ECOLOGY OF NON – MARINE OSTRACODA FROM LA FE RESERVOIR (EL RETIRO, ANTIOQUIA) AND THEIR POTENTIAL APPLICATION IN PALEOENVIRONMENTAL STUDIES

By

Andrea Torres Saldarriaga[1] , José Ignacio Martínez[1]

Abstract

Torres Saldarriaga, A., J. I. Martínez: Ecology of non – marine ostracoda from La Fe reservoir (El Retiro, Antioquia) and their potential application in paleoenvironmental studies**.** Rev. Acad. Col. Cienc. **34** (132): 397-409, 2010. ISSN 0370-3908.

Littoral macrophytes from the La Fe reservoir (El Retiro, Antioquia) were sampled for ostracoda during June and September of 2008. This allowed the identification of four genera and six species of ostracoda belonging to the Cyprididae and Candonidae families, where *Chlamydotheca* and *Cypridopsis* were found to be the dominant genera. *Chlamydotheca unispinosa* was the most abundant species in the assemblage. Furthermore, the environmental variables: temperature, electric conductivity, dissolved oxygen, and pH were also measured, in order to establish their relation to ostracoda taxa, using Canonical Correspondence Analysis (CCA). Results confirm the cosmopolitan character of *Cypridopsis vidua* and evidence the importance of plant substrate on the occurrence and distribution of the Cyprididae family. The possible application of the recorded ostracoda assemblage in paleoenvironmental interpretations is discussed.

Key words: La Fe reservoir, non – marine ostracoda, Neotropics, ostracoda ecology, environmental and paleoenvironmental indicators.

Resumen

El muestreo de las macrófitas asociadas a la zona litoral entre los meses de junio y septiembre de 2008 del embalse La Fe (El Retiro, Antioquia), permitió el reconocimiento de cuatro géneros y seis especies de ostrácodos no marinos pertenecientes a las familias Cyprididae y Candonidae, siendo *Chlamydotheca* y *Cypridopsis* los géneros dominantes en la asociación. *Chlamydotheca unispinosa* fue la especie con abundancia más alta en toda la asociación. Además, las variables ambientales temperatura, conductividad eléctrica, oxígeno disuelto y pH se midieron in situ para

1 Área Ciencias del Mar, Dpto. Geología, Universidad EAFIT. Crr. 49 No 7 sur 50, Medellín. Correo electrónico: atorress@eafit.edu.co

establecer su relación con la ocurrencia de las especies de ostrácodos a partir de un Análisis de Correspondencia Canónica (CCA). Con base en los resultados obtenidos se confirma el carácter cosmopolita de *Cypridopsis vidua* y la importancia del sustrato vegetal en la ocurrencia y distribución de la familia Cyprididae. Finalmente, se discute la posible aplicación de la asociación de ostrácodos encontrados en interpretaciones paleoambientales.

Palabras clave: Embalse La Fe, ostrácodos no marinos, Neotrópico, ecología de ostrácodos, indicadores ambientales y paleoambientales.

1. Introduction

Non– marine ostracoda are found in all continental environments, both lotic and lentic (e.g. **Holmes & Chivas**, 2002a). However, its distribution is limited to zoogeographical regions (Fig.1), being the Palaearctic (PA) the region with the highest number of genera and species occur when compared to the Neotropics (NT), which is one of the regions with the lowest diversity of ostracoda. This pattern is possibly biased by the incomplete exploration of many areas (**Martens *et al*.**, 2008). The strategic geographical location of northern South America and the high biological diversity product of a great variety of ecosystems and microclimates make Colombia a key region for paleoenvironmental and paleoclimate studies of a regional and global significance. Non – marine ostracoda have shown to be useful in paleoecological and ecological interpretations elsewhere in South America (e.g. **Wirrmann & Mourguiart**, 1995; **Mourguiart *et al.***, 1998; **Whatley & Cusminsky**, 1999, **Higuti**, 2006; **Laprida**, 2006), North America (**Curry**, 1999) and Europe (**Mezquita *et al.***, 1999a; **Mezquita *et al.***, 2005, **Kiss**, 2007). By comparison, studies of non-marine ostracoda in Colombia are scarce and are focused on taxonomic aspects (**Roessler**, 1985, 1986a, 1986b, 1990a and 1990b). This is why, little is known about ostracoda ecology and its possible applications to environmental studies. Therefore, this study intends to contribute to the knowledge of the non – marine neotropical ostracoda ecology at La Fe reservoir, and the relation of ostracoda assemblages with some measured environmental variables.

The ecology of other micro-organism groups, such as the thecamoebians (testaceous Rhizophods; **Escobar *et al.***, 2005a), and insect larvae (**Roldán & Ramírez**, 2008), have been studied in La Fe reservoir which make this water body a natural laboratory and a modern analogue for paleolimnological studies.

2. Artificial reservoirs: Habitat for non – marine ostracoda

One suitable environment for the establishment and diversification of non – marine ostracoda are reservoirs.

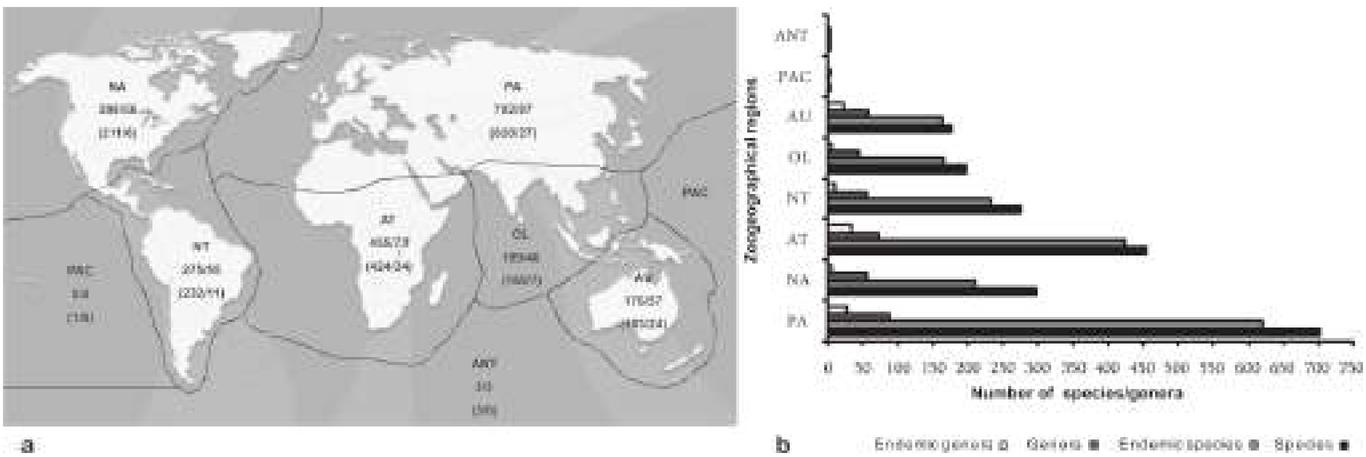

Figura 1. Non – marine ostracoda diversity in the world. a) Values indicate species and genera and in parentheses endemic species and genera. Zoogeographical regions: PA = Paleoarctic, NA = Neoarctic, AT = Afrotropical, NT = Neotropical, OL = Oriental, AU = Australasian, PAC = Pacific Oceanic Islands and ANT = Antarctic. Note that PAC and ANT regions apparently show the lowest diversity (modified from **Martens *et al.***, 2008). b) The largest number of endemic genera is shown in Australia (AU) and the Afrotropical region (AT), whereas the number of endemic species is generally high for all regions.

These environments, similarly to natural lakes, offer different environmental conditions that influence the occurrence and distribution of animals and plants. The environmental conditions of reservoirs are highly dependent on the physicochemical properties of rivers and streams that feed them, the surrounding geology, reservoir age, depth, area and use, among others (**Roldán & Ramírez**, 2008). Futhermore, their paleolimnological study provides the basis for their management (**Escobar *et al.***, 2005b).

The water body covered by this study is La Fe reservoir located in the municipality of El Retiro (southeastern Antioquia) at an approximate 2175 masl (Fig. 2). The catchment area overlies a series of metamorphic rocks and the Antioquia Batholith (**González**, 2001) and directly receives the water of Las Palmas stream in the north, and Potreros, La Miel and Espíritu Santo streams in the west.

3. Methods

Sampling of littoral macrophytes was performed during June, August and September of 2008. Sampling stations were located using a Garmin GPS, where rooted and floating vegetation was at the littoral zone of the reservoir and at streams mouths. Some macrophytes have a seasonal occurrence and in some cases are removed because of reservoir maintenance (e.g. *Egeria densa*). This explains the difference in the number of stations between sampling months.

Samples were collected with a 85 μm zooplankton mesh net and stored in plastic bags. Measurements of four environmental variables (temperature, pH, electric conductivity and dissolved oxygen) were taken in situ using a portable Metrhom 740 pH, Handylab LF1 conductivity and ICM 31520 oxygen meters. In the laboratory samples were washed with tap water using 355 and 63 ìm sieves. The retained material was examined under a stereomicroscope in 0.8 ml aliquots to extract the ostracoda and make the count of species. Samples were not fixed in the field to avoid changes in their valves, bleaching and softening. This was done in the laboratory using 70% ethanol. The identification of ostracoda was based on the internal and external characteristics of the valves and taxonomic keys (e.g. **Moore**, 1961; **van Morkhoven**, 1963; **Roessler**, 1985, 1986a, 1986b; **Laprida**, 2006; **Higuti**, 2006).

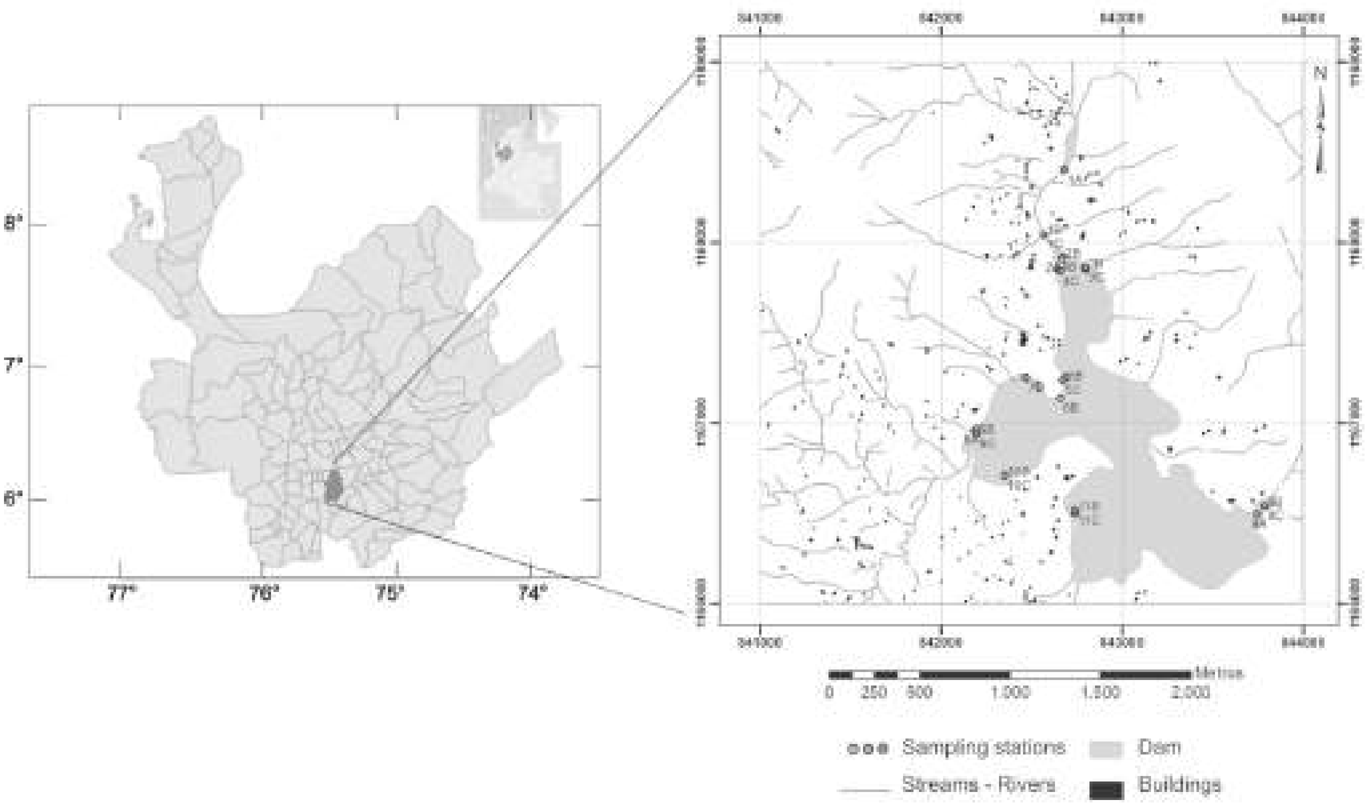

Figura 2. Location map of La Fe reservoir (Retiro, Antioquia). The inset shows sampling locations.

For the description and species identification, individual specimens of ostracoda were separated based on their morphology, and fixed again in 70% ethanol for 4 days to avoid valve disarticulation and to extract their soft parts. Slides of all specimens were prepared with glycerol and examined under a petrographic microscope for a detailed description.

Ostracoda count, their relative percentage abundances, and physicochemical data were submitted to Canonical Correspondence Analysis using MVSP (Multi-Variate Statistical Package) which allows relating the species composition with the environmental descriptors (**Legendre & Legendre**, 1998).

4. Results

4.1 Environmental variables

Electrical conductivity, pH, water temperature, and dissolved oxygen were the environmental variables measured in the mixed layer of the water column, i.e. between 0 and 50 cm. Electrical conductivity shows the lowest recorded values in June. Maximum values of 192.6 and 144.2 µS/cm were recorded at stations 1 and 9, close to the streams mouths in August, whereas maximum values of 167.0 and 128.4 µS/cm was recorded in September. In general, pH values recorded in La Fe reservoir were between 6.5 and 7.5 for all sampling months, and therefore within the range of pH reported by **Roldán & Ramírez** (2008) for Colombian reservoirs. 19.3°C was the lowest temperature recorded at station 1 in June, whereas 24.8°C and 24.4°C were the highest values measured at stations 10 and 11 in September. Dissolved oxygen values showed no significant spatial variations during the sampled months. 4.4 and 4.2 mg/l were the lower values of dissolved oxygen at stations 1 and 3, respectively, during the August sampling campaign.

4.2 Ostracoda diversity at La Fe reservoir

Four genera and six species of ostracoda, with the conspicuous dominance of *Chlamydotheca* and *Cypridopsis* genera, and *C. colombiensis*, *C. unispinosa* and *C. vidua* species (Plate I), were recorded during June and September of 2008. The remaining species, *Strandesia bicuspis* show high abundances, whereas *Candona* sp 1 and *Cypridopsis* sp 1 (Plate I) show low abundances in few stations.

Cypridopsis sp 1 represented 85.82% of the assemblages at station 1, whereas *C. vidua* was the most abundant species with a relative abundance of 91.92% at station 9 during June (Fig 3a). It is remarkable that *Cypridopsis* species were recorded with high abundance at stations close to the streams mouths. *Chlamydotheca unispinosa*, *S. bicuspis* and *C. vidua* were recorded in high abundances at stations 3, 4, 8 and 9, respectively, during August (Fig. 3b). *Strandesia bicuspis* was recorded for the first time in La Fe reservoir in August and the remaining species were recorded for single stations with low abundances.

On the other hand, *C. colombiensis*, *C. vidua* and *C. unispinosa* were the most abundant species at stations 4, 5 and 8, respectively, during September. The high abundance of *C. unispinosa* in all sampled stations is conspicuous, whereas *S. bicuspis* was recorded again at station 4 with a lower abundance than in August (Fig. 3c).

Favor insertar Fig.3 Aquí

Cypridopsis vidua showed an increasing abundance pattern in a N-S direction in all sampling months when compared to *C. unispinosa* and *C. colombiensis* which were recorded with variable abundance at all stations. *Candona* sp 1 occurred in few samples with low abundance which might be related to the sampling method used considering that *Candona* sp 1 is mostly a benthic species and sediment samples were not collected. Therefore, its occurrence in some samples might be accidental and due to sediment mixing by the dragging of the plankton net.

4.3 Distribution of plant species

Aquatic plants provide adequate resources for the development of a variety of macro-invertebrates. It includes all, floating, submerged or emergent vegetation that grow along the littoral area of rivers, lakes and reservoirs (**Roldán & Ramírez**, 2008). In La Fe reservoir the development of macrophytes during the sampled months were present mainly in the western margin of the reservoir. The plants found include *Egeria densa*, *Eichhornia crassipes*, *Nymphoides indica*, *Nymphaea caerulea* and some *Ludwigia* species. Although, there were no clear evidences to relate the occurrence of the ostracoda species with a specific macrophyte type, *Nymphaea caerulea* and *E. densa* were the only macrophyte taxa at station 4 where *S. bicuspis* was reported. Similarly, *E. crassipes* was the only macrophyte taxon at station 1, close to the Las Palmas stream mouth, where *Cypridopsis* sp 1 was the dominant species. *Ludwigia* macrophyte species were common at stations 3, 6 and 7, where *Chlamydotheca* and *Cypridopsis* genera were dominant. *Nymphoides indica* was characteristic at station 9 where *C. vidua* was recorded in high abundance.

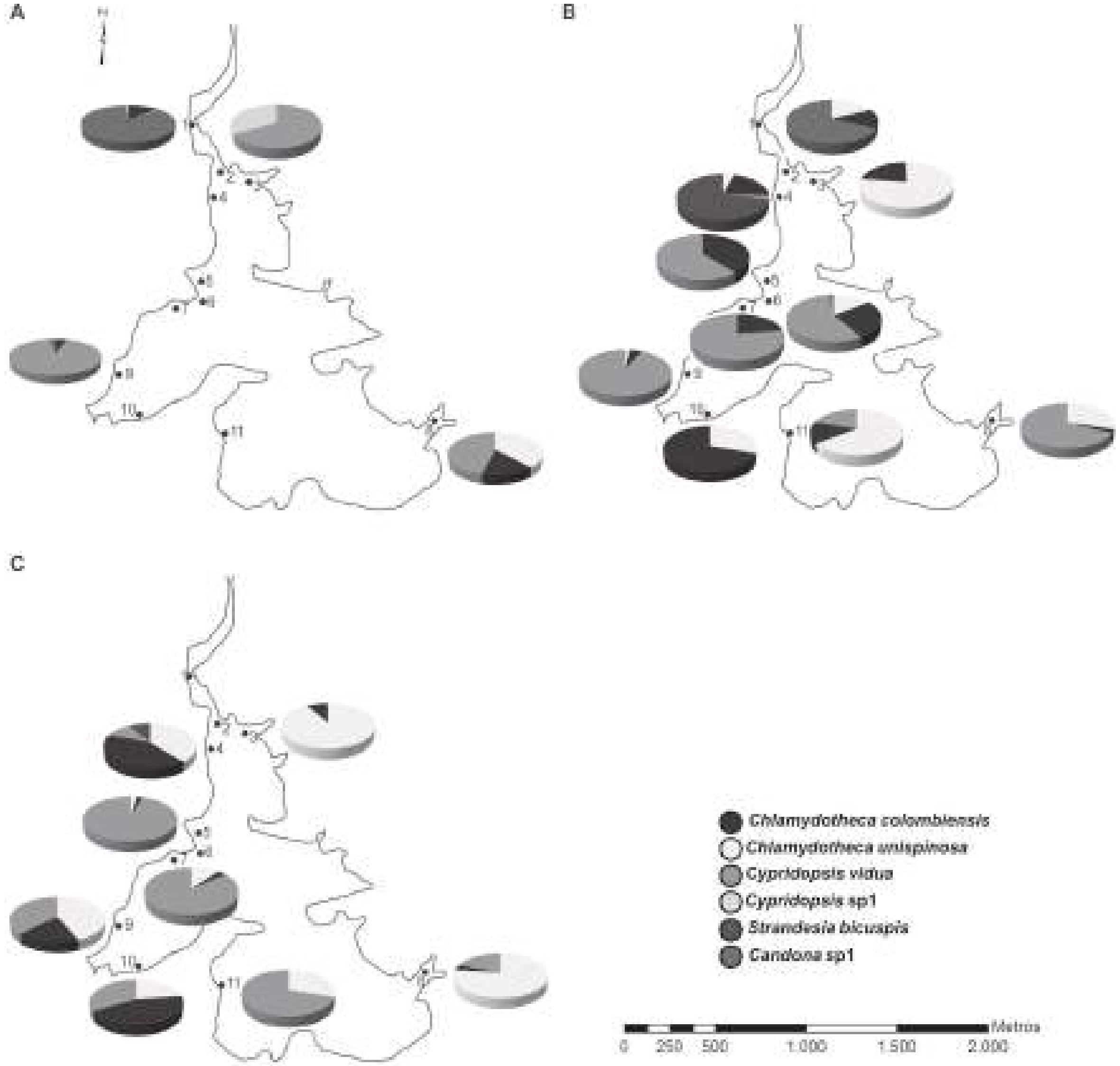

Figura 3. La Fe reservoir map showing the ostracoda distribution and relative percentage abundances at sampled stations in June (A), August (B) and September (C) of 2008. Note: a) the predominance of the *Cypridopsis* genus, b) the pattern distribution of *C. vidua* in direction N-S, and the first occurrence of *S. bicuspis* at station 4, c) the dominance of the *Chlamydotheca* genus.

4.4 Environmental preferences of ostracoda species from La Fe reservoir

Of the six species of ostracoda recorded in La Fe reservoir, *C. vidua* presented a constant occurrence during all sampled months. The highest diversity was recorded at station 4. The CCA diagram (Fig. 4), shows that all species occur close to the center, except for *Cypridopsis* sp 1, suggesting that all species have similar environmental preferences. The species – environment correlation was 0.87 for axis 1 and 0.50 for axis 2. In axis 1, the most important environmental variable in the species ordering is temperature with a – 0.90 canonical coefficient, whereas in axis 2 it is dissolved oxygen with a canonical coefficient of 0.83.

According to the CCA diagram, *C. unispinosa* is located in the center. Therefore, this species presents no apparent correlation with the measured variables. This might mean that *C. unispinosa* tolerates variations of the measured environmental variables along the sampling stations and, therefore, these variables do not explain its

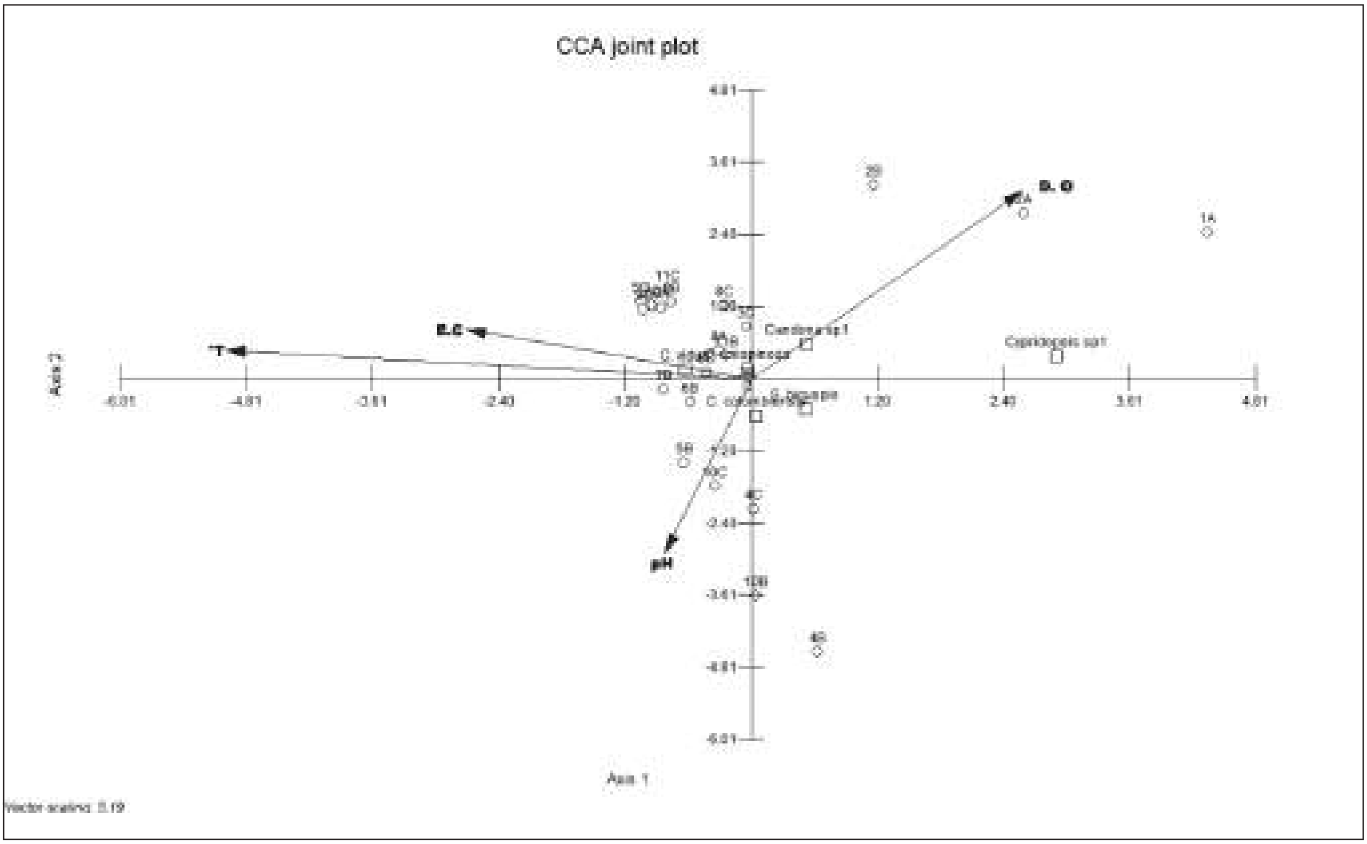

Figura 4. Canonical Correspondence (CCA) diagram showing the relation between the six ostracoda species and the four measured environmental variables (→ = environmental variables, ○ = stations, □ = species) in La Fe reservoir. D.O = dissolved oxygen, E.C = electrical conductivity, T = temperature.

occurrence. *Cypridopsis vidua* shows a positive correlation with electrical conductivity and water temperature which supports its characterization as a cosmopolitan species with a wide tolerance to these environmental conditions, i.e. occurring in a range of electrical conductivity between 14.7 and 167 µS/cm and temperature between 21.6 and 24.4°C (e.g. **Külköylüoðlu**, 2004; **Külköylüoðlu & Yilmaz**, 2006; **Dügel *et al.***, 2008). On the other hand, the occurrence of *Chlamydotheca colombiensis* seems to be influenced by pH (between 6.05 and 9.16) according to the CCA diagram. However, its distribution within the reservoir is no clear. *Strandesia bicuspis* shows a negative correlation with temperature and a positive correlation with dissolved oxygen and pH. *Cypridopsis* sp 1 shows a negative correlation with temperature and a positive correlation with dissolved oxygen. Finally, *Candona* sp 1 shows a positive correlation with dissolved oxygen. However, because of its epibenthic mode of life (**van Morkhoven**, 1963), it is possible that the environmental variables measured in the mixed layer do not explain its occurrence in La Fe reservoir.

5. Discussion

The ostracoda community recorded at La Fe reservoir is mainly represented by the Cyprididae family, with only one species of the Candonidae family.

The western littoral zone of the reservoir, where floating and submerged vegetation dominated during the sampling period, was characterized by four ostracoda species: *C. vidua*, *C. unispinosa*, *C. colombiensis* y *S. bicuspis*, whereas the eastern littoral zone, where submerged plants were common, was characterized by *C. unispinosa* and *C. vidua*. *Candona* sp 1 was recorded in the north of the reservoir in proximity to Las Palmas stream, associated to the sediment substrate in shallow water. *Cypridopsis* sp 1 was recorded at station 1, influenced by Las Palmas stream, so this species appears to be more characteristic of lotic than lentic environments, thus suggesting that it was carried by the Potreros or Espiritu Santo streams to the reservoir where it occurred in low abundance at station 9. In none of the stations where lacustrine conditions are dominant *Cypridopsis* sp 1 was recorded, so it is suggested that it is an "allocthonous" species.

The apparent correlation of the Cyprididae family with floating and submerged vegetation suggests that this type of substrate largely determines the ostracoda occurrence and distribution in La Fe reservoir. This relationship was also observed by **Wurdig & Freitas**, (1988), who found the same species of the Cyprididae family in the Emboada Lake (Rio Grande do Sul, Brazil) in close associating with plant substrate. Similarly, **Wurdig *et al***. (1990), and **Albertoni & Wurdig** (1996), based on the meso and macrofauna composition analysis of Lago de Gentil (Rio Grande do Sul, Brazil), suggest that aquatic vegetation provides optimal conditions for the establishment of ostracoda communities, i.e. for about 97.6% of the ostracoda assemblage.

Chlamydotheca unispinosa, the most abundant species that constitute 41.2% of the assemblage, showed no apparent correlation with the measured environmental variables. Therefore its occurrence might be related to the substrate type or to its ecological relationship within other ostracoda in the assemblage. In this sense, it is suggested that *C. unispinosa* percentage abundance decreases with the increase in abundance of other species (e.g. *C. vidua*) and vice versa. This pattern can also be attributed to the percentage abundance data which behaves like a closed statistical systems where variables are interdependent (e.g. **Woronow**, 1991; **Swan & Sandilands**, 1995; **Kucera & Malmgren**, 1998).

The second most important species in the reservoir, *C. vidua* which represents 29.8% of the total ostracoda assemblage, is considered cosmopolitan and shows a wide range of tolerance to different environmental variables (e.g. **Külköylüoðlu**, 2004; **Külköylüoðlu & Yilmaz**, 2006; **Yilmaz & Külköylüoðlu**, 2006; **Laprida**, 2006; **Karan - •nidaršiè & Petrov**, 2007; **Külköylüoðlu *et al.***, 2007; **Dügel *et al.***, 2008). An interpretation also noted in our CCA results, i.e a positive correlation with temperature and electrical conductivity. Although *C. vidua* showed a wide distribution within the reservoir, its highest abundance was found in samples taken at stations close to the streams mouths (mainly the Espiritu Santo stream). This species has a close dependence to plant substrate (**Wurdig & Freitas**, 1988; **Wurdig *et al.***, 1990; **Yozzo & Steineck**, 1994; **Karan - •nidaršiè & Petrov**, 2007). However, it does not appear to have a preference for a macrophyte type, because it was found living associated to floating and submerged plants indistinctly. Its preference for macrophytes might be due to its small size (~ 0.6 mm), and the protection from predators offered by plants. Also, its wide distribution may be related to its highly nektonic character because this species has longer natatory setae (**Wurdig *et al.***, 1990; **Hunt *et al.***, 2007), which facilitate its displacement between different habitats.

According to results obtained by the CCA diagram, *S. bicuspis* occurs in high abundances when the pH is slightly acid to neutral, temperatures are low and within the range recorded in La Fe reservoir, and conductivities are lower than 60 ìS/cm, thus suggesting that its range of tolerance is very narrow. Although, there is no clear evidence of the influence of the biotic variables in the ostracoda community, it is suggested that *S. bicuspis* percentage abundance might be high when the abundance of the other species of *Chlamydotheca* genus and *C. vidua* decrease. As pointed out before, this might also be an artifact of the percentage abundance data, i.e. a closed statistical system (e.g. **Woronow**, 1991; **Swan & Sandilands**, 1995; **Kucera & Malmgren**, 1998).

During the September sampling period, an increase in the percentage abundance of *C. colombiensis* and *C. unispinosa* was observed. Both species were found in the developed juvenile stage (~ 4 y 3 mm) at station 4, where macrophytes characterized by a greatest leaf area and density as *N. caerulea* and *E. densa* were dominant. These macrophyte types might be preferred by large species of ostracoda as a place of incubation because plants offer protection against predators and food resources (**Ramírez**, 1967; **Würdig *et al.***, 1990; **Albertoni & Würdig**, 1996; **Higuti**, 2006; **Laprida**, 2006; **Kiss**, 2007).

5.1. Paleoecological application of La Fe reservoir ostracoda assemblage

Due to its calcareous nature only the ostracoda carapace is normally preserved in the sedimentary record. Therefore, its taxonomic identification in the paleontological record can be complex sometimes. Nonetheless the biological aspects of ostracoda are important in Quaternary paleoenvironment interpretations (e.g. **De Deckker**, 2002).

In the ostracoda assemblage found in La Fe reservoir, the *Chlamydotheca* genus dominates. Roessler (1985, 1986a, 1986b) recorded seven species and four subspecies of the *Chlamydotheca* genus from lentic environments in Colombia. *Chlamydotheca* genus characterized by its morphological diversity and larger size (between 3 and 4.6 mm) is amenable of taxonomic determinations in fossil specimens. Like *Chlamydotheca*, the *Strandesia* genus is restricted to lacustrine environments. **Roessler** (1990a, 1990b) recorded a high diversity of *Strandesia* species in

Colombia, which he found exclusively in temporary and permanent lentic environments. By contrast, the *Cypridopsis* genus shows a wide distribution within non – marine aquatic environments (**Mourguiart & Montenegro**, 2002). In La Fe reservoir two different species of *Cypridopsis* were recorded with similar morphological shell features, which could make difficult the specific identification of microfossils if soft parts are not preserved.

In La Fe reservoir the ostracoda community found has a low diversity, thus limiting the interpretation in terms of ecological tolerance. However, ostracoda morphology, moulting, evidence of carapace dissolution, and change in faunal composition can be indicative of salinity, temperature, nutrients level variation, water level change, and sedimentation rates (**De Deckker**, 2002). For these reasons, knowledge of living ostracoda ecology is basic for the assessment of fossil ostracoda assemblages preserved in sediments. This knowledge, when combined with ostracoda valve chemistry (e.g. Mg/Ca, Sr/Ca), leads to more precise paleoenvironmental interpretations (e.g. **Holmes & Chivas**, 2002b; **Ito**, 2002).

Because, fossil ostracoda assemblages recorded in this study characterize lentic conditions and occurs in shallow, warm to temperate and relatively oxygenated water characterized by frequent level variations associated to the littoral zone and high plant coverage, Holocene sedimentary lacustrine successions are potential targets for paleolimnological reconstruction based on them. This, however, would be only possible in alkaline environments and/or during sedimentary diagenesis. Otherwise, ostracoda shells would be dissolved.

6. Conclusions

From the study of the ostracoda assemblage ecology of La Fe reservoir it is concluded that:

1. A low diversity of ostracoda occurred during all sampled months and was represented by *Chlamydotheca*, *Cypridopsis*, *Strandesia* and *Candona* genera. Being *Chlamydotheca unispinosa* the most abundant species (41.3% of the assemblage).

2. *Chlamydotheca unispinosa* distribution within the reservoir might depend on its ecological relations with other ostracoda species and/or its preference to dense plant substrates which would offer protection and food to reproduction and development.

3. *Cypridopsis vidua* was the only species that showed a clear pattern of spatial distribution in a north – south direction, thus confirming its wide tolerance to environmental variable changes according to its cosmopolitan character and high swimming ability.

4. Apparently, electrical conductivity and the abundance increase of *C. unispinosa* and *C. vidua* were the cause of the significant decrease of *S. bicuspis* through the August and September sampling campaigns.

5. *Cypridopsis* sp 1, occurred in high percentage abundance at station 1, located on Las Palmas stream. This suggests that *Cypridopsis* sp 1 is an “allocthonous” species whose eventual occurrence in lacustrine samples might be due to stream transport.

6. Even though, it is necessary more detail study to link the occurrence of ostracoda species to specific macrophyte type, there is a close dependence of the ostracoda to aquatic plant substrate.

7. Our study contributes to the knowledge of the diversity and ecology of ostracoda in the Neotropics and demonstrates the potential of its use in paleolimnological reconstruction of the Holocene.

7. Acknowledgments

We thank Professor Gladys Bernal at the Universidad Nacional de Colombia (Medellín) and Dr. Jaime Escobar (University of Florida) for their comments and suggestions, which helped to improve this work. Dr. Inés César at the Universidad de La Plata provided valuable literature and suggestions for samples preparation, whereas Dr. Carlos Jaramillo (Smithsonian Tropical Research Institute) provided the electron microscope photographs, Universidad EAFIT, Geology Department, helped with the laboratory and transport, and EPM (Empresas Públicas de Medellín) allowed and helped with the reservoir sampling.

8. References

Albertoni, EF., Würdig, NL. 1996. Comunidade de ostracodes associada à macrófitas aquáticas na Lagoa do Gentil Tramandaí, RS. Acta Limnol. Brasil 8: 103-114.

Curry, BB. 1999. An environmental tolerance index for ostracods as indicators of physical and chemical factors in aquatic habitats. Palaeogeogr. Palaeoclimatol. Palaeoecol. 148: 51-53.

De Deckker, P. 2002. Ostracod Paleoecology. In: The Ostracoda: Applications in Quaternary Research. Geophysical Monograph (eds. Holmes, J.A & Chivas, A.R), Washington. 121-134.

Dügel, M., Külköylüoðlu, O., Kilic, M. 2008. Species assemblages and habitat preferences of Ostracoda (Crustacea) in Lake Abant (Bolu, Turkey). Bel. J. Zool. **138**(1): 50-59.

Escobar, J., Martínez, JI., Parra, LN. 2005a. Thecamoebians (Testaceous Rhizopods) from a tropical lake: La Fe reservoir, Antioquia, Colombia. Caldasia **27**(2): 293-298.

Escobar, J., Restrepo, JC., Martínez, JI. 2005b. La paleolimnología como herramienta para el estudio y manejo de embalses. Gestión y Ambiente **8**(2): 51-59.

Ferguson, E. Jr. 1964**.** Freshwater Ostracods From Florida with a Description of *Cypris floridensis* n. sp. American Midland Naturalist. **72**(1): 129-132.

González, H. 2001. Memoria explicativa Mapa Geológico del Departamento de Antioquia. Ingeominas, Bogotá. 240 p.

Holmes, JA., Chivas, AR. (eds.) 2002a. The Ostracoda: Applications in Quaternary Research. Geophysical Monograph, Washington. 1-4.

______. 2002b. Ostracod shell chemistry – overview. In: Holmes, J.A & Chivas, A.R. (eds.). The Ostracoda: Applications in Quaternary Research. Geophysical Monograph. Washington. 185-204.

Higuti, **J.** 2006. Fatores reguladores da biodiversidade de ostracoda (Crustacea) no vale aluvial do Alto Rio Paraná. Doctoral Thesis. Universidade Estadual de Maringá, Brazil. 73 p.

Hunt, G., Park, L.E., Labarbera, M. 2007. A novel Crustacea Swimming Stroke Coordinated Four-Paddled Locomotion in the Cypridoidean Ostracode *Cypridopsis vidua* (Müller). Biol. Bull. 212: 67-73.

Ito, E. 2002. Mg/Ca, Sr/Ca, ä^{18}O and ä^{13}C Chemistry Lacustrine Ostracode Shells From the North American Continental Interior. In: Holmes, J.A & Chivas, A.R (eds.). The Ostracoda: Aplications in Quaternary Research. Geophysical Monograph. Washington. 267-278.

Karan-•nidaršiè, T., Petrov, B. 2007. Non- marine Ostracoda (Crustacea) of Banat district in Serbia. Hydrobiologia 585: 57-66.

Kesling, RV., Crafts, FC. 1962. Ontogenetic Increase in Archimedian Weigth of the Ostracod Chlamydotheca unispinosa (Baird). The American Midland Naturalist **68**(1): 149-153.

Kiss, A. 2007. Factors affecting spatial and temporal distribution of Ostracoda assemblages in different macrophyte habitats of a shallow lake (Lake Fehér, Hungary). Hydrobiologia 585: 89-98.

Külköylüoðlu, O. 2004. On the usage of ostracods (Crustacea) as bioindicator species in different aquatic habitats in the Bolu region, Turkey. Ecological Indicators 4: 139-147.

______**, Yilmaz, F.** 2006. Ecological requirements of Ostracoda (Crustacea) in three types of springs in Turkey. Limnologica 36: 172-180.

______**, Dügel, M., Kilic, M.** 2007. Ecological requirements of Ostracoda (Crustacea) in heavily polluted shallow lake, Lake Yeniçaða (Bolu, Turkey). Hydrobiologia (585): 119-133.

Kucera, M., **Malmgren, BA.** 1998. Logration transformation of compositional data – a resolution of the constant sum constraint. Marine Micropaleontology 34: 117-120.

Laprida, C. 2006. Ostrácodos recientes de la llanura pampeana, Buenos Aires, Argentina: ecología e implicancias paleolimnológicas. Ameghiniana **43**(1): 181-204.

Legendre, P., Legendre, L. 1998. Numerical Ecology. Second Edition. Elsevier Publishing. Amsterdam. 836 p.

Martens, K., Schon, I., Meisch, C., Horne, DJ. 2008. Global diversity of ostracod (Ostracoda, Crustacea) in freshwater. Hydrobiologia 595: 185-193.

Meisch, C., Mary-Sasal, N., Colin, JP., Wouters, K. 2007. Freshwater Ostracoda (Crustacea) collected from the islands of Futuna and Wallis, Pacific Ocean, with a checklist of the non-marine Ostracoda of the Pacific Islands. Bull. Soc. Nat. Luxemb. 108: 89-103.

Mezquita, F., Tapia, G., Roca, JR. 1999a. Ostracoda from the Springs on the Eastern Iberian Peninsula: ecology, biogeography and palaeolimnological implications. Palaeogeogr. Palaeoclimatol. Palaeoecol. 148: 65-85.

______**, Roca, JR., Reed, JM., Wansard, G.** 2005. Quantifying species – environment relationships in non-marine Ostracoda for ecological and palaeoecological studies: Examples using Iberian data. Palaeogeogr. Palaeoclimatol. Palaeoecol. 225: 93-117.

Moore, R.C. 1961. Treatise on Invertebrate Paleontology. Geological Society of America & University of Kansas, p Q442.

Mourguiart, PH., Montenegro, ME. 2002. Climate Changes in the Lake Titicaca Area: Evidence From Ostracod Ecology. In: Holmes, J.A & Chivas, A.R (eds). The Ostracoda: Applications in Quaternary Research. Geophysical Monograph. Washington. 151-165 p.

______**, Corrège, T., Wirrmann, D., Argollo, J., Montenegro, ME., Pourchet, M., Carbonel, P.** 1998. Holocene paleohydrology of Lake Titicaca estimated from an ostracod-based transfer function. Palaeogeogr. Palaeoclimatol. Palaeoecol. 143: 51-72.

Ramírez, FC. 1967. Ostrácodos de las Lagunas de la Provincia de Buenos Aires. Revista del Museo de la Plata, Sección Zoología 73: 5-54.

Roldán, G., Ramírez, JJ. 2008. Fundamentos de limnología Neotropical. Second Edition Universidad de Antioquia, Universidad Católica de Oriente, Accefyn. 421 p.

Roessler, EW. 1985. Estudios taxonómicos, ontogénicos, ecológicos y etológicos sobre ostrácodos de agua dulce en Colombia. V- Estudio taxonómico del género *Chlamydotheca* Saussure 1858, (Ostracoda, Podocopida, Cyprididae). Parte I. Aspectos morfológicos de una nueva especie colombiana del género *Chlamydotheca*. Caldasia 67: 329-354.

______. 1986a. Estudios taxonómicos, ontogénicos, ecológicos y etológicos sobre ostrácodos de agua dulce en Colombia. V- Estudio taxonómico del género *Chlamydotheca* Saussure 1858, (Ostracoda, Podocopida, Cyprididae). Parte II. El grupo *Chlamydotheca colombiensis* Roessler , 1985. Caldasia 68-70: 585-615.

______. 1986b. Estudios taxonómicos, ontogénicos, ecológicos y etológicos sobre ostrácodos de agua dulce en Colombia. V-

Estudio taxonómico del género Chlamydotheca Saussure 1858, (Ostracoda, Podocopida, Cyprididae). Parte III. El grupo *Chlamydotheca Iheringi* (Sars, 1901). Caldasia 68-70: 617-650.

______. 1990a. Estudios sobre los ostrácodos de agua dulce en Colombia. VI-IV Estudio taxonómico del grupo "*Strandesia Psittacea Psittacea* (Sars, 1901)". Caldasia 77: 215-229.

______. 1990b. Estudios taxonómicos, ontogénicos, ecológicos y etológicos sobre ostrácodos de agua dulce en Colombia (Ostracoda, Podocopida, Cyprididae). VI. Estudios taxonómico del género "*Strandesia* Stuhlmann 1888. Parte III. El grupo *Strandesia Elliptica* (Sars 1901)". Revista de la Academia Colombiana de Ciencias Exactas, Físicas y Naturales **17**(67): 795-804.

Swan, ARH., Sandilands, M. 1995. Introduction to Geological Data Analysis. Blackwell Science. 446 pp.

van Morkhoven, FP. 1963. Post – Paleozoic Ostracoda: Their Morphology, Taxonomy and Economic Use, Generic Descriptions. Elsevier Publishing, Amsterdam. Vol II, 478 p.

Whatley, RC., Cusminsky, GC. 1999. Lacustrine Ostracoda and Late Quaternary palaeoenvironments from the Lake Cari-Laufquen region, Rio Negro province, Argentina. Palaeogeogr. Palaeoclimatol. Palaeoecol. 151: 229-239.

Wirrmann, D., Mourguiart, P. 1995. Late Quaternary Spatio-temporal Limnological Variations in the Altiplano of Bolivia and Peru. Quaternary Research 43: 344-354.

Woronow, A. 1991. Enigmas and Solutions in the Analyses of Compositional Data. Journal of Geological Education 39: 299-302.

Würdig, NL., Freitas, SF. 1988. Distribuçâo espacial e temporal da comunidade de ostrácodes na Lagoa Emboada, Rio Grande do Sul, Brasil. Acta Limnol. Brasil 2: 677-700.

______, Freitas, SF., Fausto, I. 1990. Comunidade de ostracodes asscociada ao bentos e macrófitas aquáticas de Lagoa do Gentil, Tramandaí, Rio Grande do Sul. Acta Limnol. Brasil 3: 807-828.

Yilmaz, F., Külköylüoðlu, O. 2006. Tolerance, optimum ranges, and ecological requirements of freshwater Ostracoda (Crustacea) in Lake Aladað (Bolu, Turkey). Ecol Res. 21: 165-173.

Yozzo, DJ., Steineck, PL. 1994. Ostracoda From Tidal Freshwater Wetlands at Stockport, Hudson River Estuary: Abundance, Distribution, and Composition. Estuaries 17 (3): 680-684.

Recibido: junio 21 de 2010.

Aceptado para su publicación: septiembre 14 de 2010.

9. Taxonomic notes

Philum: Crustacea Pennant, 1777

Class: Ostracoda Latreille, 1806

Subclass: Podocopa G. W Müller, 1894

Order: Podocopida Sars, 1866

Superfamily: Cypridoidea Baird, 1845

Family: Cyprididae Baird, 1845

Genus: *Chlamydotheca* Saussure, 1858

Chlamydotheca colombiensis Roessler, 1985

Geographical distribution: *Chlamydotheca colombiensis* was described by **Roessler** (1985) as a common species from the Colombian lowlands, especially in the Cauca and Magdalena valleys. In this work *C. colombiensis* is recorded for the first time in the Andean forest belt (~2175 masl). This species was recorded by **Higuti** (2006) in the Paraná River floodplain.

Description: Large adult specimen with unequal valves, anterior end pointed and posterior end rounded. The right valve overlaps the left valve at the anterior end (rv / lv). The side view of the right valve shows a crescent-shaped outline, whereas the side view of the left valve shows an oval outline. The marginal area is extensively developed (vestibulum), in both anterior and posterior ends, and is characterized by straight pores canals. The carapace is perforated by numerous pores which appear as simple points and which are associated to sensory hairs or short sensillas. The marginal, posterior ventral area of the right valve is characterized by well developed long sensillas. The carapace is smooth with a yellow background color and dark green cross-bands. Size: rv = 3.2 mm, lv = 3.05 mm. Height: rv = 1.65 mm, lv = 1.7 mm. (Plate II)

Chlamydotheca unispinosa Baird, 1862

Geographical distribution: *C. unispinosa* is one of the largest non-marine species (**Kesling & Crafts**, 1962). Similarly to *C. colombiensis*, this species is found in the Colombian lowlands (Cauca river valley; **Roessler**, 1986b). Specimens of this species have also been recorded in Brazil (**van Morkhoven**, 1963), Jamaica, North America, Mexico (**Ferguson**, 1964) and Hawaii (**Meisch *et al.***, 2007).

Description: *C. unispinosa* is a large size species, with an elongated and flattened carapace compared to other species of the genus. The carapace is more pointed at the anterior than at the posterior end, and the maximum height is in the posterior part behind the center. The right valve is slightly longer than the left one (rv/lv), because the former has a posteroventral spine that extends over the caudal edge of the carapace, and has numerous sensillas, as small spines around the posterior margin. Both valves have large tubercles on the postero-ventral part. The secondary marginal zone is poorly developed in the anterior part of both valves. Like *C. colombiensis*, the *C. unispinosa* carapace is smooth with numerous simple pores associated to short sensillas. The anterior and posterior margins are covered by sensillas. The background color of the carapace is light yellow with light green irregular bands. Size: rv = 4.6 mm, lv = 4.4 mm. Height: rv = 2.2 mm, lv = 2.2 mm. (Plate II)

Genus: *Cypridopsis* Brady, 1867

Cypridopsis vidua O.F Muller, 1776

Description: Adult specimen with an oval carapace with the anterior end narrower than the posterior one. Both ends are rounded. The dorsal margin arched with the maximum height slightly behind the midline. The ventral margin is sinuous. Both valves are slightly reticulated and covered with many sensillas. The vestibulum is developed in both valves. Though the carapace is yellow with black bands it may vary slightly under varying environmental conditions (**Barclay**, 1968). Size: rv= 0.65 mm, lv = 0.65 mm. Height: rv = 0.41 mm, lv = 0.43 mm (Plate II)

Cypridopsis sp 1

Description: Adult specimens of *Cypridopsis* sp 1 have an oval carapace with anterior and posterior ends which are rounded. The dorsal margin is arched with the maximum height approximately at the midline, whereas the ventral margin is sinuous. There is a well developed vestibulum at the anterior end of both valves. The carapace is smooth with many simple pores and is covered by short sensillas. The carapace is yellow in color with irregular light green bands. It differs from *C. vidua* because of its smaller size, less arched dorsal margin and less pointed anterior and posterior ends. It also has a less developed vestibulum, smooth shell with little predominant sensillas, and different color carapace. Size: rv = 0.62 mm, lv = 0.62 mm. Height: rv = 0.35 mm, lv = 0.37 mm. (Plate II)

Genus: *Strandesia* Stuhlmann, 1888

Strandesia bicuspis Claus, 1892

Geographical distribution: *Strandesia bicuspis* has been recorded in the floodplain of the Paraná River (**Higuti**, 2006).

Description: Adult specimens of *S. bicuspis* have an elongated carapace with rounded anterior and posterior ends. The right valve is larger than the left one. It has a well developed dorsal spine that arises from the antero-dorsal part of the valve, whereas the ventral margin of both valves is straight Vestibulum (secondary marginal zones) are present in the anterior and posterior ends of both valves. Short sensillas extend over all the ventral edge of both valves and are associated to inflated or bulbous pore canals. The carapace is light yellow in color with light green spots. Size: rv = 2.3 mm, lv = 2.2 mm. Height: rv = 1.3 mm, lv = 1.1 mm. (Plate II)

Family Candonidae

Genus: *Candona* Baird, 1845

Candona sp 1

Description: Adult specimen of *Candona* sp 1 are medium size, have a narrow anterior end and a wide posterior one. In lateral view the carapace has a bean shape. The caudal process in the postero-dorsal part of the carapace ends at an obtuse angle creating a kind of hump. The carapace is smooth, shiny and has small punctuated pores. The marginal zone is very narrow because pore canals are not easily visible. The vestibulum is well developed in the anterior end and is narrow in the posterior one. The ventral margin shows a conspicuous sinuosity. The carapace is translucent and shows a rosette pattern of muscle scars whose shape is different to the Cyprididae family. Size: rv = 1.25 mm, lv = 1.26 mm. Height: rv = 0.66 mm, lv = 0.8 mm. (Plate II)

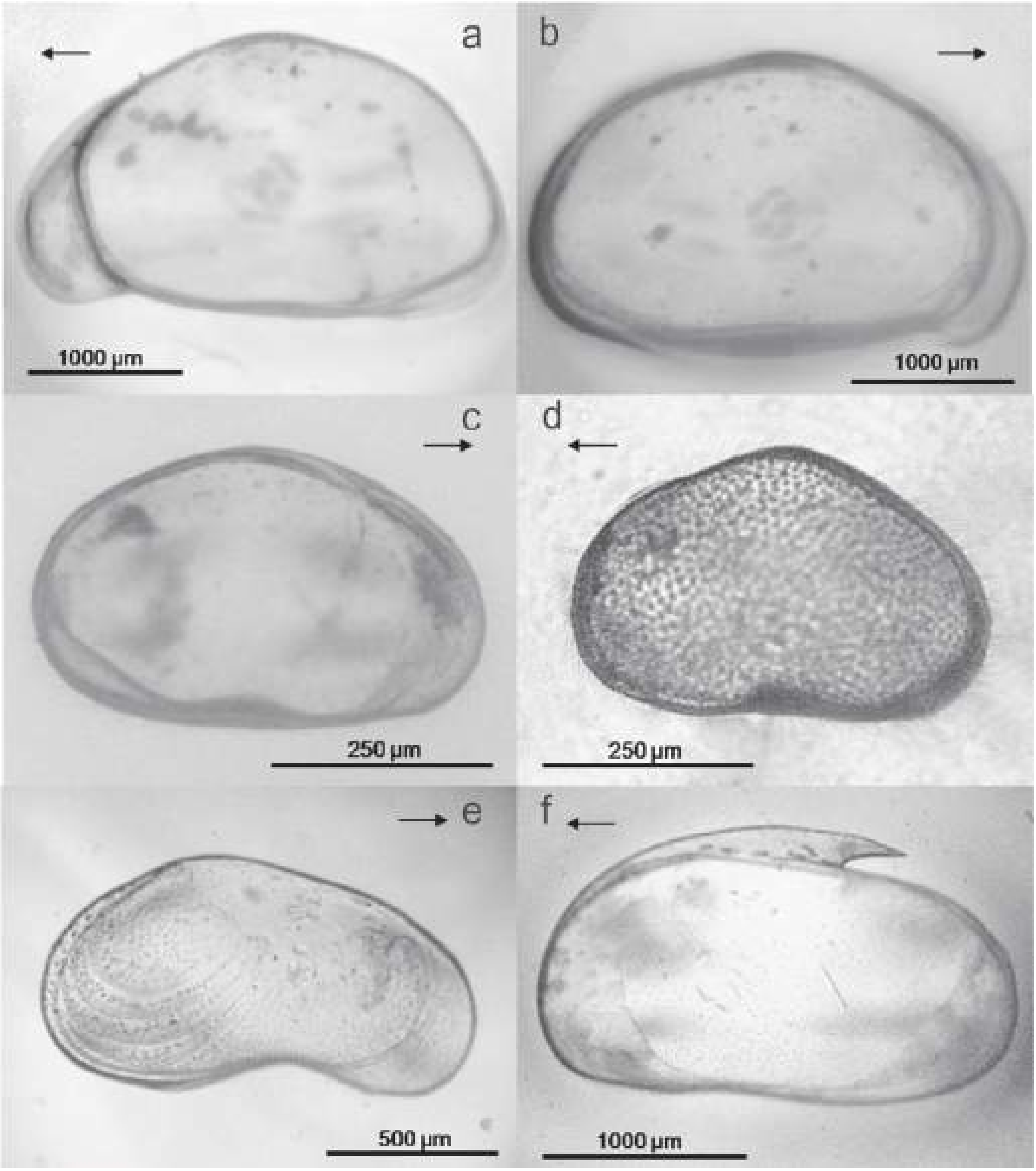

Plate I. Petrographic microscope photographs, a) *Chlamydotheca colombiensis* lv/intv, b) *Chlamydotheca colombiensis* rv/intv, c) *Cypridopsis* sp 1 lv/intv, d) *Cypridopsis vidua* rv/intv, e) *Candona* sp1 lv/intv, f) *Strandesia bicuspis* rv/intv. lv = left valve, rv = right valve, intv = internal view. Arrows indicate the anterior part.

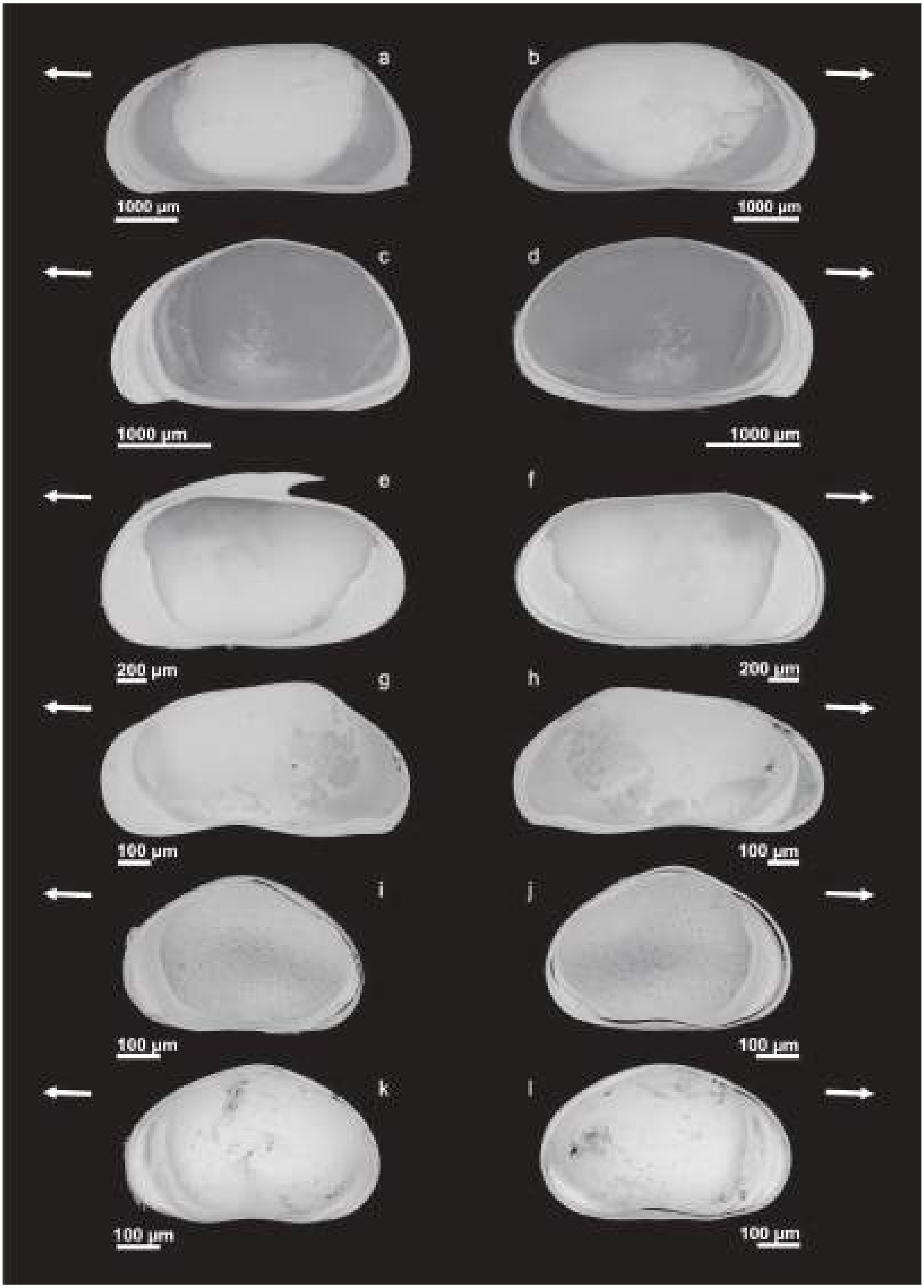

Plate II. Electron microscope photographs, a) C*hlamydotheca. unispinosa* rv/intv, b) *Chlamydotheca unispinosa* lv/intv, c) *Chlamydotheca colombiensis* rv/intv, d) *Chlamydotheca colombiensis* lv/intv, e) *Strandesia bicuspis* rv/intv, f) *Strandesia bicuspis* lv/intv, g) *Candona* sp1 rv/intv, h) *Candona* sp1 lv/intv, i) *Cypridopsis vidua* rv/intv, j) *Cypridopsis vidua* lv/intv, k) *Cypridopsis* sp1 rv/intv, l) *Cypridopsis* sp1 lv/intv . rv = right valve, lv = left valve, intv = internal view. Arrows indicate the anterior part.