

# Late Quaternary lacustrine ostracods (Ostracoda, Crustacea) and charophytes (Charophyta, Charales) from the Puna Plateau, Argentina

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**Abstract:** Relatively little is known about the recent palaeontological records of the high-altitude closed basin lakes of the Central Andes, but a great need exists to remedy this knowledge gap if microfossils are to be used to infer climatic and ecological transitions from lake sediment cores. Here, eight species of non-marine ostracods and two calcareous algae are recorded from modern sediments and late Quaternary strata from Laguna de los Pozuelos, Jujuy Province, northwestern Argentina. Four species, *Limnocythere alexanderi*, *Limnocythere foresteri*, *Limnocythere lysandrosi* and *Limnocythere ruipunctifinalis*, are described as new species. *Limnocythere titicaca* Lerner-Seggev, 1973 has only been recorded in Lake Titicaca prior to this study and this is the first time the species is recognized outside of Bolivia. The cypridoideans *Ilyocypris ramirezi* Cusminsky & Whatley, 1996, *Eucypris virgata* Cusminsky & Whatley, 1996 and *Chlamydotheca pseudobrasiliensis* Martens & Behen 1994 are known species that are rare in the stratigraphic sequence in core LP06-6A. Also, the gyrogonites of two well-known species of Charophyta, *Chara filiformis* Hertzsch and *Chara vulgaris* Linnaeus, are occasionally present in the sediment from Laguna de los Pozuelos. The results provide a new vehicle for clarifying the Quaternary palaeohydrological history of the Pozuelos Basin, which is a RAMSAR wetland that is likely to be sensitive to global environmental change.

**Keywords:** Ostracoda; Charophyta; taxonomy; biostratigraphy; northwestern Argentina

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The main objective of this paper is to report on the ostracod and charophyte content in core LP06-6A, which was obtained from the centre of Laguna de los Pozuelos, Jujuy, northwestern Argentina (Noroeste Argentino; NOA) (McGlue *et al.* 2013). With a length of almost 4 m, core LP06-6A shows a complex lithostratigraphy described in McGlue *et al.* (2013). The basal calibrated radiocarbon date from LP06-6A is *c.* 37.2 ka, which indicates that much of the late Pleistocene and Holocene is captured in the sequence. Due to its complexity, this study has been divided into the taxonomic analysis of the flora and fauna (this paper) and the palaeoecological reconstruction currently in preparation by the present authors. The taxonomic study includes the description of four new species of limnocytherids, a known limnocytherid, and three known cypridoideans, as well as two species of charophytes that occur periodically in the lake sediments.

## Study area

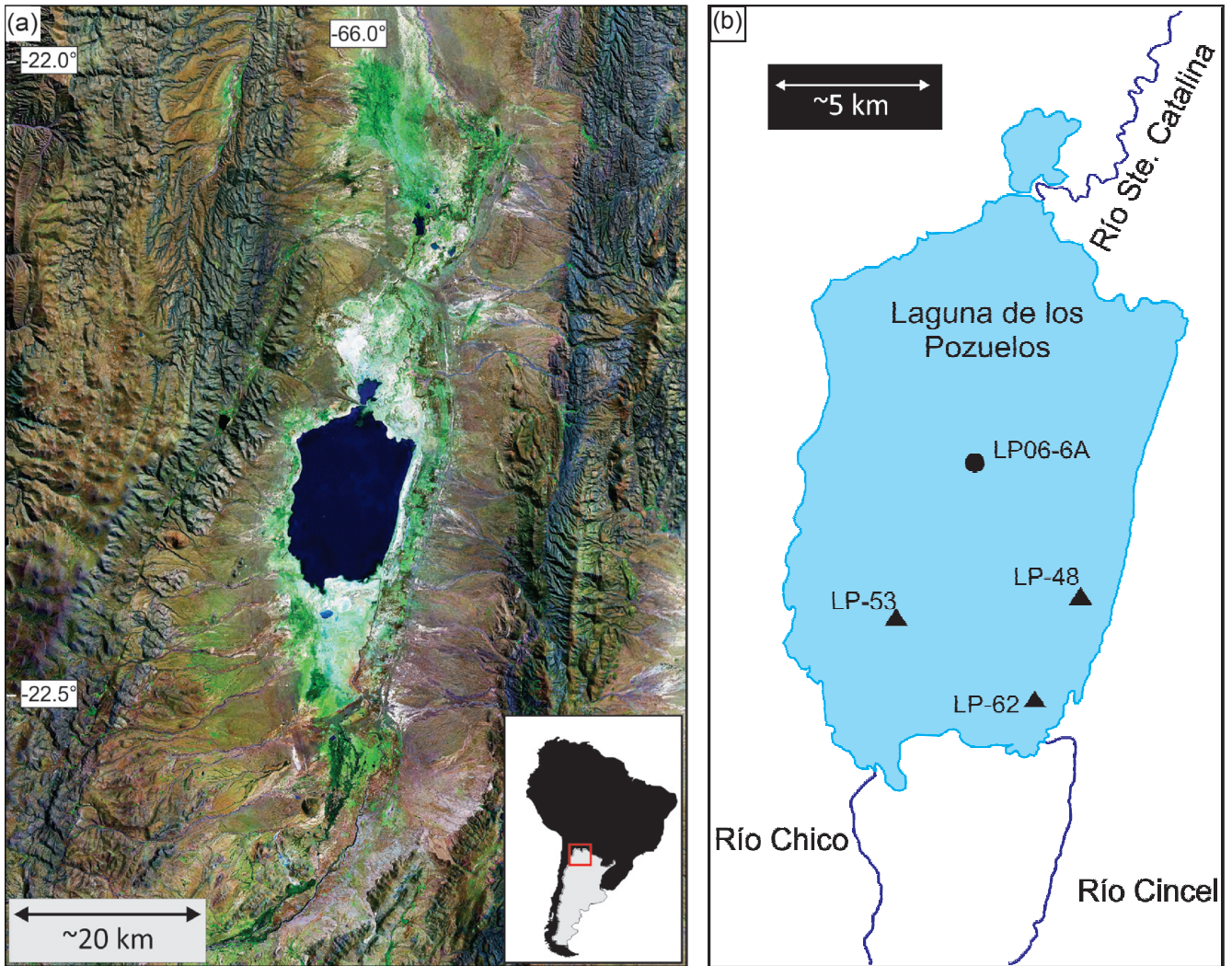
The Pozuelos Basin is located in the NW corner of Jujuy Province (Argentina), at approximately 22° S latitude and 66° W longitude (Igarzábal 1978). It is a high altitude, elongate, piggyback structure with a NNE orientation (McGlue *et al.* 2012). The basin floor (*c.* 3663 m above sea-level (asl)) is flanked by mountains that reach more than 4000 m asl, and the spill point of this endorheic system is about 40 m above the modern playa-lake (Fig. 1).

Formed during the Oligocene, the origins of the Pozuelos Basin are tectonically complex, and the most recent deformation is associated with extensional normal faulting and volcanism (Cladouhos *et al.* 1994; Cohen *et al.* 2014). However, the marginal topography

has been generated by thrust faults. Neogene ignimbrites occur along the eastern margin of the basin, whereas Cretaceous non-marine sediments crop out to the south. The western basin margin is dominated by Ordovician siliciclastic and volcanic rocks. Miocene non-marine carbonates, evaporites and tuff (e.g. Cara Cara Formation; Cladouhos *et al.* 1994) are exposed along the eastern basin margin, potentially supplying hard water to the playa lake from the east.

The Puna region of NOA is extremely arid and relatively cold; monthly mean air temperatures range between 3°C and 13°C (Legates & Willmott 1990a, b). Strongly seasonal precipitation is dominantly from eastern sources, with about 70% of rainfall occurring during the austral summer. The average precipitation is about 320 mm a<sup>-1</sup>. The South American summer monsoon (SASM; Zhou & Lau 1998) controls the climate and, as with most of the Puna plateau, the El Niño Southern Oscillation (ENSO) phenomenon and North Atlantic sea surface temperatures regulate patterns of modern precipitation over the Pozuelos Basin (Garreaud *et al.* 2009). Grasses, shrubs, succulents and macrophytes constitute the vegetation cover, characterizing a mixture of C<sub>3</sub> and C<sub>4</sub> plants that are distributed in the area following topographic and soil-moisture gradients (Bonaventura *et al.* 1995; McGlue *et al.* 2012, 2013).

The concentration of solutes is relatively high in extant Laguna de los Pozuelos (LP), with Na<sup>+</sup> and Ca<sup>2+</sup> (553 mg l<sup>-1</sup> and 129 mg l<sup>-1</sup>, respectively) dominating the cation composition, and Cl<sup>-</sup> and HCO<sub>3</sub><sup>-</sup> are the most significant anions (761 mg l<sup>-1</sup> and 198 mg l<sup>-1</sup>). Magnesium is present at a concentration of 30 mg l<sup>-1</sup>, indicating a relatively low Mg/Ca<sub>water</sub>. Playa waters are oxygen saturated, brackish (4 to 29 ppt), basic (mean pH of 8.7) and



**Fig. 1.** (a) Satellite image of Laguna de los Pozuelos, Jujuy Province, Argentina (inset shows the position of the basin in South America); and (b) schematic map showing Laguna de los Pozuelos, major riverine inputs and the approximate location of core LP06-6A (filled circle) and three surface samples (filled triangles) discussed in this paper (modified from McGlue *et al.* 2013).

appear to be spatially homogeneous based on available measurements (McGlue *et al.* 2012). These patterns probably result from wind mixing of the shallow water column and a low groundwater table.

Laguna de los Pozuelos is a hydrologically closed basin that is sensitive to changes in effective precipitation (P-E; McGlue *et al.* 2012); hence, its surface area is subject to annual variations that may expand to about 135 km<sup>2</sup> during years above average precipitation to a dry-playa as the lake desiccates during prolonged droughts (Mirande & Tracanna 2009; McGlue *et al.* 2013). No evidence has yet been discovered that would suggest that LP water levels reached the basin spill point and overflowed in the late Quaternary. The basin floor is flat, favouring the lateral expansion of the playa-lake that, at maximum depth, does not exceed 1.5 m. The available evidence indicates that LP is polymictic; weak southeasterly summer winds and stronger westerly winter winds prevent the lake from developing persistent stratification. Ground and surface waters feed the lake; the Ríos Cincel and Chico are largely permanent rivers and form axial deltas at the southern end of Laguna de los Pozuelos, whereas the Río Santa Catalina is an ephemeral drainage that forms a seasonally subaerial terminal splay complex at the opposite end of the lake (McGlue *et al.* 2012). Numerous small and ephemeral streams form alluvial fans along the lake's lateral margins (McGlue *et al.* 2012). At times, it is likely that the inflowing rivers may have ceased during extreme

arid periods, but our core records are not spatially extensive enough to resolve if LP ever fully dried out.

### Material and methods

Sediment core LP06-6A was collected from LP in 2006, using a gasoline-powered hammer coring device on loan from the Universidad Nacional de Jujuy. The core was retrieved from a central axial position in the playa-lake (*c.* 22.333° S latitude, *c.* 66.003° W longitude) during the dry season, when water levels had receded. A total of 372 cm of sediment was recovered in multiple drives from the site (McGlue *et al.* 2013). The core was sealed in the field and transported to the National Lacustrine Core Repository (Laccore) in Minneapolis, Minnesota (USA) for processing and analysis. Core top sediments from the 6A site were barren of ostracods, and core top sediments from other LP cores were likewise dominated by siliciclastic material and the absence of calcareous microfossils. Therefore, in order to assess the modern biota, several (*n*=3) lake floor grab samples were processed from the southern end of Laguna de los Pozuelos, where standing water can be encountered more frequently due to the presence of inflowing rivers. The specific details of modern sediment sampling have been presented elsewhere (McGlue *et al.* 2012).

Thirty-seven samples from core LP06-6A were analysed for microfossils (ostracods and calcareous algae). The sample

intervals are identified in centimetres below ground surface (cm bgs). Samples were prepared using routine procedures (Forester 1988) modified by Palacios-Fest (1994). In order to disaggregate the samples, they were air-dried, weighed and soaked in boiling water with 1 g of Alconox. Following the boiling Alconox bath, the samples were left to sit at room temperature for five days; each sample was vigorously stirred once per day. Using a set of three sieves, the samples were then washed under a gentle shower to separate the coarse (>1 mm), medium (>106 µm) and fine (>63 µm) sand-size fractions. The sand-size fraction consisted mostly of biogenic materials and some detrital particles; all samples were examined to identify fossil content and evidence of biological assemblages.

## Systematic palaeontology

### The Ostracoda

The ostracod species identified in this study are described based on hard-part carapace morphology and not on soft parts. Holotypes are deposited in the collections of the Micropaleontology Laboratory of Museo de la Plata (MLP), Argentina, under the prefix MLP-Mi 1948–1968, and are archived under the photographic catalogue numbers TNESR-Cat.-0001–0103 inclusive. A set of paratypes is kept at Terra Nostra Earth Sciences Research, LLC, whereas the specimens used for scanning electron microscopy (SEM images) are archived at the Laboratorio de Micropaleontología del Instituto de Ciencias del Mar y Limnología, National Autonomous University of Mexico under the prefix ICMLO-2535–2560. All dimensions are given in millimetres; RV, right valve; LV, left valve; C, articulate carapace; J, juvenile. The size conventions used in this study are as follows: <0.40=very small, 0.40–0.50=small, 0.50–0.70=medium, 0.70–1.00=large, >1.00=very large. The abbreviations used in this paper are as follows: EVRV, exterior view, right valve; IVRV, interior view, right valve; EVLV, exterior view, left valve; IVLV, interior view, left valve. The higher classification is based on Martens & Savatnalinton (2011).

Class **Ostracoda** Latreille, 1806  
 Subclass **Podocopa** Muller, 1894  
 Order **Podocopida** Sars, 1866  
 Suborder **Cypridocopina** Baird, 1845  
 Superfamily **Cypridoidea** Baird, 1845  
 Family **Ilyocyprididae** Kaufmann, 1900  
 Subfamily **Ilyocypridinae** Kaufmann, 1900

Genus *Ilyocypris* Brady & Norman, 1889

**Type species.** *Ilyocypris gibba* (Ramdohr, 1808)

*Ilyocypris ramirezi* Cusminsky & Whatley, 1996  
 (Pl. 1, fig. 1)

1996 *Ilyocypris ramirezi* Cusminsky & Whatley: pl. I, figs 11–14.  
 ?1967 *Ilyocypris gibba* (Ramdohr, 1808); Ramírez: 21, pl. 2, figs 4–9.  
 1981 *Ilyocypris gibba* (Ramdohr, 1808); Zabert: pl. 1, fig. 4; pl. 2, fig. 8.  
 1990 *Ilyocypris gibba* (Ramdohr, 1808); Bertels & Martínez: pl. 1, fig. 16.  
 2002 *Ilyocypris ramirezi* Cusminsky & Whatley; Schwalb *et al.*: pl. 1, fig. 12.  
 2005 *Ilyocypris ramirezi* Cusminsky & Whatley; Cusminsky *et al.*: pl. 3, figs 6–8.

**Material.** One adult valve.

**Brief description.** A large species of *Ilyocypris* with subdued swellings and sulci in the antero-dorsal region. Sub-marginal spinose tubercles anteriorly and posteriorly and a regular reticulum of sub-rounded to sub-cribrose fossae.

**Dimensions.** Female RV, TNESR 0098: L 0.840 mm, H 0.420 mm; MLP-Mi 1949, LP06-6A:62, modern surface.

**Occurrence.** *Ilyocypris ramirezi* occurs only once in surface sediments in Laguna de los Pozuelos (LP06-62; cf. McGlue *et al.* 2012).

**Distribution.** The species was first reported from Los Juncos Lake, Estación Perito Moreno, Rio Negro Province, from sample 6, 100 cm from top of core; 41° 03' S latitude, 71° 0' W longitude.

**Remarks.** As with Cusminsky & Whatley's (1996) specimens, the single valve identified in this study is slightly smaller than *I. gibba* from Ramirez's (1967) study from Lago Monte, Buenos Aires, and Bertels and Martínez's (1990) investigation from Quaternary deposits in the south of Buenos Aires province. Cusminsky & Whatley (1996) found this species in the beds of both Los Juncos Lake (samples 5, 6, 7) and La Salina Lake (sample 6) in northern Patagonia. Schwalb *et al.* (2002) and Cusminsky *et al.* (2005) found this species in running water and in ephemeral lakes, such as Laguna Cari-Laufquen. It also occurs in permanent lakes in northern Patagonia but inhabits predominantly streams and spring seeps (Cusminsky *et al.* 2005). D'Ambrosio *et al.* (2015) described the species soft parts for specimens recovered seasonally from a spring creek and the river delta in the Cuyo region, western Argentina. Its geographical range may be extended to Laguna de los Pozuelos, Jujuy, northern Argentina.

Family **Cyprididae** Baird, 1845  
 Subfamily **Eucypridinae** Bronshtein, 1947

Genus *Eucypris* Vávra, 1891

**Type species.** *Monoculus virens*, Jurine 1820.

*Eucypris virgata* Cusminsky & Whatley, 1996  
 (Pl. 1, fig. 2)

1996 *Eucypris virgata* Cusminsky & Whatley: pl. I, figs 17, 18; pl. II, figs 1–3.  
 2002 *Eucypris virgata* Cusminsky & Whatley; Schwalb *et al.*: pl. 1, fig. 4.  
 2005 *Eucypris virgata* Cusminsky & Whatley; Cusminsky *et al.*: pl. 2, figs 5–7.

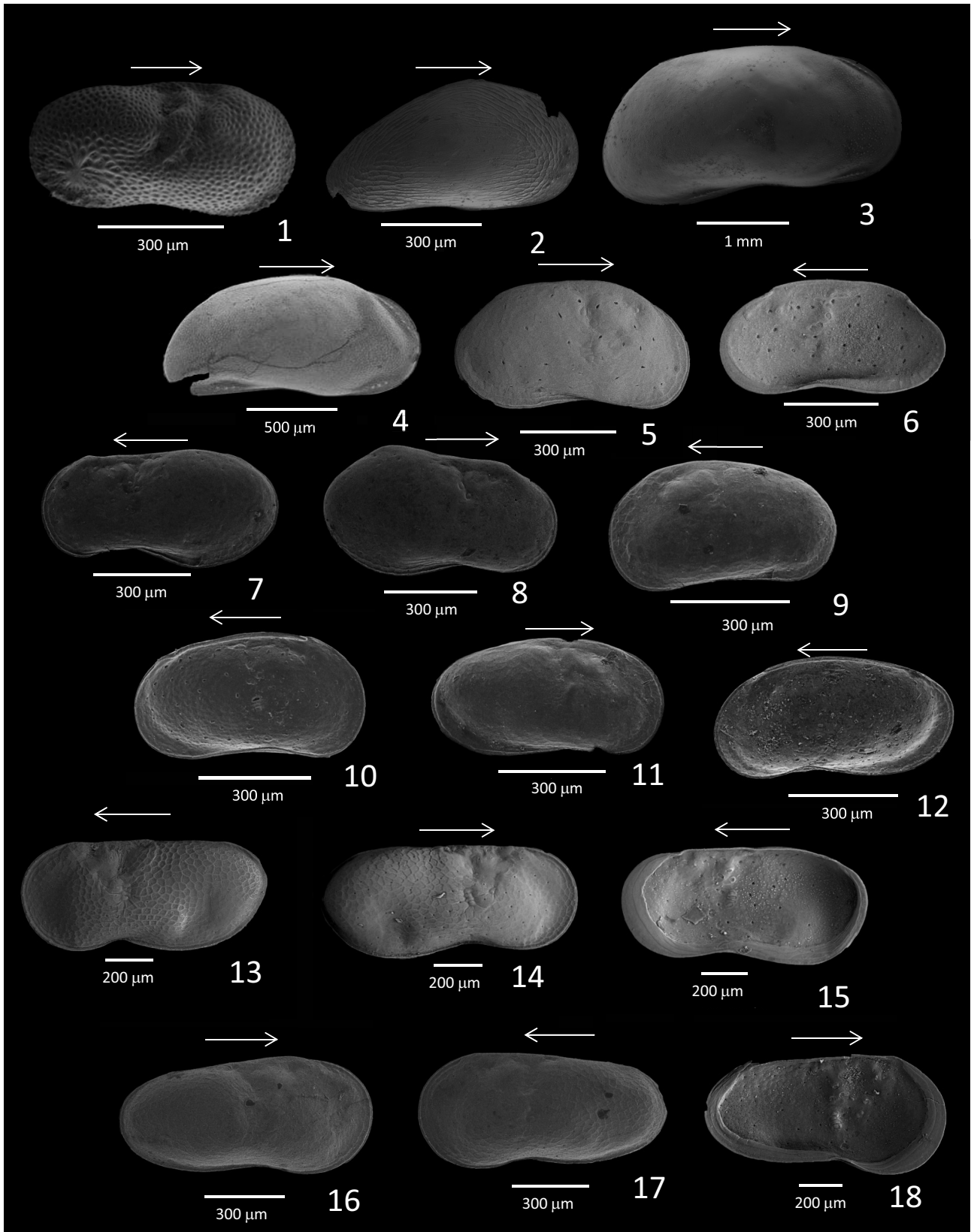
**Material.** One juvenile RV.

**Brief description.** Large species of *Eucypris* characterized by a rather narrowly rounded anterior margin and a very pointed posterior, virgate ribbing, marginal reticulation and pustule-like tubercles.

**Dimensions.** RV, TNESR 0099: L 0.640 mm, H 0.320 mm; MLP-Mi 1950, LP06-6A, 299.5–301.5 cm bgs.

**Occurrence.** Occurs once in core LP06-6A in Laguna de los Pozuelos (Core LP06 at c. 299.5–301.5 cm).

**Distribution.** This juvenile valve has the characteristic ornamentation of the species described by Cusminsky & Whatley (1996) and it occurs especially in permanent ponds, lakes, springs, creeks and non-permanent aquatic environments of northern Patagonia (Cusminsky & Whatley 1996; Schwalb *et al.* 2002; Cusminsky *et al.* 2005). Its occurrence in Laguna de los Pozuelos extends its presence to northern Argentina.



**Explanation of Plate 1.** **fig. 1.** *Ilyocypris ramirezi* Cusminsky & Whatley, 1996; adult female, exterior view, right valve, MLP-Mi-1949. **fig. 2.** *Eucypris virgata* Cusminsky & Whatley, 1996; juvenile exterior view, right valve, MLP-Mi- 1950. **figs 3, 4.** *Chlamydotheca pseudobrasiliensis* Martens, 1994: **3,** pre-adult (A-1) exterior view, right valve, MLP-Mi-1951; **4,** juvenile (A-3) exterior view, right valve, ICMLO-2535. **figs 5–8.** *Limnocythere alexanderi* n. sp.: **5,** adult female, exterior view, right valve, paratype, ICMLO-2536; **6,** adult female, interior view, right valve, paratype, ICMLO-2536; **7,** adult male, exterior view, left valve, paratype, ICMLO-2537; **8,** adult male, exterior view, right valve, paratype, ICMLO-2538. **figs 9–12.** *Limnocythere foresteri* n. sp.: **9,** adult female, exterior view, left valve, paratype, ICMLO-2539; **10,** adult female, interior view, left valve, paratype, ICMLO-2539; **11,** adult male, exterior view, right valve, paratype, ICMLO-2540; **12,** adult male, interior view, right valve, paratype, ICMLO-2540. **figs 13–18.** *Limnocythere lysandrosi* n. sp.: **13,** adult male, exterior view, left valve, paratype, ICMLO-2541; **14,** adult male, exterior view, right valve, paratype, ICMLO-2542; **15,** adult male, interior view, right valve, paratype, ICMLO-2542; **16,** adult female, exterior view, right valve, paratype, ICMLO-2543; **17,** adult female, exterior view, left valve, paratype, ICMLO-2544; **18,** adult female, interior view, left valve, paratype, ICMLO-2544.

**Remarks.** This species is distinguished from *E. sarsi* Daday, 1902 [= *E. fontana* (Graf, 1931)] from the Recent of southern Patagonia in shape and size. The latter species has its highest point more posterior than the present species. Although Daday's illustrations are very poor, his material seems to have a similar type of ornament. The species differs from *E. labyrinthica* Cusminsky & Whatley (1996) in its stronger ornamentation and its more elongate shape and pointed posterior. Although the adults of this species are very distinctive and demonstrate clear adult characteristics, especially with respect to the nature of the inner lamella, the juveniles are rather similar to those illustrated by De Deckker (1981) as juveniles of *E. fontana* (Graf). We interpret this single juvenile valve as a form of *E. virgata* described by Cusminsky & Whatley (1996).

Subfamily **Cypridinae** Baird, 1845

Genus *Chlamydotheca* Saussure, 1858

**Type species.** *Cypris (Chlamydotheca) azteca* Saussure, 1858.

*Chlamydotheca pseudobrasiliensis* Martens & Behen, 1994  
(Pl. 1, figs 3, 4)

1949 *Chlamydotheca brasiliensis* Tressler: 72, fig. 13d–g.

1994 *Chlamydotheca pseudobrasiliensis*: Martens in Martens & Behen: 9.

**Material.** 26 adults and juveniles (mostly fragmented).

**Brief description.** Large carapace with both valves similar in shape characterized by a moderately developed anterior flange. LV overlaps RV. Greatest height slightly anterior of centre in dorsal margin. Ocular region slightly indented. Anterior end more broadly rounded than posterior. Ventral margin slightly convex in the centre. Surface of valves smooth. Hyaline border and pore canals lacking. No males known.

**Dimensions.** Female (A-1) (SEM) EVRV, TNESR 0102: L 3.100 mm, H 1.900 mm; MLP-Mi 1951, LP06-6A, modern surface. Female (A-3) (SEM) EVRV, TNESR 0100: L 1.120 mm, H 0.560 mm; ICMLO-2535, LP06-6A, 276.5–278.5 cm bgs.

**Occurrence.** *Chlamydotheca pseudobrasiliensis* occurs rarely in LP (core LP06-6A at depths of approximately 131 cm, 277.5 cm, 299.8–323.5 cm, 347.5 cm and 361.5 cm, as well as modern samples LP06-48 and LP06-53).

**Distribution.** Tressler (1949) reports the species in an artificial lake near Lavras, Ceará, Brazil in low numbers. Rare also in this study. Holotype, USNM No. 83012.

**Remarks.** The present material closely resembles *Chlamydotheca pseudobrasiliensis* Martens, 1994 as illustrated by Tressler (1949). The specimens differ in detail from those documented by Diebel & Pietrzeniuk (1975), Calderoni *et al.* (1994), Tunoglu *et al.* (1995) and Zhencheng *et al.* (1999). Our specimens, however, are very fragmentary. One adult RV and several juvenile forms appear to form the scarce population in LP. The adult form is broken but larger than 3 mm in length and 2 mm high.

Superfamily **Cytheroidea** Baird, 1850  
Family **Limnocytheridae** Klie, 1938  
Subfamily **Limnocytherinae** Klie, 1938  
Tribe **Limnocytherini** Klie, 1938

Genus *Limnocythere* Brady, 1968

**Type species.** *Cythere inopinata* Baird, 1843.

*Limnocythere alexanderi* n. sp.  
(Pl. 1, figs 5–8; Fig. 3a, b)

**Derivation of name.** In honour of Alexander Qais, the senior author's third grandson.

**Diagnosis.** Subtrapezoidal carapace, dorsal margin straight. Well-defined cardinal angles, especially the anterodorsal. Ventral margin concave in the middle (oral incurvature). Surface weakly reticulate with fine muri and polygonal fossae. Large pore canals. Bisulcate, the anterior sulcus shallower than the posterior sulcus. Female and male well differentiated.

**Holotype.** Male right valve; MLP-Mi-1952; LP06-6A:276.5–278.5 cm bgs.

**Paratypes.** Both valves of male and female specimens; MLP-Mi-1953/1955; SEM image specimens: ICMLO-2536/2539; LP06-6A:276.5–278.5 cm bgs, LP06-6A:360.5–362.5 cm bgs.

**Material.** 274 adults and juveniles.

**Type locality.** Laguna de los Pozuelos (c. 22.333° S latitude, c. 66.003° W longitude).

**Description.** Female: Shape subquadrate in side view, greatest height anteriorly of middle, dorsal margin straight. Ventral margin concave in the middle; well-defined obtuse cardinal angles, especially the anterodorsal. Anterior margin broadly rounded; posterior margin rounded, slightly acuminate in the middle to rounded towards the postero-ventral margin. One or two nodes at the anterior and posterior ends of the hinge may or may not be present. Parallel to the dorsal margin is a sulcus intercepted by two longitudinal sulci. The anterior sulcus is shallower than the posterior sulcus. Surface of valves weakly reticulate, transparent or translucent with fine muri and polygonal fossae; normal pores common, large and cribose type. Muscle scars as in genus. Inner lamella moderately narrow, sloping inward; inner margin and line of concrescence coincide throughout, subparallel to outer margin. Marginal pore canals few, simple, nearly straight. Hinge as in genus.

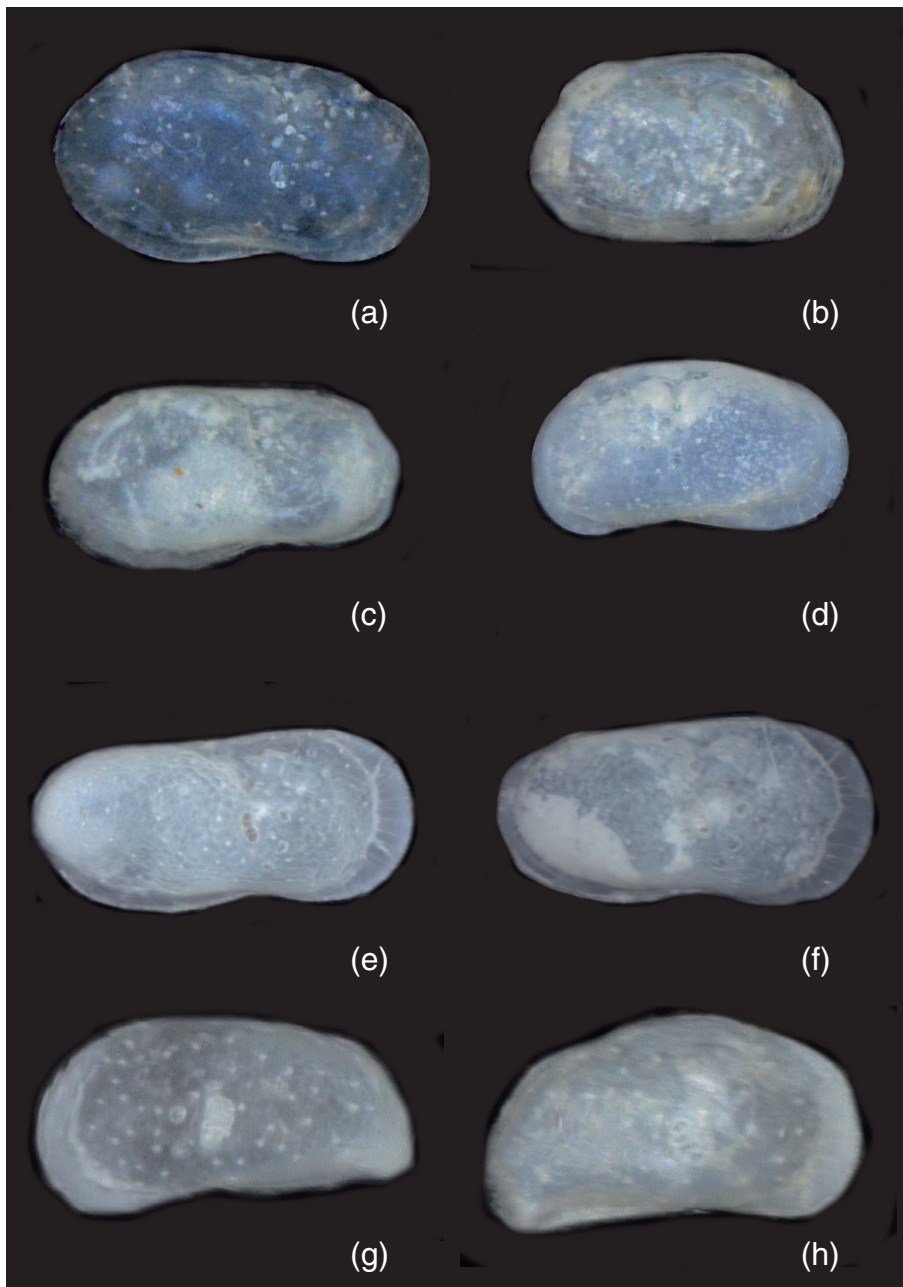
Male: Differs from females in being slightly more elongate with a club-shaped posterior half. Surface of valves reticulate. The hinge nodes may be more prominent and the posterior sulcus deeper than that of the female. Its greatest height lies in the posterior half of the valve. Other characteristics same as in female.

**Dimensions.** Male RV holotype, TNESR 0054: L 0.675 mm, H 0.0350 mm; MLP-Mi 1952, LP06-6A, 276.5–278.5 cm bgs. Male LV paratype, TNESR 0055: L 0.745 mm, H 0.410; MLP-Mi-1953, LP06-6A, 276.5–278.5 cm bgs. Female LV paratype, TNESR 0056: L 845 mm, H 0.495; MLP-Mi 1954, LP06-6A, 360.5–362.5 cm bgs. Female RV paratype, TNESR 0057: L 0.650 mm, H 0.370; MLP-Mi 1955, LP06-6A, 360.5–362.0 cm bgs. Male (SEM) EVRV, TNESR 0064: L 0.745 mm, H 0.410; ICMLO-2536, LP06-6A, 276.5–278.5 cm bgs. Male (SEM) EVLV, TNESR 0066: L 0.710 mm, H 0.395 mm; ICMLO-2537, LP06-6A, 276.5–278.5 cm bgs. Female (SEM) EVRV, TNESR 0068: L 0.682 mm, H 0.364 mm; ICMLO-2538, LP06-6A, 276.5–278.5 cm bgs. Female (SEM) IRVR, TNESR 0069: L 0.700 mm, H 0.360 mm; ICMLO-2539, LP06-6A, 276.5–278.5 cm bgs.

**Occurrence.** *Limnocythere alexanderi* n. sp. occurs throughout core LP06-6A in LP and is as abundant as *L. lysandrosi* n. sp.

**Distribution.** This species is recorded for the first time from Quaternary sediments in LP. To the best of our knowledge the species has not been recovered anywhere else.

**Remarks.** *Limnocythere alexanderi* n. sp. resembles *L. variabilis* of Purper & Pinto (1980); however, it clearly differs in the absence of a deep sulcus and the two diagnostic nodes in the anterior half of the valve that characterize *L. variabilis*. The specimens described here



**Fig. 2.** (a) Holotype: male RV, *Limnocythere alexanderi* n. sp., 225x. Dimensions: L 0.675 mm; H 0.350. MLP-Mi 1952. (b) Paratype: female LV, *Limnocythere alexanderi* n. sp., 225x. Dimensions: L 0.845; H 0.495. MLP-Mi 1954. (c) Holotype: male RV, *Limnocythere foresteri* n. sp., 225x. Dimensions: L 0.700; H 0.390. MLP-Mi 1956. (d) Paratype: female LV, *Limnocythere foresteri* n. sp., 225x. Dimensions: L 0.590; H 0.290. MLP-Mi 1959. (e) Holotype: male RV, *Limnocythere lysandrosi* n. sp., 225x. Dimensions: L 1.420; H 0.465. MLP-Mi 1960. (f) Paratype: female RV, *Limnocythere lysandrosi* n. sp., 225x. Dimensions: L 1.161; H 0.511. MLP-Mi 1963. (g) Holotype: male LV, *Limnocythere ruipunctifinalis* n. sp., 225x. Dimensions: L 0.560; H 0.279. MLP-Mi 1964. (h) Paratype: female RV, *Limnocythere ruipunctifinalis* n. sp., 225x. Dimensions: L 0.571; H 0.296. MLP-Mi 1966.

show an acuminate posterior margin, lack of denticulations in the postero-ventral margin of left valve. It is significant that the males of *L. alexanderi* differ from those of *L. variabilis* in having the nodes at the extremes of the hinge, whereas the nodes of *L. variabilis* are both in front of the deep sulcus one above the other. Purper & Pinto (1980) positively compare the female valves of *L. variabilis* to *L. staplini* Gutentag & Benson, 1962, highlighting that the only difference is the slight sinuosity in the central dorsal margin. Dorsal margin in *L. alexanderi* is straight or slightly convex throughout. Therefore, we conclude that *L. alexanderi* is a new species.

*Limnocythere foresteri* n. sp.  
(Pl. 1, figs 9–12; Fig. 3c, d)

**Derivation of name.** In honour of Dr Richard M. Forester for his invaluable contributions to micropalaeontology and ostracod research worldwide.

**Diagnosis.** A small form of *Limnocythere* characterized by a rectangular carapace; slightly convex dorsal margin. Pronounced

antero-dorsal smooth tubercle; crystalline, smooth surface. Compressed anterior and ventro-dorsal margins giving them an acuminate appearance. Female and male well differentiated.

**Holotype.** Male right valve; MLP-Mi-1956; LP06-6A:232–234 cm bgs.

**Paratypes.** Both valves of male and female specimens; MLP-Mi-1957/1959; SEM image specimens: ICML0-2540/2543; LP06-6A:59–61 cm bgs; LP06-6A:232–234 cm bgs, and LP06-6A:360.5–362.5 cm bgs.

**Material.** 206 adults and juveniles.

**Type locality.** Laguna de los Pozuelos (c. 22.333° S latitude, c. 66.003° W longitude).

**Description.** Female: Shape subrectangular in side view; greater height anteriorly of middle; dorsal margin straight to slightly convex. Ventral margin somewhat concave toward the anterior end from the middle; anterior margin broadly rounded; posterior mar-

gin narrowly rounded. Carapace elliptical in dorsal view; greatest width posteriorly; anterior end bluntly pointed; posterior end somewhat rounded. Surface of valves weakly reticulate, fine muri and polygonal fossae, transparent to translucent weak, antero-dorsal sulcus; normal pores common, small, and simple type; however, several large pores appear to be cribose. Muscle scars as in genus. Inner lamella moderately narrow, sloping inward; inner margin and line of concrescence coincide throughout, subparallel to outer margin. Marginal pore canals few, simple, nearly straight. Hinge as in genus.

**Male:** Males differ from females in being more elongate, in having a slightly sinuous shape, a more concave ventral margin, anterior and posterior margins broadly rounded. Its greatest height lies just behind the sulcus, and the antero-dorsal sulcus is deeper.

**Dimensions.** Male RV holotype, TNESR 0075: L 0.700 mm, H 0.390 mm; MLP-Mi 1956, LP06-6A, 232–234 cm bgs. Male LV paratype, TNESR 0076: L 0.530 mm, H 0.280 mm; MLP-Mi 1957, LP06-6A, 232–234 cm bgs. Female RV paratype, TNESR 0077: L 0.530 mm, H 0.280 mm; MLP-Mi 1958, LP06-6A, 360.5–362.5 cm bgs. Female LV paratype, TNESR 0078: L 0.590 mm, H 0.290 mm; MLP-Mi 1959, LP06-6A, 232–234 cm bgs. Female (SEM) EVLV, TNESR 0082: L 0.540 mm, H 0.290 mm; ICMLO-2540, LP06-6A, 59–61 cm bgs. Female (SEM) IVLV, TNESR 0083: L 0.540 mm, H 0.290; ICMLO-2541, LP06-6A, 59–61 cm bgs. Male (SEM) EVRV, TNESR 0084: L 0.630 mm, H 0.330 mm; ICMLO-2542, LP06-6A, 360.5–362.5 cm bgs. Male (SEM) IVRV, TNESR 0085: L 0.630 mm, H 0.330 mm; ICMLO-2543, 360.5–362.5 cm bgs.

**Occurrence.** *Limnocythere foresteri* n. sp. occurs throughout core LP06-6A in LP but it is moderately abundant to rare. It reaches its maximum abundance in the modern playa-lake.

**Distribution.** This species is recorded for the first time from Quaternary sediments in LP. To the best of our knowledge the species has not been recovered anywhere else. To the best of our knowledge the species has not been recovered anywhere else.

**Remarks.** Male specimens of *Limnocythere foresteri* n. sp. found in LP look like juvenile specimens of *L. titicaca* Lerner-Seggev, 1973. However, the well-developed valves of *L. foresteri* strongly suggest mature adults of a smaller species than *L. titicaca*. The females are more subquadrate than the females of *L. titicaca* and also much smaller. The clear dimorphism in small *L. foresteri* indicates these specimens are adults different from *L. titicaca*. *Limnocythere foresteri* is also similar to *L. parascutariense* Delorme, 1971; however, it differs in the surface reticulation which in *L. foresteri* is weak whereas *L. parascutariense* is heavily reticulated.

*Limnocythere lysandrosi* n. sp.

(Pl. 1, figs 13–18, Pl. 2, figs 1–3; Fig. 3e, f)

**Derivation of name.** In honour of Lysandros Emiliano, the senior author's first grandson.

**Diagnosis.** A very large form of *Limnocythere*. Dorsal margin straight, ventral margin strongly concave in the anterior third giving it a 'lobulated' aspect, especially at the postero-ventral margin where it reaches its greatest height. Surface strongly reticulate with shallow sulci (bisulcate). Female and male about the same size but female more subrectangular than male.

**Holotype.** Male right valve; MLP-Mi-1960; LP06-6A:59–61 cm bgs.

**Paratypes.** Both valves of male and female specimens; MLP-Mi-1961/1963; SEM image specimens: ICMLO-2544/2549; LP06-6A: 59–61 cm bgs, LP06-6A:241.5–243.5 cm bgs.

**Material.** 2231 adults and juveniles.

**Type locality.** Laguna de los Pozuelos (c. 22.333° S latitude, c. 66.003° W longitude).

**Description.** Female: Shape subrectangular to subtrapezoidal in side view; greatest height anteriorly of middle; dorsal margin straight, ventral margin very concave towards the anterior half; anterior margin broadly rounded, posterior margin forms an obtuse angle in the dorsal area that turns acute towards the ventral margin. Carapace elliptical in dorsal view; greatest width posteriorly; anterior and posterior margins rather rounded at about mid-height. Surface of valves strongly reticulate, transparent to translucent; well-defined muri with thick margins and polygonal fossae, bisulcate, sulci shallow; normal pores few, medium-size, simple type, difficult to observe because of surface reticulation. Muscle scars as in genus. Inner lamella moderately broad, sloping inward; inner margin and line of concrescence coincide; anterior and posterior inner margins coincide throughout; anterior and posterior inner margins are semi-circular; marginal pore canals few, simple or bifurcate, and nearly straight; selvage weak. Hinge as in genus.

**Male:** Differs from female in being smaller and more elongate with greatest height posteriorly. The ventral margin is strongly concave towards the anterior half of the length. The anterior margin is broadly rounded and the posterior margin forms almost a straight angle at the end of the carapace.

**Dimensions.** Male RV holotype, TNESR 0001: L 1.420 mm, H 0.465 mm; MLP-Mi 1960, LP06-6A, 59–61 cm bgs. Male LV paratype, TNESR 0002: L 1.452 mm, H 0.595 mm; MLP-Mi 1961, LP06-6A, 59–61 cm bgs. Female LV paratype, TNESR 0003: L 1.466 mm, H 0.520 mm; MLP-Mi 1962, LP06-6A, 59–61 cm bgs. Female RV paratype, TNESR 0004: L 1.161 mm, H 0.511 mm; MLP-Mi 1963, LP06-6A, 59–61 cm bgs. Male (SEM) EVRV, TNESR 0009: L 1.171 mm, H 0.651 mm; ICMLO-2544, LP06-6A, 241.5–243.5 cm bgs. Male (SEM) IVRV, TNESR 0010: L 1.171 mm, H 0.651; ICMLO-2545, LP06-6A, 241.5–243.5 cm bgs. Male (SEM) EVLV, TNESR 0011: L 1.153 mm, H 0.446 mm; ICMLO-2546, LP06-6A, 241.5–243.5 cm bgs. Female (SEM) IVLV, TNESR 0012: L 0.986 mm, H 0.482 mm; ICMLO-2547, 241.5–243.5 cm bgs. Female (SEM) EVRV, TNESR 0013: L 0.954 mm, H 0.449 mm; ICMLO-2548, LP06-6A, 241.5–243.5 cm bgs. Female (SEM) EVLV, TNESR 0014: L 0.980 mm, H 0.468 mm; ICMLO-2549, LP06-6A, 241.5–243.5 cm bgs.

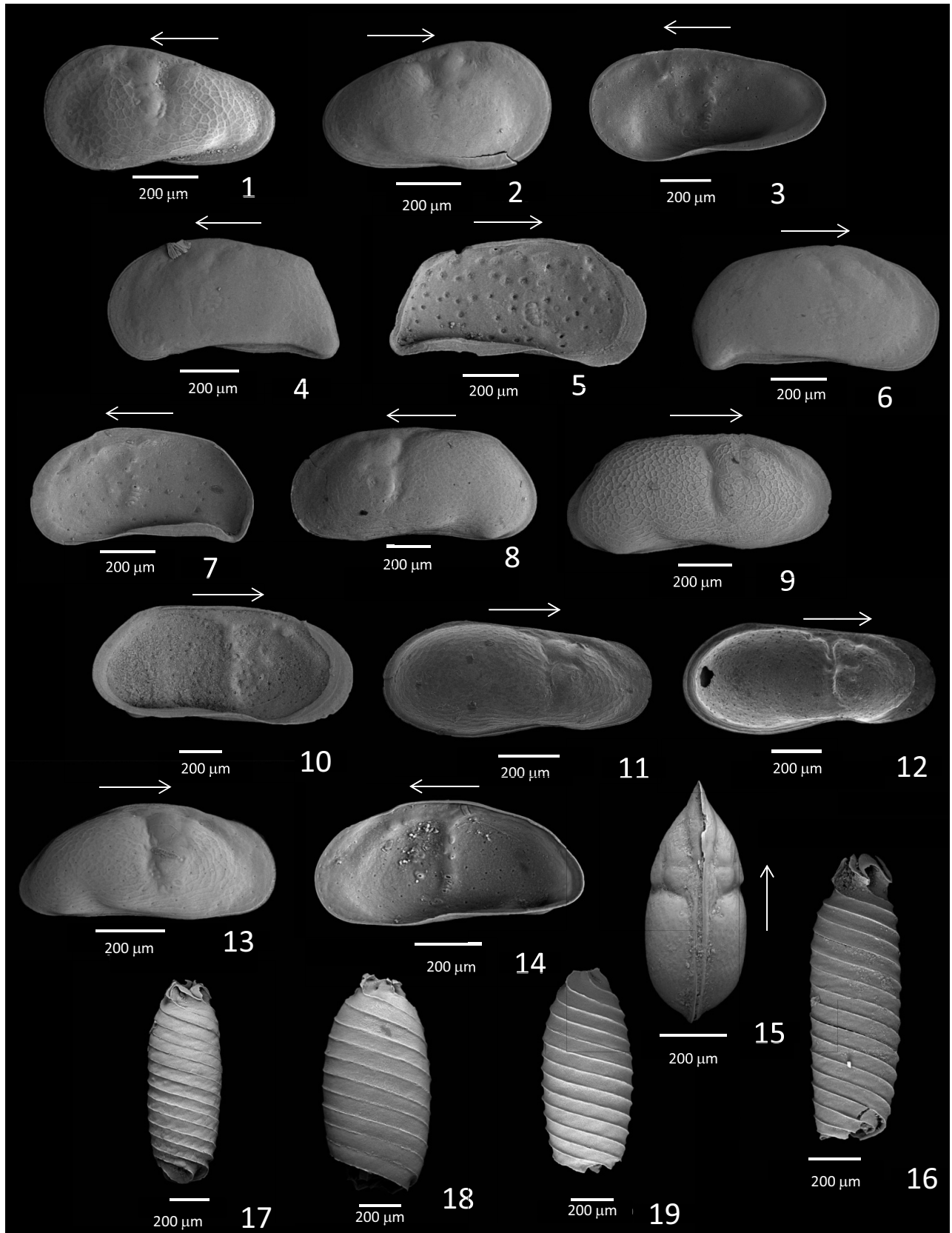
**Occurrence.** *Limnocythere lysandrosi* n. sp. occurs throughout core LP06-6A in LP. It is the most common species in the core.

**Distribution.** This species is recorded for the first time from Quaternary sediments in LP. To the best of our knowledge the species has not been recovered anywhere else.

**Remarks.** Specimens of *Limnocythere lysandrosi* n. sp. found in LP appear similar to *L. jobimi* of Purper & Pinto (1980). The individuals described here differ in the larger size, the more acuminate and truncated posterior margin of the males, the more delicate ornamentation, and the weaker sulci in both females and males.

*Limnocythere ruipunctifinalis* n. sp.

(Pl. 2, figs 4–7; Fig. 3g, h)



**Explanation of Plate 2.** **figs 1–3.** *Limnocythere lysandrosi* n. sp.: 1, juvenile, exterior view, left valve, paratype, ICMLO-2545; 2, juvenile, exterior view, right valve, paratype, ICMLO-2546; 3, juvenile, interior view, right valve, paratype, ICMLO-2547. **figs 4–7.** *Limnocythere ruipunctifinalis* n. sp.: 4, adult male, exterior view, left valve, paratype, ICMLO-2548; 5, adult male, interior view, left valve, paratype, ICMLO-2548; 6, adult female, exterior view, right valve, paratype, ICMLO-2549; 7, adult female, interior view, right valve, paratype, ICMLO-2549. **figs 8–15.** *Limnocythere titicaca* Lerner-Seggev, 1973: 8, adult female, exterior view, left valve, ICMLO-2550; 9, adult female, exterior view, right valve, ICMLO-2551; 10, adult female, interior view, left valve, ICMLO-2550; 11, adult male, exterior view, right valve, ICMLO-2552; 12, adult male, interior view, left valve, ICMLO-2552; 13, juvenile, exterior view, right valve, ICMLO-2553; 14, juvenile, interior view, right valve, ICMLO-2554; 15, juvenile, dorsal view, ICMLO-2555. **figs 16, 17.** *Chara filiformis* Hertzsch, 2007, gyrogonite, lateral view: 16, MLP-Mi-1972; 17, ICMLO-2556. **figs 18, 19.** *Chara vulgaris* Linnaeus, 1753, gyrogonite, lateral view: 18, MLP-Mi-1973; 19, ICMLO-2557.



**Derivation of name.** A combination derived from the senior author's second grandson, Rui Ricardo, and the species most characteristic feature, its posteroventral hook.

**Diagnosis.** A small species of *Limnocythere* characterized by a pointed hook at the postero-ventral margin. Posterior margin truncated obliquely. Dimorphism is difficult to recognize.

**Holotype.** Male left valve; MLP-Mi-1964; LP06-6A:59–61 cm bgs.

**Paratypes.** Both valves of male and female specimens; MLP-Mi-1965/1967; SEM image specimens: ICMLO-2550-/2553; LP06-6A:59–61 cm bgs. LP06-6A:232–234 cm bgs.

**Material.** 842 adults and juveniles.

**Type locality.** Laguna de los Pozuelos (*c.* 22.333° S latitude, *c.* 66.003° W longitude).

**Description.** Female: Shape subrectangular in side view; greatest height anteriorly of middle; dorsal margin slightly convex, ventral margin concave, anterior margin broadly rounded, posterior margin obliquely truncated towards the ventral margin with slight sub-ventral acumination, giving the margin a downturned appearance. Carapace elliptical in dorsal view; greatest width posteriorly; anterior end bluntly pointed but posterior end slightly bulbous. Surface of valves smooth, transparent to translucent; bisulcate, sulci shallow; normal pores common, medium to large simple type, clearly seen on the translucent surface. Muscle scars as in genus. Inner lamella moderately narrow, sloping inward; inner margin and line of conchescence coincide in ventral margin; anterior inner margin is semi-circular; whereas posterior inner margin is angular, selvage weak; inner list marked specially in the postero-ventral margin. Marginal pore canals few, simple and nearly straight. Hinge as in genus.

Male: The dorsal margin of males is straighter than females. The carapace of male differs from female in being subtrapezoidal and more elongate. Female's height slightly greater.

**Dimensions.** Male LV holotype, TNESR 0015: L 0.560 mm, H 0.279 mm; MLP-Mi 1964, LP06-6A, 59–61 cm bgs. Male RV paratype, TNESR 0016: L 0.600 mm, H 0.595 mm; MLP-Mi 1965, LP06-6A, 59–61 cm bgs. Female RV paratype, TNESR 0017: L 0.571 mm, H 0.296 mm; MLP-Mi 1966, LP06-6A, 59–61 cm bgs. Female LV paratype, TNESR 0018: L 0.579 mm, H 0.300 mm; MLP-Mi 1967, LP06-6A, 59–61 cm bgs. Male (SEM) EVRV, TNESR 0019: L 0.683 mm, H 0.350 mm; ICMLO-2550, LP06-6A, 232–234 cm bgs. Male (SEM) IVRV, TNESR 0020: L 0.725 mm, H 0.346; ICMLO-2551, LP06-6A, 232–234 cm bgs. Female (SEM) EVLV, TNESR 0021: L 0.677 mm, H 0.308 mm; ICMLO-2552, LP06-6A, 232–234 cm bgs. Female (SEM) IVLV, TNESR 0022: L 0.683 mm, H 0.350 mm; ICMLO-2553, 232–234 cm bgs.

**Occurrence.** *Limnocythere ruipunctifinalis* n. sp. occurs throughout core LP06-6A in LP; it is relatively abundant.

**Distribution.** This species is recorded for the first time from Quaternary sediments in LP. To the best of our knowledge the species has not been recovered anywhere else.

**Remarks.** *Limnocythere ruipunctifinalis* n. sp. found in LP appears similar to specimens of *Limnocythere* sp. figured by Cusminsky *et al.* (2005); the latter, however, presents a strongly reticulate surface, whereas *L. ruipunctifinalis* does not. Cusminsky *et al.* (2005) do not report males, as observed in LP. *Limnocythere* sp. of Cusminsky *et al.* (2005) occurs in Lago Cardiel, Province of Santa Cruz, southern Patagonia, an ephemeral, brackish-water body

apparently similar to LP where *L. ruipunctifinalis* thrives. While Lago Cardiel has a pH of 9.11, a high concentration of sodium bicarbonate (>1046 mg l<sup>-1</sup>), chloride (>335 mg l<sup>-1</sup>) and sulphate (>906 mg l<sup>-1</sup>) (Cusminsky *et al.* 2005), average values for LP appear to be lower (mean pH 8.7, sodium bicarbonate concentration of 283 mg l<sup>-1</sup>). The difference in water chemistry preferences suggests they are two different species or at least that under sulphate-rich conditions the species is parthenogenetic.

*Limnocythere titicaca* Lerner-Seggev, 1973  
(Pl. 2, figs 8–15)

1973 *Limnocythere titicaca* Lerner-Seggev: text-figs 2, 3, pl. 1.

1998 *Limnocythere titicaca* Lerner-Seggev, 1973; Mourguiart & Corrège: pl. 2, fig. L.

**Material.** 1394 adults and juveniles.

**Brief description.** A large species of the genus *Limnocythere*. Female valves subtrapezoidal in lateral view, posterodorsal margin truncate, and heavily reticulate surface. Maximum height slightly anterior of middle. Male trapezoidal in lateral view, dorsal margin straight, posterior end broadly rounded, and weakly reticulate surface. Maximum height posterior of middle.

**Dimensions.** Female RV, TNESR 0042: L 0.840 mm, H 0.395 mm; MLP-Mi 1968, LP06-6A, 276.5–278.5 cm bgs. Female LV, TNESR 0045: L 0.900 mm, H 0.400 mm; MLP-Mi 1969, LP06-6A, 276.5–278.5 cm bgs. Male RV, TNESR 0064: L 0.980 mm, H 0.485 mm; MLP-Mi 1970, LP06-6A, 276.5–278.5 cm bgs. Male LV, TNESR 0065: L 0.960 mm, H 0.430 mm; MLP-Mi 1971, LP06-6A, 276.5–278.5 cm bgs. Female (SEM) EVRV, TNESR 0050: L 0.815 mm, H 0.360 mm; ICMLO-2554, LP06-6A, 276.5–278.5 cm bgs. Female (SEM) EVLV, TNESR 0052: L 0.906 mm, H 0.413; ICMLO-2555, LP06-6A, 276.5–278.5 cm bgs. Female (SEM) IVLV, TNESR 0053: L 0.812 mm, H 0.365 mm; ICMLO-2556, LP06-6A, 276.5–278.5 cm bgs. Male (SEM) EVRV, TNESR 0071: L 1.050 mm, H 0.510 mm; ICMLO-2557, 360.5–362.5 cm bgs. Male (SEM) IVRV, TNESR 0072: L 1.050 mm, H 0.510 mm; ICMLO-2558, LP06-6A, 360.5–362.5 cm bgs.

**Occurrence.** *Limnocythere titicaca* occurs in the lower portion of core LP06-6A (abundant from *c.* 131–361.5 cm) in LP and in modern surface samples. It is scarce in the upper part of the stratigraphic column.

**Distribution.** This species was first recorded from Quaternary sediments in Lake Titicaca, Bolivia (Lerner-Seggev 1973; Mourguiart & Corrège 1998). Our specimens were recovered from Quaternary sediments in LP (McGlue *et al.* 2013).

**Remarks.** The valves from LP have a well-defined reticulation. They appear similar to Whatley & Cholich's (1974) types of *L. multiperforata*. The specimens described here differ from *L. multiperforata* in the large size, the more acuminate posterior margin and the absence of pore canal clusters and reticulate surface. Juveniles are subtrapezoidal in side view with a sharply acuminate postero-dorsal margin.

### The Charophyta

Calcareous algae are represented by the gyrogonites of two species showing a relative variability, as documented in the next section.

Class **Charophyceae** Smith, 1938  
Order **Charales** Lindley, 1836  
Family **Characeae** Agardh, 1824

Genus *Chara* Linnaeus, 1753

**Type species.** *Chara vulgaris* Linnaeus, 1753.

*Chara filiformis* Hertzsch, 2007  
(Pl. 2, figs 16–17)

2007 *Chara filiformis* Hertzsch in Zviedre: 142.

**Material.** 45 gyrogonites.

**Description.** The oogonia of *Chara filiformis* are thin and elongated, solitary or geminate. Their height is greater than 0.750 mm, width 0.300–0.400 mm. *Chara filiformis* is characterized by 12–15 convolutions (Wood 1959).

**Dimensions.** Dimensions of specimens are given as largest polar axis (LPA) and largest equatorial diameter (LED): Gyrogonite, TNESR 0090: LPA 0.900 mm, LED 0.400 mm; MLP-Mi 1972, LP06-6A, 276.5–278.5 cm bgs. Gyrogonite (SEM), TNESR 0093: LPA 0.900 mm, LED 0.280 mm; ICMLO-2559, LP06-6A, 276.5–278.5 cm bgs.

**Occurrence.** *Chara vulgaris* occurs in the lower portion of core LP06-6A and very rarely in the modern sediment samples from LP.

**Remarks.** *Chara vulgaris* is a common form frequently associated with *C. filiformis*. The few specimens identified in this study appear to correspond to Wood's (1959) diagnosis according to the following dimensions. Our gyrogonites range in size from 0.700–0.900 mm in length (LPA median=0.860 mm) and 0.280–0.400 mm in width (LED; median=0.299 mm). Isopolarity index averaged 277 (225–320); circumvolutions ranged from 12 to 15 (median=13). Other characteristics as discussed by Wood (1959).

**Modern ecology and palaeobiogeography.** *Chara filiformis* shares the same type of environments identified for *C. vulgaris*. The species lives in alkaline waters with a pH between 7.5 and 10.5, it prefers high pH (9.5–10.5), Ca-rich, lotic or lentic waters; occasionally in spring seeps. It is intolerant of high nutrient conditions. The species thrives in permanent or ephemeral aquatic systems preferably during the late spring–summer, but may occur year-round. With a wide temperature range (5–25°C) its optimal temperature is 17–22°C. No records of *C. filiformis*, however, are available from South America. The specimens here identified may well be *C. vulgaris* var. *kirghisorum* forma *filiformis*.

*Chara vulgaris* Linnaeus, 1753  
(Pl. 2, figs 18–19)

1967 *Chara vulgaris* Linnaeus, 1753; Wood: 12–13, figs 1–9.

**Material.** 7 gyrogonites.

**Description.** The oogonia of *Chara vulgaris* are highly polymorphic, solitary or geminate. They range in height from 0.525 to 0.800 mm, width 0.335–0.525 mm. *Chara vulgaris* is characterized by 13–16 convolutions (Wood 1959).

**Dimensions.** Gyrogonite, TNESR 0100: LPA 0.750 mm, LED 0.400 mm; MLP-Mi 1973, LP06-6A, 117.5–119.5 cm bgs. Gyrogonite (SEM), TNESR 0101: LPA 0.550 mm, LED 0.430 mm; ICMLO-2560, LP06-6A, 241.5–243.5 cm bgs.

**Occurrence.** *Chara vulgaris* occurs in the lower portion of core LP06-6A in LP (LP06-6A c. 242.5–254.5 cm and at 361.5 cm).

**Remarks.** *Chara vulgaris* is a common form frequently associated with *C. filiformis*. The few specimens identified in this study appear

to correspond to Wood's (1959, 1967) diagnosis accordingly to the following dimensions. Our gyrogonites range in size from 0.550–0.750 mm in length (LPA, median=0.720 mm) and 0.400–0.550 mm in width (LED; median=0.430 mm). Isopolarity index averaged 175 (128–200); circumvolutions ranged from 13 to 16 (median=15). Other characteristics are discussed in Wood (1967).

**Modern ecology and palaeobiogeography.** The species lives in alkaline waters with a pH between 7.5 and 10.5, it prefers high pH (9.5–10.5), Ca-rich, lotic or lentic waters; occasionally in spring seeps. It is intolerant of high nutrient conditions. The species thrives in permanent or ephemeral aquatic systems preferably during the late spring–summer, but may occur year-round. With a wide temperature range (5–25°C), its optimal temperature is 17–22°C. Currently, the species has been identified living in hypo- to oligo-saline lakes (salinity 0–5000 mg l<sup>-1</sup> total dissolved solids; TDS) with a wide ionic composition at water depths not greater than 2 m (Romanov & Barinova 2012). The genus is known to prefer littoral conditions. In Argentina *Chara vulgaris* has been recorded in Lago Pellegrini, Embalse E. R. Mexia in the provinces of Río Negro and Neuquén (García 1994).

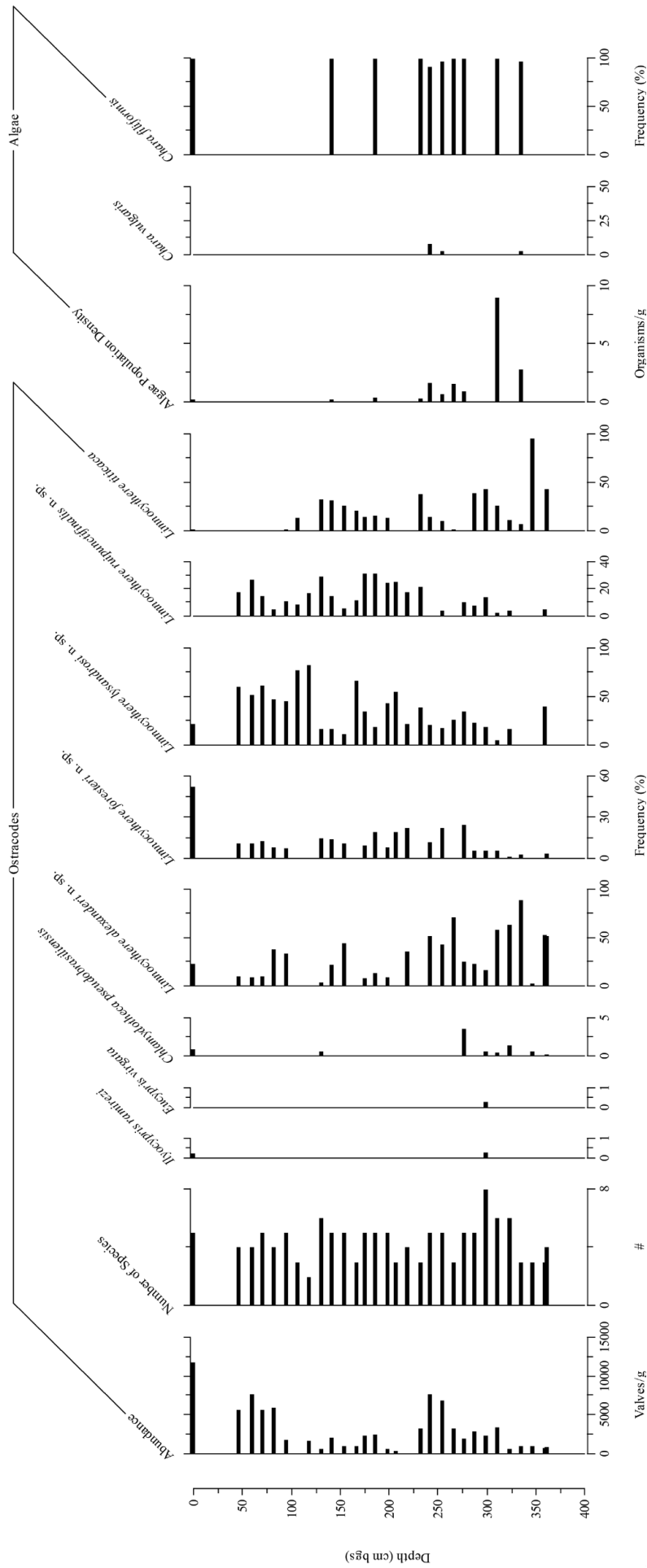
## Discussion

The stratigraphic and palaeoecological distribution of the species described in this paper will be discussed in detail in a future work by McGlue *et al.* The distribution of the Ostracoda and Charophyta in core LP06-6A are summarized here.

Figure 3 shows the relative stratigraphic distribution and abundance of ostracods and calcareous algae recovered from LP06-6A (McGlue *et al.* 2013). A total of eight ostracod and two calcareous algae species occur in LP. Diversity per sample ranges between two and eight species. From bottom to top, ostracods slowly increase in abundance to an abrupt decrease at about 225 cm bgs, then gradually the group re-establishes in the stratigraphic column reaching another maximum peak between about 80 cm bgs and 45 cm bgs. Calcareous algae followed a similar pattern, being more abundant in the lower portion of the core (below 225 cm bgs) than in its upper part. Two limnocytherids are the most common and abundant throughout the record, *L. lysandrosi* and *L. ruipunctifinalis*, closely followed by *L. alexanderi*, *L. foresteri* and *L. titicaca*. Amongst the cypridoideans, *C. pseudobrasiliensis* occurs more frequently near the base of the core but very seldom in its upper portion, whereas *L. ramirezi* occurs only twice at about 300 cm bgs and the modern playa-lake. A juvenile form of *E. virgata* (A-2) is recorded around 300 cm bgs at the only time when all species are present. The Characea, *C. filiformis* and *C. vulgaris*, occur more randomly in the stratigraphic column, with the former being more common and abundant than the latter.

*Limnocythere lysandrosi* appears to be the most tolerant of a variety of ecological conditions, as it occurs during the most extreme environments recorded in LP, as well as during milder settings. Similarly, *L. ruipunctifinalis* is present throughout most of core LP06-6A, although in lower concentrations than *L. lysandrosi*, thus sharing with this species an apparent tolerance of a high range of salinity.

*Limnocythere alexanderi* is more abundant in the lower portion of the core (below 225 cm bgs), decreasing and sometimes disappearing from the record in the upper portion. Above 225 cm bgs, *L. alexanderi* is characterized by low concentrations, implying the potential for some environmental restrictions. With respect to the other limnocytherids, *L. foresteri* is the less abundant, yet relatively common throughout the stratigraphic column. With the exception of the modern samples, the species represents less than 30% of the total population and it occasionally disappears from the record altogether. Calcareous algae, particularly *C. filiformis*, are more abundant at intervals where *L. alexanderi* is also more



**Fig. 3.** Distribution of ostracods and calcareous algae along core LP06-6A. Frequency is shown as percentage of species in the assemblage in each sample. The lowest available radiocarbon date is approximately 37.2 cal ka at 371.5 cm bgs (McGlue *et al.* 2013).

abundant; however, *C. filiformis* does not seem to be limited to co-existing with *L. alexanderi*. By contrast, *C. vulgaris* is extremely rare in the record but does not show a specific association with any ostracod species.

In spite of being fairly common, *L. titicaca* is the most vulnerable species to environmental change, as shown by the stratigraphic record and its distribution patterns. Dominant at the base of the core record where stratigraphic data indicate a permanent lake setting (McGlue *et al.* 2013), the species decreases in abundance and remains in low concentrations throughout two-thirds of the core. *Limnocythere titicaca* is last observed to occur in sediments horizons at approximately 100 cm bgs. No modern specimens of this ostracod are identified in LP. The species is associated with the three cypridoideans present in the basin, as well as all of the limnocytherids, implying attenuate salinity between 350 and 225 cm bgs. Fluctuations in simple species diversity throughout core LP06-6A seem to be in response to changes in pH and salinity, as well as desiccation of the basin, which is much more drastically in evidence above 40 cm bgs.

The biological record identified in LP includes a moderately diverse ostracod fauna but poorly diverse algal flora that fluctuate from relatively poor (22 specimens/sample) to very abundant (>450 specimens/sample), implying that the lake experienced periodic events of flooding and desiccation that, in consequence, affected the history of salinization of the basin. With few modern records of the species present in the core LP06-6A and three surface samples, we can only infer the possible trends in salinity through time. The faunal assemblage and periodic occurrence of calcareous algae, in concert with stratigraphic and geochemical data from other sediment cores, allow us to interpret that LP evolved from a relatively freshwater lake to saline lake and a wetland during the past 37.2 ka (McGlue *et al.* 2013). Calcareous algae suggest flowing waters at the time these organisms occurred in the lake. Like ostracods, the presence of charophytes indicates a variable environment ranging from oligohaline to mesohaline, which, as the group disappears, turns hypersaline.

It is likely that, at times, the inflowing rivers may have ceased during extreme arid periods, but our core records are not spatially extensive enough to resolve if LP ever fully dried out. If some deeper parts of the basin retained isolated, permanent water bodies, then this is potentially very interesting in terms of the development of individual ostracod lineages and the changes when the lake refilled and these water bodies were reunited.

## Conclusions

LP shows a rich and diverse biological record, both in the modern lake and the Quaternary record, which will permit us to reconstruct a high resolution environmental history in response to episodes of lake expansion and contraction of this piggyback basin in northwestern Argentina. The analysis of a core and three surface samples resulted in the identification of four new ostracod species and new records of previously described species and calcareous algae that will contribute to our understanding of Andean lakes. Future additional research in NOA is required to validate the extent of endemism in the Pozuelos Basin.

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*Scientific editing by Alan Lord*

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