranging from 2,000 mm/year or higher to the West, at the base of the Andes, and to 200 mm/year to the East, in the *Patagonian steppe* ecoregion (Paruelo et al., 1998; Premoli et al., 2005). Consequently, the steppe presents a dry (600 mm/year at the western part of the steppe and 200 mm/year to the eastern section of this ecoregion), cold (3.0–12.0°C average annual temperature), and windy climate. The soils of this ecoregion are poorly developed, with a low organic matter content (Paruelo et al., 2005; Matteucci, 2012). In the *Monte* ecoregion, the climate is temperate-arid, with an average annual temperature between 10 and 14°C and annual precipitations varying between 300 and 800 mm/year (Pol et al., 2005). Finally, the *Espinal* is characterized by a temperate and semi-arid climate, with an average annual temperature of about 16°C and 300–600 mm/year precipitations. Even though most of the Patagonia is dominated by the *westerlies*, air masses coming from the Pacific Ocean (Paruelo et al., 1998), the *Espinal* ecoregion is also influenced by the northeast winds, determined by the Subtropical Atlantic anticyclone pressure center (Menéndez & La Rocca, 2006).

Additionally, sampling sites were selected to represent a heterogeneous gradient of freshwater habitat types in each ecoregion: permanent, semi-permanent and temporary ponds as well as lentic, springs, and streams environments.

Field and laboratory work

Sampling was carried out during austral spring (November and December) of the years 2011, 2012, and 2013. Ostracod samples were collected with a hand net (D frame, 200 µm mesh aperture) along the water–sediment interface, in a 1–6-m-long transect

Table 1 Geographical localization and habitat description of the sampled sites

Site	Code	Ecorreg.	Latitude (S)	Longitude (W)	Altitude	Hydroperiod seasonality	Water flow velocity
Fantasma	Fa	APF	41°05′33″	71°27′00″	828	Temporary	Stagnant
Mallín Grande	MG	APF	41°38′45″	71°27′32″	774	Temporary	Flowing
Reserva El Foyel	EF	APF	41°19′18″	71°21′17″	824	Temporary	Flowing
Steffen	Sf	APF	41°31′13″	71°27′23″	943	Temporary	Stagnant
Teleférico	Te	APF	41°07′40″	71°22′46″	816	Semi-permanent	Stagnant
Arroyo Salitral	As	PS	39°52′32″	70°36′38″	1,159	Temporary	Flowing
Arroyo La Fragua	Fr	PS	41°03′28″	70°59′46″	908	Permanent	Flowing
Arroyo Valcheta	Va	PS	40°40′35″	66°09′56″	179	Permanent	Flowing
Charca Los Juncos	Cha1	PS	41°03′39″	71°04′03″	1,045	Temporary	Flowing
Charca Virgen Guadalupe	VG	PS	41°38′24″	68°17′12″	1,042	Temporary	Stagnant
Chorrillo Carrilauquén 1	Ch1	PS	40°13′37″	70°21′24″	892	Temporary	Flowing
Chorrillo Carrilauquén 2	Ch2	PS	40°13′38″	70°21′26″	893	Temporary	Stagnant
Chorrillo Carrilauquén 3	Ch3	PS	40°13′38″	70°21′25″	894	Temporary	Flowing
Ea. Rinconada Mallín	RM	PS	39°58′47″	70°47′29″	699	Temporary	Stagnant
El Cóndor 1	C1	PS	41°15′13″	71°01′27″	1,161	Temporary	Stagnant
El Cóndor 2	C2	PS	41°11′20″	71°06′41″	839	Temporary	Flowing
El Toro	ET	PS	40°19′14″	70°25′13″	1,021	Semi-permanent	Stagnant
Fortín Chacabuco	Fch	PS	41°00′56″	71°08′43″	778	Semi-permanent	Stagnant
La Vertiente	LV	PS	41°30′24″	68°36′38″	930	Permanent	Stagnant
Los Juncos	LJ	PS	41°03′32″	71°00′31″	909	Semi-PERMANENT	Stagnant
Ñeluan	Ñe	PS	41°30′04″	68°37′30″	912	Permanent	Stagnant
Ñireco	Ñi	PS	40°10′52″	71°19′13″	906	Temporary	Stagnant
Punta de Agua Chica	PAC	PS	40°34′49″	66°03′47″	123	Permanent	Stagnant
Punta de Agua Grande	PAG	PS	40°35′09″	66°03′29″	116	Permanent	Stagnant
Refugio de Jesús	RJ	PS	41°07′10″	71°13′09″	829	Temporary	Stagnant
Rinconada 15	R15	PS	39°59′55″	70°50′14″	657	Temporary	Stagnant
Acequia Ea. La Fueguina	ELF	M	40°05′35″	64°28′21″	66	Permanent	Flowing
Bañado Choele-Choel	Pch	M	39°17′35″	65°40′54″	134	Temporary	Stagnant
Charca Ea. La Esmeralda	LE	M	39°16′25″	65°43′44″	126	Temporary	Stagnant
Laguna Club Pesca	CPCh	M	39°18′44″	65°40′17″	121	Permanent	Stagnant
Laguna San Juan, 1	CSJ1	M	40°04′08″	64°33′47″	59	Permanent	Stagnant
Laguna San Juan, 2	CSJ2	M	40°04′08″	64°33′47″	59	Permanent	Flowing
Laguna Ruta 250	R250-1	M	40°05′19″	64°34′24″	61	Temporary	Stagnant
Laguna La Araña	R250-2	M	40°05′50″	64°31′10″	61	Temporary	Stagnant
Laguna Asansa	LA	E	39°00′15″	64°06′25″	77	Permanent	Stagnant
Vertiente Anzoategui	Sa	E	39°00′14″	63°46′31″	5	Semi-PERMANENT	Flowing

Abbreviations of ecoregions: *APF* Andean-Patagonian forest, *PS* Patagonian steppe, *M* Monte, *E* Espinal. Latitudes and longitudes according to WGS84

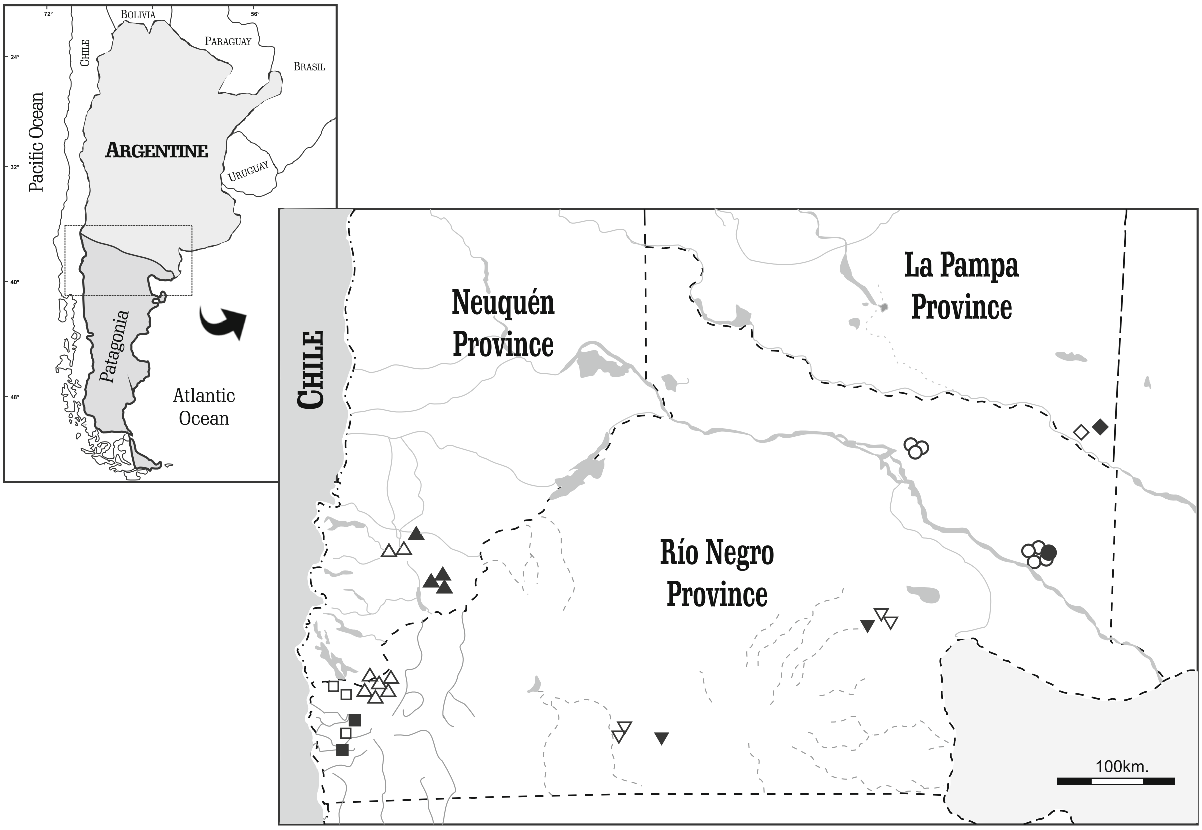

Fig. 1 Location of the studied sampling sites. Abbreviations: squares = *Andean-Patagonian forest*, triangle = eastern *Patagonian steppe*, inverted triangle = western *Patagonian steppe*, circle = *Monte* and rhombus = *Espinal*. In white environments with stagnant waters and in black with flowing waters

depending on the environment (Schaffer et al., 1994). In the field, samples were fixed with ethanol (50%), and once in the laboratory ostracods were transferred into 70% ethanol solution for permanent storage. Ostracods were identified under a microscope using both valves and body appendages following Cusminsky & Whatley (1996), Meisch (2000), Cusminsky et al. (2005) and Karanovic (2012). Ostracod valves were illustrated using Scanning Electron Microscopy (Phillips SEM 515, CNEA Bariloche, Argentina).

Hydroperiod seasonality (i.e., temporary, semi-permanent, or permanent), water flow velocity (i.e., stagnant or flowing waters), maximum depth (*m*), temperature (*T*, °C), pH (Hanna Instruments 8424), conductivity (*C*, µS/cm, ORION 115) and dissolved oxygen concentration (DO, mg/l, Hanna Instruments 9142) were measured in situ. Sediment samples were collected and returned to the laboratory to analyze organic matter content estimated by loss on ignition (LOI; Heiri et al., 2001).

Data analysis

For ecological analysis and interpretation, only adult ostracods alive at the sampling moment have been used. The true diversity of the ostracod assemblages in question has been summarized by the exponential of Shannon index (H'; Jost, 2006). An unweighted pair group mean average (UPGMA) with Jaccard's coefficient was applied to assess similarity between species assemblages. Clustering significance level was evaluated with a one-way analysis of similarities (ANOSIM). In addition, a "similarity profile" (SIMPROF) permutation method (with 999 simulations) was implemented with the UPGMA procedure to test the null hypothesis that samples within the same cluster (representing a group of similar site assemblages) do not differ from each other in their multivariate structure (Clarke et al., 2008). A similarity percentage analysis (SIMPER) was performed to asses which ostracod taxa was primarily responsible for the observed difference between those groups. Additionally, a principal components analysis (PCA) was applied to characterize each sampled site and summarize the most important environmental gradients. From a total of twelve variables, four were used for the ordination analysis after eliminating strongly correlated variables ($R > 0.7$, Spearman's correlation coefficients). Environmental variables were centered and standardized; conductivity values were log transformed prior to ordination analysis (Lepš & Šmilauer, 2003).

A detrended correspondence analysis (DCA) was used to measure the gradient length in environmental data. This analysis revealed a gradient length >4 standard deviation, showing that the dataset has a unimodal response and suggesting that a unimodal-based canonical correspondence analysis (CCA) is more appropriate (Lepš & Šmilauer, 2003). In this context, relationships between ostracod species with more than two occurrences and the environmental parameters have been analyzed by a CCA. Species with two occurrences were added as supplementary variables, taking a passive role and standardized by standard deviation, conductivity was the only variable log transformed. Additionally, the hydroperiod seasonality (permanent, semi-permanent, or temporary) and the water flow velocity (stagnant or flowing) were included in the CCA analysis as factor variables. A forward selection with 999 Monte Carlo permutations have been used to identify the variables that explained significantly ($P < 0.05$) ostracod abundance and distribution (Ter Braak & Prentice, 1988; Lepš & Šmilauer, 2003). Not significant variables had been added as supplementary in CCA diagram.

Environments located closer are likely to be more similar; however, environmental characteristics will affect the species distribution. Therefore, if environmental characteristics fully explained the distribution of the ostracod data, we should find no evidence of spatial autocorrelation in the residuals of our regression models (CCA) (Diniz-Filho et al., 2003). To evaluate this possibility, a Mantel correlation coefficient has been calculated, and its significance has been estimated based on 10,000 random permutations of one of the matrices (Legendre & Fortin, 1989). For this analysis, two distance matrices have been correlated; one of them with the geographic distances between sampled sites, and the other, with the absolute differences between residuals for each pair of environments. Residuals have been estimated from CCA model, averaging the residuals for each ostracod assemblage per site.

Species optimum estimates (u_k) and ecological tolerance range (t_k) have been calculated trough the weighted-averaging (WA) method. The species optimum values have been obtained by calculating the weighted averaging of the values of the environmental variables in the samples where the species were present. Additional data have been obtained for environmental tolerance index (ETI). This index is used to calculate relative tolerance ranges of ostracod species for different environmental variables from the formula ETI = (range of X species)/(range of X dataset) (Curry, 1999). Accordingly, ETI ranges from zero (no tolerance) to one (higher tolerance).

Statistical procedures have been run with Canoco 5, C2, SigmaPlot 12.0, PAST (3.10), and PRIMER ver. 6.1.10. software packages.

Results

Living ostracods were recorded in 36 of the 40 sampled sites. A total of 22 ostracod species have been identified (Table 2; Fig. 2). Only five of these taxa have presented sexual populations (i.e., male and female presence): *A. argentinensis, A. nobilis, Eucypris fontana, H. hyalinus,* and *L. cusminskyae.*

The average number of species per site was 2.3 ± 1.5, with a maximum richness of six species and fourteen monospecific sites. The mean value of the exponential Shannon index (H') was 1.9 ± 1.11; Lake Ñeluan presented the highest true diversity ($H' = 4.73$), while the minimum ($H' = 0$) was recorded at the fourteen monospecific sites. Not significant differences were found per sampling site between ecoregions both in the average species richness ($P = 0.738$) and in the true diversity (H'; $P = 0.867$). *Eucypris virens*, *H. incongruens*, *I. ramirezi*, and *T. lutaria* were the most abundant species, while *D. stevensoni, E.* aff. *fontana, H. salina, L. cusminskyae,* and *P. smaradigna* were less frequent.

Two statistical approaches have been used to characterize the sampled sites, a clustering method based on the species occurrence data (UPGMA), and an ordination method based on environmental features (PCA). In the first one (Fig. 3a), four groups of ostracod assemblages have been identified and then

Table 2 List of identified ostracods and their occurrence in the study area (codes of sampling sites as in Table 1)

Species	Sites
Superfamily Cytheroidea Baird, 1850	
Family Limnocytheridae Klie, 1938	
Limnocythere cusminskyae Ramón Mercau et al. 2014	LA
Limnocythere patagonica Cusminsky & Whatley 1996	LJ, Ñe
Superfamily Darwinuloidea Brady & Norman, 1889	
Family Darwinulidae Brady & Norman, 1889	
Darwinula stevensoni (Brady & Robertson, 1870)	Va
Superfamily Cypridoidea Baird, 1845	
Family Cyprididae Baird, 1845	
Bradleystrandesia fuscata (Jurine, 1820)	Fa, Te, R15
Chlamydotheca incisa (Claus, 1892)	ELF, Pch
Cypris pubera O.F. Müller, 1776	LJ, RJ, R15
Cypridopsis vidua (O.F. Müller, 1776)	R15, ELF, Pch, CPCh, LE
Potamocypris smaragdina (Vávra, 1891)	Ñe
Potamocypris unicaudata Schäfer, 1943	VG, LJ, PAC, PAG
Sarscypridopsis aculeata (Costa, 1847)	Va, LJ, PAC, PAG, LE, LA
Heterocypris hyalinus Klie, 1930	LE, CSJ1, CSJ2, R250-1, R250-2
Heterocypris incongruens (Ramdohr, 1808)	AS, VG, CH1, CH2, CH3, RM, C2, Sa
Heterocypris salina (Brady, 1868)	Sa
Amphicypris argentinensis Fontana & Ballent, 2005	PAC, PAG
Amphicypris nobilis Sars, 1901	Fa, C1
Eucypris fontana (Graf, 1931)	ET, LV
E. affinis *fontana*	LJ
Eucypris virens (Jurine, 1820)	Fa, Te, Fr, RM, C2, Fch, LJ, Ñi, PAG, RJ, R15, Pch
Tonnacypris lutaria (Koch, 1838)	MG, EF, Sf, Te, Cha1, RJ, R15
Herpetocypris intermedia Kaufmann, 1900	Va, R250-2
Family Ilyocyprididae Kaufmann, 1900	
Ilyocypris ramirezi Cusminsky & Whatley, 1996	Va, CH1, CH3, PAC, PAG, ELF, LCSJ2, R250-2
Family NotodromadidaeKaufmann, 1900	
Newnhamia patagonica (Vávra, 1898)	ÑE, PAG

corroborated by a SIMPROF significance test ($\pi = 2.097$; $P = 0.02$). An ANOSIM test has shown significant differences among the ostracod assemblage groups (ANOSIM, $R_{\text{global}} = 0.60$, $P = 0.001$). In reference to PCA analysis, the first two axes have explained 65.2% of the total observed environmental variance (Fig. 3b). The first axis was correlated with conductivity (0.84) and dissolved oxygen concentrations (−0.49), while the second axis was positively related with temperature (0.68) and organic matter content (0.69).

Based on SIMPER, the first assemblage type (I) (Fig. 3a) exhibits an average faunal similarity of 22.43% and was characterized by *A. argentinensis* (at 45% of the sites), with *P. unicaudata* and *S. aculeata* as accompanying species (Fig. 3a). This group linked the sites LJ, PAC, PAG, and LA, located to the eastern of the sampled transect (*Patagonian steppe* ecoregion). These environments were characterized by temperate waters of moderate to high conductivity and poor sediments in organic matter content (Fig. 3b; Table 3). The second assemblage type (II) (Fig. 3a)

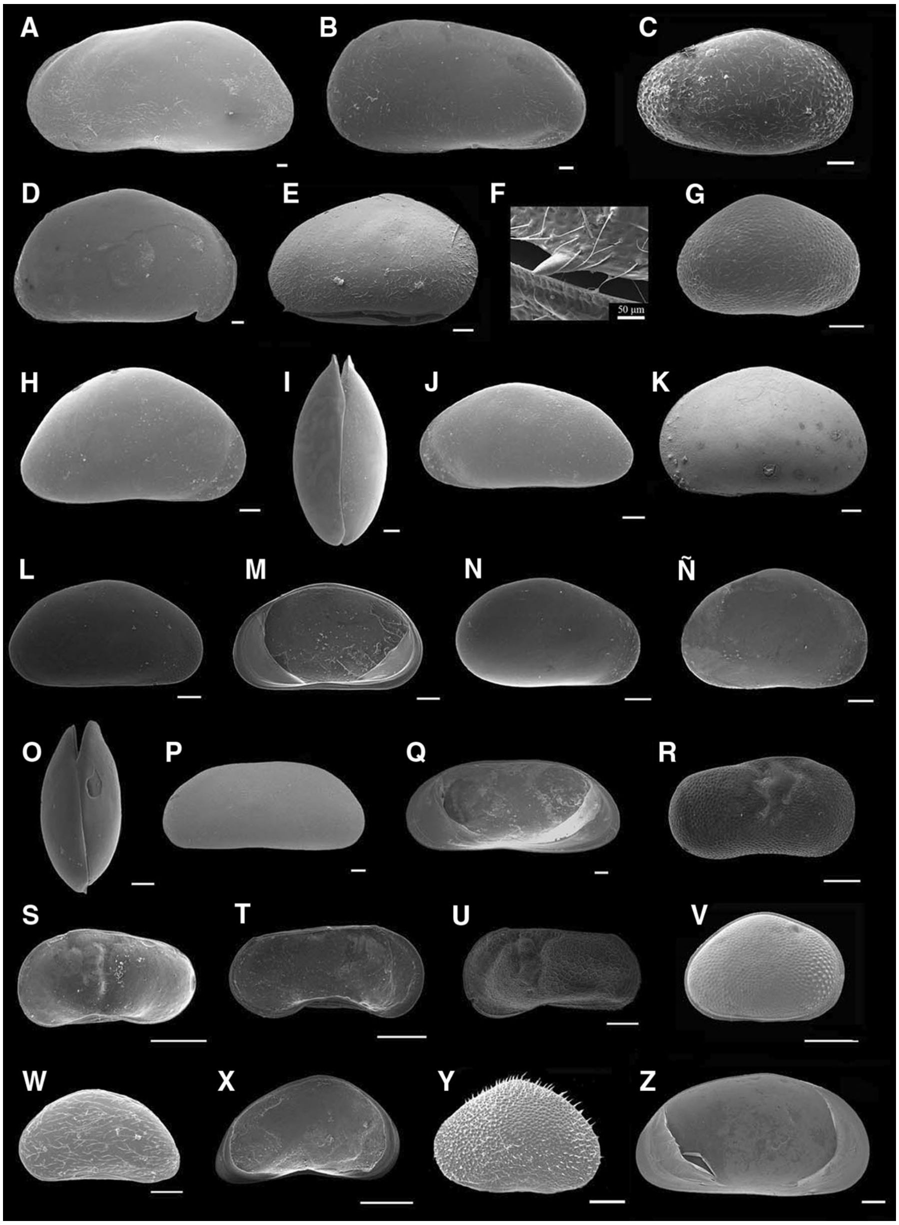

Fig. 2 Ostracod species identified, scale bar 200 μm. *RV* right valve; *LV* left valve; *C* carapace. **A** *Amphicypris argentinensis,* adult female. LV in external view. **B** *Amphicypris nobilis,* adult male. RV in external view. **C** *Bradleystrandesia fuscata,* adulte female. RV in external view. **D** *Chlamydotheca incisa,* adult female. RV in external view. **E–F** *Cypris pubera,* adult female. **E** C in lateral view. **F** spine detail. **G** *Cypridopsis vidua,* adult female. RV in external view. **H**–**I** *Eucyris fontana,* adult male. **H** RV in external view. **I** C in dorsal view. **J** *Eucypris* affinis *fontana,* adult male. LV in external view. **K** *Eucypris virens,* adult female. LV in external view. **L**–**M** *Heterocypris hyalinus,* adult female. **L** RV in external view. **M** RV in internal view. **N** *Heterocypris incongruens,* adult female. RV in external view. **Ñ–O** *Heterocypris salina,* adult female. **Ñ** RV in external view. **O,** C in dorsal view. **P–Q** *Herpetocypris intermedia,* adult female. **P** LV in external view. **Q** RV in internal view. **R** *Ilyocypris ramirezi,* RV in external view. **S**–**T** *Limnocythere cusminskyae.* **S** adult female. RV in internal view. **T** adult male. LV in internal view. **U** *Limnocythere patagonica,* adult female. LV in external view. **V** *Newnhamia patagonica,* adult female. RV in external view. **W** *Potamocypris smaragdina,* adult female. LV in external view. **X** *Potamocypris unicaudata,* adult female. LV in internal view. **Y** *Sarscypridopsis aculeata,* adult female. LV in external view. **Z** *Tonnacypris lutaria,* adult female. LV in internal view

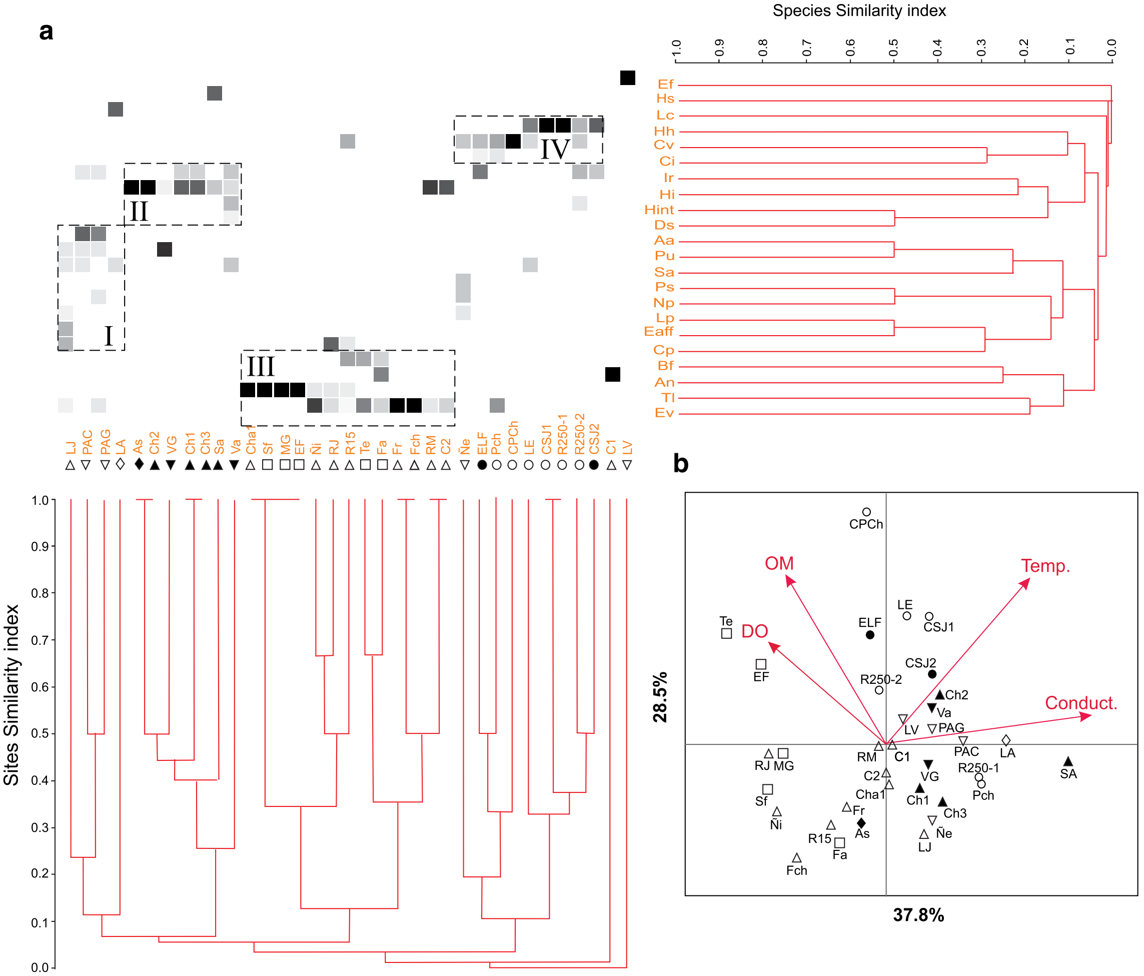

Fig. 3 **a** UPGMA dendrogram obtained on the basis of Jaccard similarity (%) matrix among ostracod assemblages from the 36 sampled sites. Statistically significant separations of the genuine clusters (i.e., main ostracod assemblage types) demonstrated by the SIMPROF test are marked by punctuated squares. Abbreviations: squares = *Andean-Patagonian forest*, triangles = eastern *Patagonian steppe*, inverted triangles = western *Patagonian steppe*, circles = *Monte* and rhombus = *Espinal*. In white environments with stagnant waters and in black with flowing waters. **b** Samples scores and first factorial plane of principal components analysis (PCA) for the 36 sampled sites. *DO* dissolved oxygen concentration; *OM* organic matter content, *Temp*. temperature, *Conduct*. Conductivity. Sampling sites codes as in Table 1

Table 3 Range of examined parameters in the different habitats

Ecoregion	Depth	% Veg.	Temp.	DO	Conduct.	MO	pH
Andean-Patagonian forest	0.1–1.4	25–100	12.9–15.4	7.4–17.5	24–137	5–30	6.8–7.4
Patagonian steppe	0.1–6.0	2–100	8.1–23.5	6–11.8	59–15,500	2–20	6.0–9.9
Monte	0.2–4.0	40–90	17.3–28.7	3.9–13.2	215–7,090	3–39	7.5–9.9
Espinal	0.1–2.5	30–40	20.6–22.4	2.7–9.6	10,950–11,390	3–10	7.9–8.3

Depth maximum depth (m), *% Veg* vegetation cover (%), *Temp*. temperature (°C), *DO* dissolved oxygen concentration (mg/L), *Conduct*. Conductivity µS/cm, *OM* organic matter content (%)

has shown an average faunal similarity about 36.43% and was defined by a 92% frequency of occurrence of *H. incongruens,* together with *I. ramirezi.* This group included most of the environments with flowing waters sampled (90%, Table 1), As, Ch2, VG, CH1, CH3, Sa, and Va, most of them belonging to the *Patagonian steppe* ecoregion. The third assemblage type (III) (Fig. 3a) (average faunal similarity of 22.11%) has exhibited a high occurrence of *E. virens* (47%) and *T. lutaria* (43%), along with *B. fuscata*, grouping sites from the *Andean-Patagonian forest* and western of the *Patagonian steppe* ecoregions. The major part of these environments has been situated on the left side of the PCA (Fig. 3b), associated to low values of conductivity and temperature, coupled with high-dissolved oxygen and organic matter concentrations (Table 3). The last assemblage type (IV) (Fig. 3a) (average faunal similarity of 28.11%) has displayed the presence of *H. hyalinus* and *C. vidua* as its main feature (occurring at 56 and 35% of the sites, respectively). These aquatic systems, mainly placed in *Monte* ecoregion, were characterized by warm waters, with moderate conductivity and dissolved oxygen concentrations and sediments rich in organic matter (Fig. 3b; Table 3). *Eucypris fontana* and *H. salina* were not clustered in either group.

After the estimation of the gradient length by DCA (5.7), a CCA analysis has been performed to relate ostracod distribution and abundance (response variables) with the environmental parameters (explanatory variables). Conductivity ($F = 3.0$, $P = 0.002$), temperature ($F = 2.5$, $P = 0.016$), and water flow velocity ($F = 2.2$, $P = 0.016$) have been identified by forward selection as the variables that significantly explained the variation in ostracod data. The first two axes have accounted 19% of the total variance of the species data. The species-environmental correlations were 0.88 for the first axis and 0.72 for the second axis (Table 4). *Sarscypridopsis aculeata, H. hyalinus, C. vidua,* and *P. unicaudata* have been placed in the right lower quadrant, associated to stagnant and temperate waters with moderate to high conductivity. On the right upper quadrant, *I. ramirezi* and *H. incongruens* have shown preference for flowing waters, with medium values of temperature and conductivity. To the left side of the plot *T. lutaria, B. fuscata.E. virens* and *C. pubera* have been situated, associated to cold waters of low conductivity. The former taxa have also been linked to running waters, while the other species preferred stagnant waters (Fig. 4).

For each pair of sampled sites, absolute difference between residuals, extracted from CCA, and geographic distance that separate them were compared. Both variables were not correlated (Mantel test, $r = -0.05$; $P = 0.60$) indicating that the unexplained variance cannot be explained by the spatial structure.

Optimum (u_k), tolerance (t_k), and ETI values for the most significant environmental variables have been estimated for the species with at least two occurrences (Table 5). Optimum values obtained for each species agreed with CCA ordination results. Almost all taxa exhibited low ETI values (<0.15) for the variable conductivity.

Discussion

Ninety percent of the 40 sampled sites have presented living ostracods, confirming the high success of this group as colonizers (Martens et al., 2008). In this study, only the 36 samples with ostracods have been analyzed. With such small data reduction, the focus was on species responses to environmental gradients, disregarding ecological requirements of Ostracods as a

Table 4 Summary statistics for CCA analysis

Axes	1	2	3	4	Total inertia
Eigenvalues	0.689	0.408	0.143	0.879	5.739
Species—environment correlation	0.884	0.722	0.447	0.000	
Cumulative percentage variance of species data	12.0	19.1	21.6	36.9	
Cumulative percentage variance of species–environment relation	55.5	88.5	100.0	0.0	
Sum of all eigenvalues					5.7392
Sum of all canonical eigenvalues					1.2400

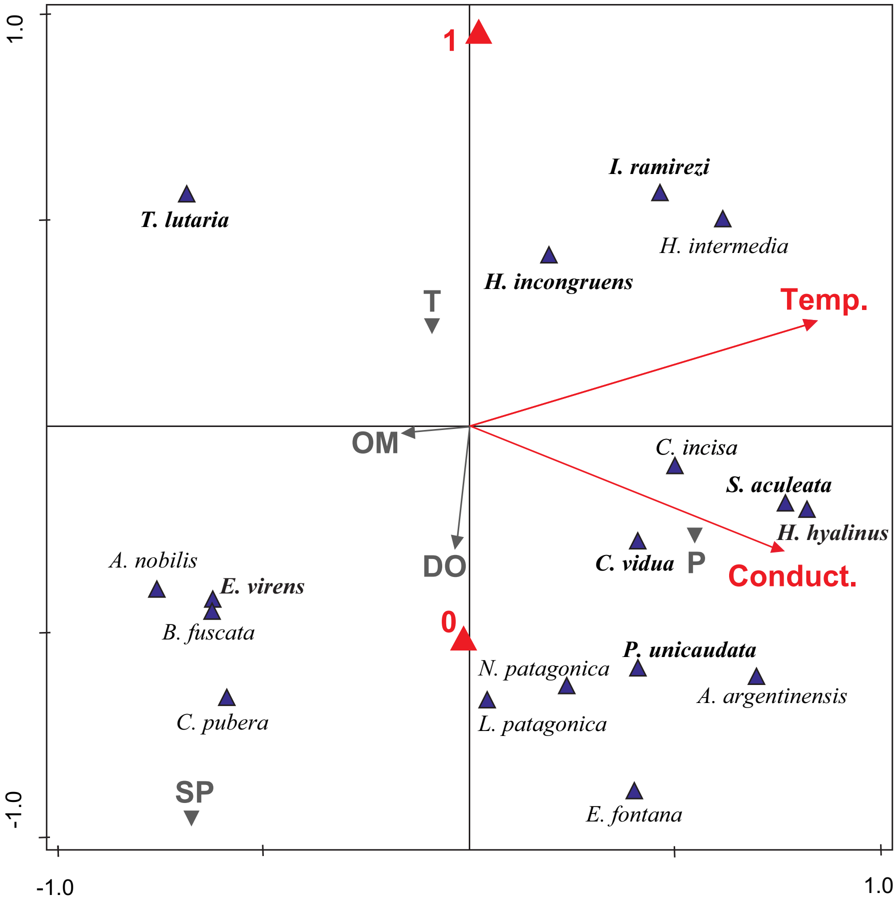

Fig. 4 CCA ordination of ostracod assemblages and environmental factors in the space defined by the first two canonical axes. Only the species with at least two occurrences were taken into consideration. *Temp.* temperature, *Conduct.* Conductivity, 0 = stagnant waters, 1 = flowing waters, *DO* dissolved oxygen concentration, *OM* organic matter content, *P* permanent, *SP* semi-permanent and *T* temporary environments. Significant variables in *red*, non-significant parameters in *gray* and species with almost four occurrences in *bold*

group and, at the same time, reducing the effect of not finding a species where it possibly was (Mezquita et al., 2005). Regarding the sites without ostracods, we suggest that the absence could be due to a low-dissolved oxygen concentration. Previous studies had established a significant positive relationship between the number of individuals and the dissolved oxygen concentration (Dügel et al., 2008) and relating the total absence of this group with low-oxygen contents (Mezquita et al., 1999).

We reported 22 species alive, three of which (*Bradleystrandesia fuscata, Herpetocypris intermedia,* and *Potamocypris unicaudata*) represent new records for the Neotropical region and one (*Heterocypris hyalinus*) for Argentina. *Bradleystrandesia fuscata* and *P. unicaudata* have been previously recorded for Palearctic and Nearctic regions, whereas *H. intermedia* is only distributed in the Palearctic region (Martens & Savatenalinton, 2011). This region has the highest number of ostracod genera (87) and species (702), constituting more than twice the taxa surveyed in the Neotropical region (55 genera and 275 species) (Martens et al., 2008). This pattern is probably skewed by an incomplete exploration for many areas (Martens et al., 2008). Likewise, the first record of *H. hyalinus* in Argentina possibly is consequence of a lack of sampling in the region and not of a real absence of the species (Martens & Behen, 1994). The scarce information available about these unexplored areas frequently leads to an underestimation of the specific richness (Yavuzatmaca et al., 2015). On the other hand, the lack of extant and/or fossil record of these species could be also due to a recent colonization. Most of these taxa have been sampled in temporary environments; hence they have biological features, such as resistant eggs and parthenogenetic reproduction that allow them a successful dispersal (Koenders et al., 2012). Unfortunately, lack of sampling in potential intermediate habitats impairs our ability to hypothesize about the colonization tracks

Table 5 Descriptive statistics, optimum (u_k), tolerance (t_k), and environmental tolerance index (ETI) values of seventeen species for five variables based on N2 values

Species	Count	Max	N2	Temperature			DO			OM			pH			Conductivity		
				u_k	t_k	ETI	u_k	t_k	ETI	u_k	t_k	ETI	u_k	t_k	ETI	u_k	t_k	ETI
A. argentinensis	2	70	2.0	20.6	0.4	0.02	10.1	2.2	0.21	4.6	2.1	0.08	9.9	>0.01	>0.01	1,987	216	0.03
A. nobilis	2	100	1.9	19.2	6.6	0.55	7.2	0.2	0.03	6.9	2.1	0.08	6.5	1.0	0.36	73	2	>0.01
B. fuscata	3	43	2.8	13.5	1.2	0.06	12.2	5.4	0.68	10.8	9.2	0.41	7.3	0.1	0.03	117	23	>0.01
C. incisa	2	10	1.8	20.5	4.2	0.29	6.2	4.8	0.46	13.0	4.2	0.16	7.9	0.9	0.33	1,432	807	0.12
C. vidua	7	100	4.9	21.5	6.0	0.56	8.2	2.6	0.63	21.5	15.7	0.92	8.1	0.8	0.67	719	643	0.12
C. pubera	3	75	2.1	10.0	3.5	0.26	10.0	2.5	0.27	14.1	10.6	0.41	7.9	1.4	0.56	546	408	0.07
E. fontana	2	100	2.0	14.3	5.0	0.34	10.1	0.8	0.07	6.5	6.4	0.24	9.1	0.7	0.25	5,730	4,005	0.91
E. virens	12	100	6.5	12.9	3.9	0.66	10.0	3.8	0.92	9.1	6.2	0.49	7.3	0.8	1.00	371	583	0.13
H. intermedia	2	30	1.6	22.3	3.2	0.70	10.9	2.1	0.20	7.8	10.6	0.41	8.4	0.6	0.23	901	204	>0.01
H. hyalinus	5	100	4.5	23.9	5.6	0.55	10.6	1.8	0.31	9.0	6.1	0.43	8.5	0.8	0.59	2,443	2,689	0.44
H. incongruens	9	100	6.9	19.5	3.3	0.56	8.4	2.0	0.58	5.3	2.7	0.19	8.2	1.0	0.87	967	2,116	0.73
I. ramirezi	8	64	5.7	22.3	3.8	0.51	9.8	1.6	0.31	10.5	7.5	0.43	8.5	0.7	0.59	628	492	0.13
L. patagonica	2	10	1.8	14.7	1.3	0.09	6.9	0.4	0.03	4.7	0.7	0.03	9.1	0.4	0.15	1,072	98	0.01
N. patagonica	2	25	1.7	16.7	3.5	0.24	8.1	3.6	0.35	4.4	1.4	0.05	9.2	0.7	0.26	1,209	313	0.05
S. aculeata	5	25	4.4	21.4	3.7	0.49	10.8	2.3	0.40	7.1	5.6	0.22	9.2	0.8	0.41	3,116	3,380	0.64
P. unicaudata	4	95	1.7	18.7	2.6	0.35	9.8	1.5	0.30	3.3	1.3	0.08	9.4	0.3	0.13	1,246	310	0.07
T. lutaria	7	100	4.5	14.7	2.6	0.48	9.1	2.1	0.78	15.7	9.9	0.70	7.2	0.3	0.15	78	53	0.01

of these species in Patagonia (Coviaga et al., 2015). Therefore, we suggest that the taxa afore-mentioned could be more widespread than previously thought. However, more complete data are needed concerning their distribution and dispersal mode in the Neotropical region. Also, genetic data are crucial for differentiating histories and geographical pathways of colonizations from anthropogenic introductions (Koenders et al., 2012).

In this survey, we recorded 22 species alive in 36 sampled sites, while Schwalb et al. (2002) found eleven in seventeen environments, and Ramón-Mercau et al. (2012) fourteen species in ten sites. Both studies have shown the maximum diversity in southern Patagonian lakes (around 49°–50° to 52°S) but probably it has been a consequence of the sampling design, biased toward southern environments (three and four sites from Northern versus fourteen and six from Southern Patagonia, in Schwalb et al., 2002 and Ramón-Mercau et al., 2012, respectively). Our results suggest that north and southern Patagonia display similar species diversity.

Previous studies on recent ostracod fauna have shown low richness in the north Patagonian region, being three the maximum number of living species reported for one environment (Schwalb et al., 2002; Cusminsky et al. 2005; Ramón-Mercau et al., 2012). In general, we found higher richness in our sampled sites, with a maximum of six species in the ecotonal shallow lake Los Juncos. We suggest that these dissimilarities can be attributed to differences in both sampling methods and sampling seasons. From bibliographic data (Holmes, 2001; De Deckker, 2002; Mesquita-Joanes et al., 2012) and personal observations, we conclude that many ostracods species are swimming in the water column. Therefore, using a hand net along the water–sediment interface allows us to recover almost all those ostracods crawling in the sediment as well as those swimming in the water column, keeping in mind that our sampled systems are mainly shallow (maximum depth 0.9 ± 1.3 m) (Schaffer et al., 1994). Moreover, in the *Patagonian steppe,* most of the small and shallow lakes begin its hydroperiod after the rainy winter season and finish them toward the summer, due to the extremely high evaporation rates during this season (Coviaga et al., 2015). Thus, selecting the wet and warm season (spring) for sampling (from mid-September to mid-December), the probabilities to sample a well-developed ostracods community rise. In previous studies, only surface sediment has been sampled during summer and early fall, so we suspect that these could be the reasons for low richness previously reported in north Patagonia (Schwalb et al., 2002; Ramón-Mercau et al., 2012).

The integrated analysis of UPGMA cluster, CCA analysis, optima, tolerance, and ETI estimated values allowed us to identify three types of ostracod assemblages based on environmental features.

The first group linked taxa associated to stagnant and temperate waters with moderate to high conductivity. Representative species of this group were *S. aculeata, P. unicaudata, H. hyalinus* and *C. vidua*. *Sarscypridopsis aculeata* was found in diverse types of environments, displaying a broad tolerance for the physical and chemical parameters studied. However, this taxon presented a high optimum for temperature and conductivity of host waters. In agreement, previous reports showed that *S. aculeata* prefers slightly saline waters bodies, being rare in pure freshwater environments (Holmes, 1996; Meisch, 2000; Mischke et al., 2003). Indeed, Martínez-García and co-workers have shown that conductivity is the main factor controlling *S. aculetata* dominance, showing a positive correlation with this parameter (Martínez-García et al., 2015). *Potamocypris unicaudata* was found in environments quite different, e.g., springs, semi-permanent, and permanent ponds. Their presence in a wide variety of habitats also was reported in Europe (Meisch, 2000). Similarly, in previous studies, it has been characterized as a frequent taxon in slightly saline waters (Meisch, 1985, 2000; Löffler, 1990; Scharf, 1998), with a temperature optimum value of 17.2°C (Viehberg, 2006). *Heterocypris hyalinus* and *C. vidua,* besides their association to stagnant and temperate waters with moderate to high conductivity, have shown preference for high-dissolved oxygen concentrations and sediments rich in organic matter. This study represents the second record of *H. hyalinus,* until now only found in Paraguay in 1930, when it was taxonomically described (Klie, 1930). Thereby, these results represent the first dataset of its ecological preferences. *Heterocypris hyalinus* was widespread in *Monte* ecoregion, associated to temperate and moderate conductivity waters within a broad range for the variables considered (ETI > 0.3). Based on this information, we suggest that the lack of records for this species is due to a deficiency of sampling in potential habitats and not to a real absence in the region. *Cypridopsis vidua* is a swimmer species, which habits a wide range of aquatic habitats, principally vegetated (Meisch, 2000). In this study, *C. vidua* presented a high optimum for water temperature (21.5°C), dissolved oxygen (8.2 mg l^{-1}), and organic matter (21.5%) concentrations. Previous reports have also reported a preference for warm temperature (Bunbury & Gajewski, 2005; Külköylüoğlu et al., 2007; Külköylüoğlu & Sari, 2011) and requirements of high oxygen concentrations (≥ 5 mg l^{-1}) (Kiss, 2007; Iglikowska & Namiotko, 2012) for this taxon. The high optimum value for organic matter concentration was probably linked with its preference for vegetated environments (e.g., Mbahinzireki et al., 1991; Meisch, 2000). Nevertheless, *C. vidua* exhibited high tolerance and ETI values for most of the parameters which considered (>0.56). These results support earlier studies that documented its relatively large tolerance to variation of physical and chemical parameters (Meisch, 2000; Külköylüoğlu, 2004; Külköylüoğlu et al., 2007; Martínez-García et al., 2015).

Amphicypris argentinensis, *E. fontana, N. patagonica,* and *L. patagonica* have also shown preference for temperate waters of moderate to high conductivity. These taxa have been recorded twice throughout this survey. Therefore, ecologic inferences must be conducted with carefulness. Nevertheless, our results agree with previous reports (Schwalb et al., 2002; Cusminsky et al., 2005; Fontana & Ballent, 2005; Ramón-Mercau et al., 2012; Ramón-Mercau & Laprida, 2016). This survey represents the second record of *A. argentinensis,* until now only found in Caliba Lake (Buenos Aires, Argentina), living in similar conditions, e.g., temperate waters (24°C) of high conductivity (8.9 mS cm^{-1}) (Fontana & Ballent, 2005). Although the ecological information of *A. argentinensis* remains scarce, the high concordance of the data allows us to postulate these taxa as indicator of temperate waters of high conductivity. *Eucypris fontana* was recorded in two lakes with conductivities differing by a magnitude order (ET = 15,500 µS cm^{-1}; LV = 1,460 µS cm^{-1}), in agreement with previous Patagonian reports, which recorded this species under a wide range of ionic concentrations (Schwalb et al., 2002; Cusminsky et al., 2005). Indeed, these results support the hypothesis that *E. fontana* is widely tolerant with respect to the salinity and ionic composition of the aquatic systems that are inhabited (Ramón-Mercau et al., 2012). *Newnhamia patagonica* and *L. patagonica* are characteristic species of permanent ponds and lakes in Patagonia (Schwalb et al., 2002; Cusminsky et al., 2005). Both taxa have been associated to environments of moderate conductivity, presenting a low tolerance range for this variable. In this study, *N. patagonica* displayed a conductivity optimum of about 1,209 µS cm^{-1}, in agreement to the value estimated by Ramón-Mercau & Laprida, 2016 (WA 1,455 µS cm^{-1}). Furthermore, we present an optimum of 1,072 µS cm^{-1} for *L. patagonica*, similar to previous reports (Ramón-Mercau et al., 2012; Ramón-Mercau & Laprida, 2016). The results presented on this work support the characterization of *L. patagonica* as a stenohaline taxon.

Ilyocypris ramirezi and *H. incongruens* conformed the second assemblage type, positively related to flowing waters. These species showed a broad tolerance level for the variables considered, suggesting that their presence and abundance were more influenced by the degree of energy than by the physical and chemical features of the waters. *Ilyocypris ramirezi* was widespread in Patagonia, being frequently found in lotic environments (Schwalb et al., 2002; Cusminsky et al., 2005; Ramón-Mercau et al., 2012; D'Ambrosio et al., 2015). This species prefers fresh to low salinity environments, but is able to inhabit waters with a wide range of conductivity, temperature, pH, dissolved oxygen, and total dissolved solids concentrations (Cusminsky et al., 2005; Laprida, 2006; Ramón-Mercau et al., 2012; D'Ambrosio et al., 2015). Our results confirm that this species has the ability to develop within a broad spectrum of limnological features, due to its high tolerance and ETI estimated values, and its preference for running waters, given that it was exclusively found in flowing waters. It is worth mentioning that the high-energy environments preferred by this species usually are springs, seeps, and streams associated with irrigation systems. *Heterocypris incongruens* is a cosmopolitan common species inhabiting shallow seasonal pools and small water bodies (Meisch, 2000). According to previous results, this species has shown a high tolerance for temperature, conductivity, dissolved oxygen, and organic matter concentrations (Mezquita et al., 1999; Meisch, 2000; Külköylüoğlu, 2004; Martins et al., 2010). *Heterocypris incongruens* was positively correlated to flowing waters, confirming previous finding of this species in springs and streams from Patagonia (Schwalb et al., 2002). Indeed, the isotopic analysis of *H. incongruens* valves has shown low δ^{18}O and δ^{13}C values, close to equilibrium with environments with high flow in Patagonia (Schwalb et al., 2002).

The third group, associated to cold and low conductivity waters, was characterized by *T. lutaria, E. virens,* and *B. fuscata.* The former species also were found together in Lake Aladağ (Bolu, Turkey), suggesting that these taxa had similar ecological requirements (Yilmaz & Külköylüoğlu, 2006). *Tonnacypris lutaria* was recorded exclusively under conditions of low conductivity, cold waters, and pH relatively neutral, being present at the lower ionic concentration (24 µS cm^{-1}) documented in this survey. This taxon is considered as an early form that prefers freshwater and low temperature (Meisch, 2000; Altinsaçli, 2001; Yılmaz & Külköylüoğlu, 2006; Van der Meeren et al., 2009). Indeed, previous studies in North Patagonia (Coviaga et al., 2015) have reported this species at the beginning of the rainy season, when the ponds were characterized by low values of conductivity, temperature and chlorophyll *a* concentration, and high-dissolved oxygen concentration. *Tonnacypris lutaria* was also associated to environments with flowing waters. This species is characteristic for temporary waters, recorded in springs, and waters connected to springs (Meisch, 2000). *Eucypris virens* was the most frequent species within the sampled sites, displaying a broad tolerance for the variables considered. These results agree with its characterization as a cosmopolitan taxon, very tolerant to low ionic concentration and fluctuating and unpredictable environments (Meisch, 2000; Pieri et al., 2006; Martins et al., 2009). Although our results confirm that *E. virens* tolerates high variation in temperature and ionic concentration (8.1–21.7°C; and 59–2,040 µS cm^{-1}), we suggest that it prefers low temperature and conductivity conditions (WA 12.9 ± 3.9 and 371 ± 620 µS cm^{-1}, respectively). In agreement with this, Mezquita et al. (1999) have shown that *E. virens* tends to occur in water with an upper temperature limit of about 20.0°C, and Yılmaz & Külköylüoğlu (2006) estimated an optimum value quite similar (WA 15.2 ± 3.9°C and 94.5 ± 12.6 µS cm^{-1}). Particularly for Patagonia, in a recent study, *E. virens* was defined as limnetic, with an optimum estimated about 258 µS cm^{-1} (Ramón-Mercau & Laprida, 2016). *Bradleystrandesia fuscata* was found in temporary environments, characterized by cold waters, low conductivity, and high-dissolved oxygen concentration. It is a characteristic inhabitant of seasonal pools, rarely reported from permanent waters (Meisch, 2000; Nagorskaya & Keyser, 2005). *Bradleystrandesia fuscata* is defined as a pure freshwater form (Meisch, 2000), but ecological information on this species is still being scarce. Moreover, this work represents its first record for the Neotropical region and therefore, the first dataset of its ecological preferences in the region.

Ostracod ecological preferences identified in our study confirm the relevance of these organisms as environmental indicators. In this context, those which are present in the Holocene record of Patagonia take special relevance, being potential tools in paleoenvironmental interpretations. A greater knowledge about the auto-ecology species is essential to carry out precise interpretations of the associations preserved in the sediments (Torres Saldarriaga & Martínez, 2010), allowing us the ultimate goal of identifying environmental changes and past climates (Lorenschat & Schwalb, 2013). Normally, only the ostracod carapace is preserved in the sediments, so its taxonomic identification in the paleontological record can be complex sometimes (Torres Saldarriaga & Martínez, 2010). Therefore, taxonomic identification on living individuals (e.g., with valves and appendages) becomes an excellent tool for elucidating the taxonomic status of the different specimens in lacustrine sequences.

From the 22 species recorded in this survey, eight are present in Quaternary sequences from Patagonia: *A. argentinensis, E. fontana, I. ramirezi, L. patagonica, N. patagonica, P. unicaudata, C. vidua,* and *S.aculeata.* The last two taxa have shown a broad tolerance to the variations of physical and chemical variables (Meisch, 2000), suggesting that they are not a good indicator of water conditions. On the other hand, the former six are truly bioproxies for environmental reconstructions.

Ilyocypris ramirezi is widely distributed in Holocene sequences from Patagonia (Cusminsky & Whatley, 1996; Markgraf et al., 2003; D'Ambrosio, 2014; Coviaga, 2016). In this study, we establish a close relationship between *I. ramirezi* presence and flowing waters of low to moderate conductivity, confirming its use as indicator of lotic and lentic environments fed by streams and springs (Schwalb et al., 2002; Cusminsky et al., 2005). In Lago Cardiel (49°S–71°W, Southern Patagonia, Argentine), the presence of *I. ramirezi* at the lowermost zone (>*c.* 9500 BP) of the core CAR-98-2L suggests a significant input of stream water. This result, coupled with the presence of benthic diatoms, served to establish the initial lake transgression above the present-day shoreline (Markgraf et al., 2003). The same interpretation occurs in northern Patagonia, where *I. ramirezi* occurrence along a sequence extracted from Laguna Cari Laufquen Grande (41°S–69°W, Northern Patagonia, Argentine) indicated periods of an increase in the water input to the lake. This result was corroborated by the study of sedimentary proxies in the same sequence, e.g., magnetic susceptibility and organic matter content, allowing to inferring wetter periods through the last 3,000 years (Coviaga, 2016).

Limnocythere patagonica, E. fontana, N. patagonica, P. unicaudata, and *A. argentinensis* were associated to temperate waters of moderate to high conductivity. The former taxon is extensively distributed in Patagonia (Cusminsky & Whatley, 1996; Whatley & Cusminsky, 1999; Markgraf et al., 2003; Cusminsky et al., 2005, 2011; Ramón-Mercau et al., 2012; Ohlendorf et al., 2014). In this survey, *L. patagonica* was associated to cold waters of moderate conductivity, in agreement with previous reports (Schwalb et al., 2002; Cusminsky et al., 2005; Ramón-Mercau et al., 2012; Ramón-Mercau & Laprida, 2016). *Eucypris fontana* was recorded in a wide spectrum of conductivity values (1,460–15,500 µS cm^{-1}) confirming its euryhaline character (Schwalb et al., 2002; Cusminsky et al., 2005; Ramón-Mercau et al., 2012). This broad tolerance allows coexisting with the halophile *Limnocythere rionegroensis,* which is considered as an indicator of high conductivity waters in Patagonia (Cusminsky & Whatley, 1996; Whatley & Cusminsky, 1999; Schwalb et al., 2002; Cusminsky et al., 2005, 2011; Ramón-Mercau et al., 2012; Ramón-Mercau & Laprida, 2016). The replacement of these taxa along the Holocene sequences allowed determining variations in lakes salinity conditions. Particularly, in a Lago Cardiel core (CAR 99-7P), the substitution of *L. rionegroensi* by *E. fontana* and *L. patagonica* suggested a decrease of the conductivity associated to reduced evaporation and an increase of lake level during 13000–4100 cal BP (Cusminsky et al., 2011). In the same way, in Laguna Cháltel, a marked increase of *L. patagonica* occurrence, substituting *L. rionegroensis* at 50–1720 cal BP, indicated a decrease in salinity consequence of a lake level rise (Ohlendorf et al., 2014).

Newnhamia patagonica, P. unicaudata, and *A. argentinensis* have been recently recovered in Quaternary sediments from Laguna Cari Laufquen Grande core CLG 99-5b (Coviaga, 2016). This sequence has been mainly dominated by *L. rionegroensis.* However, the presence of *N. patagonica, P. unicaudata,* and *A. argentinensis* together with *E. fontana* and *I. ramirezi,* suggests repeated changes between high and moderate conductivity conditions though the last 3000 years BP. This interpretation was also supported by the study of sedimentary proxies, e.g., magnetic susceptibility and density (Ariztegui et al., 2008; Coviaga, 2016). Likewise, paleolimnological changes were correlated with dry-warm and wet-cold periods identified with other proxies, e.g., pollen (Mancini, 2001), glacier fluctuations (Glasser et al., 2004), tree rings (e.g., Villalba, 1994) and sedimentary features (e.g., Bertrand et al., 2005).

Conclusions

The study of modern freshwater ostracods in North Patagonia shows that their diversity and abundance are largely influenced by the host water features, among which conductivity and temperature are the most important. Based on our analysis, three assemblage types have been recognized: (1) stagnant and temperate waters, with moderate to high conductivity, were characterized by *S. aculeata, P. unicaudata, H. hyalinus,* and *C. vidua*; (2) environments with flowing waters, with medium values of temperature and conductivity, were dominated by *I. ramirezi* and *H. incongruens,* whereas (3) environments with cold and low conductivity waters presented *T. lutaria, E. virens,* and *B. fuscata* as typical fauna. Several of the identified species were recognized in Holocene sequences from Patagonia, highlighting the usefulness of lacustrine ostracods as a proxy in paleo-environmental reconstructions and the importance of autoecological studies for correct interpretation of past environments.

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