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PROVINCIALITY OF OSTRACODA (CRUSTACEA) IN THE NORTHEASTERN AND EASTERN BRAZILIAN SHELVES BASED ON NEONTOLOGICAL AND PALEONTOLOGICAL ANALYSES

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ABSTRACT– This study analyzes the geographical distribution of 131 podocopid ostracod species recovered from the Brazilian continental shelf between Cabo de São Roque (lat. 05°30’S) and Cabo Frio (lat. 23ºS). This very large area corresponds to the northeastern and eastern Brazilian marine regions. The 104 samples studied were collected in water depths ranging from 12 to 110 m as part of the legs 4 and 7 of the REMAC Project. The cosmopolitan species, as well as those shared with the Caribbean and/or Gulf of Mexico region, represent a small part of the ostracods herein studied and it is assumed that their dispersion was prompted by processes linked to events of relative sea level changes during the Neogene and Quaternary. The fossil record of some species spans to the Neogene, mostly from the Atlantic coast of North and Central America, while one species has Tethyan origin. Three species known from the Neogene of the Caribbean have been recorded as relicts in the study area. From the 131 species herein identified, 36.5% are more widespread in temperate waters south of Cabo Frio town, 46.5% of warm waters north of Cabo Frio town, 4% are present only in the studied area, and 11.5% are rare and probably restricted to the E region. A new province – the Brazilian Province – is herein proposed based on the species occurrence.

Keywords: South Atlantic, biodiversity, Podocopida, neritic zone.

RESUMO – Este trabalho analisa a distribuição geográfica de 131 espécies de ostracodes podocopídeos registradas na plataforma continental brasileira entre o Cabo de São Roque (lat. 05°30’S) e Cabo Frio (lat. 23ºS), uma imensa área correspondente às regiões marinhas nordeste e leste. As 104 amostras estudadas foram coletadas em profundidades de 12 a 110 m como parte das expedições números 4 e 7 do Projeto REMAC. As espécies cosmopolitas, assim como as compartilhadas com a região do Caribe e/ou Golfo do México, representam uma pequena parte dos ostracodes aqui analisados, e supõe-se que sua dispersão foi influenciada por processos ligados a eventos de mudanças relativas do nível do mar durante o Neógeno e o Quaternário.O registro fóssil de algumas espécies se estende ao Neógeno, principalmente da costa atlântica das Américas do Norte e Central, enquanto uma espécie tem origem no Mar de Tétis. Três espécies conhecidas do Neógeno do Caribe foram registradas como relictos na área de estudo. Das 131 espécies identificadas, 36,5% são mais amplamente distribuídas nas águas temperadas ao sul da cidade de Cabo Frio, 46,5% ocorrem nas águas quentes ao norte da cidade de Cabo Frio, 4% estão presentes apenas na área estudada e 11,5% são raras e provavelmente restritas para a região leste. Uma nova província, denominada Província Brasileira, é aqui proposta respaldada no padrão de distribuição das espécies.

Palavras-chave: Atlântico Sul, biodiversidade, Podocopida, zona nerítica.

INTRODUCTION

This contribution is part of a larger study on podocopid marine ostracods of the Brazilian shelf led mainly by the second author, in collaboration with reasearchers from Brazil and abroad. It is concerned with species richness, zoogeography and paleozoogeographical aspects of these microcrustaceans along the eastern and northeastern Brazilian marine regions (Figure 1). Although studies on some benthonic ostracods have already been conducted in these two regions, this is the first to provide a comprehensive survey of the ostracods for this very large shelf zone.

Pinto *et al.* (1978) published a very preliminary study on the zoogeography of the ostracod genera along the Brazilian continental shelf recording around 50 genera, some of them in open nomenclature. Their faunal survey inspired many other taxonomic and zoogeographical studies, which resulted in the description of taxa typical of warm or temperate waters and a better understanding of the distribution patterns of the Brazilian benthonic shelf ostracods (*e.g.* Purper & Ornellas, 1987a,b, 1989; Coimbra & Ornellas, 1986, 1987, 1989; Ramos, 1994, 1996; Coimbra *et al.*, 1994, 1995, 1999a,b, 2004, 2020; Fauth & Coimbra, 1998; Carmo & Sanguinetti, 1999; Ramos *et al.*, 1999, 2004, 2009, 2012, 2014; Coimbra & Fauth, 2002; Coimbra & Carreño, 2002; Coimbra & Carmo, 2002; Bergue & Coimbra, 2002; Machado & Drozinsnki, 2002; Coimbra & Bergue, 2003; Aiello *et al.*, 2004; Machado *et al.*, 2005; Luz & Coimbra, 2015; Bergue *et al.*, 2016; Coimbra & Morais, 2016; Morais & Coimbra, 2019).

The first study to examine the relationship between benthonic ostracod distribution and water masses in Brazil was undertaken by Coimbra & Ornellas (1989) who, based on the occurrences of species of the subfamily Oriononinae, proposed the existence of three assemblages: Northern/Eastern, Southern and Transitional. The Northern/Eastern assemblage is found on the continental shelf influenced by the warm waters of both the North Brazil (= Guyana, of some authors) and Brazil currents. The Southern assemblage is in an area characterized by terrigenous sediments and temperate/cold waters influenced by the Rio de la Plata estuary plume and the seasonal oscillation at the confluence of the Brazil and Malvinas (= Falkland) currents, which carries sub-Antarctic waters. They proposed a Transitional Zone (15°S – 21°S) between the Northern/Eastern and the Southern ones composed of species that are somewhat tolerant to environmental changes, such as temperature and bottom sediments, representing a faunal mixture between the Northern/Eastern and Southern assemblages. Coimbra *et al.* (1995) extended the southern boundary of the Transitional Zone to the latitude 23°S.

Other Brazilian zoogeographical units based on ostracods were identified by Ramos (1996) and Coimbra *et al.* (1999a). The former proposed a subdivision of the Brazilian continental shelf into two sub-provinces: the North Sub-province between 4°N and 23°S and the South Sub-province, between 23°S and 34°S. Three years later, Coimbra *et al.* (1999a) identified two informal zoogeographical units along the entire Brazilian equatorial shelf divided by the Amazon/Pará River outflow.

Figure 1. Map of the Brazilian continental shelf and its marine regions. The boundaries of the marine regions follow Martins & Coutinho (1981).

Whatley *et al.* (1998b), based on a series of previous studies of Argentinian littoral and shelf ostracods, and the data from the unpublished PhD thesis of Ramos (1998), tried to draft a first approach to the provincial distribution of benthonic species in the SW Atlantic between Beagle Channel (lat. 55°S) and Rio de Janeiro State (lat. 21°S). They subdivided the SW Atlantic into four zoogeographical units, from south to north: (i) Antarctic Province, (ii) Sub-Antarctic Province, (iii) Bonaerensian Province, and (iv) Brazilian Province. Except by the Bonaerensian Province, the other three were subdivided into subprovinces. The Brazilian Province was preliminarily subdivided into three sub-provinces, although, in fact, the authors analyzed only the data taken from the aforementioned thesis, which studied the ostracods of the Brazilian shelf below the latitude 21°S. The Platensian/Uruguayan/Pelotensis Subprovince was delimited between 36°S to 31/30°S, while the Southern Brazilian Subprovince was located between

31/30°S to 22/21°S. It was also registered the existence of a North Brazilian/West Indian Province, but it was not discussed nor defined in the paper of Whatley *et al.* (1998b).

Ramos (1998) studied the taxonomy of the Brazilian shelf ostracods between Cabo Frio (~23°S) and Chuí (33°41'S). She modified the zoogeographical model of Whatley *et al.* (1998b) by lowering the Brazilian Province to a subprovince of the Argentinian Province (52°S – 21°/22°S), a very large province proposed in her study.

Wood *et al.* (1999) described key patterns in the distribution of 140 Oligocene–Recent ostracod genera recorded in South America. However, due to the little knowledge about South American ostracods at the time, and because it was a study at the genus level and based exclusively on bibliography review, the results, although significant, were preliminary.

The central aim of this work is to analyze the richness and the distribution of all podocopid species on the east and northeast shelves of Brazil. The comparison with previous studies carried out in other regions of the Brazilian shelf, integrated with paleontological data, allowed the authors to propose a new biogeographic province.

STUDY AREA

The Brazilian continental shelf is approximately 8,000 km long and, in the northern portion, it reaches a width of 330 km, close to the Amazon River mouth, while in the southeastern/southern reaches 200–220 km (Knoppers *et al.*, 2002). According to Muehe & Garcez (2005), besides the significant contribution of sediments and nutrients from the Amazon River in the north and Rio de la Plata estuary in the south, the rest of the Brazilian shelf is marked by low productivity due to nutrient depletion. Martins & Coutinho (1981) divided the Brazilian shelf into six physiographic provinces from north to south, as follows: (i) the Cabo Orange–Parnaíba Delta (northern region), (ii) the Parnaíba Delta–Cabo de São Roque (north-northeastern region), (iii) the São Roque Cape–Belmonte (northeastern region), (iv) the Belmonte–Cabo Frio (eastern region), (v) the Cabo Frio–Cabo de Santa Santa Marta (southeastern region), and (vi) the Cabo de Santa Marta–Chuí (southern region) (see Figure 1).

The names of the physiographic provinces reflect the location of the regions (northern, north-northeastern, northeastern, eastern, southeastern, and southern) and intend to facilitate their identification (Figure 1). The 15°S–23°S interval, proposed by Carannante *et al.* (1988) for the eastern region, differs slightly from Martins & Coutinho (1981), and was adopted herein (Figure 1). In this work, the eastern region corresponds to the Transitional Zone of Coimbra *et al.* (1995).

The study area therefore, corresponds to the northeastern and eastern regions (Figure 1) whose bottom sediments are composed predominantly of calcareous algae (Coutinho, 2000; Knoppers *et al.*, 2002) (Figure 2). The northeastern section, between Cabo de São Roque and Belmonte, is characterized by poor terrigenous input and a rich supply of biogenic carbonates, mainly *Halimeda* (calcareous algae) and branching coralline algae, which are common throughout the region (Carannante *et al.*, 1988). This part of the shelf is narrower and shallower comparing to the remaining of the Brazilian continental shelf (Martins & Coutinho, 1981). The width ranges from 42 km off Maceió to 8 km off Salvador (Figure 1). The maximum depth is approximately 60 m (Coutinho, 2000).

The eastern marine region has irregular width due to the development of large biogenic structures on the summit of volcanic formations. The widest portion (246 km) occurs off Caravelas, while the narrowest (48 km) is near to Regência (Figure 1). The depth seldom exceeds 60 m and the calcareous sedimentation is relatively abundant, with predominance of coralline algae (north of the Vitória-Trindade Island chain; Figure 1), and bryozoans toward the south of the chain (Carannante *et al.*, 1988; Coutinho, 2000).

The Brazil Current (**BC**) is the most important current in the study area, however, the northernmost part of the Brazilian shelf is under the influence of the North Brazil Current (**NBC**) (Figures 2, 3). The BC (~26°C) begins along the southernmost branch of the South Equatorial Current (**SEC**)

Figure 2. Simplified map of the distribution of sedimentary facies along the Brazilian continental shelf (modified from Coutinho, 2000).

(Stramma, 1991; Silveira *et al.*, 2000) and flows southward, bordering South America until the Subtropical Convergence (33–38ºS), where it joins the Malvinas (= Falkland) Current flowing offshore (Martins, 1984; Silveira *et al.*, 2000). The NBC and the BC originate at the same area, but the former flows northwest toward the equator (Stramma, 1991; Stramma & England, 1999; Silveira *et al.*, 2000; Cirano *et al.*, 2006) (Figure 3).

The BC includes the Tropical Water (**TW**) and the South Atlantic Central Water (**SACW**), which are typical South Atlantic water masses. Near its origin, the BC is a shallow, warm and salty current composed primarily of the TW and flowing along the continental shelf break. Located close to 20ºS, it is notably influenced by the SACW, becoming deeper and with a higher transport competence (Silveira *et al.,* 2000).

The southern limit of the study area in Cabo Frio (23ºS) is marked by the occurrence of strong upwelling. According to Weber (1994), upwellings have highest intensities between the spring and the summer, when drops the water temperature to 13–18°C at the surface and to 5°C or less between 20 and 30 m. Southward the shelf water temperature is relatively colder (~18°C) due to the subtropical gyre and the Rio de la Plata estuary plume inputs as well as the seasonal oscillation of the Brazil-Malvinas (= Falkland) currents confluence, which carries sub-Antarctic waters (Campos *et al.*, 1996, 1999; Piola *et al.*, 1999; Pimenta *et al.*, 2005).

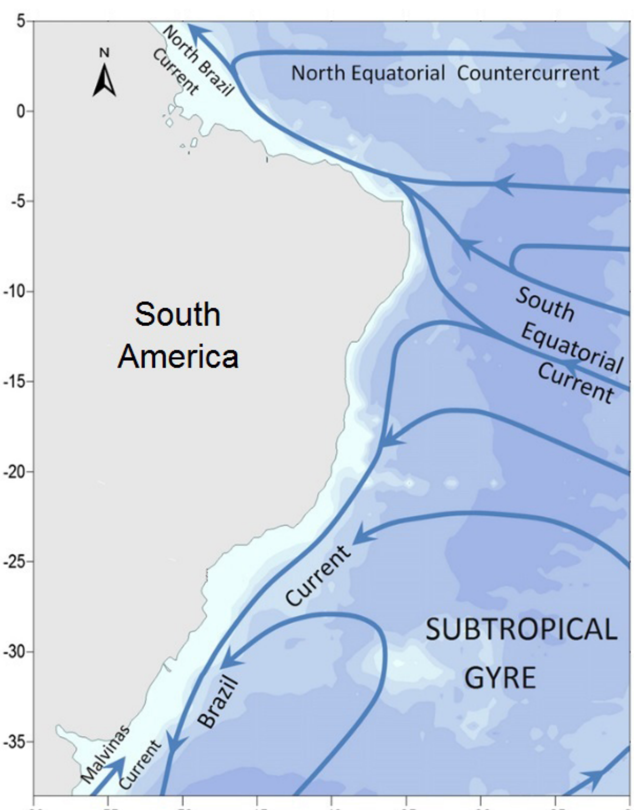

Figure 3. Oceanographic map of the SW Atlantic indicating the position and direction of flow of the major currents (modified from Peterson & Stramma, 1991 and Pivel *et al.*, 2013).

MATERIAL AND METHODS

The 104 dry bottom sediment samples used in this study were collected in 1973 during the REMAC project (*Reconhecimento Global da Margem Continental Brasileira*) at different stations ranging from the Cabo São Roque (Rio Grande do Norte State) to the Cabo Frio (Rio de Janeiro State) (legs 4 and 7). The sampling process used mainly Van Veen grab sampler at depths between 12 and 110 m.

The dry sediments were washed through three sieves: 0.250, 0.177 and 0.074 mm and all ostracod empty carapaces and valves from the two coarser fractions were collected for the analysis of the total fauna. The zoogeographical analysis was based on the first and last latitudinal (north to south) occurrences of each species. Supplementary information from the literature concerning species distributions was also included in this study.

The relative frequency (F) of each species in the samples was calculated using the formula:

$$F = p \text{ X } 100/P$$

where p = the number of samples in which the species occurs and P = the total number of samples analyzed. In this study, frequency levels have been analyzed according to the following definitions: abundant (F > 50%); common (50% ≥ F > 30%); frequent (30% ≥ F > 20%); scarce (20% ≥ F > 10%) and rare (F ≤ 10%).

The illustrated specimens are held in the collections of the Museu de Paleontologia Irajá Damiani Pinto, Universidade Federal do Rio Grande do Sul (**UFRGS**), Section of Ostracoda, under the curatorial numbers MP-O-2249 to MP-O-2401. The scanning electron microscopy (= **SEM**) images were taken at the Centro de Microscopia e Microanálise at UFRGS.

RESULTS

Faunal analysis

One hundred and thirty-one ostracod species were identified in the eastern and northeastern Brazilian shelf regions, of which one third are left in open nomenclature. Even though most of the species left in open nomenclature are probably new, many of them are rare, hindering detailed taxonomic analysis. All species recorded are illustrated in Figures 4 to 12. Table 1 enrolls the limits of their geographic distribution whose northern or southern boundary occurs within the region here studied. Appendix 1 presents an updadet and complete list of species and higher taxonomic categories. Appendix 2 shows the result of a zoogeographical analysis based both on species distribution and identification of taxa with restrict occurrence.

Three families highly diversified in shallow marine environments elsewhere are also specious here: Hemicytheridae (19% of the total species), Cytheruridae (18%) and Trachyleberididae (14%). As for the more specious genera, the following stand out: *Semicytherura* (10 spp.), *Callistocythere*

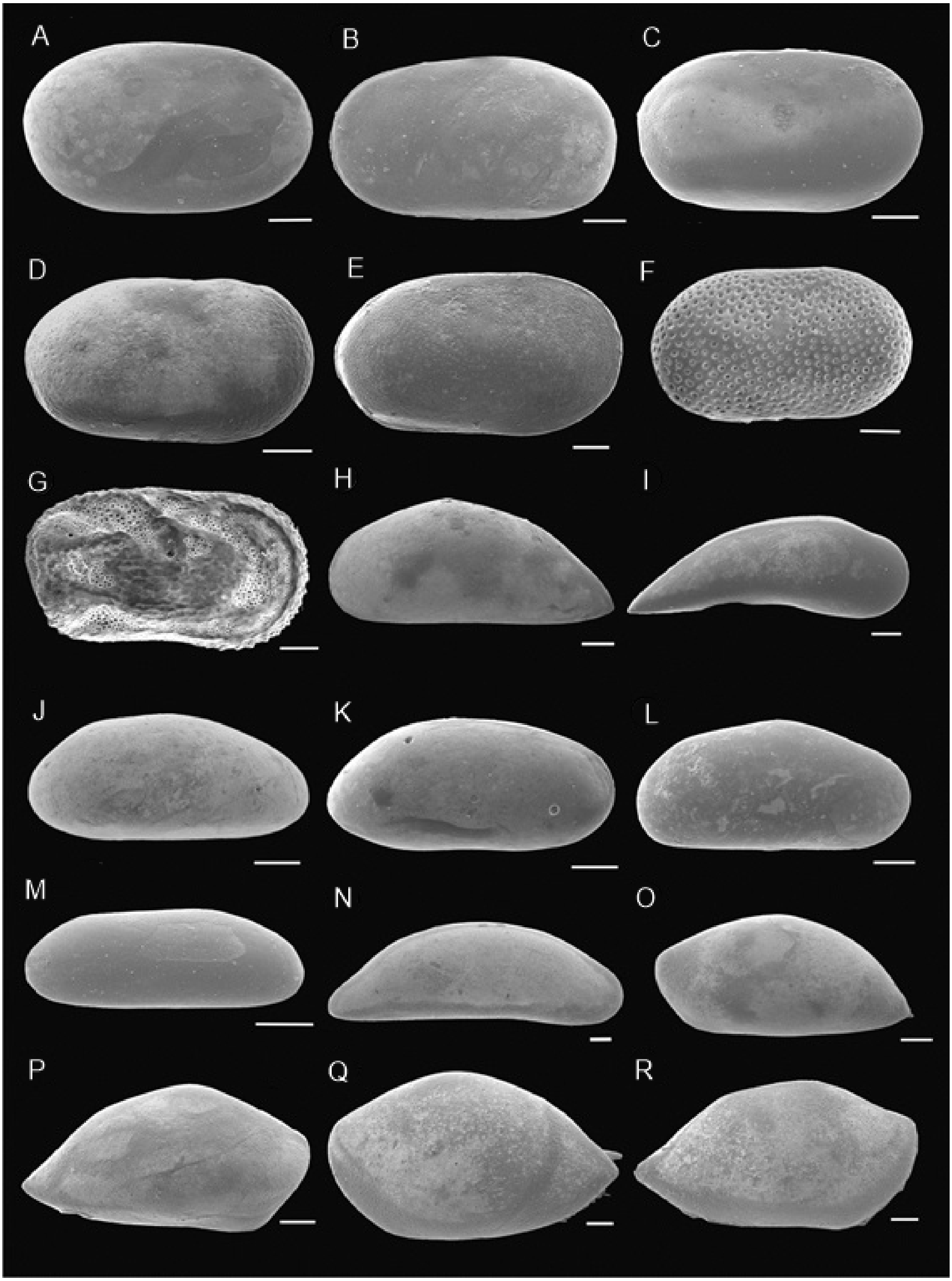

Figure 4. A–**B**, *Cytherella hermargentina* Whatley, Moguilevsky, Chadwick, Toy & Ramos, 1998; **A**, female, RV, MP-O-2249; **B**, male, LV, MP-O-2250. **C**, *Cytherella* sp. 1; RV, MP-O-2251. **D**, *Cytherella* sp. 2; RV, MP-O-2252. **E**, *Cytherella* sp. 3; RV, MP-O-2253. **F**, *Cytherella* sp. 4; female, RV, MP-O-2254. **G**, *Keijcyoidea amazonica* Bergue & Coimbra, 2002; female, RV, MP-O-2255. **H**, *Paracypris* sp. 1; LV, MP-O-2256. **I**, *Paracypris* sp. 2; RV, MP-O-2257. **J**, *Argilloecia parameridionalis* Whatley, Moguilevesky, Chadwick, Toy & Ramos, 1998; RV, MP-O-2258. **K**, *Argilloecia inflata* Ramos, Whatley & Coimbra, 2004; RV, MP-O-2259. **L**, *Argilloecia* sp.; RV, MP-O-2260. **M**, *Australoecia neritica* Sartori & Coimbra, 2010; RV, MP-O-2261. **N**, *Yemanja* sp.; RV, MP-O-2262. **O–P**, *Neonesidea equatorialis* Coimbra & Carreño, 2002; **O**, LV, MP-O-2263; **P**, RV, MP-O-2264. **Q–R**, *Neonesidea* sp.; **Q**, LV, MP-O-2265; **R**, RV, MP-O-2266. **Abbreviations: RV**, right valve; **LV**, left valve. Scale bars = 100 µm.

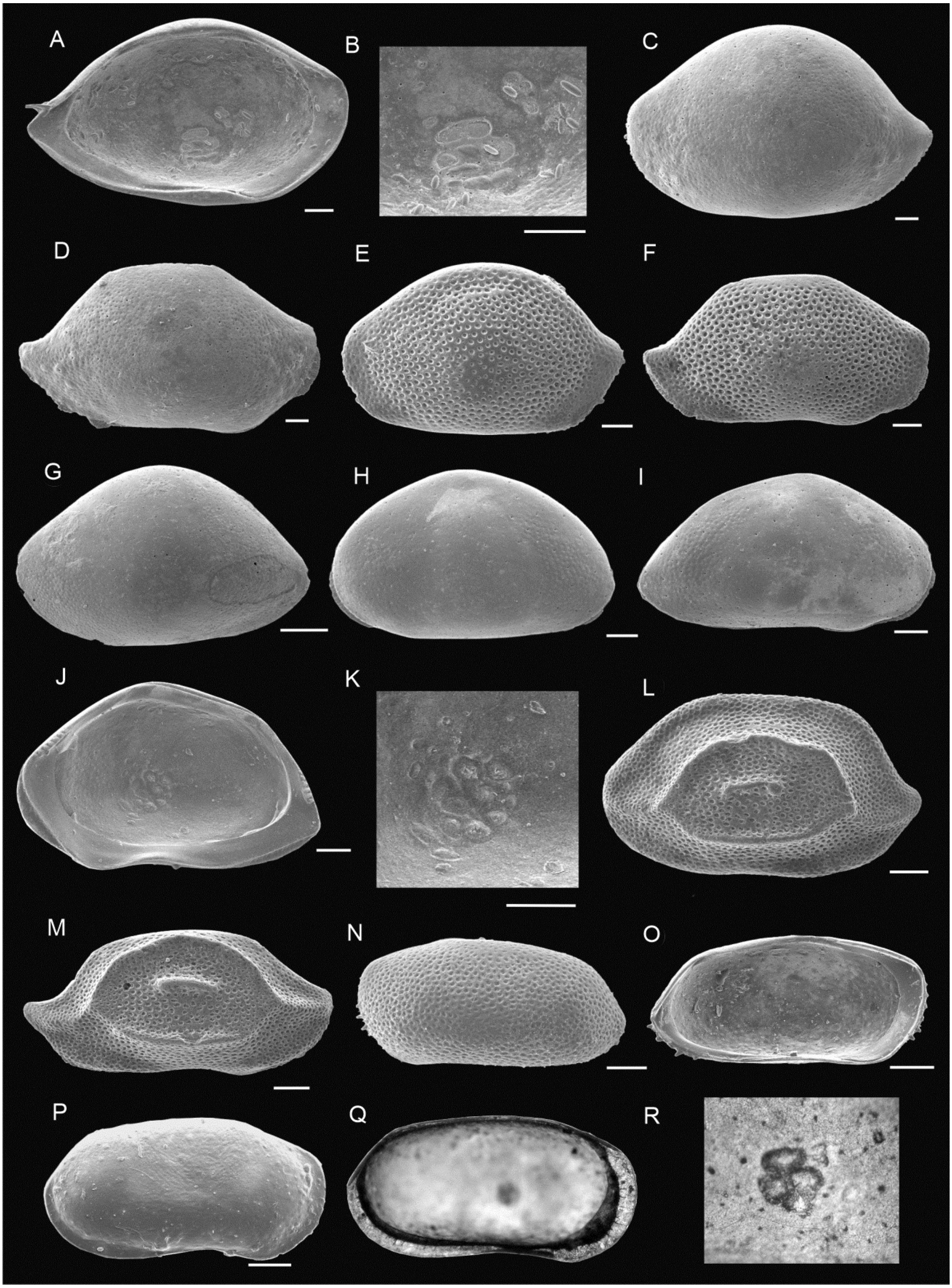

Figure 5. A–**B**, *Neonesidea* sp.; **A**, LV, internal view, MP-O-2265; **B**, LV, same specimen internal view, detail of the central muscle scars, MP-O-2265. **C**–**D**, *Paranesidea parabipustulosa* Coimbra & Carreño, 2002; **C**, LV, MP-O-2267; **D**, RV, MP-O-2268. **E**–**F**, ?*Paranesidea* ex gr. *bensoni* Teeter, 1975; **E**, LV, MP-O-2269; **F**, RV, MP-O-2270. **G**, *Bairdoppilata sudbrasiliensis* Coimbra & Carreño, 2002; LV, MP-O-2271. **H**–**K**, *Bairdoppilata* sp.; **H**, LV, MP-O-2272; **I**, RV, MP-O-2273; **J**, RV, internal view, MP-O-2273; **K**, RV, detail of the central muscle scars, MP-O-2273. **L**–**M**, *Glyptobairdia coronata* (Brady, 1870); **L**, LV, MP-O-2274; **M**, RV, MP-O-2275. **N**–**O**, *Triebelina* sp.; **N**, LV, MP-O-2276; **O**, LV, internal view, MP-O-2276.**P**–**R**, *Anchistrocheles*? sp.; **P**, RV, MP-O-2277; **Q**, LV, internal view, optical microscopy transmitted light, 60x, MP-O-2278; **R**, LV, detail of the central muscle scars, optical microscopy transmitted light 270x, MP-O-2278. **Abbreviations: RV**, right valve; **LV**, left valve. Scale bars = 100 µm.

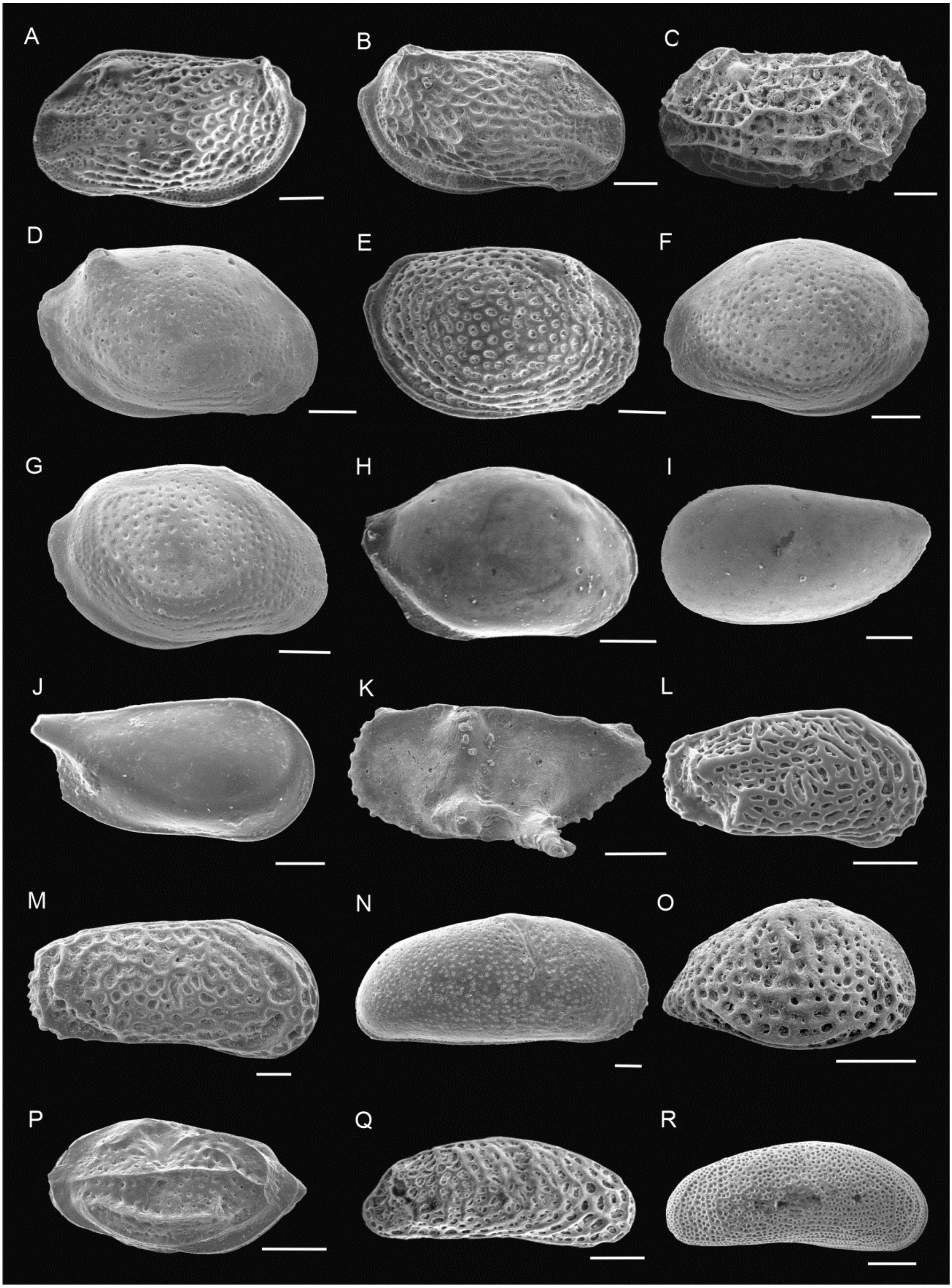

Figure 6. A–B, *Loxocorniculum tricornatum* Krutak, 1971; **A**, LV, MP-O-2279; **B**, RV, MP-O-2280. **C**, *Loxocorniculum* sp.; LV, MP-O-2281. **D**, *Loxoconcha bullata* Hartmann, 1956; female, RV, MP-O-2282. **E**, *Loxoconcha forda* Bold, 1968; RV, MP-O-2283. **F**–**G**, *Loxoconcha* sp.; **F**, LV, MP-O-2284; **G**, RV, MP-O-2285. **H**, *Phlyctocythere* sp. 1; RV, MP-O-2286. **I**, *Nealocythere* sp.; LV, MP-O-2287. **J**, *Pseudocythere* sp.; RV, MP-O-2288. **K**, *Vandenboldina* aff. *V. droogeri* (Bold, 1965); LV, MP-O-2289. **L**, *Kotoracythere inconspicua* (Brady, 1880); RV, MP-O-2290. **M**, *Keijia demissa* (Brady, 1868); female, RV, MP-O-2291. **N**, *Cyprideis multidentata* Hartmann, 1955; RV, MP-O-2292. **O**, *Gangamocytheridea dictyon* Bold, 1963; RV, MP-O-2293. **P**, *Neomonoceratina mediterranea mediterranea* Ruggieri, 1953; LV, MP-O-2294. **Q**, *Hulingsina toreuma* Bergue & Coimbra, 2002; RV, MP-O-2295. **R**, *Cushmanidea*? *echevarriae* Bertels & Martínez, 1997; male, RV, MP-O-2296. **Abbreviations: RV**, right valve; **LV**, left valve. Scale bars = 100 µm.

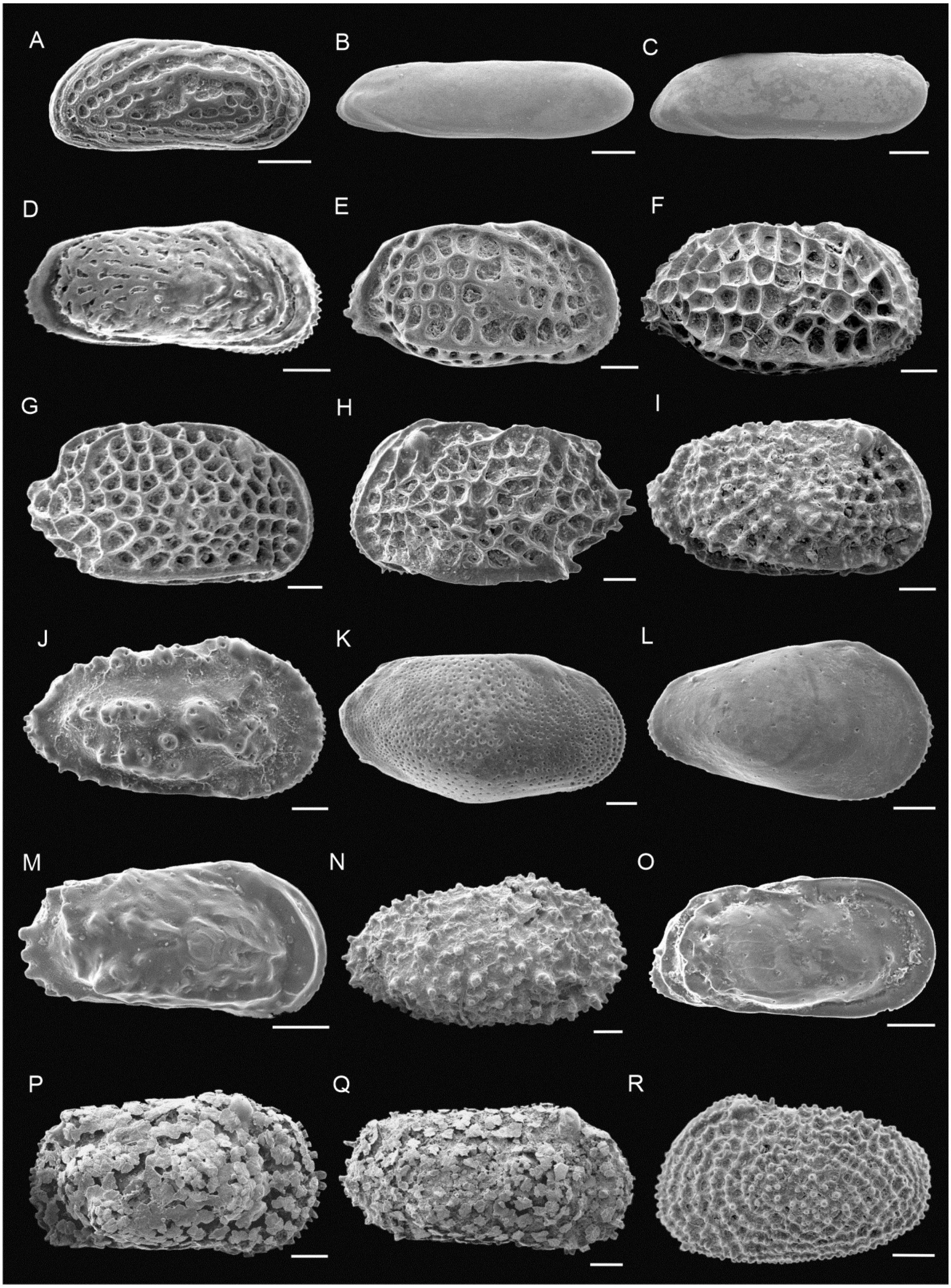

Figure 7. A, *Papillosacythere parallela* Whatley, Chadwick, Coxill& Toy, 1987; LV, MP-O-2297. **B**, *Copytus* sp.; LV, MP-O-2298. **C**, *Copytus wuerdigae* Coimbra, Bergue & Ramos, 2020; LV, MP-O-2299. **D**, *Muellerina cribosa* Ramos, Coimbra & Whatley, 2009; RV, MP-O-2300. **E**, *Bradleya kaesleri* Ramos, Coimbra & Whatley, 2009; female, RV, MP-O-2301. **F**, *Bradleya pseudonormani* Ramos, Coimbra and Whatley, 2009; male, RV, MP-O-2302. **G**, *Quadracythere venusta* (Ramos, Coimbra & Whatley, 2009) Ramos, Coimbra & Whatley, 2011; RV, MP-O-2303. **H**, *Quadracythere* sp.; LV, MP-O-2304. **I**, *Brasilicythere reticulispinosa* Sanguinetti, Ornellas & Coimbra, 1991; female, RV, MP-O-2305. **J**, *Actinocythereis brasiliensis* Machado & Drozinski, 2002; female, RV, MP-O-2306. **K**, *Argenticytheretta laevipunctata* Sanguinetti, Ornellas & Coimbra, 1991; female, RV, MP-O-2307. **L**, *Argenticytheretta*? sp.; juvenile, RV, MP-O-2308. **M**, *Puriana variabilis* Chukewiski & Purper, 1985; RV, MP-O-2309. **N**, *Legitimocythere megapotamica* Bergue, Coimbra & Ramos, 2016; male RV, MP-O-2310. **O**, *Ambocythere* sp.; RV, MP-O-2311. **P–Q**, *Henryhowella tuberculiclaviforma* Coimbra, Ramos, Whatley & Bergue, 2004; **P**, female, RV, MP-O-2312; **Q**, male, RV, MP-O-2313. **R**, *Apatihowella inflata* (Ramos, Coimbra, Bergue & Whatley, 2012); male, LV, MP-O-2314. **Abbreviations: RV**, right valve; **LV**, left valve. Scale bars = 100 µm.

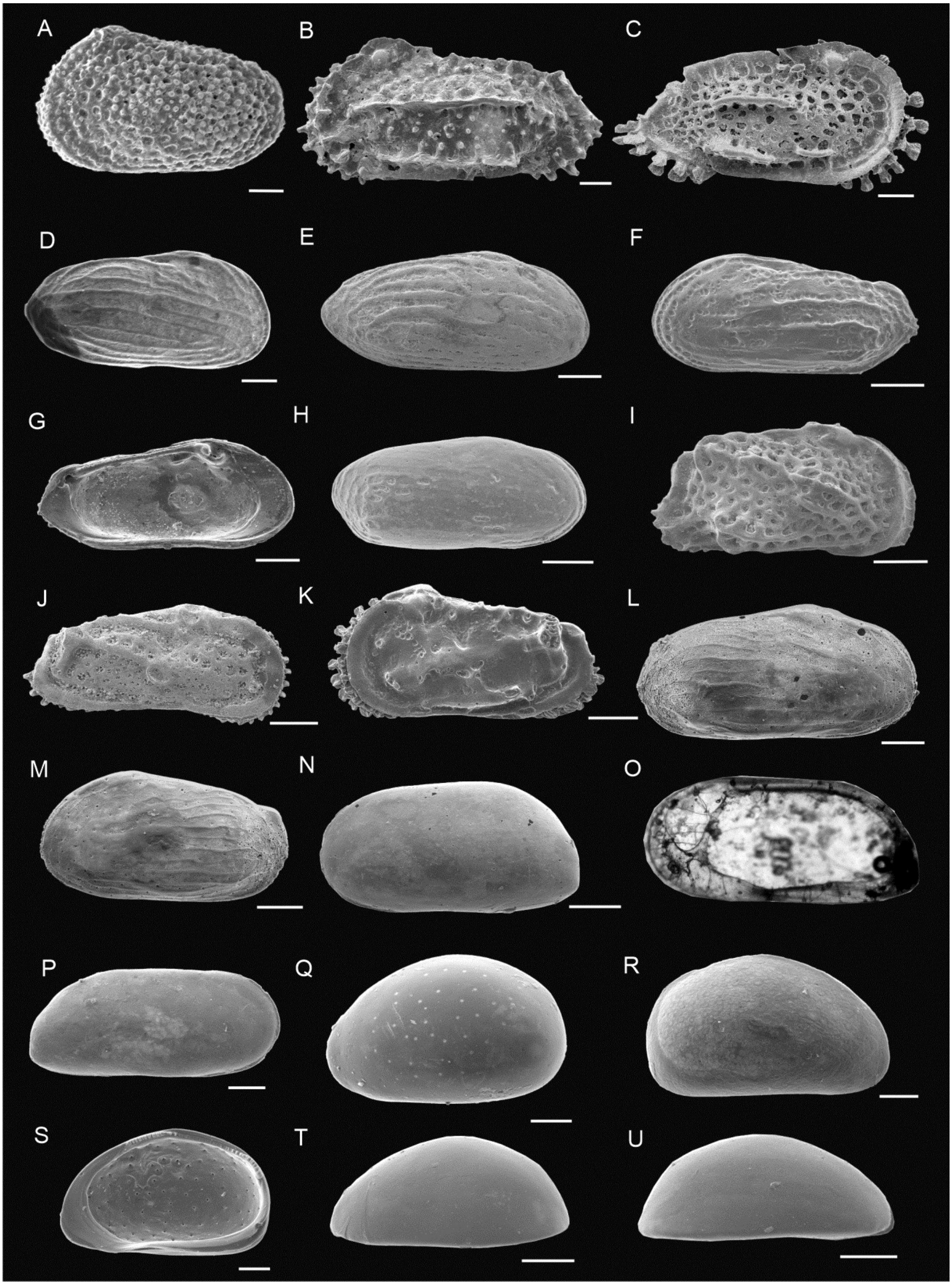

Figure 8. A, *Apatihowella* sp.; female, LV, MP-O-2315. **B**, *Cativella sudbrasiliensis* Ramos, Coimbra, Bergue & Whatley, 2012; LV, MP-O-2316. **C**, *Cativella* sp.; RV, MP-O-2317. **D**, *Cytheretta* sp. 1; RV, MP-O-2318. **E**, *Cytheretta* sp. 2; RV, MP-O-2319. **F–G**, *Protocytheretta* sp.; **F**, LV, MP-O-2320; **G**, LV, internal view, MP-O-2320. **H**, *Basslerites multicostata* Ramos, Coimbra, Bergue & Whatley, 2012; female, RV, MP-O-2321. **I**, *Neohornibrookella* ex gr. *transoceanica* (Teeter, 1975); RV, MP-O-2322. **J**, *Neocaudites subimpressus* (Edwards, 1944); male, RV, MP-O-2323. **K**, *Neocaudites triplistriatus* (Edwards, 1944); female, LV, MP-O-2324. **L–M**, *Australimoosella polypleurum* Coimbra, Ramos, Whatley & Bergue, 2004; **L**, RV, MP-O-2325; **M**, LV, MP-O-2326. **N–P**, *Krithe gnoma* Carmo & Sanguinetti, 1999; **N**, female, LV, MP-O-2327; **O**, female, LV, optical microscopy transmitted light, 60x, MP-O-2328; **P**, male, RV, MP-O-2329. **Q**, *Xestoleberis umbonata* Whatley, Moguilevsky, Chadwick, Toy & Ramos, 1998; LV, MP-O-2330. **R–S**, *Xestoleberis inesae* Luz & Coimbra, 2015; **R**, RV, MP-O-2331; **S**, RV, internal view, MP-O-2331. **T–U**, *Xestoleberis* sp.; **T**, LV, MP-O-2332; **U**, RV, MP-O-2333. **Abbreviations: RV**, right valve; **LV**, left valve. Scale bars = 100 µm.

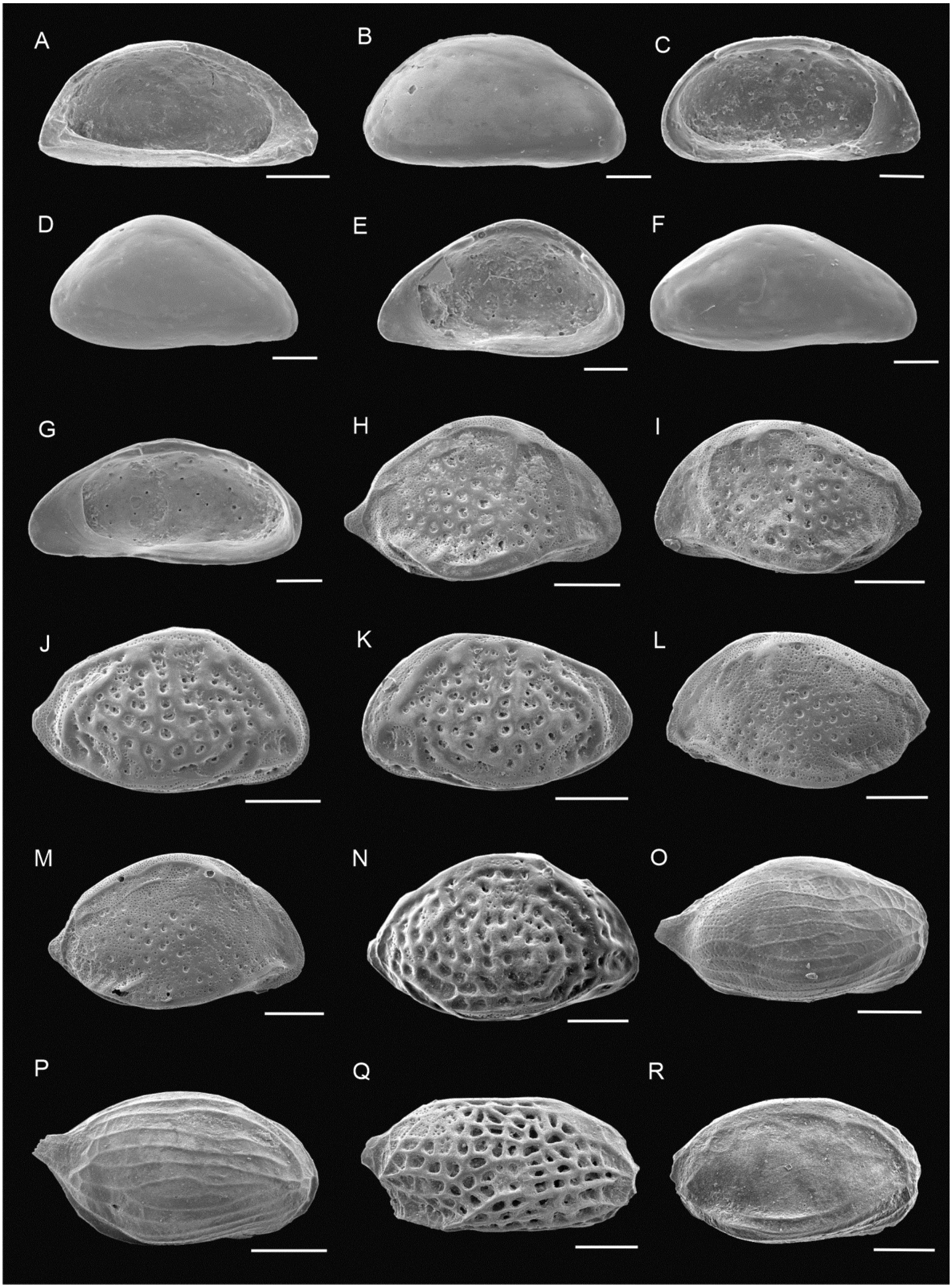

Figure 9. A, *Xestoleberis* sp.; LV, internal view, MP-O-2332. **B–C**, *Semixestoleberis* sp. 1; **B**, male, RV, MP-O-2334; **C**, male, LV, internal view, MP-O-2335. **D–G**, *Semixestoleberis* sp. 2; **D**, female, RV, MP-O-2336; **E**, female, RV, internal view, MP-O-2336; **F**, male, RV, MP-O-2337; **G**, male, RV, internal view, MP-O-2337. **H–I**, *Oculocytheropteron pintoi* Coimbra, Carreño & Michelli, 1999; **H**, female, RV, MP-O-2338; **I**, male, LV, MP-O-2339. **J–K**, *Oculocytheropteron circumcostatum* Ramos, Coimbra, Whatley & Moguilevsky, 1999; **J**, female, RV, MP-O-2340; **K**, female, LV, MP-O-2341. **L**–**M**, *Oculocytheropteron delicatum* Ramos, Coimbra, Whatley & Moguilevsky, 1999; **L**, female, LV, MP-O-2342; **M**, female, RV, MP-O-2343. **N**, *Oculocytheropteron macropunctatum* Whatley, Chadwick, Coxill & Toy, 1988; female, RV, MP-O-2344. **O**, *Semicytherura caudata* Ramos, Coimbra, Whatley & Moguilevsky, 1999; female, RV, MP-O-2345. **P**, *Semicytherura parallelocostata* Coimbra, Carreño & Michelli, 1999; female, RV, MP-O-2346. **Q**, *Semicytherura rugosoreticulata* Whatley, Chadwick, Coxill & Toy, 1988; female, RV, MP-O-2347. **R**, *Semicytherura* sp. 1; RV, MP-O-2348. **Abbreviations: RV**, right valve; **LV**, left valve. Scale bars = 100 µm.

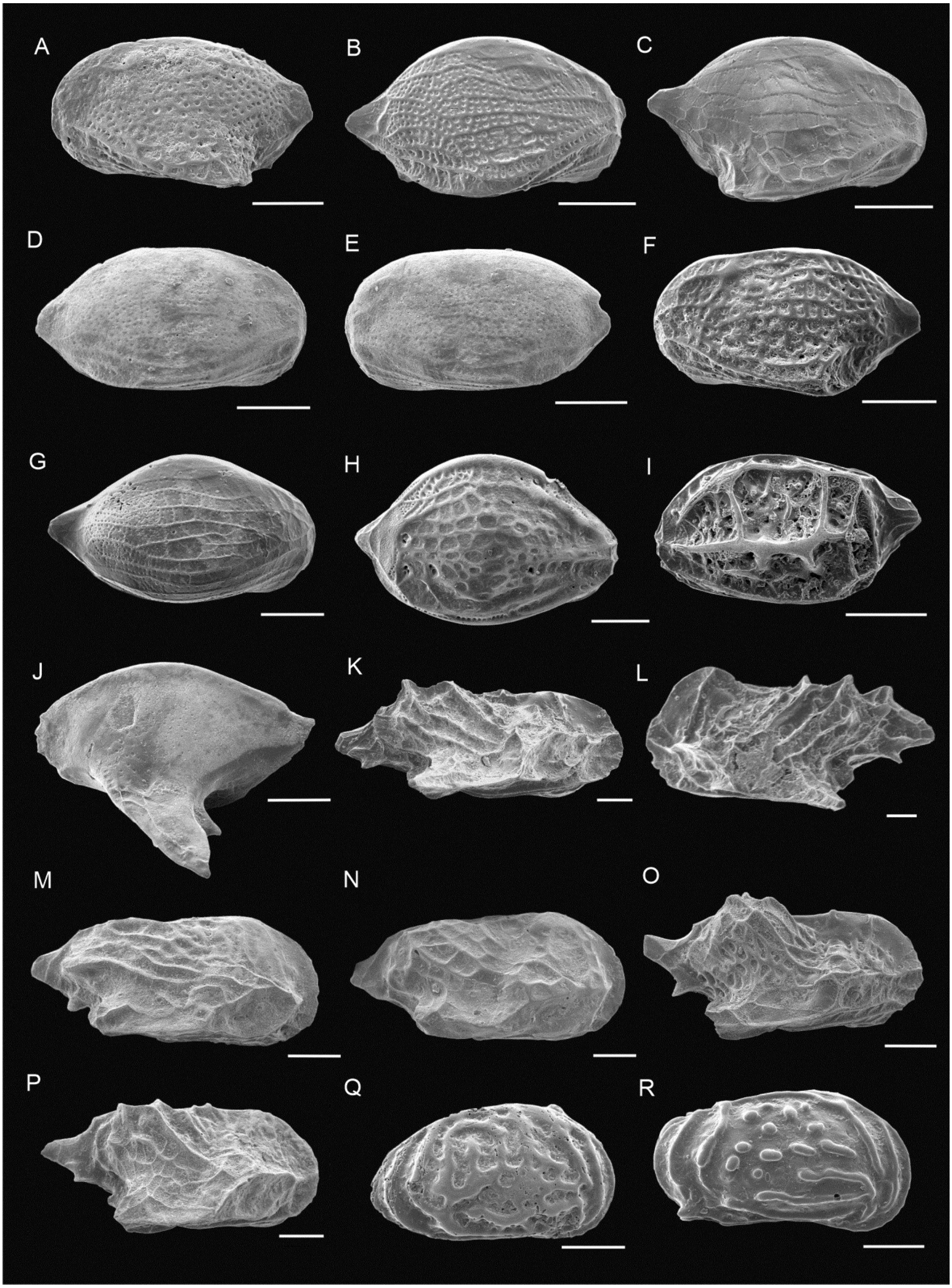

Figure 10. A, *Semicytherura* sp. 2; LV, MP-O-2349. **B**, *Semicytherura* sp. 3; RV, MP-O-2350. **C**, *Semicytherura* sp. 4; RV, MP-O-2351. **D–E**, *Semicytherura* sp. 5; **D**, RV, MP-O-2352; **E**, LV, MP-O-2353. **F**, *Semicytherura* sp. 6; LV, MP-O-2354. **G**, *Semicytherura* sp. 7; RV, MP-O-2355. **H**, *Hemicytherura auriculata* Ramos, Coimbra, Whatley & Moguilevsky, 1999; RV, MP-O-2356. **I**, *Hemicytherura bradyi* Puri, 1960; LV, MP-O-2357; **J**, *Aversovalva wurdigae* Coimbra, Carreño & Michelli, 1999; LV, MP-O-2358. **K–L**, *Paracytheridea paralelicostata* Purper & Ornellas, 1989; **K**, male RV, MP-O-2364; **L**, male, RV, MP-O-2359. **M**, *Paracytheridea batei* Purper & Ornellas, 1987; female, RV, MP-O-2360. **N**, *Paracytheridea inflata* Purper & Ornellas, 1987; male, RV, MP-O-2361. **O**, *Paracytheridea bulbosa* Purper & Ornellas, 1989; male, RV, MP-O-2362. **P**, *Paracytheridea tschoppi* van de Bold, 1946; female, RV, MP-O-2363. **Q**, *Callistocythere nucleoperiscum* Whatley, Moguilevsky, Toy, Chadwick & Ramos, 1997; female, RV, MP-O-2365. **R**, *Callistocythere ornata* (Hartmann, 1956); female, RV, MP-O-2366. **Abbreviations: RV**, right valve; **LV**, left valve. Scale bars = 100 µm.

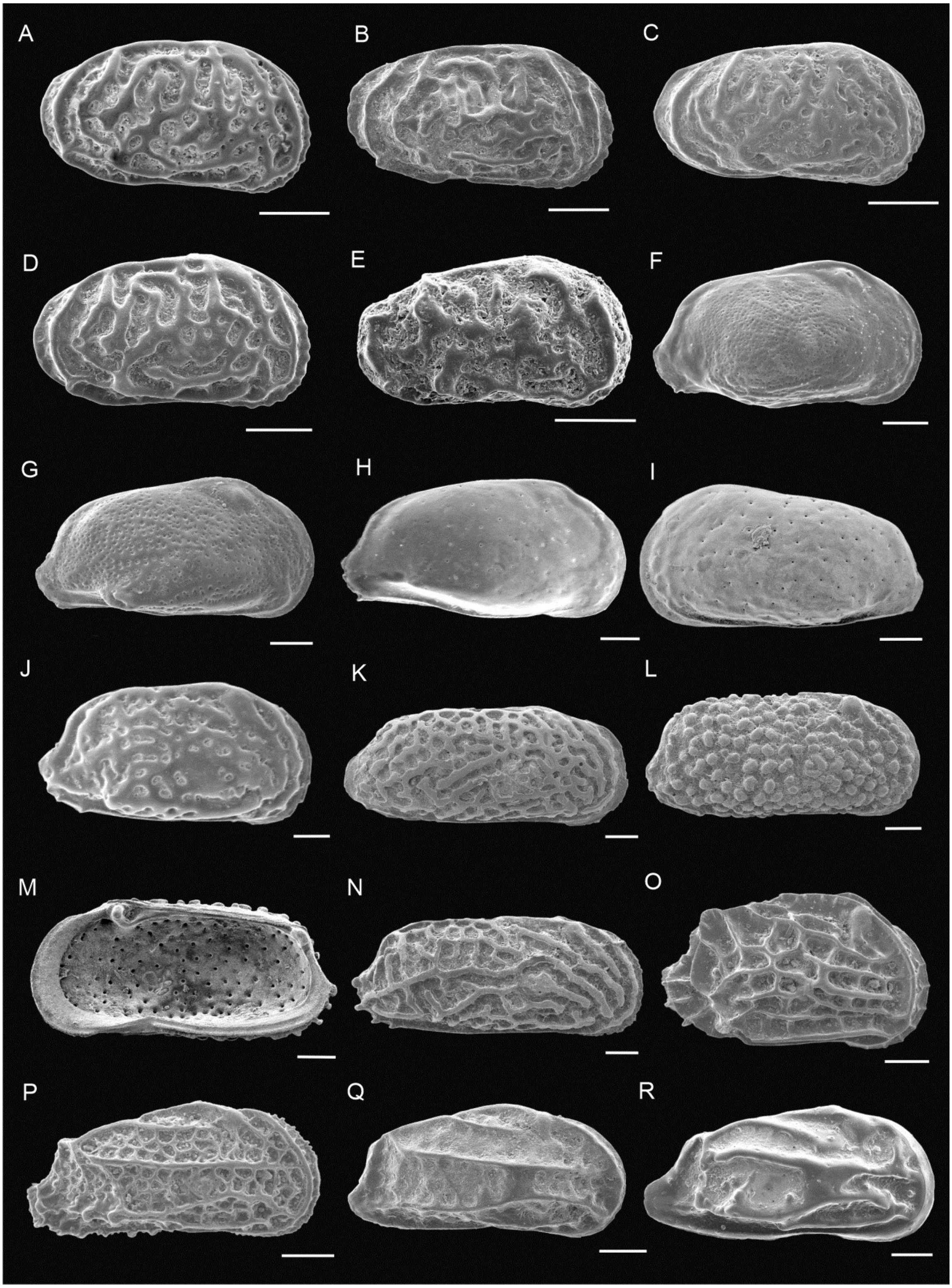

Figure 11. A, *Callistocythere sigmocostelata* Coimbra, Sanguinetti & Bittencourt-Calcagno, 1995; female, RV, MP-O-2367. **B**, *Callistocythere laminata* Coimbra, Sanguinetti & Bittencourt-Calcagno, 1995; female, RV, MP-O-2368. **C**, *Callistocythere fossulata* Coimbra, Sanguinetti & Bittencourt-Calcagno, 1995; female, RV, MP-O-2369. **D**, *Callistocythere multicellulosa* Coimbra, Sanguinetti & Bittencourt-Calcagno, 1995; male, RV, MP-O-2370. **E**, *Callistocythere cranekeyensis* (Puri, 1960); RV, MP-O-2371. **F**, *Meridionalicythere*? sp. 1; RV, MP-O-2372. **G**, *Meridionalicythere*? sp. 2; RV, MP-O-2373. **H**, *Meridionalicythere*? sp. 3; RV, MP-O-2374. **I**, *Meridionalicythere*? sp. 4; LV, MP-O-2375. **J**, *Ruggiericythere perspicua* Aiello, Coimbra & Barra, 2004; female, RV, MP-O-2376. **K**, *Ruggiericythere batistae* Aiello, Coimbra & Barra, 2004; male, RV, MP-O-2377. **L–M**, *Bulbocythere calida* Coimbra & Morais, 20172019; **L**, RV, MP-O-2378; **M**, RV, internal view, MP-O-2379. **N**, *Ruggiericythere dimorphica* (Whatley, Moguilevsky, Chadwick, Toy & Ramos, 1998) Aiello, Coimbra & Barra, 2004; male, RV, MP-O-2380. **O**, *Auradilus convolutus* (Brady, 1868); RV, MP-O-2381. **P**, *Orionina bradyi* Bold, 1963; RV, MP-O-2382. **Q**, *Orionina similis* Bold, 1963; RV, MP-O-2383. **R**, *Caudites ohmerti* Coimbra & Ornellas, 1987; female, RV, MP-O-2384. **Abbreviations: RV**, right valve; **LV**, left valve. Scale bars = 100 µm.

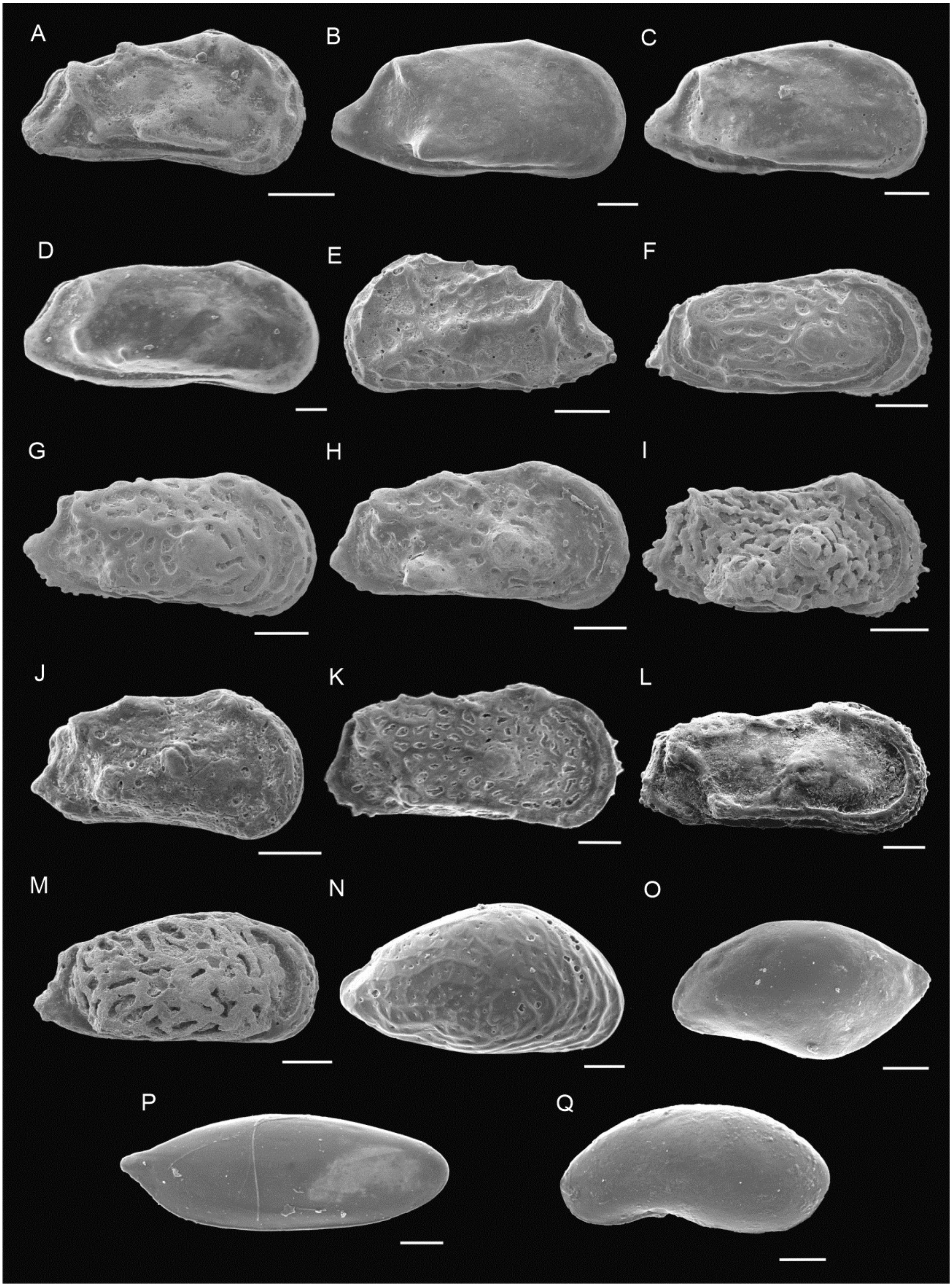

Figure 12. A, *Caudites nipeensis* Bold, 1946; RV, MP-O-2385. **B**, *Caudites vandenboldi* Coimbra & Ornellas, 1987; RV, MP-O-2386. **C**, *Caudites gnomus* Coimbra & Ornellas, 1987; female, RV, MP-O-2387. **D**, *Caudites fluminensis* Coimbra & Ornellas, 1987; male, RV, MP-O-2388. **E**, *Caudites exmouthensis* Hartmann, 1978; LV, MP-O-2389. **F**, *Coquimba tenuireticulata* Kotzian, 1982; male, RV, MP-O-2390. **G**, *Coquimba ornellasae* Ramos, 1994; female, RV, MP-O-2391. **H**, *Coquimba punctata* Ramos, 1994; female, RV, MP-O-2392. **I**, *Cornucoquimba decorata* Ramos, 1996; female, RV, MP-O-2393. **J**, *Cornucoquimba nana* Ramos, 1996; female, RV, MP-O-2394. **K**, *Cornucoquimba ramosae* Coimbra & Carmo, 2002; male, RV, MP-O-2395. **L**, *Cornucoquimba lutziana* Zabert, 1978; male, RV, MP-O-2396. **M**, *Nanocoquimba pulchra* Ramos, 1996; female, MP-O-2397. **N**, *Eucythere* sp.; RV, MP-O-2398. **O**, *Pellucistoma* ex. gr. *magniventra*; LV, MP-O-2399. **P**, *Paradoxostoma* sp.; RV, MP-O-2400. **Q**, *Sclerochilus* sp.; LV, MP-O-2401. **Abbreviations: RV**, right valve; **LV**, left valve. Scale bars = 100 µm.

Table 1. Species whose geographical distribution has its northern limit (temperate water species) or its southern limit (warm water species) within the eastern or the northeastern Brazilian marine regions.

Temperate water species	Northern limit (lat. °S)	Warm water species	Southern limit (lat. °S)
Actinocythereis brasiliensis	16.49	*Anchistrocheles*? sp.	09.19
Argenticytheretta laevipunctata	21.58	*Auradilus convolutus*	23.31
Argenticytheretta? sp.	19.31	*Australimoosella polypleurum*	21.35
Argilloecia inflata	22.31	*Australoecia neritica*	22.55
Argilloecia parameridionalis	22.24	*Aversovalva wurdigae*	18.27
Bairdoppilata sudbrasiliensis	22.01	*Bairdoppilata* sp.	17.12
Basslerites multicostata	23.07	*Callistocythere fossulata*	22.65
Bradleya pseudonormani	22.42	*Callistocythere cranekeyensis*	07.01
Bradleya kaesleri	22.24	*Callistocythere laminata*	21.58
Brasilicythere reticulispinosa	17.00	*Callistocythere multicellulosa*	22.51
Callistocythere nucleoperiscum	21.58	*Callistocythere ornata*	22.51
Cativella sudbrasiliensis	19.53	*Callistocythere sigmocostelata*	22.10
Caudites gnomus	19.50	*Caudites nipeensis*	21.02
Caudites ohmerti	18.26	*Caudites exmouthensis*	20.50
Caudites vandenboldi	15.00	*Copytus* sp.	11.25
Copytus wuerdigae	19.31	*Coquimba ornellasae*	22.10
Coquimba tenuireticulata	22.03	*Coquimba punctata*	20.48
Cornucoquimba lutziana	19.53	*Cornucoquimba decorata*	22.46
Cushmanidea? *echevarriae*	19.32	*Cornucoquimba nana*	20.39
Cyprideis multidentata	16.23	*Cornucoquimba ramosae*	21.10
Cytherella sp. 4	19.53	*Cytherella* sp. 1	17.00
Cytherella hermargentina	22.03	*Cytherella* sp. 2	11.09
Hemicytherura auriculata	22.42	*Cytheretta* sp. 2	11.25
Apatihowella inflata	22.42	*Gangamocytheridea dictyon*	18.53
Apatihowella sp.	19.53	*Bulbocythere calida*	21.12
Krithe gnoma	22.25	*Glyptobairdia coronata*	21.12
Loxoconcha bullata	16.23	*Hemicytherura bradyi*	20.50
Meridionalicythere? sp. 4	18.26	*Henryhowella tuberculiclaviforma*	21.54
Meridionalicythere? sp.	19.31	*Neohornibrookella* ex gr. *transoceanica*	16.57
Muellerina cribosa	15.57	*Hulingsina toreuma*	18.59
Nanocoquimba pulchra	19.31	*Keijcyoidea amazonica*	21.12
Oculocytheropteron circumcostatum	22.01	*Keijia demissa*	23.00
Oculocytheropteron delicatum	18.49	*Kotoracythere inconspicua*	23.00
Oculocytheropteron macropunctatum	21.58	*Loxoconcha forda*	22.03
Papillosacythere paralela	22.03	*Loxoconcha tricornatum*	21.12
Paracypris sp. 2	22.31	*Loxocorniculum* sp.	08.03
Paracytheridea bulbosa	22.03	*Loxoconcha* sp.	11.25
Pseudocythere sp.	22.31	*Yemanja* sp.	22.18
Quadracythere venusta	17.02	*Meridionalicythere*? sp. 1	22.25
Ruggiericythere batistae	20.26	*Neomonoceratina m. mediterranea*	23.00
Ruggiericythere dimorphica	18.35	*Neonesidea equatorialis*	20.46
Ruggiericythere perspicua	18.15	*Neonesidea* sp.	21.37
Semicytherura caudata	18.26	*Neocaudites subimpressus*	21.12
Semicytherura rugosoreticulata	22.01	*Oculocytheropteron pintoi*	20.02
Semicytherura sp. 7	22.03	*Orionina bradyi*	23.00
Semixestoleberis sp. 1	18.26	*Orionina similis*	18.59
Legitimocythere megapotamica	22.42	*Paracypris* sp. 1	20.16
Xestoleberis umbonata	20.36	*Paracytheridea batei*	22.31

Table 1. Cont.

Temperate water species	Northern limit (lat. °S)	Warm water species	Southern limit (lat. °S)
—	—	*Paracytheridea inflata*	22.03
—	—	*Paracytheridea tschoppi*	20.48
—	—	?*Paranesidea* ex gr. *bensoni*	21.12
—	—	*Paranesidea parabipustulosa*	20.48
—	—	*Pellucistoma* ex gr. *magniventra*	18.59
—	—	*Protocytheretta* sp.	22.03
—	—	*Vandenboldina* aff. *V. droogeri*	17.59
—	—	*Puriana variabilis*	18.59
—	—	*Triebelina* sp.	09.19
—	—	*Semicytherura* sp. 1	18.26
—	—	*Semicytherura* sp. 4	17.00
—	—	*Xestoleberis inesae*	18.27
—	—	*Xestoleberis* sp.	21.24

(seven spp.), *Paracytheridea* (six spp.) and *Caudites* (six spp.). The species with higher relative frequencies are *Loxoconcha forda* (41.34%), *Paranesidea parabipustulosa* (38.46%) and *Henryhowella tuberculiclaviforma* (38.46%). This is the first record of *L. forda* for South America.

For the Eastern and Northeastern Brazilian marine regions, 34 out of the 131 species herein identified are restricted to them (see Appendix 2, species numbers 50–83). The remaining 97 species with broader distribution are discussed subsequently.

Seven out of the 34 species with occurrences restricted to the study area were recorded only in the northeastern region, 17 only in the eastern region and 10 were found in both regions (see Appendix 2, species numbers 50–83). Except for *Bulbocythere calida*, *Caudites fluminensis*, *Triebelina* sp., *Xestoleberis* sp., *Semicytherura* sp. 1 and *Pseudocythere* sp., the remaining in this group were recorded in Brazil for the first time in this work.

In this study, 36.5% of the species were considered to be typical temperate water dwellers, 46.5% exclusive to warm water, 4% were possibly eurythermic and 11.5% were probably restricted to the Transitional Zone (= eastern marine region) discussed below in the subchapter ‘Biogeography’ (Figure 13; Table 2). The distinction between warm and temperate water species was based on the geographic

Table 2. Species probably restricted to the Transitional Zone (lat. 15ºS to 23ºS).

Species	Species
Ambocythere sp.	*Paracytheridea* sp.
Argilloecia sp.	*Quadracythere* sp.
Cativella sp.	*Sclerochilus* sp.
Caudites fluminensis	*Semicytherura* sp. 2
Cytherella sp. 3	*Semicytherura* sp. 3
Cytheretta sp. 1	*Semicytherura* sp. 6
Meridionalicythere? sp. 2	*Semixestoleberis* sp.

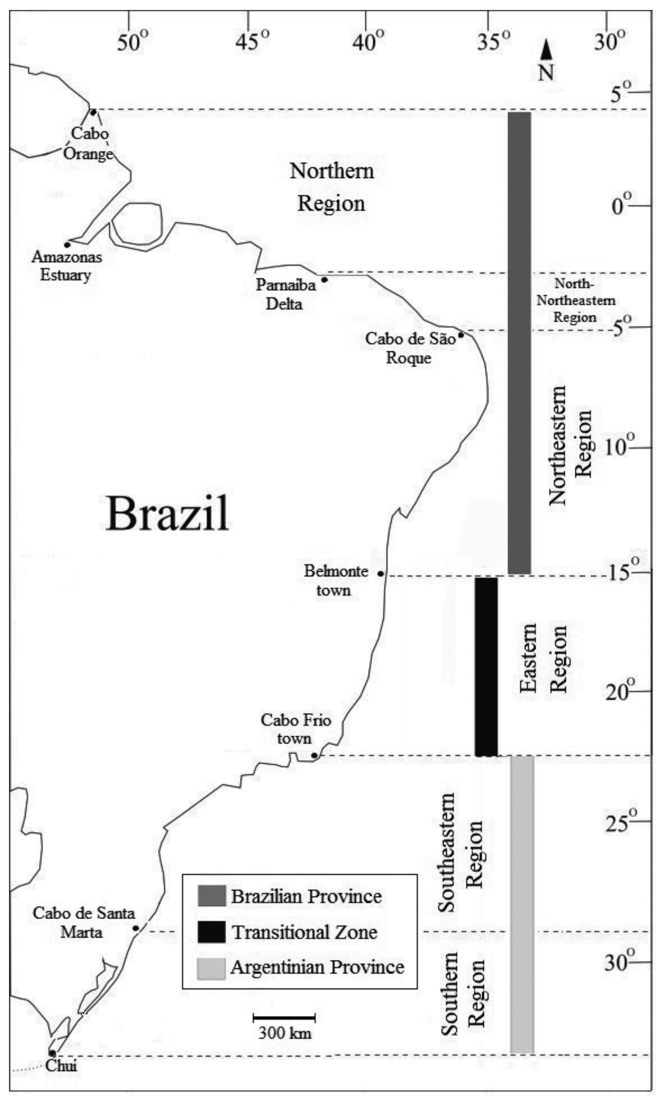

Figure 13. Biogeographic units defined based on the study of benthonic ostracods along the Brazilian continental shelf. For details of the southern extension of the Argentinian Province and the northern extension of the Brazilian Province, see the text.

distribution data obtained in this work and in previous studies (see Appendix 2 and 'Introduction' above).

The species *Neocaudites triplistriatus* (Caribbean region–28ºS), *Semicytherura parallelocostata* (00º08'S–26º56'S), *Phlyctocythere* sp. 1(00º10S–31º48.3'S), *Paracytheridea paralelicostata* (10º32'S–31º23'S) and *Semicytherura* sp. 5 (10º32'S–34º11.6'S) are possibly eurythermic because they have been recorded in both warm and temperate waters. For this reason, they were not considered in the interpretation of the boundaries of the Transitional Zone.

The intersection between warm and temperate water faunas indicates that the northern and southern boundaries of the Transitional Zone (= eastern marine region) are, respectively, at 15°S and 23°S, as formerly proposed for the Transitional Zone of Coimbra & Ornellas (1989), and slightly modified by Coimbra *et al.* (1995) based on the distribution of *Caudites*, *Orionina* and *Callistocythere*. The 17 species restricted to the Transitional Zone in the present study (Table 2) occurred in less than four samples and were represented by few specimens (≤ 7 valves and/or carapaces each species) (see Appendix 2, species numbers 67–83). The species *Cytherella* sp. 3 (1 valve), *Cativella* sp. (1 valve), *Paracytheridea* sp. (1 valve), *Quadracythere* sp. (2 valves) and *Sclerochilus* sp. (1 valve) were recorded only in the samples from the southernmost part of the Transitional Zone. *Caudites fluminensis*, also a rare species, presented a slightly wider distribution into the Transtional Zone, *i.e.*, between 20°S and 22°S (see Appendix 2).

Biogeography

The new Brazilian Province proposed herein ranges from the extreme north of the northern Brazilian marine region until the southern limit of the northeastern region, *i.e.*, from ~5°N (Cabo Orange) to 15°/16°S (Belmonte) (see Figures 1 and 13). This province is characterized by the absence of temperate water species and by high richness and abundance of ostracods mainly in carbonate sediment. It has affinities to the faunas from the Caribbean, Gulf of Mexico, and northern South America (*e.g.* Trinidad and Tobago).

The complete disappearance of temperate species was placed at 15ºS, while the northern boundary of the Brazilian Province is still unclear due to lack of data from a large area which includes Guyana, Suriname and French Guyana, and the scarcity of data on marine ostracods off Venezuela and Colombia. However, Wilson (2007, 2008) observed that 12 out of the 37 shallow-water ostracod species registered in Trinidad and Tobago, also occur in the Brazilian Province, as follows: *Bairdopillata dorsoangulata*, *Bythoceratina carmoi*, *Callistocythere fossulata*, *Caudites nipeensis*, *Costa variabilicostata recticostata*, *Cytherura* sp. (= *Cytherura duracina* Coimbra, Carreño & Michelli, 1999), *Gangamocytheridea dictyon*, *Kangarina ancyla*, *Paracytheridea tschoppi*, *Pellucistoma* ex gr. *magniventra*, *Vandenboldina* aff. *V. droogeri,* and *Radimella ovata.* However, *B. dorsoangulata*, *B. carmoi*, *C. v. recticostata*, *C. duracina*, *K. ancyla* and *R. ovata*, were not recorded in the 104 samples herein analyzed for the Eastern and Northeastern Brazilian marine regions. In Brazil, these last five species occur only in the equatorial section of the Brazilian Province (for details on the distribution of the ostracods in the north of Brazil see the papers by Coimbra and collaborators listed in the References).

The Brazilian Province has 15 species in common with the Caribbean and/or Gulf of Mexico, as follows: *Callistocythere cranekeyensis*, *Callistocythere fossulata*, *Caudites nipeensis*, *Gangamocytheridea* sp. aff. *G. dictyon*, *Glyptobairdia coronata*, *Hemicytherura bradyi*, *Loxoconcha forda*, *Loxocorniculum tricornatum*, *Neocaudites triplistriatus*, *Orionina bradyi*, *Orionina similis*, *Paracytheridea batei*, *Pellucistoma* ex. gr. *magniventra*, ?*Paranesidea* ex. gr. *Bensoni* and *Vandenboldina* aff. *V. droogeri*, totalling 12% of the ostracod species recorded in this province.

Eight species/subspecies with different degree of pandemism are also recorded in the Brazilian Province (6%), as follows: *Auradilus convolutus*, *Caudites exmouthensis*, *Keijia demissa*, *Kotoracythere inconspicua*, *Neocaudites subimpressus*, *Neomonoceratina m. mediterranea*, *Paracytheridea tschoppi*, and *Neohornibrookella* ex gr. *transoceanica*. All of them are known in the Indian and/or Pacific oceans as well (see Allison &Holden, 1971; Teeter, 1975; Hu, 1979; Whatley & Zhao, 1988; Cronin, 1988; Witte, 1993; Zhao & Whatley, 1988; Fauth & Coimbra, 1998).

Forty-eight species found in the samples examined in this study also occur in the northern portion of the Argentinian Province of Ramos (1998) (see Discussion for more details), which lies below ~23°S. This ostracod community has been identified in several studies based on neritic ostracods (*e.g.* Coimbra & Ornellas, 1989; Coimbra *et al.*, 1995; Ramos, 1996; Carmo & Sanguinetti, 1999; Machado & Drozinski, 2002; Ramos *et al.*, 2004, 2009, 2012), and is composed of species recorded along the Southeastern and Southern Brazilian marine regions (see Figures 1 and 13). Many of these ostracods reach the Uruguayan and Argentinian shelves, occurring in terrigenous sediments.

The Transitional Zone, located in the Eastern Brazilian shelf, is composed of warm water species from the north and cooler water species from the south (Figure 13; Appendix 2). It is a marine ecotone, since it includes species of adjacent bordering communities, besides a small number of typical ostracods restricted to this area. The 15 species that seem restricted to the Transitional Zone belong to well-known neritic genera (see Table 2). However, 11 out of 15 species are represented by only three or less valves, hindering detailed taxonomic study. The four remaining species (*Ambocythere* sp., *Nealocythere* sp., *Semicytherura* sp. 3 and *Semixestoleberis* sp.) have also scarce material and no complete carapace was recorded. We believe that these 15 species are probably new, living either in very small populations on the shelf, or are more abundant in coastal environments and occasionally transported to the shelf. If the latter hypothesis become suported by future studies, the occurrence of these species in the Transitional Zones should be considered accidental (for comparison see Morais & Coimbra, 2019).

Paleobiogeography

The cosmopolitan species, as well as those shared with the Caribbean and/or Gulf of Mexico, represent a small part of the ostracods herein studied, and their dispersal possibly prompted by process linked to relative sea level change events during the Neogene and Quaternary (see Cronin, 1988; Cronin & Schmidt, 1988). These sea level changes might have enabled, for instance, the crossing of barriers imposed by the discharge from the Amazon River as already discussed by Coimbra *et al.* (1999a). This hypothesis has been put forward to explain the dispersion patterns of reef fishes along the equatorial Brazilian continental shelf by Rocha (2003).

The fossil record of some of the species studied here spans to the Neogene, mostly from the Atlantic coasts of North and Central America (see Coimbra *et al.*, 1999a). The exception is *Paracytheridea tschoppi* with a Tethyan origin and a long period of evolutionary stasis and a very impressive geographical dispersion since the Miocene (see Witte, 1993 and Coimbra *et al.*, 1999b for more details).

It is noteworthy that *Neocaudites subimpressus* has its earliest record in the Duplin Marl Formation (North Caroline, USA), whose age is between the latest Miocene/Pliocene. Currently, *N. subimpressus* lives in warm waters in the study area and in the West Atlantic, Caribbean and East Pacific (Clipperton Island) (see Coimbra *et al.*, 2004 for more details).

Paracytheridea batei (Pliocene? of Cuba) and *Orionina similis* (Upper Miocene–Pliocene of Trinidad), have been recorded from the Recent only in Brazil. Considering that the same distribution pattern has been recorded for *Semicytherura bertelsae* (Neogene of Dominican Republic) by Coimbra *et al.* (1999b), the occurrence of these three species in Brazil might be considered relicts.

The fossil and Recent absence of both *Auradilus convolutus* and *Caudites exmouthensis* in the Caribbean indicate an east-westward dispersion route for some species of the Brazilian ostracod fauna. *A. convolutus* has been recorded along the Indian and Pacific oceans, including a record for the Pleistocene of Taiwan (Hu, 1979; Jellinek, 1995). This species has also been recorded along the tropical Brazilian shelf and from the oceanic Trindade Island, located off the southeastern Brazilian coast (Figure 1). *Caudites exmouthensis* has been recorded living in the Indian, Pacific, and Atlantic oceans, including Trindade Island and the Rocas Atoll (Brazil) (more details in Coimbra *et al.*, 1999a; Coimbra *et al.*, 2009; Coimbra & Carreño, 2012). Some authors have suggested that *A. costatus* migrated from the Indo-Pacific to the western Atlantic during the Pleistocene (Jellinek, 1995; Fauth & Coimbra, 1998; and Coimbra *et al.*, 2009). Besides these two species, *Caudites seminudus,* a very shallow species recorded in the Brazilian coast, Trindade Island and Rocas Atoll, was previously described from the Reunion Island, Indian Ocean (Machado *et al.*, 2005; Coimbra *et al.*, 2009; Coimbra & Carreño, 2012; Morais & Coimbra, 2019). It was suggested that some species of Ostracoda might have passively migrated into the Atlantic Ocean during the Quaternary, reaching the Brazilian coast through the Vitória-Trindade seamounts (see Figure 1). They might have been dispersed attached to algae fragments and holdfasts in long transoceanic journeys as already discussed, among other authors, by Morais & Coimbra (2019). It is possible that a passive dispersion by sweepstakes acted as an important mechanism for the dispersion between Trindade Island and the Brazilian shelf during the Quaternary (Coimbra & Carreño, 2012). Throughout its history, Trindade Island has barely been occupied and is currently used only as a Brazilian Navy base. It is assumed, therefore, that the absence of commercial activity implies a low possibility of transport of species by the ballast water of ships.

DISCUSSION

Briggs (1974) is an essencial reading for studying marine biogeography, especially in relation to the continental shelves. He proposed provinces based on at least 10% of endemism assembled within biogeographical regions that covered large geographic areas with biotic contrast. The distribution pattern of corals, hydrozoans, echinoderms, shrimps (Penaeidea), mollusks, and fishes inspired Briggs (1974) to propose the Brazilian Province, ranging from the Orinoco Delta (Venezuela, 08°56’N/60°47’W) to Cabo Frio (Brazil, ~23°S/42°02’W). In 2012, based on new taxonomic studies conducted by different authors, Briggs and Bowen revised the boundaries of the provinces delimited in 1974. The biogeographic units along the Western Atlantic Region were modified, including the merger of the West Indian Province with the Caribbean Province under the latter denomination. Based on Floeter *et al.* (2008), who studied reef fishes, Briggs & Bowen (2012) assumed a new extension of the Brazilian Province from the mouth of the Amazon River to the Santa Catarina State (28°S).

Spalding *et al.* (2007) proposed smaller biogeographical units, *i.e.*, 232 marine ecoregions distributed throughout the world as internal subdivisions of 62 provinces, most of them provinces previously defined by Briggs (1974, 1995). Concerning the continental shelf of Brazil, the area above Cabo Frio (~ 23°S) would be part of the Tropical Atlantic Realm, subdivided into two provinces, as follows: North Brazil Shelf Province and Tropical Southwestern Atlantic Province. Based on fig. 2 of Spalding *et al.* (2007), the North Brazil Shelf Province extends from Paranaíba Delta (Brazil, 02°54’S) to southern Venezuela, and is subdivided in the Guiana and Amazonia ecoregions. The Tropical Southwestern Atlantic Province extends from Paranaíba Delta to Cabo Frio (~23°S), and encloses five ecoregions, being three related to oceanic islands and two to the continental shelf. Regarding to the last two units, the Northeastern Brazil ecoregion spreads along the north-northeastern shelf and part of the northeastern shelf, while the Eastern Brazil ecoregion extends from Salvador (~12°S) to Cabo Frio (~23°S).

Madeira-Falcetta (1977) and Forti-Esteves (1984) analyzed bottom sediments colletect along the entire Brazilian shelf between Amapá State (05°05’N) and Rio Grande do Sul State (34°30’S). The first author studied the benthic foraminifers, but not their biogeographic aspects, while the latter analyzed Palaeotaxodonta and Pteriomorphia mollusks

(Bivalvia), with preliminary biogeographic remarks. The results of Forti-Esteves (1984) are in accordance with the benthonic foraminifer model proposed by Boltovskoy (1976), who places the latitude ~23°S as the boundary between the North Brazilian Subprovince and the South Brazilian Subprovince. That author also sustains that the north boundary of the Brazilian Province is the Western Indian Province, near the Venezuela coast.

Diaz (1995) and Boschi (2000 a,b), studying gastropods and decapods, respectively, discussed the zoogeographical significance of these groups in the Caribbean and in Americas. Diaz (1995) worked with beach and shelf samples from a wide region between Costa Rica and Suriname, including large islands off Venezuela, such as Aruba, Bonaire, Curaçao and Margarita, as well as smaller ones. He concluded that the region between the Orinoco Delta and Suriname is abruptly impoverished in Caribbean gastropods, with gradual enrichment of Brazilian species eastward and, therefore, being a transitional area toward the Brazilian Province. That author also reinforces the low dispersion capacity of the neogastropods during the larval stage, similarly to the podocopid ostracods, which increases their biogeographic applicability. Boschi (2000a,b) registered a group of decapod species between the Orinoco Delta (Venezuela, 08°56'N/60°47'W) and Cabo Frio (Brasil, ~23°S/42°02'W), which was denominated Brazilian Province. The author based the proposal in the marine current, water temperature and species diversity both in coastal and neritic areas (supratidal zone to 200–300 m water depth).

It is noteworthy that Briggs (1974), Boltovskoy (1976), Madeira-Falcetta (1977), Forti-Esteves (1984), Diaz (1995), and Boschi (2000a,b) did not sustain the occurrence of a Transitional Zone between 23°S and 15°S, as indicated by ostracods.

Whatley *et al.* (1998b) proposed a provincial model for Argentina, Uruguay, and southern/southeastern Brazil based on the latitudinal distribution of 128 species of benthonic ostracods (mostly in open nomenclature) between 55°S and 20°S. As already mentioned, Whatley's *et al.* (1998b) data were compiled from papers which adopted different sampling methodologies: intertidal samples were collected by hand, sublittoral by divers, and shelf samples by a variety of grabs and dredges. In addition, most of intertidal and sublittoral ostracods were collected alive in algae, while those from the shelf were picked from dry sediments. In our opinion, the model by Whatley *et al.* (1998b) is inadequate because it assembles intertidal, sublittoral, and neritic species (some of them occurring at more than 100 m water depth). Concerning Brazil, they established the Brazilian Province with two subprovinces, the Platensian-Uruguayan-Pelotensian Subprovince (36°S–31°/30°S) and the Southern Brazilian Subprovince (31°/30°S–22°/21°S). In both they registered 38 species, three of them restricted to the first, and six to the second subprovince (see Whatley *et al.*, 1998b; tab. 1). Among the three species exclusive of the Platensian-Uruguayan-Pelotensian Subprovince, *Perissocytheridea kroemmelbeini* Pinto & Ornellas, 1970 is typically mixohaline. It is common in the estuary of the Rio de la Plata estuary (Uruguay) and occurs in Brazil at least from the Rio de Janeiro State (~ 23°S) to the southernmost of the country (Coimbra *et al.*, 2007). The occurrence of isolated valves and empty carapaces of this and other mixohaline species on the shelf results probably from transport by the regional hydrological system. This illustrates the relative weakness of the zoogeographical model proposed by Whatley *et al.* (1998b), and it is partially rejected in this study.

Ramos (1998), studying Brazilian shelf ostracods between Cabo Frio (~23°S) and Chuí (33º41'S), modified the zoogeographical model of Whatley *et al.* (1998b) by lowering the Brazilian Province to a subprovince of her new and very large zoogeographical unit, the Argentinian Province (52°S–21°/22°S). She subdivided the Argentinian Province as follows: Southern Patagonian/Falkland Subprovince (52°S–47°/48°S), Northern Patagonian Subprovince (47°/48°S–42/43°S), Bonaerensian Subprovince (42°/43°S–36°S), Platensian/Uruguayan/Pelotensian Subprovince (36°S–30°/31°S) and Southern Brazilian Subprovince (30°/31°S–21°/22°S).

The Argentinian Province (with two subprovinces in Brazilian territory) of Ramos (1998) added to the confirmation of a Transitional Zone and the delimitation of the new Brazilian Province, is supported on the 104 samples herein analyzed and on previous studies of the taxonomy and distribution of neritic ostracods along the Brazilian shelf, as follows: Coimbra & Ornellas (1989), Ramos (1994, 1996), Coimbra *et al.* (1994, 1995, 1999 a,b, 2004), Fauth & Coimbra (1998), Coimbra & Fauth (2002), Coimbra & Carreño (2002), Bergue & Coimbra (2002), Coimbra & Carmo (2002), Machado & Drozinski, (2002), Coimbra & Bergue (2003), Aiello *et al.* (2004), Ramos *et al.* (2009, 2012, 2014), Sartori & Coimbra (2010), Bergue *et al.* (2016), and Luz & Coimbra (2015).

As presented above, Briggs (1974, many groups), Forti-Esteves (1984, two Bivalvia families) and Boschi (2000a,b, decapods) located the northern boundary of the Brazilian Province off Venezuela, while Diaz (1995, gastropods) argues that there is a large transitional faunal zone between the Brazilian Province and the Western Indian Province. Concerned to ostracods, the north limit of the Brazilian Province, whose extension in Brazil includes the northeastern, north-northeastern and northern shelves (see Figures 1 and 13), as presented in the 'Results', remains indeterminate. Unfortunately, the absence of studies on benthonic ostracods between the Orinoco Delta (Venezuela, 08°56'N–60°47'W) and French Guiana (2°20'N–54°26'W), which corresponds to an area over 1,000 km length, precludes more conclusive statements.

CONCLUSIONS

The Brazilian shallow marine ostracod fauna is characterized by three assemblages: (i) one composed of Southern/Southeastern Brazilian species, many of them occurring also in Uruguay and northern Argentina, known as Argentinian Province (*sensu* Ramos, 1998); (ii) a tropical assemblage formally proposed in this study under the denomination of Brazilian Province, composed of species shared with the Caribbean and/or Gulf of Mexico, some pandemic species and some endemic species; (iii) and a Transitional Zone characterized by elements from the two assemblages previously mentioned, as well as 15 rare species probably restricted to this area.

Dispersal of shelf marine ostracods is constrained by complex environmental factors, including hydrology, bottom sediments, and historical factors. The presence of warm water masses and the prevalence of carbonatic bottoms are the best explanation for the distribution of the shallow water ostracods from the northern, northern-northeastern and northeastern Brazilian marine regions, which form a large area where the new Brazilian Province is settled down. The temperate waters and terrigenous bottom sediments of the Southern and Southeastern Brazilian marine regions obviously house a distinct ostracod community that is part of the Argentinian Province (*sensu* Ramos, 1998). Between these two large provinces extends a shelf where, from north to south, the waters become colder and the carbonate content of the sediments decreases, occurring a mixture of species from the north and the south. This is the Brazilian marine region known as the eastern shelf where a marine ecotone is established, the Transitional Zone (*sensu* Coimbra *et al.*, 1995).

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Appendix 1.

Suborder Platycopina Sars, 1866
Family Cytherellidae Sars, 1866
Genus *Cytherella* Jones, 1849
Cytherella hermargentina Whatley, Moguilevsky, Chadwick, Toy & Ramos, 1998
Cytherella sp. 1
Cytherella sp. 2
Cytherella sp. 3
Cytherella sp. 4
Genus *Keijcyoidea* Malz, 1981
Keijcyoidea amazonica Bergue & Coimbra, 2002
Suborder Podocopina Sars, 1866
Superfamily Cypridoidea, Baird, 1845
Family Paracyprididae Sars, 1923
Genus *Paracypris* Sars, 1866
Paracypris sp. 1
Paracypris sp. 2
Family Pontocyprididae Müller, 1894
Genus *Argilloecia* Sars, 1866
Argilloecia inflata Ramos, Whatley & Coimbra, 2004
Argilloecia parameridionalis Whatley, Moguilevsky, Chadwick, Toy & Ramos, 1998
Argilloecia sp.
Genus *Australoecia* Mckenzie, 1967
Australoecia neritica Sartori & Coimbra, 2010
Superfamily Macrocypridoidea, Müller, 1912
Family Macrocyprididae Müller, 1912
Genus *Yemanja* Brandão, 2010
Yemanja sp.
Superfamily Bairdioidea Sars, 1888
Family Bairdiidae Sars, 1888
Subfamily Bairdiinae Sars, 1888
Genus *Neonesidea* Maddocks, 1969
Neonesidea equatorialis Coimbra & Carreño, 2002
Neonesidea sp.
Genus *Paranesidea* Maddocks, 1969
Paranesidea parabipustulosa Coimbra & Carreño, 2002
?*Paranesidea* ex gr. *bensoni* Teeter, 1975
Genus *Bairdoppilata* Coryell, Sample & Jennings, 1935
Bairdoppilata sudbrasiliensis Ramos, Whatley & Coimbra, 2004
Bairdoppilata sp.
Genus *Glyptobairdia* Stephenson, 1946
Glyptobairdia coronata (Brady, 1870)
Genus *Triebelina* Bold, 1946
Triebelina sp.
Subfamily Bythocypridinae Maddocks, 1969
Genus *Anchistrocheles* Brady & Norman, 1889
Anchistrocheles? sp.
Superfamily Cytheroidea Baird, 1850
Family Loxoconchidae Sars, 1925
Genus *Loxoconcha* Sars, 1866
Loxoconcha bullata Hartmann, 1956
Loxoconcha forda Bold, 1968
Loxoconcha sp.
Genus *Loxocorniculum* Benson & Coleman, 1963.
Loxocorniculum tricornatum Krutak, 1971
Loxocorniculum sp.

Appendix 1. Cont.

Genus *Phlyctocythere* Keij, 1957
Phlyctocythere sp.
Family Bythocytheridae Sars, 1926
Subfamily Bythocytherinae Sars, 1926
Genus *Nealocythere* Schornikov, 1982
Nealocythere sp.
Genus *Pseudocythere* Sars, 1866
Pseudocythere sp.
Genus *Vandenboldina* Bold, 1965 *nomen novum* for *Pseudoceratina* (see Wilson, 2010)
Vandenboldina aff. *V. droogeri* (Bold, 1965)
Family Pectocytheridae Hanai, 1957
Genus *Kotoracythere* Ishizaki, 1966
Kotoracythere inconspicua (Brady, 1880)
Genus *Keijia* Teeter, 1975
Keijia demissa (Brady, 1868)
Family Cytherideidae Sars, 1925
Subfamily Cytherideinae Sars, 1925
Genus *Cyprideis* Jones, 1857
Cyprideis multidentata Hartmann, 1955
Family Cytheridae Baird, 1850
Genus *Gangamocytheridea* Bold, 1963
Gangamocytheridea dictyon Bold, 1963
Family Schizocytheridae Howe, 1961
Genus *Neomonoceratina* Kingma, 1948
Neomonoceratina mediterranea mediterranea Ruggieri, 1953
Family Cushmanideidae Puri, 1958
Genus *Hulingsina* Puri, 1958
Hulingsina toreuma Bergue & Coimbra, 2002
Genus *Cushmanidea* Blake, 1933
Cushmanidea? *echevarriae* Bertels & Martínez, 1997
Family Neocytherideidae Puri, 1957
Genus *Papillosacythere* Whatley, Chadwick, Coxill & Toy, 1987
Papillosacythere parallela Whatley, Chadwick, Coxill & Toy, 1987
Family Copytidae Coimbra, Bergue & Ramos, 2020
Genus *Copytus* Skogsberg, 1939
Copytus wuerdigae Coimbra, Bergue & Ramos, 2020
Copytus sp.
Family Thaerocytheridae Hazel, 1967
Subfamily Bradleyinae Benson, 1972
Genus *Bradleya* Hornibrook, 1952
Bradleya pseudonormani Ramos, Coimbra & Whatley, 2009
Bradleya kaesleri Ramos, Coimbra & Whatley, 2009
Subfamily Thaerocytherinae Hazel, 1967
Genus *Muellerina* Bassiouni, 1965
Muellerina cribosa Ramos, Coimbra & Whatley, 2009
Genus *Quadracythere* Hornibrook, 1952
Quadracythere venusta Ramos, Coimbra & Whatley, 2009 *nomen novum* for *Q. nealei* (see Ramos, Coimbra & Whatley, 2011)
Quadracythere sp.
Genus *Brasilicythere* Sanguinetti, Ornellas & Coimbra, 1991
Brasilicythere reticulispinosa Sanguinetti, Ornellas & Coimbra, 1991
Genus *Puriana* Coryel & Fields, 1953
Puriana variabilis Chukewiski & Purper, 1985
Genus *Neohornibrookella* Jellinek, 1993
Neohornibrookella ex gr. *transoceanica* (Teeter, 1975) a species erroneously attributed to *Hermanites* Puri, 1955 or *Tenedocythere* Sissingh, 1972 for most authors)

Appendix 1. Cont.

Family Trachyleberididae Silvester-Bradley, 1948
Subfamily Trachyleberidinae Silvester-Bradley, 1948
Genus *Actinocythereis* Puri, 1953
Actinocythereis brasiliensis Machado & Drozinski, 2002
Genus *Legitimocythere* Coles & Whatley, 1989
Legitimocythere megapotamica Bergue, Coimbra & Ramos, 2016
Genus *Basslerites* Howe, 1937
Basslerites multicostata Ramos, Coimbra, Bergue & Whatley, 2012
Genus *Henryhowella* Puri, 1957
Henryhowella tuberculiclaviforma Coimbra, Ramos, Whatley & Bergue, 2004
Genus *Apatihowella* Jellinek & Swanson, 2003
Apatihowella macrocicatricosa (Whatley, Moguilevsky, Chadwick, Toy & Ramos, 1998)
Apatihowella inflata (Ramos, Coimbra, Bergue & Whatley, 2012)
Genus *Cativella* Coryell & Fields, 1937
Cativella sudbrasiliensis Ramos, Coimbra, Bergue & Whatley, 2012
Cativella sp.
Genus *Neocaudites* Puri, 1960
Neocaudites subimpressus (Edwards, 1944)
Neocaudites triplistriatus (Edwars, 1944)
Subfamily Buntoniinae Apostolescu, 1961
Genus *Ambocythere* Bold, 1957
Ambocythere sp.
Subfamily Cytherettinae Triebel, 1952
Genus *Argenticytheretta* Rossi de García, 1959 *emend*. Sanguinetti, Ornellas & Coimbra (1991)
Argenticytheretta laevipunctata Sanguinetti, Ornellas & Coimbra, 1991
Argenticytheretta? sp.
Genus *Cytheretta* Müller, 1894
Cytheretta sp. 1
Cytheretta sp. 2
Genus *Protocytheretta* Puri, 1958
Protocytheretta sp.
Subfamily Phacorhabdotinae Gründel, 1969
Genus *Australimoosella* Hartmann, 1978
Australimoosella polypleurum Coimbra, Ramos, Whatley & Bergue, 2004
Family Krithidae Mandelstam, 1960
Genus *Krithe* Brady, Crooskey & Robertson, 1874
Krithe gnoma Carmo & Sanguinetti, 1999
Family Xestoleberididae Sars, 1866
Genus *Xestolebereis* Sars, 1866
Xestoleberis umbonata Whatley, Chadwick, Toy & Ramos, 1998
Xestoleberis inesae Luz & Coimbra, 2015
Xestoleberis sp.
Genus *Semixestoleberis* Hartmann, 1962
Semixestoleberis sp. 1
Semixestoleberis sp. 2
Family Cytheruridae Müller, 1894
Subfamily Cytherurinae Müller, 1894
Genus *Oculocytheropteron* Bate, 1972
Oculocytheropteron pintoi Coimbra, Carreño & Michelli, 1999
Oculocytheropteron circumcostatum Ramos, Coimbra, Whatley & Moguilevsky, 1999
Oculocytheropteron delicatum Ramos, Coimbra, Whatley & Moguilevsky, 1999
Oculocytheropteron macropunctatum Whatley, Chadwick, Coxill & Toy, 1988
Genus *Semicytherura* Wagner, 1957
Semicytherura caudata Ramos, Coimbra, Whatley & Moguilevsky, 1999
Semicytherura parallelocostata Coimbra, Carreño & Michelli, 1999
Semicytherura rugosoreticulata Whatley, Chadwick, Coxill & Toy, 1988

Appendix 1. Cont.

Semicytherura sp. 1
Semicytherura sp. 2
Semicytherura sp. 3
Semicytherura sp. 4
Semicytherura sp. 5
Semicytherura sp. 6
Semicytherura sp. 7
Genus *Hemicytherura* Elofson, 1941
Hemicytherura auriculata Ramos, Coimbra, Whatley & Moguilevsky, 1999
Hemicytherura bradyi (Puri, 1960) *emend.* Coimbra, Carreño & Michelli (1999)
Genus *Aversovalva* Hornibrook, 1952
Aversovalva wurdigae Coimbra, Carreño & Michelli, 1999
Subfamily Paracytherideinae Puri, 1957
Genus *Paracytheridea* Müller, 1894
Paracytheridea paralelicostata Purper & Ornellas, 1989
Paracyheridea batei Purper & Ornellas, 1987
Paracytheridea inflata Purper & Ornellas, 1987
Paracytheridea bulbosa Purper & Ornellas, 1989
Paracytheridea tschoppi Bold, 1946
Paracytheridea sp.
Family Leptocytheridae Hanai, 1957
Genus *Callistocythere* Ruggieri, 1953
Callistocythere nucleoperiscum Whatley, Moguilevsky, Toy, Chadwick & Ramos, 1997, a species erroneously named *Callistocythere litoralensis* (Rossi de Garcia, 1966) for most Brazilian authors
Callistocythere ornata (Hartmann, 1956)
Callistocythere sigmocostelata Coimbra, Sanguinetti & Bittencourt-Calcagno, 1995
Callistocythere laminata Coimbra, Sanguinetti & Bittencourt-Calcagno, 1995
Callistocythere fossulata Coimbra, Sanguinetti & Bittencourt-Calcagno, 1995
Callistocythere multicellulosa Coimbra, Sanguinetti & Bittencourt-Calcagno, 1995
Callistocythere cranekeyensis (Puri, 1960)
Family Hemicytheridae Puri, 1953
Subfamily Hemicytherinae Puri, 1953
Genus *Bulbocythere* Coimbra & Morais, 2017
Bulbocythere calida Coimbra & Morais, 2017
Genus *Meridionalicythere* Whatley, Chadwick, Coxill & Toy, 1987
Meridionalicythere? sp. 1
Meridionalicythere? sp. 2
Meridionalicythere? sp. 3
Meridionalicythere? sp. 4
Genus *Ruggiericythere* Aiello, Coimbra & Barra, 2004
Ruggiericythere perspicua Aiello, Coimbra & Barra, 2004
Ruggiericythere batistae Aiello, Coimbra & Barra, 2004
Ruggiericythere dimorphica (Whatley, Moguilevsky, Chadwick, Toy & Ramos, 1998)
Genus *Auradilus* Jellinek, 1995
Auradilus convolutus (Brady, 1868), a species erroneously named *Auradilus costatus* (Hu, 1979) for most Brazilian authors
Subfamily Oriononinae Puri, 1973
Genus Orionina Puri, 1954
Orionina bradyi Bold, 1963
Orionina similis Bold, 1963
Genus *Caudites* Coryell & Fields, 1937
Caudites ohmerti Coimbra & Ornellas, 1987
Caudites nipeensis Bold, 1946 *emend.* Coimbra & Ornellas (1986)
Caudites vandenboldi Coimbra & Ornellas, 1987
Caudites gnomus Coimbra & Ornellas, 1987
Caudites fluminensis Coimbra & Ornellas, 1987
Caudites exmouthensis Hartmann, 1978

Appendix 1. Cont.

Subfamily Coquimbinae Ohmert, 1968
Genus *Coquimba* Ohmert, 1968
Coquimba tenuireticulata Kotzian, 1982 *emend*. Sanguinetti, Ornellas & Coimbra (1991)
Coquimba ornellasae Ramos, 1994
Coquimba punctata Ramos, 1994
Genus *Cornucoquimba* Ohmert, 1968
Cornucoquimba decorata Ramos, 1996
Cornucoquimba nana Ramos, 1996
Cornucoquimba ramosae Coimbra & Carmo, 2002
Cornucoquimba lutziana Zabert, 1978 (senior synonym for *Neocaudites planeforma* Whatley, Moguilevsky, Toy, Chadwick & Ramos, 1997)
Genus *Nanocoquimba* Ohmert, 1968
Nanocoquimba pulchra Ramos, 1996
Family Eucytheridae Puri, 1954
Genus *Eucythere* Brady, 1868
Eucythere sp.
Family Paradoxostomatidae Brady & Normann, 1884
Genus *Pellucistoma* Coryell & Fields, 1937
Pellucistoma ex gr. *magniventra* Edwards, 1944
Genus *Paradoxostoma* Fischer, 1855
Paradoxostoma sp.
Genus *Sclerochilus* Sars, 1865
Sclerochilus sp.

Appendix 2. Zoogeographic distribution along the Brazilian shelf of the Ostracoda species herein analyzed. **Abbreviations:** relative frequency in the samples herein analyzed (**F**); Northern Region (**NOR**); North-Northeastern Region (**NNR**); Southeastern Region (**SR**); Southern Region (**SOR**); Doubtful occurrence (**?**). ■ Occurrence of species in this study. ▒ Occurrence of species according to the following literature (alphabetically by first author): Aiello *et al.* (2004), Bergue & Coimbra (2002), Bertels & Martínez (1997), Brandão (2005, 2010), Carmo & Sanguinetti (1999), Chukewiski & Purper (1985), Coimbra & Bergue (2003), Coimbra & Carmo (2002), Coimbra & Carreño (2002), Coimbra & Fauth (2002), Coimbra & Morais (2017, 2019), Coimbra & Ornellas (1986, 1987, 1989), Coimbra *et al.* (1992, 1994, 1995, 1999a,b, 2004, 2007, 2009), Dias Brito *et al.* (1988), Fauth & Coimbra (1998), Luz & Coimbra (2015), Machado & Drozinski (2002), Machado *et al.* (2005), Purper & Ornellas (1987a,b, 1989), Ramos (1994, 1996, 1998), Ramos *et al.* (1999, 2004, 2009, 2011, 2012), Sanguinetti, Ornellas & Coimbra (1991), Sartori & Coimbra (2010), Whatley *et al.* (1987, 1988, 1997, 1998a,b,), and Wilson (2010).

	Species	F (%)	NOR / NNR	Latitudes																			SR / SOR
				Northeastern Region										Eastern Region – Transition Zone									
				05°00'	06°00'	07°00'	08°00'	09°00'	10°00'	11°00'	12°00'	13°00'	14°00'	15°00'	16°00'	17°00'	18°00'	19°00'	20°00'	21°00'	22°00'	23°00'	
1	*Keijcyoidea amazonica* Bergue & Coimbra, 2002	34.61	▒	▒		■	■	■	■	■	■		■	■	■	■	■	■	■	■			
2	*Australoecia neritica* Sartori & Coimbra, 2010	11.53	▒						■						■	■	■	■	■		■		
3	*Yemanja* sp.	50	▒	▒	▒	▒	■	■	■		■	■		■	■	■	■	■	■	■	■	▒	
4	*Neonesidea equatorialis* Coimbra & Carreño, 2002	24.03	▒			■	■	■	■		■	■			■	■	■		■				
5	*Paranesidea parabipustulosa* Coimbra & Carreño, 2002	38.46	▒	▒	▒	▒	■	■	■		■	■	■	■	■	■	■		■				
6	?*Paranesidea* ex gr. *bensoni* Teeter, 1975	14.42	▒				■	■				■		■	■		■		■	■			
7	*Glyptobairdia coronata* (Brady, 1870)	6.73	▒	▒			■		■								■		■	■			
8	*Loxocorniculum tricornatum* Krutak, 1971	9.61	▒				■			■					■	■	■			■			
9	*Vandenboldina* aff. *V. droogeri* (Bold, 1965)	0.96	▒														■						
10	*Kotoracythere inconspicua* (Brady, 1880)	1.92	▒		▒	■	▒	■														▒	
11	*Keijia demissa* (Brady, 1868)	1.92	▒		▒		▒								■							▒	
12	*Gangamocytheridea dictyon* Bold, 1963a	7.69	▒	▒			▒						■		■	■	■						
13	*Neomonoceratina mediterranea mediterranea* Ruggieri, 1953	0.96	▒				▒			■												▒	
14	*Hulingsina toreuma* Bergue & Coimbra, 2002	6.73	▒												■	■	■						
15	*Puriana variabilis* Chukewiski & Purper, 1985	11.53	▒	▒	▒		■	■	■					■			■		■				
16	*Henryhowella tuberculiclaviforma* Coimbra, Ramos, Whatley & Bergue, 2004	38.46	▒			▒	■	■	■	■	■	■	■	■	■	■	■	■		■			
17	*Neohornibrookella* ex gr. *transoceanica* (Teeter, 1975)	3.84	▒	■		▒	▒	■							■								
18	*Neocaudites subimpressus* (Edwards, 1944)	13.46	▒	▒				■				■	■	■	■	■			■	■			
19	*Australimoosella polypleurum* Coimbra, Ramos, Whatley & Bergue, 2004	11.54	▒				■								■	■	■	■		■			
20	*Xestoleberis inesae* Luz & Coimbra, 2015	9.61	▒				■	■					■				■		?				
21	*Oculocytheropteron pintoi* Coimbra, Carreño & Michelli, 1999b	16.34	▒	▒					■			■	■	■	■	■	■	■	■				
22	*Hemicytherura bradyi* (Puri, 1960)	0.96	▒												■								
23	*Aversovalva wurdigae* Coimbra, Carreño & Michelli, 1999	0.96	▒														■						
24	*Paracytheridea batei* Purper & Ornellas, 1987	25.96	▒	▒	▒	▒	▒	■	■	▒	▒	■	■	■	■	■	■	■	■	■	■		
25	*Paracytheridea inflata* Purper & Ornellas, 1987	13.46	▒	▒			■	■	■		■		■	■	■		■				■		
26	*Paracytheridea tschoppi* Bold, 1946	4.80	▒	▒	▒	▒	■	▒				▒		■	■	■			■				
27	*Callistocythere ornata* (Hartmann, 1956)	10.57	▒			■			■	■					■		■	■		■	■		
28	*Callistocythere sigmocostelata* Coimbra, Sanguinetti & Bittencourt-Calcagno, 1995	12.5	▒							▒		▒	▒	▒	■	■	■	■	■	■	■		
29	*Callistocythere laminata* Coimbra, Sanguinetti & Bittencourt-Calcagno, 1995	6.73	▒		▒			■	▒	■				■	▒	▒	■	▒		■			
30	*Callistocythere fossulata* Coimbra, Sanguinetti & Bittencourt-Calcagno, 1995	1.92	▒	▒						■				▒	▒	■	▒	▒			▒		
31	*Callistocythere multicellulosa* Coimbra, Sanguinetti & Bittencourt-Calcagno, 1995	2.88	▒					▒					▒	▒	■	▒	▒	▒	■	▒	▒		
32	*Callistocythere cranekeyensis* (Puri, 1960)	0.96	▒		▒	■																	
33	*Auradilus convolutus* (Brady, 1868)	10.57	▒	▒	▒	▒	■		■	▒	■	■	▒	▒	■	■	■		▒	▒		▒	
34	*Orionina bradyi* Bold, 1963	1.92	▒		▒	▒	▒	■														▒	
35	*Orionina similis* Bold, 1963	2.88	▒					▒						▒			■						
36	*Caudites nipeensis* Bold, 1946	11.53	▒	▒	▒		■	▒	■					■	■	■	■	▒	■	■			
37	*Coquimba ornellasae* Ramos, 1994	29.80	▒		▒	▒	▒	■	▒	■			■	■	■	■	■	▒	■	■	■		
38	*Coquimba punctata* Ramos, 1994	3.84	▒												■	■			■				
39	*Cornucoquimba nana* Ramos, 1996	1.92	▒	▒	▒	▒	■								▒	▒			■				
40	*Cornucoquimba ramosae* Coimbra & Carmo, 2002	25.96	▒	▒						■		■	■	■	■		■	■	■	■			
41	*Pellucistoma* ex gr. *magniventra* Edwards, 1944	4.80	▒							■						■	■						
42	*Semicytherura* sp. 5	10.57							■					■	■		■	■	■		■		▒
43	*Cornucoquimba decorata* Ramos, 1996	24.03	▒	▒		▒	■	■	■		■		■	■	■	■	■		■	■	■		
44	*Neocaudites triplistriatus* (Edwards, 1944)	0.96	▒				▒													■			▒
45	*Paracytheridea paralelicostata* Purper & Ornellas, 1989	13.46							■	■				■	■		■	■	■	■	■	▒	▒
46	*Phlyctocythere* sp.	8.65	▒							■			■		■	■	■		■				▒
47	*Semicytherura parallelocostata* Coimbra, Carreño & Michelli, 1999	9.61	▒				■								■	■	■		■				▒
48	*Loxoconcha forda* Bold, 1968	41.34				■	■	■	■		■	■	■	■	■	■	■		■	■	■		
49	*Caudites exmouthensis* Hartmann, 1978	0.96															■						
50	*Cytherella* sp. 2	1.92							■	■													
51	*Triebelina* sp.	1.92					■	■															
52	*Anchistrocheles*? sp.	0.96						■															
53	*Loxoconcha* sp.	1.92							■	■													
54	*Loxocorniculum* sp.	1.92				■	■																
55	*Copytus* sp.	1.92							■	■													

Appendix 2. Cont.

	Species	F (%)	NOR / NNR	Latitudes: Northeastern Region										Latitudes: Eastern Region – Transition Zone									SR / SOR
				05°00'	06°00'	07°00'	08°00'	09°00'	10°00'	11°00'	12°00'	13°00'	14°00'	15°00'	16°00'	17°00'	18°00'	19°00'	20°00'	21°00'	22°00'	23°00'	
56	*Cytheretta* sp. 2	0.96								■													
57	*Protocytheretta* sp.	4.80								■							■				■		
58	*Cytherella* sp. 1	2.88								■					■	■							
59	*Neonesidea* sp.	21.15					■	■	■		■				■	■	■	■	■	■			
60	*Bairdoppilata* sp.	20.19					■	■	■	■	■		■	■	■	■							
61	*Paracypris* sp. 1	9.61							■						■	■	■	■	■				
62	*Xestoleberis* sp.	4.80						■		■	■								■	■			
63	*Semicytherura* sp. 4	1.92								■						■							
64	*Meridionalicythere*? sp. 1	27.88						■	■	■				■			■	■	■	■	■		
65	*Bulbocythere calida* Coimbra & Morais, 2017	15.38					■	■	■	■				■		■	■			■			
66	*Semicytherura* sp. 1	1.92												■			■						
67	*Paradoxostoma* sp.	3.84													■	■			■	■			
68	*Cytherella* sp. 3	0.96																			■		
69	*Argilloecia* sp.	2.88															■			■	■		
70	*Ambocythere* sp.	2.88															■				■		
71	*Caudites fluminensis* Coimbra & Ornellas, 1987	1.92																	▒		■		
72	*Cativella* sp.	0.96																			■		
73	*Cytheretta* sp. 1	1.92																■		■			
74	*Meridionalicythere*? sp. 2	3.84															■	■	■				
75	*Nealocythere* sp.	3.84																■	■		■		
76	*Paracytheridea* sp.	0.96																			■		
77	*Quadracythere* sp.	1.92																			■		
78	*Sclerochilus* sp.	0.96																			■		
79	*Eucythere* sp.	2.88																		■	■		
80	*Semicytherura* sp. 2	0.96															■						
81	*Semicytherura* sp. 3	2.88														■		■	■				
82	*Semicytherura* sp. 6	1.92													■		■						
83	*Semixestoleberis* sp.	1.92															■				■		
84	*Pseudocythere* sp.	0.96																			■		▒
85	*Copytus wuerdigae* Coimbra, Bergue & Ramos, 2020	3.84																■			■		▒
86	*Cytherella hermagentina* Whatley, Moguilevsky, Chadwick, Toy & Ramos, 1998a	4.80																			■	■	▒
87	*Cytherella* sp. 4	1.92																■			■	■	▒
88	*Paracypris* sp. 2	0.96																			■		▒
89	*Argilloecia inflata* Ramos, Whatley & Coimbra, 2004	1.92																			■	■	▒
90	*Bairdoppilata sudbrasiliensis* Ramos, Whatley & Coimbra, 2004	1.92																			■	▒	▒
91	*Loxoconcha bullata* Hartmann, 1956	0.96													■	■			■	■	■	▒	▒
92	*Cyprideis multidentata* Hartmann, 1955	2.88													■		■				▒	▒	▒
93	*Cushmanidea*? *echevarriae* Bertels & Martínez, 1997	4.80																■	■	■	■		▒
94	*Papillosacythere parallela* Whatley, Chadwick, Coxill & Toy, 1987	0.96																			■		▒
95	*Bradleya kaesleri* Ramos, Coimbra & Whatley, 2009	0.96																			▒	■	▒
96	*Bradleyapseudonormani* Ramos, Coimbra & Whatley, 2009	1.92																			■	■	▒
97	*Muellerina cribosa* Ramos, Coimbra & Whatley, 2009	6.73											■			■	■	■		▒	▒	▒
98	*Quadracythere venusta* Ramos, Coimbra & Whatley, 2009	10.57													■		■	■		■	■	▒
99	*Brasilicythere reticulispinosa* Sanguinetti, Ornellas & Coimbra, 1991	2.88													■		■			■	■	▒
100	*Actinocythereis brasiliensis* Machado & Drozinski, 2002	6.73												■			■	■		■	■	▒
101	*Legitimocythere megapotamica* Bergue, Coimbra & Ramos, 2016	1.92																		■	■	▒
102	*Apatihowella inflata* (Ramos, Coimbra, Bergue & Whatley, 2012)	0.96																		▒	■	▒
103	*Apatihowella* sp.	2.88															■			■	▒	▒
104	*Cativella sudbrasiliensis* Ramos, Coimbra, Bergue & Whatley, 2012	2.88															■			■	■	▒
105	*Argenticytheretta laevipunctata* Sanguinetti, Ornellas & Coimbra, 1991	1.92																	■	■	■	▒
106	*Argenticytheretta*? sp.	1.92															■	■		■	■	▒
107	*Krithe gnoma* Carmo & Sanguinetti, 1999	1.92																		■		▒
108	*Xestoleberis umbonata* Whatley, Chadwick, Toy & Ramos, 1998	2.88																■		■	■	▒
109	*Semixestoleberis* sp. 1	1.92														■				■		▒
110	*Oculocytheropteron circumcostatum* Ramos, Coimbra, Whatley & Moguilevsky, 1999	1.92																		■	▒	▒
111	*Oculocytheropteron delicatum* Ramos, Coimbra, Whatley & Moguilevsky, 1999	10.57														■		■	■	■	▒	▒
112	*Oculocytheropteron macropunctatum* Whatley, Chadwick, Coxill & Toy, 1988	3.84																	■	■	■	▒
113	*Semicytherura caudata* Ramos, Coimbra, Whatley & Moguilevsky, 1999	9.61														■	■	■	■	■	▒	▒
114	*Semicytherura rugosoreticulata* Whatley, Chadwick, Coxill & Toy, 1988	0.96																		■	▒	▒
115	*Semicytherura* sp. 7	1.92															▒			■		▒
116	*Hemicytherura auriculata* Ramos, Coimbra, Whatley & Moguilevsky, 1999	0.96																		■	▒	▒
117	*Paracytheridea bulbosa* Purper & Ornellas, 1989	3.84																	■	■	■	▒
118	*Callistocythere nucleoperiscum* Whatley, Moguilevsky, Toy, Chadwick & Ramos, 1997	1.92																	■	■	▒	▒
119	*Meridionalicythere*? sp. 3	7.69															■	■	■	■	■	▒
120	*Meridionalicythere*? sp. 4	0.96														■				▒	▒	▒
121	*Ruggiericythere perspicua* Aiello, Coimbra & Barra, 2004	8.65														■		■	■	■	▒	▒
122	*Ruggiericythere batistae* Aiello, Coimbra & Barra, 2004	2.88																	■	▒	▒	▒
123	*Ruggiericythere dimorphica* (Whatley, Moguilevsky, Chadwick, Toy & Ramos, 1998)	11.53														■	■	■	■	■	■	▒
124	*Caudites ohmerti* Coimbra & Ornellas, 1987	3.84														■	▒	▒		■	■	▒
125	*Caudites vandenboldi* Coimbra & Ornellas, 1987	14.42											■	■		■	■	■	■	■		▒
126	*Caudites gnomus* Coimbra & Ornellas, 1987	0.96																▒		■	▒	▒
127	*Coquimba tenuireticulata* Kotzian, 1982	4.80																		■	■	▒
128	*Cornucoquimba lutziana* Zabert, 1978	5.76															■	■	■			▒
129	*Argilloecia parameridionalis* Whatley, Moguilevsky, Chadwick, Toy & Ramos, 1998a	0.96																			■	▒
130	*Basslerites multicostata* Ramos, Coimbra, Bergue & Whatley, 2012	0.96																			■	▒
131	*Nanocoquimba pulchra* Ramos, 1996	3.84															■	▒	■	■	■	▒