

Overview of Recent and Holocene ostracods (Crustacea) from brackish and marine environments of Portugal

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ABSTRACT – An extensive overview of Recent and Holocene ostracods from brackish and marine environments of Portugal is presented for the first time. 178 species belonging to 75 genera have been found and all are listed and illustrated with SEM images. From those species only 30 were found alive, most of them living in marginal-marine environments. Some comments on the 30 species found alive and a summary of main results are also presented. The data come from unpublished notes, reports of several research projects, observations on Recent ostracods in sediments from different estuaries of the western coast of Portugal and from the western Algarve continental shelf and slope, Masters theses and published papers. *J. Micropalaeontol.* 32(2): 135–159, July 2013.

KEYWORDS: *Ostracoda list, marginal-marine, continental shelf, Quaternary, Portugal*

INTRODUCTION

There are very few papers about the Recent marine and brackish ostracods of mainland Portugal. The first contribution was published by Paulo (1969), where only five species (1 brackish, 4 freshwater) from Castelo do Queijo, Porto were described. Later, Paulo & Moutinho (1983) listed 33 species, most of them from freshwater habitats. More recently, in Loureiro *et al.* (2009), ostracods of the Mira estuary were studied, both alive (autochthonous) and transported by tidal currents. Cabral *et al.* (2011b) is the first reference to the ostracods from the Portuguese continental shelf. In these two latter works some species are figured.

Information about Holocene ostracods has started appearing more recently, with several papers published since 1999: Hindson & Andrade (1999), Hindson *et al.* (1999), Cearreta *et al.* (2003), Cabral *et al.* (2006, 2011a), Hilbich *et al.* (2008), van der Schriek *et al.* (2008), Almeida *et al.* (2009) and Lord *et al.* (2011). In all these papers ostracods come from long boreholes taken from marginal-marine sediments; the ostracods are figured only in Cabral *et al.* (2006) and Lord *et al.* (2011).

In spite of their specific merits, most of these works lack scanning electron microscope (SEM) illustrations, which would have rendered them much more useful for comparison with ostracods from other Atlantic and Mediterranean coastal regions. In this work we present, for the first time, an overview of the distribution of Recent and Holocene brackish and marine ostracods in Portugal, with full SEM photographic documentation. In addition, gathering a broad dataset in a single survey allows us to make well-supported conclusions on palaeoenvironmental, palaeogeographical and stratigraphical issues. Freshwater ostracods are not considered in this work, though some of the known species live in slightly saline inland and coastal environments. Recently, an overview of these freshwater Portuguese species was published by Martins *et al.* (2010).

MATERIAL AND METHODS

The list presented here is based on unpublished notes (MCC), reports of several research projects (MCC), observations of one of the authors (MCC) on Recent ostracods in sediments from different estuaries of western Portugal and from the Algarve continental

shelf and slope (south Portugal), Masters degree theses and published papers. We consider here only the papers that have illustrations of the mentioned ostracods, or whose study material has been identified by the authors (Cearreta *et al.*, 2003; Cabral *et al.*, 2006, 2011a, b; Loureiro *et al.*, 2009; Lord *et al.*, 2011). All the unpublished theses were supervised by MCC in the Department of Geology, Faculty of Sciences, University of Lisbon and are archived and accessible in the Central Library of the Faculty of Sciences and in the Library of the Department of Geology.

The taxa have been identified only on the basis of carapaces without soft parts. Most of the Recent marine taxa, from the continental shelf or slope and from the tidal flats of the lower part of the estuaries, were found in fine-grained sediments, as separate valves, therefore limiting knowledge of where they really live today in the areas where they have been found. The material from the continental shelf and slope was frequently abundant, well preserved and represented by several ontogenic stages suggesting, in this case, that it was *in situ*. The material from the tidal flats was generally represented by rare valves of each species, frequently worn.

The brackish forms from the tidal marshes were generally collected in muddy sediment, and most of them were found alive, as indicated in the list. Only a few brackish forms from the tidal marshes were collected in fine sand or silty sand substrates. The brackish/marine forms from rock tidal pools and from the transect along the Laje River were collected both on algae and on sandy substrate. The marine forms from the continental shelf and slope were collected with a Smith-McIntyre (SMT) grab, in fine sediment patches (sand fraction generally <50%). Forms were identified as alive when containing the soft parts (appendages) and pink staining due to Rose Bengal. The material from the tidal marshes was collected in two different seasons, generally in autumn and spring, very rarely at the beginning of winter and of summer; the material from the continental shelf and slope was collected during winter (January 2008) and spring (June 2008). Salinity and temperature values from tidal flat, low and high marsh sampling points were measured at low tide in the interstitial sediment water. The records were collected up to May 2012.

The taxonomy follows Horne *et al.* (2002). For the identification of most of the species, Athersuch *et al.* (1989) and Bonaduce

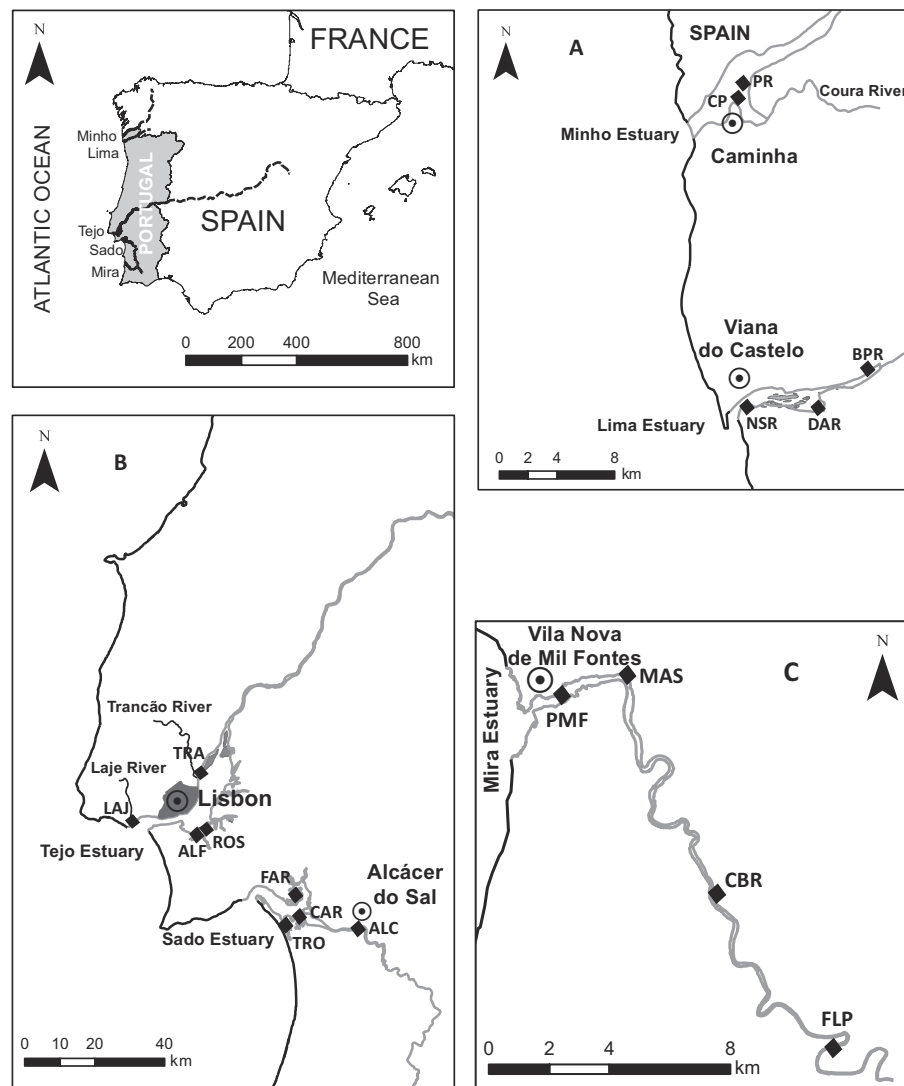


Fig. 1. Location map of the transects in the Portuguese estuaries: **A** – Minho estuary (CP and PR) and Lima estuary (NSR, DAR, BPR). **B** – Tejo estuary (LAJ, TRA, ALF and ROS) and Sado estuary (FAR, CAR, TRO and ALC). **C** – Mira estuary (PMF, MAS, CBR and FLP).

et al. (1976) were used. For some genera or species, several other works were also used: Aiello *et al.* (1996), Athersuch (1976b), Athersuch & Horne (1987), Barbeito-González (1971), Breman (1975), Ciampo (1976), Colalongo & Pasini (1980), Coles *et al.* (1994, 1996), Horne & Whittaker (1985), Horne *et al.* (2004), Lachenal (1989), Schornikov & Keyser (2004), Whitley & Masson (1980) and Yassini (1969, 1979) and many *Stereo-Atlas of Ostracod Shells* papers, e.g. Athersuch (1976a, 1981), Athersuch & Horne (1983), Athersuch & Whittaker (1982a, b, 1976), Doruk (1974), Guillaume (1988), Horne (1989), Horne & Robinson (1982, 1985) and Whittaker (1978a, b).

All the studied specimens are deposited in the Cabral Collection of the Department of Geology, Faculty of Sciences, University of Lisbon.

STUDY AREA

Recent material comes from several different estuaries of the western Portuguese coast, two in the NW, three in the SW

(Fig. 1) – transects of tidal marsh zones, across the tidal flat, low marsh (*Spartina*) and high marsh (*Salicornia*) – and from the Algarve continental shelf and slope (Fig. 2):

Minho River and its Coura tributary – 2 transects, 1 in the Coura confluence with the Minho River (CP), 1 in the lower Minho estuary (PR).

Lima River – 1 transect in the lower estuary (NSR), 2 transects in the mid-estuary (DAR and BPR).

Tejo River and its Trancão and Laje tributaries – 2 transects in the lower Tejo estuary (ALF and ROS), 1 transect in the lower Trancão estuary (TRA), 100m from the confluence with Tejo (mid Tejo estuary), 1 transect along the lower Laje River estuary (LAJ), from the mouth to 350m upriver (lowest part of Tejo estuary/Atlantic ocean) and 2 rock intertidal pools nearby, in Santo Amaro de Oeiras beach.

Sado River – 3 transects in the lower estuary (FAR, CAR, TRO), 1 transect in the mid-estuary (ALC).

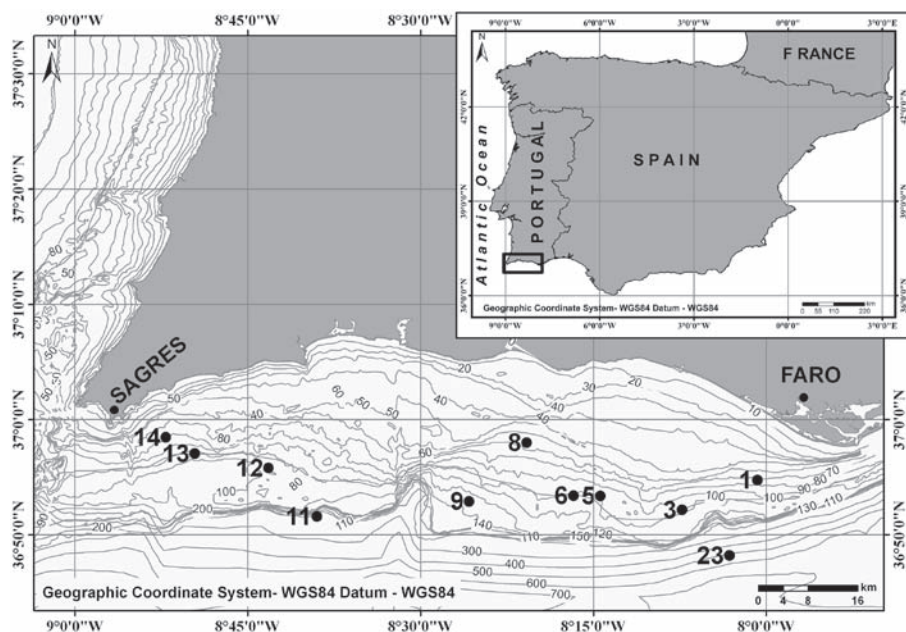


Fig. 2. Location of the studied sites on the western continental shelf and slope of Algarve.

Mira River – 2 transects in the lower estuary (PMF and MAS), 2 transects in the mid-estuary (CBR and FLP).

Material also comes from the continental shelf and slope of western Algarve (south Portugal), between Sagres and Faro – 9 sites in the continental shelf (1, 3, 5, 6, 8, 9, 12, 13 and 14) ranging in depth from –58 to –125 m and 2 sites in the continental slope (11 and 23), respectively at *c.* –220m and *c.* –500m deep.

Holocene material comes from several boreholes located in coastal lagoons or estuaries (Fig. 3). From north to south: Pederneira lagoon, west Portugal – 2 long boreholes, both in the Recent alluvial plain of Alcoa River, 1 in the inner ancient lagoon (S2), another in the middle ancient lagoon (S3). Sizandro estuary/lagoon, west Portugal – 1 long borehole in the alluvial plain of Sizandro River, around 10km from coast (RS06_1). Tejo estuary – 1 long borehole in Lisboa central urban area (esteiro da Baixa), Praça do Comércio (PC), and a 4m core from a marsh area in Seixal bay (DWK2). Melides lagoon, SW Portugal – 2 long boreholes, one in the alluvial plain of the Recent lagoon (MIGM), another in the sand barrier (MB). Santo André lagoon, SW Portugal – 1 long borehole in the alluvial plain of the Recent lagoon (LSA).

LIST OF BRACKISH AND MARINE OSTRACODA FOUND IN PORTUGAL

Systematics according to Horne *et al.* (2002). Identifications based primarily on Athersuch *et al.* (1989) and Bonaduce *et al.* (1976). Note that primary author sources for individual species have been consulted but, for brevity, are not all listed in the References.

Note: Includes all records, both live forms and dead carapaces/valves. The localities (generally estuaries) where the Recent forms occurred are ordered from north to south; the localities where the Holocene forms occurred are ordered alphabetically. Species

which are referred as *cf.* compare fairly closely with known species (they present almost all the characteristics of the species, but differ in one or two details, frequently because they are either worn or juveniles); species referred as *aff.* are probably new, but present some similarities with existing species.

Class **Ostracoda** Latreille, 1806
 Subclass **Myodocopa** Sars, 1866
 Order **Halocyprida** Dana, 1853
 Suborder **Cladocopina** Sars, 1866
 Superfamily **Cladocopoidea** Sars, 1866
 Family **Polycopeidae** Sars, 1866
 Genus *Polycope* Sars, 1866

Polycope reticulata G. W. Müller, 1894 – Mira (Pl. 1, fig. 1)

Subclass **Podocopa** Sars, 1866
 Order **Platycopida** Sars, 1866
 Suborder **Platycopina** Sars, 1866
 Superfamily **Cytherelloidea** Sars, 1866
 Family **Cytherellidae** Sars, 1866
 Genus *Cytherella* Jones, 1849

Cytherella alvearium Bonaduce, Ciampo & Masoli, 1976 – continental shelf and slope (Pl. 1, fig. 2)
Cytherella robusta Colalongo & Pasini, 1980 – continental shelf and slope (Pl. 1, fig. 3)
Cytherella thrakiensis Stambolidis, 1980 – Mira (Pl. 1, fig. 4)
Cytherella cf. vulgata Ruggieri, 1962 – continental shelf (Pl. 1, fig. 5)
 Genus *Cytherelloidea* Alexander, 1929
Cytherelloidea cf. sordida (G. W. Müller, 1894) – Holocene Lisboa (Pl. 1, fig. 6)

Order **Podocopida** Sars, 1866
 Suborder **Cytherocopina** Gründel, 1967
 Superfamily **Cytheroidea** Baird, 1850
 Family **Bythocytheridae** Sars, 1866

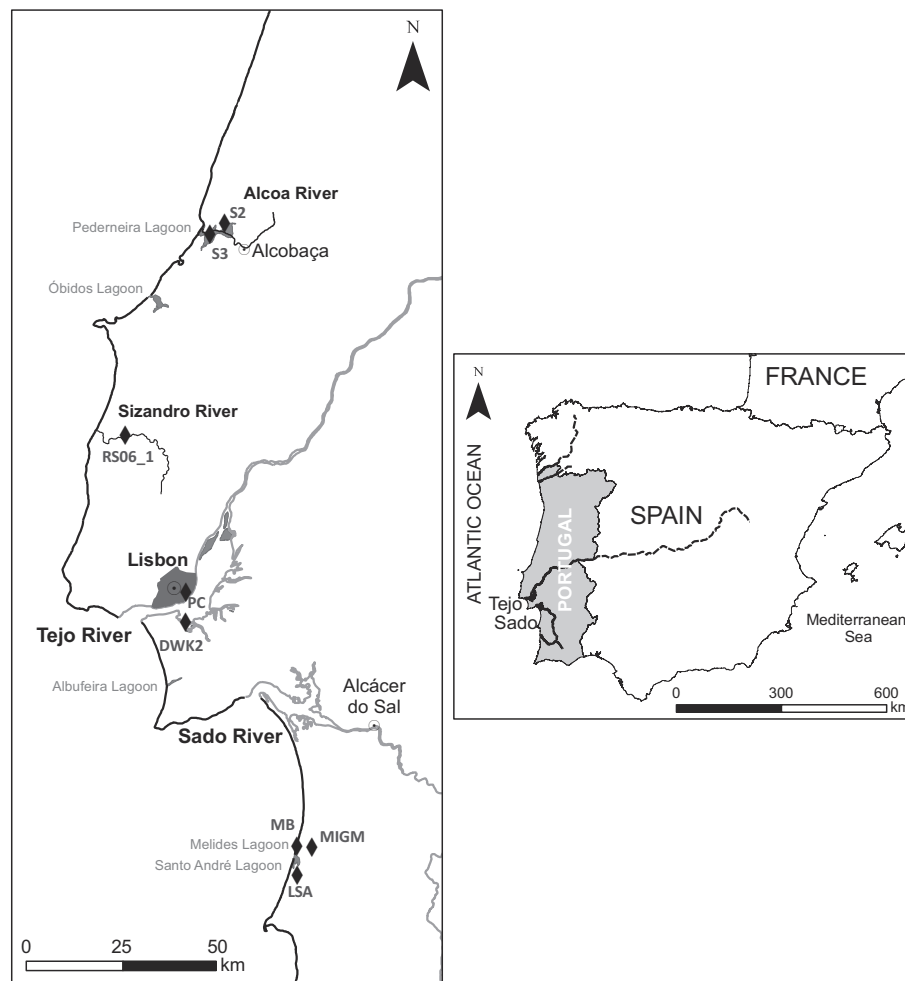


Fig. 3. Location map of the Holocene boreholes: Pederneira lagoon (S3 and S2); Sizandro river (RS06_1); Tejo estuary (PC and DWK2); Melides lagoon (MB and MIGM); Santo André lagoon (LSA).

Genus *Bythocythere* Sars, 1866

Bythocythere bradyi Sars, 1926 – Mira (Pl. 1, fig. 7)

Bythocythere intermedia Elofson, 1938 – Mira, Holocene Lisboa
(Pl. 1, fig. 8)

Genus *Pseudocythere* Sars, 1866

Pseudocythere caudata Sars, 1866 – continental shelf, Mira
(Pl. 1, fig. 9)

Genus *Sclerochilus* Sars, 1866

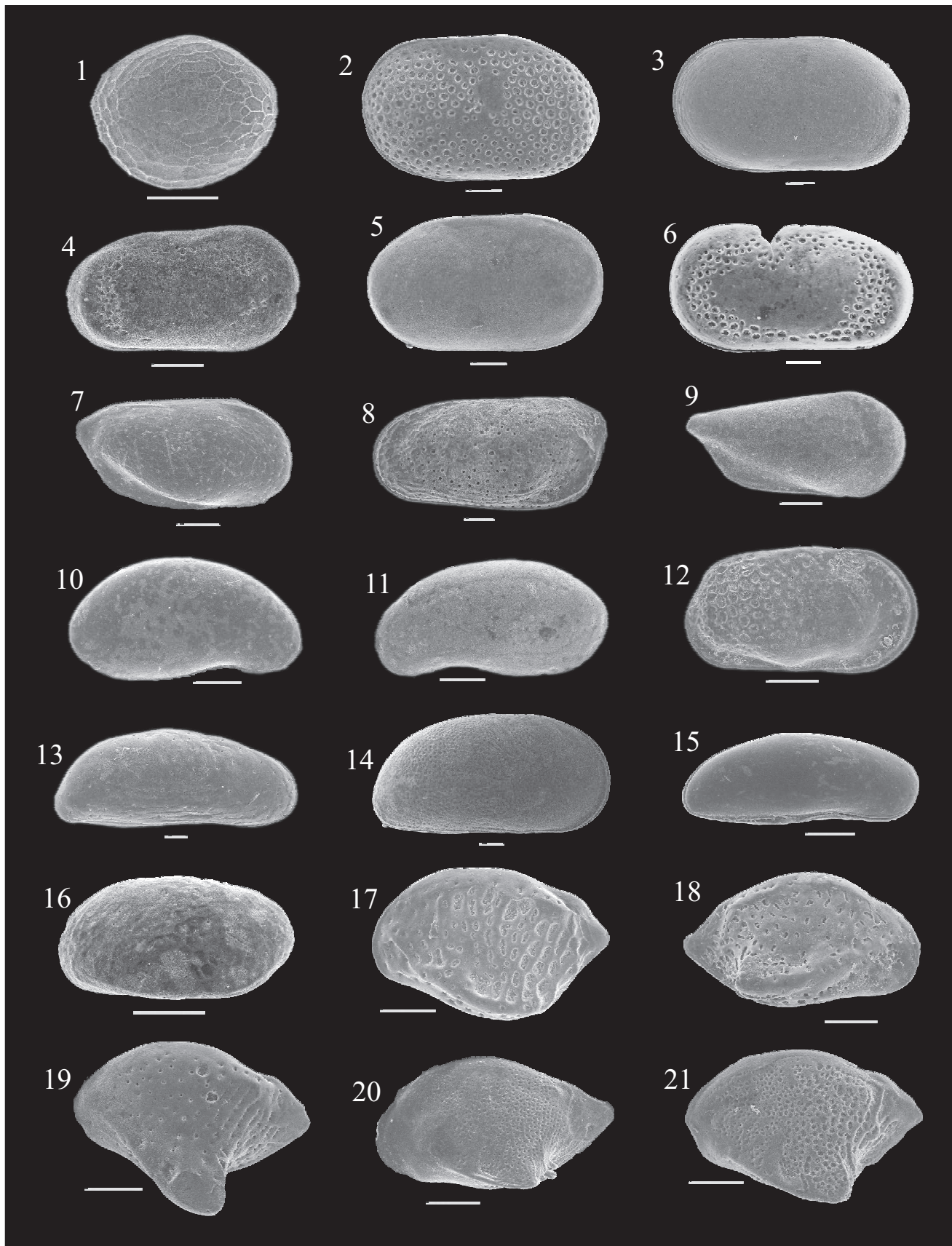
Sclerochilus cf. *abbreviatus* Brady & Robertson, 1869 – Mira,
Holocene Lisboa (Pl. 1, fig. 10)

Sclerochilus gewemuelleri Dubowsky, 1939 – Lima, Mira (Pl. 1,
fig. 11)

Family *Cuneocytheridae* Mandelstam, 1959

Explanation of Plate 1. LV, left valve; RV, right valve; C, carapace; f, female; m, male; j, juvenile; aut., autumn; spr., spring. Scale bar 100 µm.

fig. 1. *Polycopse reticulata* G. W. Müller, 1894, LV, external; Mira-PMF, P2 (aut.). **fig. 2.** *Cytherella alvearium* Bonaduce, Ciampo & Masoli, 1976, LV, external; site 12 (POP 0108). **fig. 3.** *Cytherella robusta* Colalongo & Pasini, 1980, LV, external; site 11 (POP 0108). **fig. 4.** *Cytherella thrakiensis* Stambolidis, 1980, RV, external, j; Mira-MAS, P1 (spr.). **fig. 5.** *Cytherella* cf. *vulgata* Ruggieri, 1962, RV, external; site 12 (POP 0608). **fig. 6.** *Cytherelloidea* cf. *sordida* (G. W. Müller, 1894), LV, external; Lisboa, PC-10.66-10.67. **fig. 7.** *Bythocythere bradyi* Sars, 1926, RV, external, j; Mira-PMF, P2 (spr.). **fig. 8.** *Bythocythere intermedia* Elofson, 1938, LV, external, m; Lisboa, PC-22.30-22.31. **fig. 9.** *Pseudocythere caudata* Sars, 1866, RV, external, ?m; Mira-MAS, P1 (spr.). **fig. 10.** *Sclerochilus* cf. *abbreviatus* Brady & Robertson, 1869, RV, external, ?f; Mira-MAS, P1 (aut.). **fig. 11.** *Sclerochilus gewemuelleri* Dubowsky, 1939, LV, external, ?m; Mira-MAS, P1 (spr.). **fig. 12.** *Cuneocythere semipunctata* (Brady, 1868), RV, external, m; Mira-MAS, P2 (aut.). **fig. 13.** *Pontocythere elongata* (Brady, 1868), RV, external, m; Pederneira, S2-3.98. **fig. 14.** *Cyprideis torosa* (Jones, 1850), RV, external, m; Melides, MI-8.765. **fig. 15.** *Cytheroma variabilis* G. W. Müller, 1894, C, right view; Mira-MAS, P1 (spr.). **fig. 16.** *Cytheropteron depressum* Brady & Norman, 1889, LV, external, j; Mira-MAS, P1 (aut.). **fig. 17.** *Cytheropteron dorsocostatum* Whatley & Masson, 1980, LV, external, Lima-NSR, P1 (spr.). **fig. 18.** *Cytheropteron latum* G. W. Müller, 1894, RV, external, m; Lisboa, PC-8.15-8.16. **fig. 19.** *Cytheropteron monoceros* Bonaduce, Ciampo & Masoli, 1976, LV, external; site 12 (POP 0108). **fig. 20.** *Cytheropteron punctatum* Brady, 1868, LV, external; site 23 (POP 0108). **fig. 21.** *Cytheropteron* aff. *punctatum* Brady, 1868, LV, external; site 11 (POP 0608).



Genus *Cuneocythere* Lienenklaus, 1894
Cuneocythere semipunctata (Brady, 1868) – continental shelf,
 Mira, Holocene Lisboa, Pederneira (Pl. 1, fig. 12)

Family **Cushmanideidae** Puri, 1974

Genus *Pontocythere* Dubowsky, 1939

Pontocythere elongata (Brady, 1868) – Lima, Mira, Holocene
 Lisboa, Melides, Pederneira, Santo André (Pl. 1, fig. 13)

Family **Cytherideidae** Sars, 1925

Genus *Cyprideis* Jones, 1857

Cyprideis torosa (Jones, 1850) – Lima, Tejo (alive), Laje, Sado
 (alive), Mira, Holocene Lisboa, Melides, Pederneira, Santo
 André, Seixal, Sizandro (Pl. 1, fig. 14)

Family **Cytheromatidae** Elofson, 1939

Genus *Cytheroma* G. W. Müller, 1894

Cytheroma variabilis G. W. Müller, 1894 – continental shelf,
 Mira, Holocene Lisboa (Pl. 1, fig. 15)

Family **Cytheruridae** G. W. Müller, 1894

Genus *Cytheropteron* Sars, 1866

Cytheropteron depressum Brady & Norman, 1889 – Mira,
 Holocene Lisboa, Melides, Pederneira (Pl. 1, fig. 16)

Cytheropteron dorsocostatum Whatley & Masson, 1980 – continental
 shelf, Lima, Mira, Holocene Lisboa, Pederneira (Pl. 1, fig. 17)

Cytheropteron latum G. W. Müller, 1894 – continental shelf and
 slope, Mira, Holocene Lisboa (Pl. 1, fig. 18)

Cytheropteron monoceros Bonaduce, Ciampo & Masoli, 1976 –
 continental shelf and slope (Pl. 1, fig. 19)

Cytheropteron punctatum Brady, 1868 – continental slope (Pl. 1,
 fig. 20)

Cytheropteron aff. *punctatum* Brady, 1868 – continental slope
 (Pl. 1, fig. 21)

Cytheropteron cf. *ruggierii* Pucci, 1956 *sensu* Bonaduce, Ciampo
 & Masoli, 1976 – continental shelf and slope (Pl. 2, fig. 1)

Cytheropteron sulcatum Bonaduce, Ciampo & Masoli, 1976 –
 continental shelf (Pl. 2, fig. 2)

Cytheropteron testudo Sars, 1869 – continental slope (Pl. 2,
 fig. 3)

Cytheropteron vespertilio (Reuss, 1850) – continental shelf, Mira
 (Pl. 2, fig. 4)

Cytheropteron volantium Whatley & Masson, 1980 – continental
 shelf (Pl. 2, fig. 5)

Cytheropteron zinzulusae Bonaduce, Ciampo & Masoli, 1976 –
 continental slope (Pl. 2, fig. 6)

Genus *Eucytherura* G.W. Müller, 1894

Eucytherura complexa (Brady, 1866) – continental shelf, Mira,
 Holocene Lisboa (Pl. 2, fig. 7)

Eucytherura mistrettai Sissingh, 1972 – continental shelf, Mira,
 Holocene Lisboa (Pl. 2, figs 8–9)

Genus *Hemicytherura* Elofson, 1941

Hemicytherura cellulosa (Norman, 1865) – continental shelf,
 Lima, Holocene Lisboa (Pl. 2, figs 10–11)

Hemicytherura defioerei Ruggieri, 1953 – continental shelf, Mira
 (Pl. 2, fig. 12)

Hemicytherura aff. *defioerei* Ruggieri, 1953 – Mira, Holocene
 Melides, Pederneira (Pl. 2, fig. 13)

Hemicytherura hoskini Horne, 1981 – continental shelf, Lima,
 Mira, Holocene Pederneira (Pl. 2, fig. 14)

Hemicytherura videns (G. W. Müller, 1894) – continental shelf,
 Lima, Mira (alive), Holocene Pederneira (Pl. 2, fig. 15)

Genus *Microcytherura* G. W. Müller, 1894

Microcytherura fulva (Brady & Robertson, 1874) – continental
 shelf and slope, Lima, Mira, Holocene Lisboa, Melides,
 Pederneira (Pl. 2, fig. 16)

Microcytherura cf. *nigrescens* G. W. Müller, 1894 – Mira (Pl. 2,
 fig. 17)

Genus *Pseudocytherura* Dubowsky, 1939

Pseudocytherura calcarata (Seguenza, 1880) – Mira, Holocene
 Lisboa (Pl. 2, fig. 18)

Genus *Semicytherura* Wagner, 1957

Semicytherura acuminata (G. W. Müller, 1894) – continental
 shelf, Mira, Holocene Lisboa (Pl. 2, fig. 19)

Semicytherura acuta (G. W. Müller, 1912) – continental shelf,
 Mira, Holocene Lisboa, Melides (Pl. 2, fig. 20)

Semicytherura acuticostata (Sars, 1866) – Mira, Holocene Lisboa
 (Pl. 2, fig. 21)

Semicytherura acuticostata ventricosa (Sars, 1866) – continental
 slope, Mira, Holocene Lisboa, Melides, Pederneira (Pl. 3, fig. 1)

Semicytherura aff. *alifera* Ruggieri, 1959 – Mira (Pl. 3, fig. 2)

Semicytherura angulata (Brady, 1868) – Lima, Holocene Lisboa,
 Pederneira (Pl. 3, fig. 3)

Semicytherura aff. *angulata* (Brady, 1868) – continental shelf and
 slope, Mira, Holocene Lisboa, Melides (Pl. 3, fig. 4)

Semicytherura arcachonensis Yassini, 1969 – Lima, Mira,
 Holocene Lisboa, Pederneira (Pl. 3, fig. 5)

Semicytherura cornuta (Brady, 1868) – Mira (Pl. 3, fig. 6)

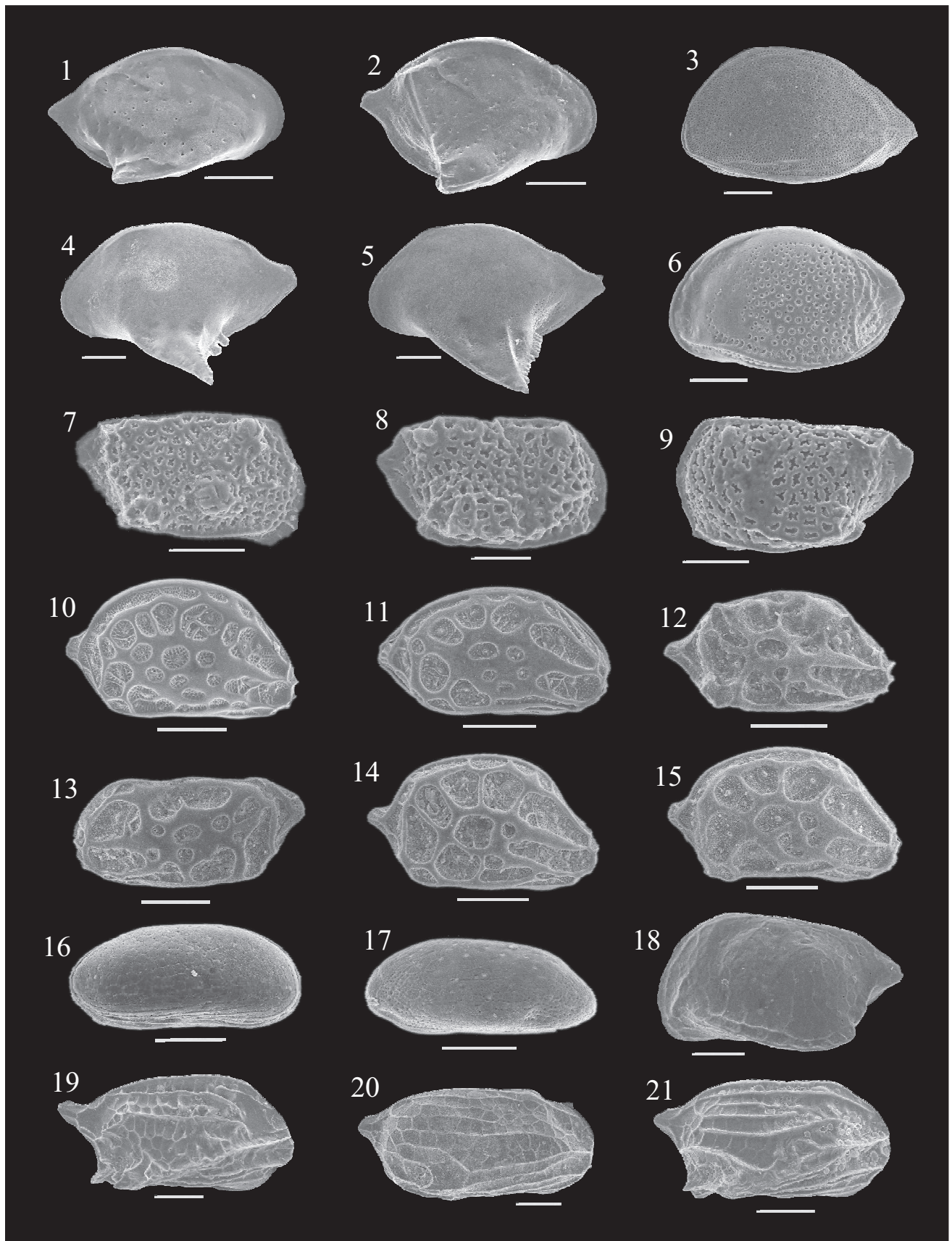
Explanation of Plate 2. LV, left valve; RV, right valve; C, carapace; f, female; m, male; j, juvenile; aut., autumn; spr., spring. Scale bar 100 µm.

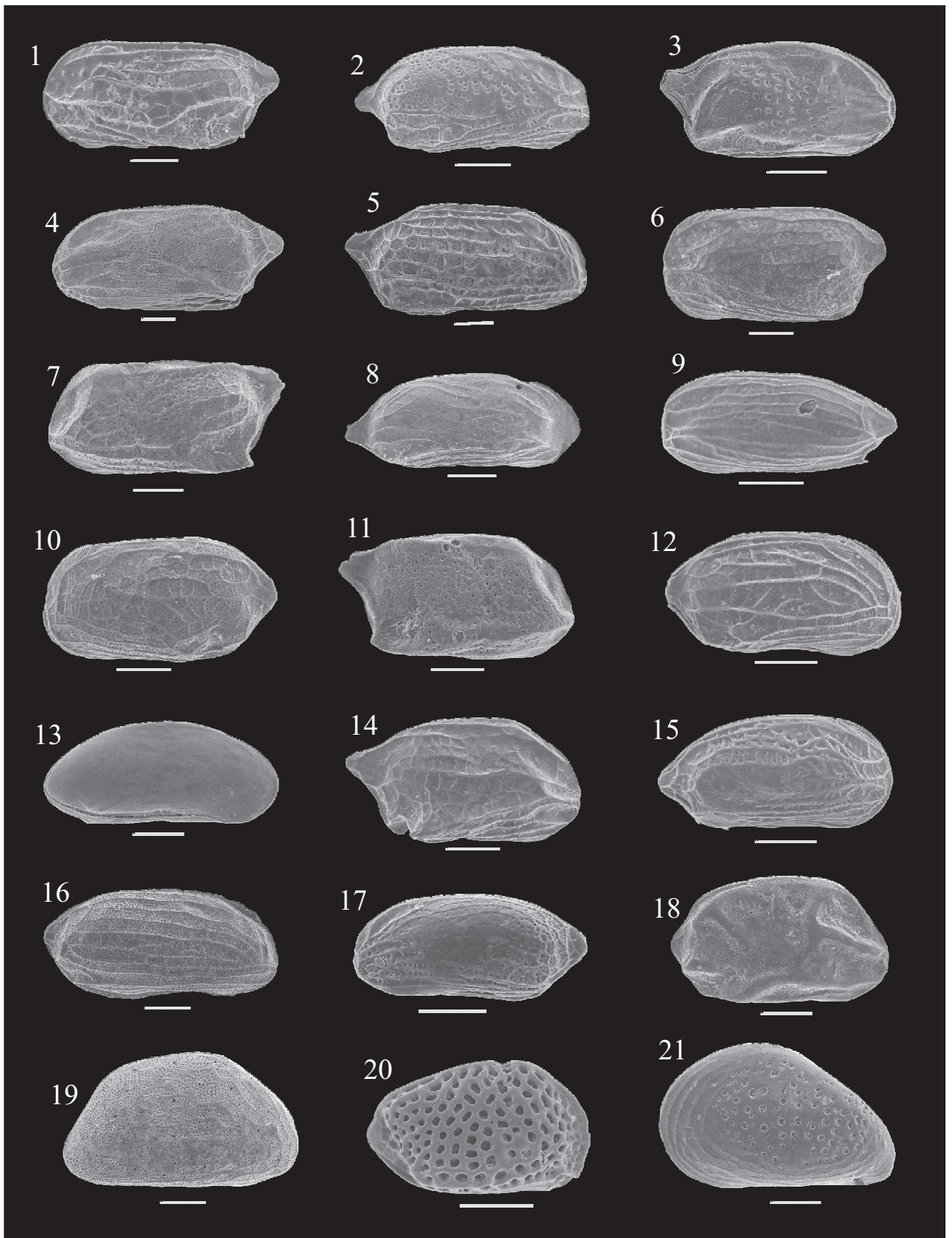
fig. 1. *Cytheropteron* cf. *ruggierii* Pucci, 1956 *sensu* Bonaduce, Ciampo & Masoli, 1976, RV, external; site 1 (POP 0108). **fig. 2.** *Cytheropteron sulcatum* Bonaduce, Ciampo & Masoli, 1976, RV, external; site 13 (POP 0608). **fig. 3.** *Cytheropteron testudo* Sars, 1869, LV, external; site 23 (POP 0108).

fig. 4. *Cytheropteron vespertilio* (Reuss, 1850), LV, external; site 12 (POP 0608). **fig. 5.** *Cytheropteron volantium* Whatley & Masson, 1980, LV, external; site 12 (POP 0108). **fig. 6.** *Cytheropteron zinzulusae* Bonaduce, Ciampo & Masoli, 1976, LV, external; site 11 (POP 0108). **fig. 7.** *Eucytherura complexa* (Brady, 1866), RV, external; site 13 (POP 0608). **figs 8, 9.** *Eucytherura mistrettai* Sissingh, 1972, site 13 (POP 0608): **8,** RV, external; **9,** LV, external, j. **figs 10, 11.** *Hemicytherura cellulosa* (Norman, 1865): **10,** RV, external, f; Lima-NSR, P1 (spr.); **11,** C, right view, m; Mira-PMF, P1 (aut.).

fig. 12. *Hemicytherura defioerei* Ruggieri, 1953, RV, external; Mira-PMF, P1 (spr.). **fig. 13.** *Hemicytherura* aff. *defioerei* Ruggieri, 1953, LV, external; Mira-MAS, P1 (aut.). **fig. 14.** *Hemicytherura hoskini* Horne, 1981, RV, external, f; Mira-PMF, P1 (aut.). **fig. 15.** *Hemicytherura videns* (G. W. Müller, 1894), RV, external, f; Mira-CBR, P2 (spr.). **fig. 16.** *Microcytherura fulva* (Brady & Robertson, 1874), C, right view; Mira-MAS, P1 (aut.).

fig. 17. *Microcytherura* cf. *nigrescens* G. W. Müller, 1894, C, left view; Mira-PMF, P5 (aut.). **fig. 18.** *Pseudocytherura calcarata* (Seguenza, 1880), LV, external, j; Mira-MAS, P1 (spr.). **fig. 19.** *Semicytherura acuminata* (G. W. Müller, 1894), RV, external, f; Mira-MAS, P1 (spr.). **fig. 20.** *Semicytherura acuta* (G. W. Müller, 1912), RV, external; Mira-MAS, P1 (spr.). **fig. 21.** *Semicytherura acuticostata* (Sars, 1866), RV, external, ?m; Mira-MAS, P1 (spr.).

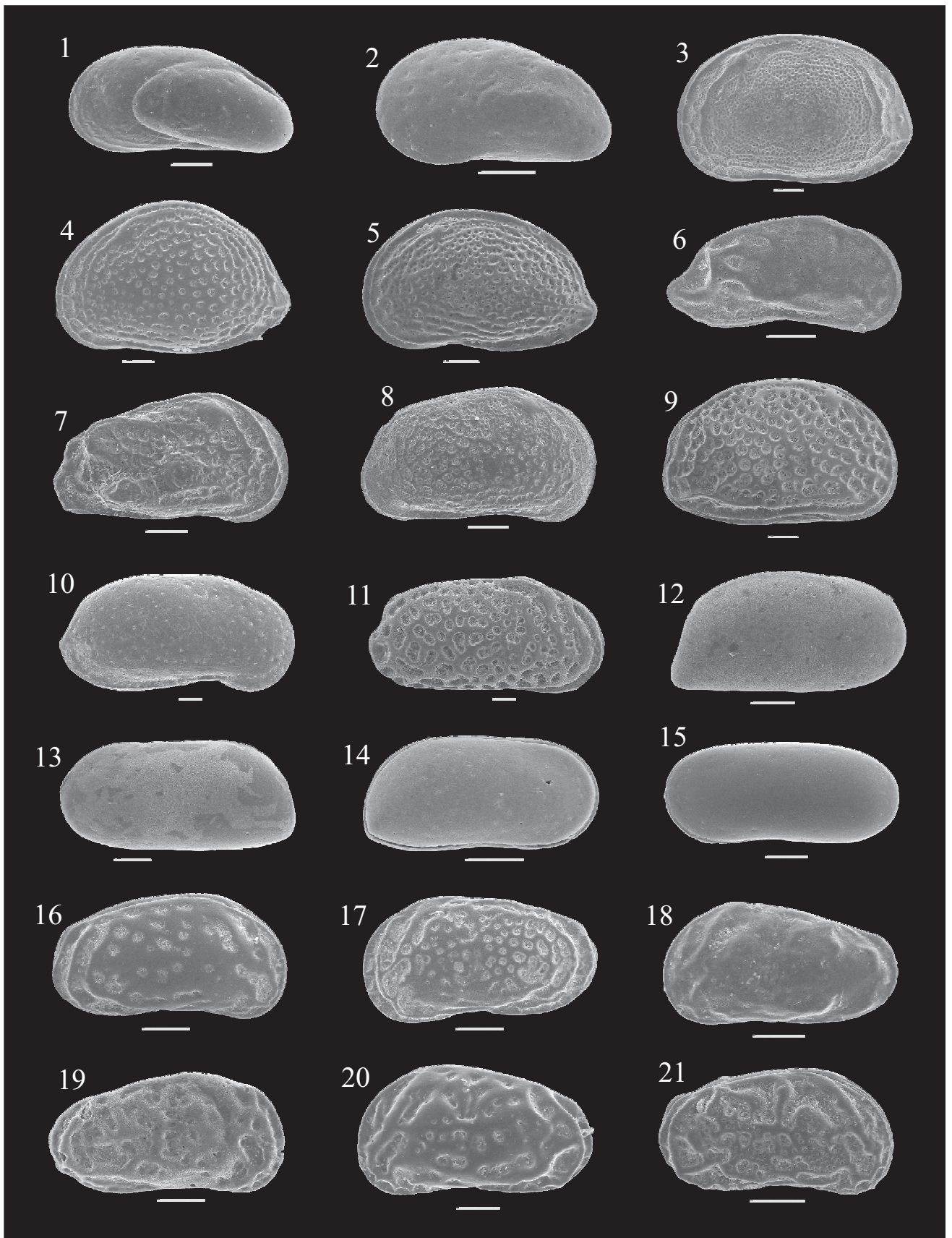




- Semicytherura occulta* Bonaduce, Ciampo & Masoli, 1976 – continental shelf, Holocene Lisboa (Pl. 3, fig. 7)
- Semicytherura* cf. *producta* (Brady, 1868) – Lima, Mira, Holocene Lisboa (Pl. 3, fig. 8)
- Semicytherura quadridentata* (Hartmann, 1953) – Mira (Pl. 3, fig. 9)
- Semicytherura robertsi* Whittaker & Horne, 2009 – Holocene Lisboa, Melides, Pederneira (Pl. 3, fig. 10)
- Semicytherura robusta* Bonaduce, Ciampo & Masoli, 1976 – continental shelf, Holocene Lisboa (Pl. 3, fig. 11)
- Semicytherura sella* (Sars, 1866) – Lima, Mira (alive), Holocene Lisboa, Melides, Pederneira (Pl. 3, fig. 12)
- Semicytherura simplex* (Brady & Norman, 1889) – Mira, Holocene Lisboa, Melides (Pl. 3, fig. 13)
- Semicytherura* cf. *stilifera* Bonaduce, Ciampo & Masoli, 1976 – continental shelf, Mira, Holocene Lisboa (Pl. 3, fig. 14)
- Semicytherura striata* (Sars, 1866) – continental shelf, Lima, Mira, Holocene Lisboa, Melides, Pederneira (Pl. 3, fig. 15)
- Semicytherura* cf. *sulcata* (G. W. Müller, 1894) – Mira, Holocene Lisboa, Melides (Pl. 3, fig. 16)
- Semicytherura tela* Horne & Whittaker, 1980 – Santo Amaro de Oeiras (rockpool, alive), Sado, Mira, Holocene Lisboa (Pl. 3, fig. 17)
- Semicytherura undata* (Sars, 1866) – Holocene Lisboa (Pl. 3, fig. 18)
Genus *Tetracytherura* Ruggieri, 1952
- Tetracytherura angulosa* (Seguenza, 1880) – continental shelf, Mira, Holocene Lisboa (Pl. 3, fig. 19)
Genus *Typhlocythere* Bonaduce, Ciampo & Masoli, 1976
Typhlocythere ruggierii Bonaduce, Ciampo & Masoli, 1976 – continental slope (Pl. 3, fig. 20)
- Family **Eucytheridae** Puri, 1954
Genus *Eucythere* Brady, 1868
- Eucythere anglica* Brady, 1868 – continental shelf and slope (Pl. 3, fig. 21)
- Eucythere argus* (Sars, 1866) – Holocene Pederneira (Pl. 4, fig. 1)
- Eucythere prava* Brady & Robertson, 1869 – Mira, Holocene Lisboa, Pederneira (Pl. 4, fig. 2)
- Family **Hemicytheridae** Puri, 1953
Genus *Aurila* Pokorny, 1955
- Aurila arborescens* (Brady, 1865) – Holocene Lisboa, Melides, Pederneira, Santo André (Pl. 4, fig. 3)
- Aurila convexa* (Baird, 1850) – continental shelf and slope, Lima, Santo Amaro de Oeiras (rockpool), Laje, Mira, Holocene Lisboa, Melides, Pederneira, Santo André (Pl. 4, fig. 4)
- Aurila woutersi* Horne, 1986 – Lima, Mira, Holocene Lisboa, Pederneira (Pl. 4, fig. 5)
Genus *Caudites* Coryell & Fields, 1937
- Caudites calceolatus* (O. G. Costa, 1853) – continental shelf, Lima, Mira, Holocene Lisboa, Pederneira (Pl. 4, fig. 6)
Genus *Finnarchinella* Swain, 1963
- Finnarchinella angulata* (Sars, 1866) – Holocene Lisboa (Pl. 4, fig. 7)
Genus *Hemicythere* Sars, 1925
- Hemicythere rubida* (Brady, 1868) – Holocene Lisboa (Pl. 4, fig. 8)
- Hemicythere villosa* (Sars, 1866) – Lima, Holocene Lisboa (Pl. 4, fig. 9)
Genus *Heterocythereis* Elofson, 1941
- Heterocythereis albomaculata* (Baird, 1838) – continental shelf, Minho, Lima, Santo Amaro de Oeiras (rockpool, alive), Laje (alive), Mira, Holocene Lisboa, Melides, Pederneira, Santo André (Pl. 4, fig. 10)
Genus *Urocythereis* Ruggieri, 1950
- Urocythereis britannica* Athersuch, 1977 – continental shelf and slope, Lima, Sado, Mira, Holocene Lisboa, Melides, Pederneira, Santo André, Seixal (Pl. 4, fig. 11)
- Family **Krithidae** Mandelstam, 1960
Genus *Kritha* Brady, Crosskey & Robertson, 1874
Kritha keyi Breman, 1978 – continental slope (Pl. 4, fig. 12)
- Kritha* aff. *praetexta* (Sars, 1866) – continental shelf (alive) and slope (Pl. 4, fig. 13)
Genus *Parakritha* Van den Bold, 1958
- Parakritha dimorpha* Bonaduce, Ciampo & Masoli, 1976 – continental slope (Pl. 4, fig. 14)
Genus *Pseudopsammocythere* Carbonnel, 1966
- Pseudopsammocythere similis* (G. W. Müller, 1894) – continental shelf and slope (Pl. 4, fig. 15)
- Family **Leptocytheridae** Hanai, 1957
Genus *Callistocythere* Ruggieri, 1953
- Callistocythere badia* (Norman, 1862) – Santo Amaro de Oeiras (rockpool, alive), Laje, Mira, Holocene Lisboa, Melides, Pederneira, Santo André (Pl. 4, fig. 16)

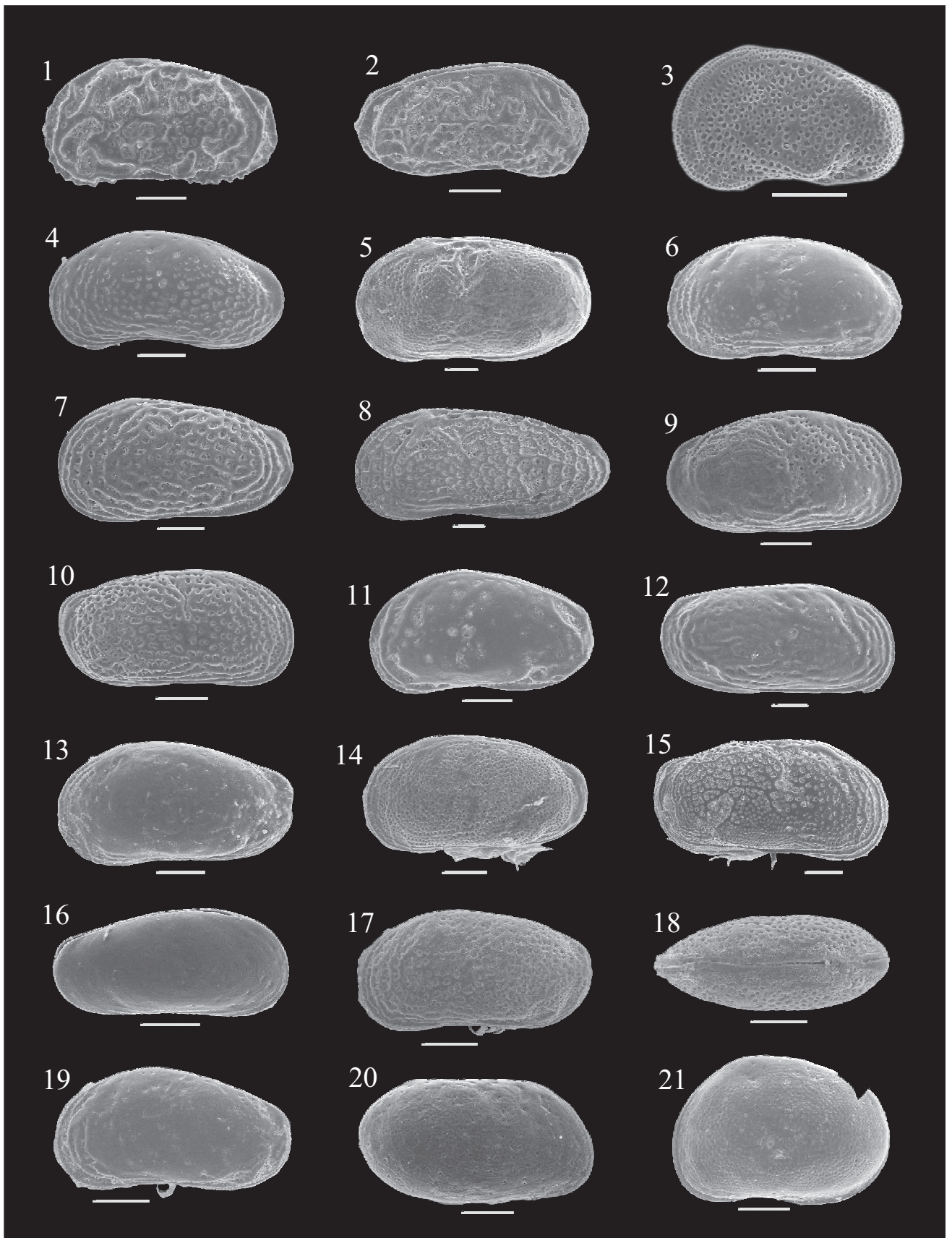
Explanation of Plate 3. LV, left valve; RV, right valve; C, carapace; f, female; m, male; j, juvenile; aut., autumn; spr., spring. Scale bar 100 µm.

fig. 1. *Semicytherura acuticostata ventricosa* (Sars, 1866), LV, external, m; Mira-MAS, P1 (aut.). **fig. 2.** *Semicytherura* aff. *alifera* Ruggieri, 1959, RV, external, m; Mira-MAS, P1 (spr.). **fig. 3.** *Semicytherura angulata* (Brady, 1868), C, right view, f; Lima-NSR, P1 (spr.). **fig. 4.** *Semicytherura* aff. *angulata* (Brady, 1868), C, left view, f; Mira-PMF, P1 (aut.). **fig. 5.** *Semicytherura arcachonensis* Yassini, 1969, RV, external, m; Mira-PMF, P1 (spr.). **fig. 6.** *Semicytherura cornuta* (Brady, 1868), LV, external, f; Mira-MAS, P1 (spr.). **fig. 7.** *Semicytherura occulta* Bonaduce, Ciampo & Masoli, 1976, LV, external, f; Lisboa, PC-8.15-8.16. **fig. 8.** *Semicytherura* cf. *producta* (Brady, 1868), RV, external; Lima-NSR, P1 (spr.). **fig. 9.** *Semicytherura quadridentata* (Hartmann, 1953), C, left view; Mira-MAS, P2 (aut.). **fig. 10.** *Semicytherura robertsi* Whittaker & Horne, 2009, LV, external, f; Pederneira, S2-3.92. **fig. 11.** *Semicytherura robusta* Bonaduce, Ciampo & Masoli, 1976, RV, external, f; site 8 (POP 0108). **fig. 12.** *Semicytherura sella* (Sars, 1866), C, right view, f; Mira-PMF, P1 (spr.). **fig. 13.** *Semicytherura simplex* (Brady & Norman, 1889), C, right view, m; Mira-MAS, P2 (aut.). **fig. 14.** *Semicytherura* cf. *stilifera* Bonaduce, Ciampo & Masoli, 1976, RV, external, f; Mira-MAS, P1 (spr.). **fig. 15.** *Semicytherura striata* (Sars, 1866), C, right view, f; Mira-MAS, P1 (spr.). **fig. 16.** *Semicytherura* cf. *sulcata* (G. W. Müller, 1894), RV, external; Mira-MAS, P1 (spr.). **fig. 17.** *Semicytherura tela* Horne & Whittaker, 1980, C, left view, m; Mira-MAS, P1 (spr.). **fig. 18.** *Semicytherura undata* (Sars, 1866), RV, external, f; Lisboa, PC-10.66-10.67. **fig. 19.** *Tetracytherura angulosa* (Seguenza, 1880), RV, external; Lisboa, PC-10.16-10.17. **fig. 20.** *Typhlocythere ruggierii* Bonaduce, Ciampo & Masoli, 1976, RV, external; site 23 (POP 0108). **fig. 21.** *Eucythere anglica* Brady, 1868, LV, external, f; site 12 (POP 0108).



- Callistocythere curryi* Horne, Lord, Robinson & Whittaker, 1990 – continental shelf and slope, Lima, Mira, Holocene Lisboa, Melides, Pederneira (Pl. 4, fig. 17)
- Callistocythere diffusa* (G. W. Müller, 1894) – Mira (Pl. 4, fig. 18)
- Callistocythere donovani* Horne, Lord, Robinson & Whittaker, 1990 – continental shelf and slope, Holocene Lisboa (Pl. 4, fig. 19)
- Callistocythere* aff. *gilva* Bonaduce, Ciampo & Masoli, 1976 – Holocene Lisboa (Pl. 4, fig. 20)
- Callistocythere littoralis* (G. W. Müller, 1894) – continental shelf, Mira, Holocene Lisboa, Melides, Pederneira (Pl. 4, fig. 21)
- Callistocythere lobiancoi* (G. W. Müller, 1894) – Holocene Lisboa, Pederneira (Pl. 5, fig. 1)
- Callistocythere murrayi* Whittaker, 1978 – Minho (alive), Lima (alive), Tejo (alive), Sado, Mira, Holocene Lisboa, Seixal, Sizandro (Pl. 5, fig. 2)
- Genus *Cluthia* Neale, 1973
- Cluthia keiji* Neale, 1975 – continental shelf, Mira (Pl. 5, fig. 3)
- Genus *Leptocythere* Sars, 1928
- Leptocythere baltica* Klie, 1929 – Minho (alive), Lima (alive) (Pl. 5, fig. 4)
- Leptocythere castanea* (Sars, 1866) – Holocene Seixal (Pl. 5, fig. 5)
- Leptocythere ciliata* Hartmann, 1957 – Minho (alive), Lima (alive), Tejo (alive), Sado (alive), Mira (alive) (Pl. 5, fig. 6)
- Leptocythere cribrata* (Brady, Crosskey & Robertson, 1874) – Holocene Lisboa (Pl. 5, fig. 7)
- Leptocythere fabaeformis* (G. W. Müller, 1894) – Lima, Tejo, Mira (alive), Holocene Lisboa, Melides, Pederneira, Santo André, Seixal (Pl. 5, fig. 8)
- Leptocythere lacertosa* (Hirschmann, 1912) – Minho (alive), Tejo (alive), Sado (alive), Mira (alive), Holocene Lisboa, Melides, Pederneira, Santo André, Seixal (Pl. 5, figs 9–10)
- Leptocythere macallana* (Brady & Robertson, 1869) – Mira, Holocene Lisboa, Melides, Pederneira, Seixal (Pl. 5, fig. 11)
- Leptocythere pellucida* (Baird, 1850) – Holocene Lisboa, Pederneira, Santo André (Pl. 5, fig. 12)
- Leptocythere porcellanea* (Brady, 1869) – Minho (alive), Lima (alive), Tejo (alive), Sado (alive), Mira (alive), Holocene Lisboa, Pederneira, Santo André, Seixal, Sizandro (Pl. 5, figs 13–14)
- Leptocythere psammophila* Guillaume, 1976 – Minho (alive) (Pl. 5, fig. 15)
- Leptocythere tenera* (Brady, 1868) – continental shelf and slope, Mira, Holocene Lisboa, Pederneira (Pl. 5, fig. 16)
- Leptocythere* sp. A – Minho (alive) (Pl. 5, figs 17–18)
- Leptocythere* sp. B – Minho (alive), Lima (alive), Holocene Melides (Pl. 5, fig. 19)
- Family **Loxoconchidae** Sars, 1925
- Genus *Elofsonia* Wagner, 1957
- Elofsonia pusilla* (Brady & Robertson, 1870) – Mira, Holocene Lisboa, Melides, Pederneira (Pl. 5, fig. 20)
- Genus *Hirschmannia* Elofson, 1941
- Hirschmannia viridis* (O. F. Müller, 1785) – Holocene Lisboa (Pl. 5, fig. 21)
- Genus *Loxocauda* Schornikov, 1969
- Loxocauda decipiens* (G. W. Müller, 1894) – Mira (Pl. 6, fig. 1)
- Genus *Loxoconcha* Sars, 1866
- Loxoconcha concentrica* Bonaduce, Ciampo & Masoli, 1976 – continental slope (Pl. 6, fig. 2)
- Loxoconcha elliptica* Brady, 1868 – continental shelf, Minho (alive), Lima (alive), Tejo (alive), Laje, Sado (alive), Mira (alive), Holocene Lisboa, Melides, Pederneira, Santo André, Seixal, Sizandro (Pl. 6, fig. 3)
- Loxoconcha malcomsoni* Horne & Robinson, 1985 – Sado (alive), Mira (alive), Holocene Lisboa (Pl. 6, fig. 4)
- Loxoconcha rhomboidea* (Fischer, 1855) – continental shelf and slope, Lima (alive), Tejo, Santo Amaro de Oeiras (rockpool), Laje, Mira (alive), Holocene Lisboa, Melides, Pederneira, Santo André, Seixal (Pl. 6, fig. 5)
- Genus *Nannocythere* Schäfer, 1953
- Nannocythere nana* (Bonaduce, Ciampo & Masoli, 1976) – Mira (Pl. 6, fig. 6)
- Nannocythere pavo* (Malcomson, 1886) – continental shelf, Mira (Pl. 6, fig. 7)
- Genus *Palmoconcha* Swain & Gilby, 1974
- Palmoconcha guttata* (Norman, 1865) – continental shelf and slope, Mira, Holocene Lisboa (Pl. 6, fig. 8)
- Palmoconcha laevata* (Norman, 1865) – continental slope, Lima, Holocene Lisboa (Pl. 6, fig. 9)
- Genus *Phlyctocythere* Keij, 1958
- Phlyctocythere pellucida* (G. W. Müller, 1894) – continental shelf (Pl. 6, fig. 10)
- Genus *Roundstonia* Neale, 1973
- Roundstonia robertsoni* (Brady, 1868) – Lima, Holocene Lisboa, Pederneira (Pl. 6, fig. 11)
- Genus *Sagmatocythere* Athersuch, 1976
- Sagmatocythere caelata* (Ciampo, 1976) – continental shelf, Mira (Pl. 6, fig. 12)

Explanation of Plate 4. LV, left valve; RV, right valve; C, carapace; f, female; m, male; j, juvenile; aut., autumn; spr., spring. Scale bar 100µm **fig. 1.** *Eucythere argus* (Sars, 1866), LV, external, m, (example of moult retention with A-1 juvenile valve attached to the adult valve); Pederneira, S2-3.98. **fig. 2.** *Eucythere prava* Brady & Robertson, 1869, C, left view, m; Mira-MAS, P1 (spr.). **fig. 3.** *Aurila arborescens* (Brady, 1865), LV, external, f; Pederneira, S2-4.29. **fig. 4.** *Aurila convexa* (Baird, 1850), LV, external; Pederneira, S2-6.20. **fig. 5.** *Aurila woutersi* Horne, 1986, LV, external, j; Mira-MAS, P1 (aut.). **fig. 6.** *Caudites calceolatus* (O. G. Costa, 1835), RV, external; Mira-MAS, P1 (aut.). **fig. 7.** *Finmarchinella angulata* (Sars, 1866), RV, external; Lisboa, PC-21.89–21.90. **fig. 8.** *Hemicythere rubida* (Brady, 1868), RV, external, j; Lisboa, PC-24.32–24.33. **fig. 9.** *Hemicythere villosa* (Sars, 1866), C, right view, f; Lima-NSR, P5 (aut.). **fig. 10.** *Heterocythereis albomaculata* (Baird, 1838), RV, external, m; Mira-MAS, P1 (spr.). **fig. 11.** *Urocythereis britannica* Athersuch, 1977, RV, external, m; site 12 (POP 0108). **fig. 12.** *Krithe Keyi* Breman, 1978, RV, external, f; site 23 (POP 0108). **fig. 13.** *Krithe* aff. *praetexta* (Sars, 1866), LV, external, m; site 6 (POP 0108). **fig. 14.** *Parakrithe dimorpha* Bonaduce, Ciampo & Masoli, 1976, C, right view, f; site 23 (POP 0108). **fig. 15.** *Pseudopsammocythere similis* (G. W. Müller, 1894), C, left view; site 6 (POP 0108). **fig. 16.** *Callistocythere badia* (Norman, 1862), C, right view, f; Mira-MAS, P1 (spr.). **fig. 17.** *Callistocythere curryi* Horne, Lord, Robinson & Whittaker, 1990, LV, external, f; Lima-NSR, P6 (spr.). **fig. 18.** *Callistocythere diffusa* (G. W. Müller, 1894), LV, external, m; Mira-MAS, P1 (spr.). **fig. 19.** *Callistocythere donovani* Horne, Lord, Robinson & Whittaker, 1990, RV, external, f; site 12 (POP 0608). **fig. 20.** *Callistocythere* aff. *gilva* Bonaduce, Ciampo & Masoli, 1976, LV, external, f; Lisboa, PC-9.66-9.67. **fig. 21.** *Callistocythere littoralis* (G. W. Müller, 1894), C, right view, f; Mira-MAS, P1 (aut.).



Sagmatocythere multifora (Norman, 1865) – continental shelf and slope, Holocene Lisboa (Pl. 6, fig. 13)

Sagmatocythere napoliana (Puri, 1963) – Holocene Lisboa (Pl. 6, fig. 14)

Sagmatocythere aff. *scrupea* Aiello & Szczechura, 2004 – Mira, Holocene Lisboa (Pl. 6, figs 15–16)

Sagmatocythere variesculpita (Ruggieri, 1962) – Mira, Holocene Pederneira (Pl. 6, fig. 17)

Genus *Tuberoloxoconcha* Hartmann, 1973

Tuberoloxoconcha cf. *atlantica* Horne, 1989 – Tejo (alive), Mira (alive) (Pl. 6, figs 18–19)

Tuberoloxoconcha sp. 1 – Minho (alive) (Pl. 6, figs 20–21)

Family **Neocytherideidae** Puri, 1957

Genus *Neocytherideis* Puri, 1957

Neocytherideis subulata (Brady, 1868) – continental shelf, Lima, Mira, Holocene Lisboa, Pederneira (Pl. 7, fig. 1)

Genus *Procytherideis* Ruggieri, 1978

Procytherideis cf. *foveolata* (G. W. Müller, 1894) – Holocene Pederneira (Pl. 7, fig. 2)

Procytherideis aff. *subspiralis* (Brady, Crosskey & Robertson, 1874) – continental shelf, Mira, Holocene Melides (Pl. 7, fig. 3)

Genus *Sahnicythere* Athersuch, 1982

Sahnicythere retroflexa (Klie, 1936) – Lima, Mira, Holocene Lisboa, Pederneira (Pl. 7, fig. 4)

Family **Paracytherideidae** Puri, 1957

Genus *Paracytheridea* G. W. Müller, 1894

Paracytheridea depressa G. W. Müller, 1894 – continental shelf, Sado, Mira, Holocene Lisboa, Melides (Pl. 7, fig. 5)

Paracytheridea triquetra (Reuss, 1850) – continental shelf, Mira, Holocene Lisboa (Pl. 7, fig. 6)

Genus *Tuberculocythere* Colalongo & Pasini, 1980

Tuberculocythere infelix (Bonaduce, Ciampo & Masoli, 1976) – continental shelf (Pl. 7, fig. 7)

Family **Paradoxostomatidae** Brady & Norman, 1889

Genus *Bradystoma* Schornikov & Keyser, 2004

Bradystoma bradyi (Sars, 1928) – Lima, Mira, Holocene Lisboa (Pl. 7, fig. 8)

Genus *Brunneostoma* Schornikov, 1993

Brunneostoma aff. *cuneatum* Schornikov & Keyser, 2004 – Mira (Pl. 7, fig. 9)

Genus *Cytherois* G. W. Müller, 1884

Cytherois fischeri (Sars, 1866) – Minho (alive), Lima, Tejo (alive), Sado (alive), Mira (alive), Holocene Lisboa, Melides, Pederneira, Santo André, Seixal (Pl. 7, fig. 10)

Cytherois cf. *stephanidesi* Klie, 1938 – Minho (alive), Lima (alive), Tejo (alive), Holocene Melides, Pederneira (Pl. 7, fig. 11)

Genus *Lanceostoma* Schornikov & Keyser, 2004

Lanceostoma aff. *tenerifense* Schornikov & Keyser, 2004 – Mira (Pl. 7, fig. 12)

Genus *Paradoxostoma* Fischer, 1855

Paradoxostoma aff. *abbreviatum* Sars, 1866 – Lima, Mira, Holocene Lisboa (Pl. 7, fig. 13)

Paradoxostoma cf. *atrum* G. W. Müller, 1894 – Mira (Pl. 7, fig. 14)

Paradoxostoma ensiforme Brady, 1868 – Lima, Mira, Holocene Lisboa, Pederneira (Pl. 7, fig. 15)

Paradoxostoma incongruens G. W. Müller, 1894 – Mira (Pl. 7, fig. 16)

Paradoxostoma robinhoodi Horne & Whittaker, 1985 – Mira, Holocene Lisboa, Pederneira (Pl. 7, fig. 17)

Paradoxostoma sarniense Brady, 1868 – Santo Amaro de Oeiras (rockpool, alive), Sado (alive), Mira (alive) (Pl. 7, fig. 18)

Paradoxostoma tenuissimum (Norman, 1869) – continental shelf (Pl. 7, fig. 19)

Paradoxostoma trieri Horne & Whittaker, 1985 – Santo Amaro de Oeiras (rockpool, alive), Sado (alive), Mira (alive) (Pl. 7, fig. 20)

Paradoxostoma cf. *versicolor* G. W. Müller, 1894 – Mira (Pl. 7, fig. 21)

Genus *Paracytherois* G. W. Müller, 1894

Paracytherois acuminata G. W. Müller, 1894 – Lima, Mira (Pl. 8, fig. 1)

Paracytherois flexuosa (Brady, 1867) *sensu* Bonaduce, Ciampo & Masoli, 1976 – Mira (Pl. 8, figs 2–3)

Paracytherois cf. *mediterranea* Bonaduce, Ciampo & Masoli, 1976 – Mira (Pl. 8, fig. 4)

Family **Thaerocytheridae** Hazel, 1967

Genus *Thaerocythere* Hazel, 1967

Thaerocythere hoptonensis (Brady, Crosskey & Robertson, 1874) – continental shelf, Lima, Santo Amaro de Oeiras (rockpool), Mira, Holocene Lisboa, Pederneira (Pl. 8, fig. 5)

Family **Trachyleberididae** Sylvester-Bradley, 1948

Genus *Basslerites*, Teichert, 1937

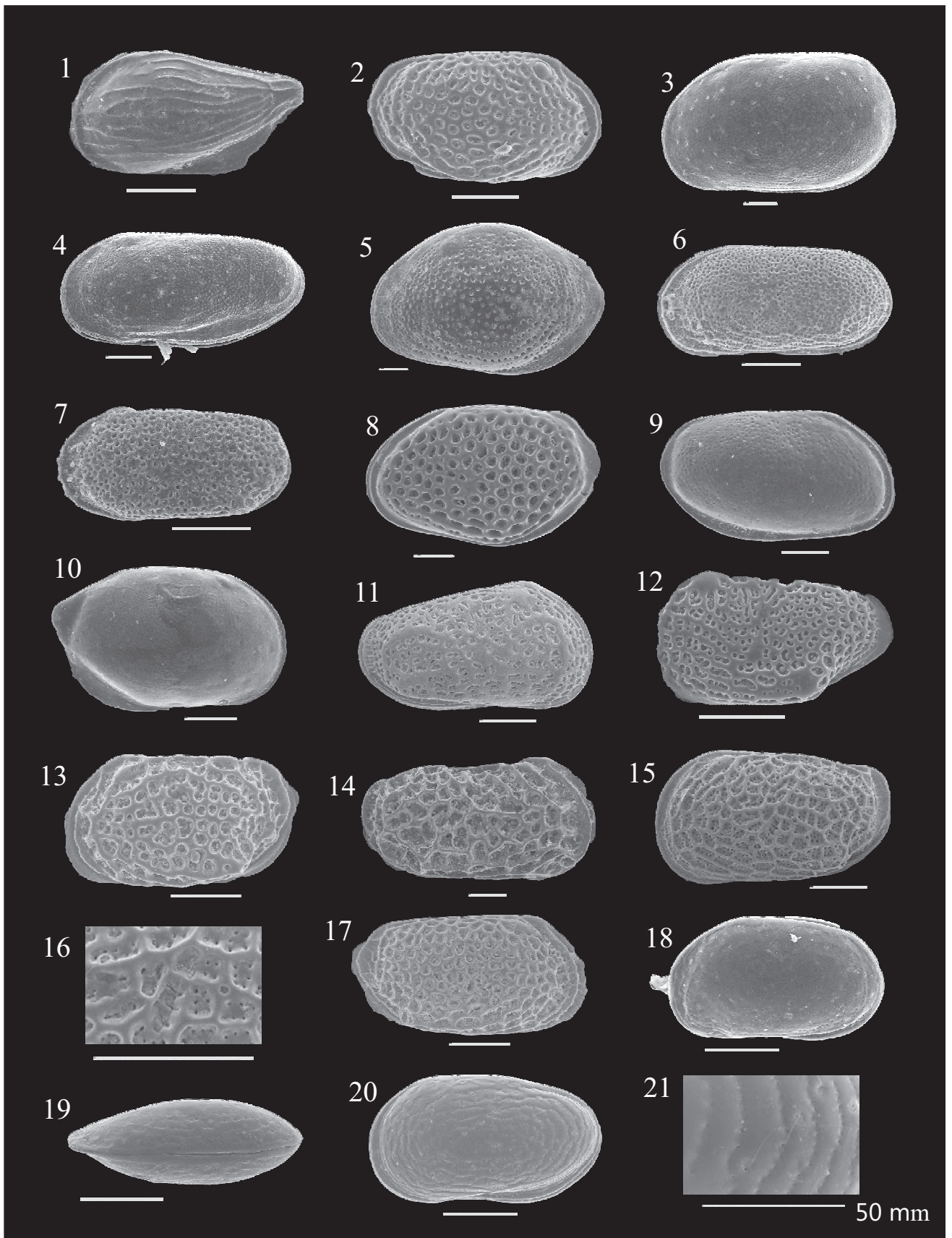
Basslerites teres (Brady, 1869) – continental shelf (alive), Mira (alive), Holocene Lisboa, Melides, Pederneira, Santo André (Pl. 8, fig. 6)

Genus *Bosquetina* Keij, 1957

Bosquetina tarentina (Baird, 1850) – continental shelf (alive) (Pl. 8, fig. 7)

Genus *Buntonia* Howe, 1935

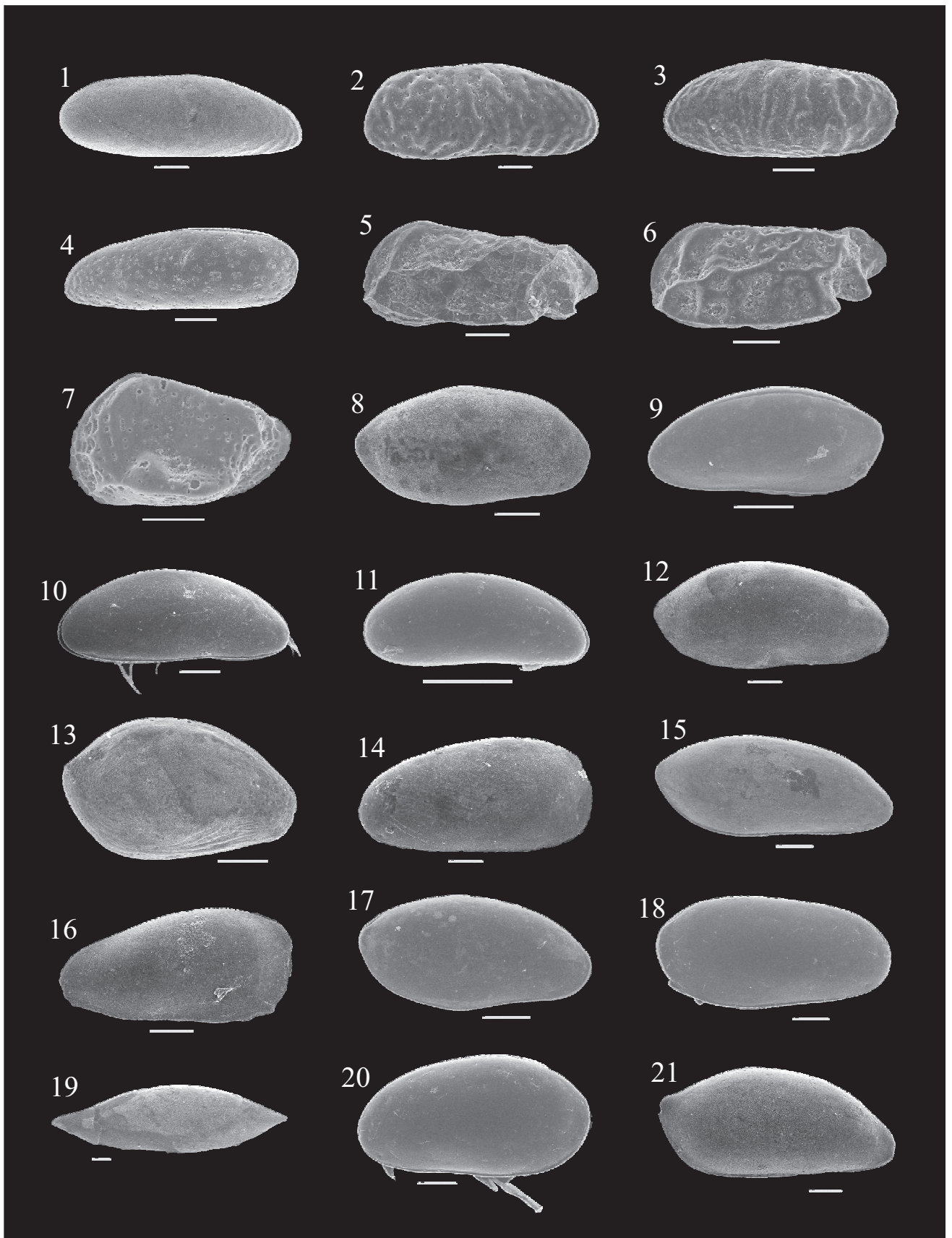
Explanation of Plate 5. LV, left valve; RV, right valve; C, carapace; f, female; m, male; j, juvenile; aut., autumn; spr., spring. Scale bar 100 µm. **fig. 1.** *Callistocythere lobiancoi* (G. W. Müller, 1894), LV, external, f; Pederneira, S3-10.84–10.85. **fig. 2.** *Callistocythere murrayi* Whittaker, 1978, C, right view, m; Mira-CBR, P1 (spr.). **fig. 3.** *Cluthia keiji* Neale, 1975, LV, external; site 1 (POP 0108). **fig. 4.** *Leptocythere baltica* Klie, 1929, C, left view, f; Lima-NSR, P1 (spr.). **fig. 5.** *Leptocythere castanea* (Sars, 1866), C, left view, f; Seixal, DWK2 285. **fig. 6.** *Leptocythere ciliata* Hartmann, 1957, C, left view, f; Lima-NSR, P6 (spr.). **fig. 7.** *Leptocythere cribrosa* (Brady, Crosskey & Robertson, 1874), LV, external, f; Lisboa, PC-23.40-23.41. **fig. 8.** *Leptocythere fabaeformis* (G. W. Müller, 1894), C, left view, m; Mira-PMF, P1 (aut.). **fig. 9.** *Leptocythere lacertosa* (Hirschmann, 1912), RV, external, f; Pederneira, S2-3.92. **fig. 10.** *Leptocythere lacertosa* (Hirschmann, 1912), C, right view, f; Minho, Camarido-2 (spr.). **fig. 11.** *Leptocythere macallana* (Brady & Robertson, 1869), C, left view, f; Pederneira, S2-3.92. **fig. 12.** *Leptocythere pellucida* (Baird, 1850), RV, external, f; Pederneira, S2-8.26. **figs 13, 14.** *Leptocythere porcellanea* (Brady, 1869): **13,** LV, external, f; Mira-CBR, P3 (aut.); **14,** C, left view, f; Minho, Camarido-2 (spr.). **fig. 15.** *Leptocythere psammophila* Guillaume, 1976, C, right view, f; Minho, Camarido-2 (spr.). **fig. 16.** *Leptocythere tenera* (Brady, 1868), C, right view, f; site 1 (POP 0108). **figs 17, 18.** *Leptocythere* sp. A, Minho-CP, P1 (spr.): **17,** C, left view, f; **18,** C, dorsal view, f. **fig. 19.** *Leptocythere* sp. B, C, left view, f; Minho-CP, P2 (aut.). **fig. 20.** *Elofsonia pusilla* (Brady & Robertson, 1870), RV, external, ?m; Melides, MI-9.095. **fig. 21.** *Hirschmannia viridis* (O. F. Müller, 1785), LV, external, f; Lisboa, PC-8.15-8.16.



- Buntonia sublatissima* (Neviani, 1906) – continental shelf and slope (Pl. 8, fig. 8)
- Buntonia textilis* Bonaduce, Ciampo & Masoli, 1976 – continental slope (Pl. 8, fig. 9)
- Genus *Carinocythereis* Ruggieri, 1956
- Carinocythereis carinata* (Roemer, 1838) – continental shelf and slope (Pl. 8, fig. 10)
- Carinocythereis whitei* (Baird, 1850) – continental shelf and slope, Lima, Mira, Holocene Lisboa, Melides, Pederneira, Santo André (Pl. 8, fig. 11)
- Genus *Celtia* Neale, 1973
- Celtia quadridentata* (Baird, 1850) – continental shelf and slope, Mira, Holocene Pederneira (Pl. 8, fig. 12)
- Genus *Costa* Neviani, 1928
- Costa runcinata* (Baird, 1850) – continental shelf and slope, Mira, Holocene Lisboa, Pederneira (Pl. 8, fig. 13)
- Genus *Falunia* Grekoff & Moyes, 1955
- Falunia* cf. *sphaerulolineata* (Jones, 1857) – Mira (Pl. 8, fig. 14)
- Genus *Henryhowella* Puri, 1957
- Henryhowella sarsii* (G. W. Müller, 1894) – continental shelf and slope (Pl. 8, fig. 15)
- Genus *Hiltermannicythere* Bassiouni, 1970
- Hiltermannicythere emaciata* (Brady, 1867) – Lima, Mira, Holocene Lisboa, Melides (Pl. 8, fig. 16)
- Genus *Occultocythereis* Howe, 1951
- Occultocythereis dohrni* (Puri, 1963) – Mira (Pl. 8, fig. 17)
- Genus *Pterygocythereis* Blake, 1933
- Pterygocythereis ceratoptera* (Bosquet, 1852) – continental shelf (Pl. 8, fig. 18)
- Pterygocythereis jonesii* (Baird, 1850) – continental shelf and slope, Mira, Holocene Lisboa (Pl. 8, fig. 19)
- Genus *Rectobuntonia* Sissingh, 1972
- Rectobuntonia miranda* Bonaduce, Ciampo & Masoli, 1976 – continental shelf and slope (Pl. 8, fig. 20)
- Rectobuntonia rectangularis* (Ruggieri, 1954) – continental shelf (alive) (Pl. 8, fig. 21)
- Family **Xestoleberididae** Sars, 1928
- Genus *Microxestoleberis* G. W. Müller, 1894
- Microxestoleberis nana* G. W. Müller, 1894 – continental shelf, Lima, Mira (Pl. 9, fig. 1)
- Microxestoleberis* cf. *pustulosa* Ciampo, 1986 – Lima, Mira (Pl. 9, fig. 2)
- Genus *Xestoleberis* Sars, 1866
- Xestoleberis labiata* Brady & Robertson, 1874 – Santo Amaro de Oeiras (rockpool, alive), Mira (alive), Holocene Lisboa, Melides, Pederneira, Santo André, Seixal (Pl. 9, fig. 3)
- Xestoleberis* cf. *nitida* (Liljeborg, 1853) – Mira (Pl. 9, figs 4–5)
- Xestoleberis* aff. *parva* G. W. Müller, 1894 – continental shelf, Lima, Mira (Pl. 9, fig. 6)
- Xestoleberis rubens* Whittaker, 1978 – continental shelf, Lima, Sado, Mira, Holocene Lisboa, Melides, Seixal (Pl. 9, fig. 7)
- Superfamily **Terrestricytheroidea** Schornikov, 1969
- Family **Terrestricytheridae** Schornikov, 1969
- Genus *Terrestricythere* Schornikov, 1969
- Terrestricythere* aff. *elisabethae* Horne, Smith, Whittaker & Murray, 2004 – Tejo (alive), Sado (alive), Mira (alive) (Pl. 9, figs 8–9)
- Suborder **Bairdiocopina** Gründel, 1967
- Superfamily **Bairdioidea** Sars, 1888
- Family **Bairdiidae** Sars, 1888
- Genus *Bairdia* McCoy, 1844
- '*Bairdia*' *subcircinata* (Brady & Norman, 1869) – continental shelf, Lima, Mira, Holocene Lisboa (Pl. 9, fig. 10)
- Genus *Neonesidea* Maddocks, 1969
- Neonesidea* cf. *corpulenta* (G. W. Müller, 1894) – Lima (Pl. 9, fig. 11)
- Neonesidea longevaginata* (G. W. Müller, 1894) – Holocene Lisboa, Pederneira (Pl. 9, fig. 12)
- Neonesidea* sp. 2 (Bonaduce, Ciampo & Masoli, 1976) – continental shelf, Lima, Mira, Holocene Lisboa, Pederneira (Pl. 9, fig. 13)
- Genus *Triebelina* Van den Bold, 1946
- Triebelina raripila* (G. W. Müller, 1894) – Holocene Melides (Pl. 9, fig. 14)
- Suborder **Cypridocopina** Jones, 1901
- Superfamily **Pontocypridoidea** G. W. Müller, 1894
- Family **Pontocypridae** G. W. Müller, 1894
- Genus *Argilloecia* Sars, 1866
- Argilloecia* aff. *conoidea* Sars, 1923 – continental slope (Pl. 9, fig. 15)
- Argilloecia minor* (G. W. Müller, 1894) – continental shelf (Pl. 9, fig. 16)
- Genus *Pontocypris* Sars, 1866
- Pontocypris* cf. *acuminata* (G. W. Müller, 1894) – continental shelf, Lima, Mira (Pl. 9, fig. 17)

Explanation of Plate 6. LV, left valve; RV, right valve; C, carapace; f, female; m, male; j, juvenile; aut., autumn; spr., spring. Scale bar 100 µm.

fig. 1. *Loxocauda decipiens* (G. W. Müller, 1894), LV, external; Mira-MAS, P1 (aut.). **fig. 2.** *Loxoconcha concentrica* Bonaduce, Ciampo & Masoli, 1976, RV, external; site 11 (POP 0608). **fig. 3.** *Loxoconcha elliptica* Brady, 1868, LV, external, m; Pederneira, S2-3.92. **fig. 4.** *Loxoconcha malcomsoni* Horne & Robinson, 1985, C, left view, m; Mira-PMF, P6 (spr.). **fig. 5.** *Loxoconcha rhomboidea* (Fischer, 1855), LV, external, f; Mira-MAS, P1 (aut.). **fig. 6.** *Nannocythere nana* (Bonaduce, Ciampo & Masoli, 1976), LV, external; Mira-PMF, P1 (spr.). **fig. 7.** *Nannocythere pavo* (Malcomson, 1886), LV, external; Mira-PMF, P1 (aut.). **fig. 8.** *Palmoconcha guttata* (Norman, 1865), LV, external, f; site 1 (POP 0108). **fig. 9.** *Palmoconcha laevata* (Norman, 1865), RV, external, f; Lisboa, PC-21.89-21.90. **fig. 10.** *Phlyctocythere pellucida* (G. W. Müller, 1894), RV, external, f; site 13 (POP 0608). **fig. 11.** *Roundstonia robertsoni* (Brady, 1868), C, right view, m; Lima-NSR, P6 (spr.). **fig. 12.** *Sagmatocythere caelata* (Ciampo 1976), LV, external; Mira-PMF, P1 (aut.). **fig. 13.** *Sagmatocythere multiflora* (Norman, 1865), LV, external, f; site 12 (POP 0608). **fig. 14.** *Sagmatocythere napoliana* (Puri, 1963), RV, external, m; Lisboa, PC-10.66-10.67. **fig. 15.** *Sagmatocythere* aff. *scrupea* Aiello & Szczechura, 2004, LV, external; Mira-MAS, P1 (spr.). **fig. 16.** *Sagmatocythere* aff. *scrupea* Aiello & Szczechura, 2004, LV, external, detail of ornamentation; Mira-MAS, P1 (spr.). **fig. 17.** *Sagmatocythere variesculpta* (Ruggieri, 1962), RV, external; Mira-MAS, P1 (spr.). **figs 18, 19.** *Tuberoloxoconcha* cf. *atlantica* Horne, 1989; Mira-PMF, P6 (spr.): **18**, C, left view; **19**, C, dorsal view. **figs 20, 21.** *Tuberoloxoconcha* sp. 1, C, left view, m; Minho-CP, P7A (aut.); **21**, detail of ornamentation.



- Pontocypris mytiloides* (Norman, 1862) – Mira (Pl. 9, fig. 18)
 Genus *Propontocypris* Sylvester-Bradley, 1947
Propontocypris cf. *intermedia* (Brady, 1868) – Mira, Holocene
 Lisboa, Melides, Pederneira, Santo André (Pl. 9, fig. 19)
Propontocypris pirifera (G. W. Müller, 1894) – Mira, Holocene
 Lisboa, Pederneira (Pl. 9, fig. 20)

Superfamily **Cypridoidea** Baird, 1845

Family **Candonidae** Kaufmann, 1900

Genus *Paracypris* Sars, 1866

- Paracypris polita* Sars, 1866 – continental shelf and slope, Lima,
 Mira (Pl. 9, fig. 21)

**COMMENTS ON RECENT OSTRACODA FOUND ALIVE
 IN PORTUGAL**

Note that taxa found only as empty carapaces or valves are not discussed below. In addition, no mention is made of fossil records of the Recent species.

Basslerites teres (Brady, 1869)

A marine/marine to slightly brackish littoral species known from the Mediterranean to western Europe, found in France (Yassini, 1969, as *Basslerites berchoni* (Brady, 1870)) and England (J. Whittaker, pers. comm.). In France, Arcachon Bay, it lives at depths of 2–8 m and salinity of 27‰ (Yassini, 1969). In Portugal found alive in the tidal flat of lower and mid-Mira estuary, in autumn and spring conditions (approximate salinity range of 32.1–33.8‰ and temperature 16.3–16.8°C, in sediment interstitial water); also found alive in sites 3 (96.5 m depth) and 5 (94.0 m depth), in western Algarve continental shelf, in spring conditions.

Bosquetina tarentina (Baird, 1850)

A marine sublittoral species, known from the Mediterranean to western Europe, in France (Guillaume *et al.*, 1985, pl. 103, figs 9–10, as *Bosquetina dentata* (G. W. Müller, 1894)); found living in the Mediterranean, in Bay of Bou-Ismaïl, Algeria, on mud and sandy mud substrates at depths of 75–220 m (Yassini, 1979, Pl. 5, figs 5–6, as *Bosquetina carinella* (Reuss, 1850)). In Portugal found alive in site 12 (105.3 m depth), on western Algarve continental shelf, in winter conditions.

Callistocythere badia (Norman, 1862)

A marine littoral species known from the Mediterranean to western Europe (Athersuch *et al.*, 1989). In Portugal found alive on green and red algae, in an intertidal rockpool near Laje River mouth, Santo Amaro de Oeiras beach, in spring conditions

(approximate salinity 36.2‰ and temperature 29.4°C, at low tide).

Callistocythere murrayi Whittaker, 1978

A brackish species (1–8‰ at the type locality – Athersuch *et al.*, 1989) known in western Europe, in British Isles and France (Chait *et al.*, 1998). In Portugal found alive from the tidal flat to the low marsh in the lower Minho, mid Lima and lower Tejo estuaries, in autumn and spring conditions (approximate salinity range of 21.0–33.1‰ and temperature 12.4–18.5°C, in sediment interstitial water).

Cyprideis torosa (Jones, 1850)

A common and widespread highly euryhaline species, from almost freshwater to over 60‰, known in Europe (as far north as Iceland), Asia, Mediterranean region, Central Africa (Athersuch *et al.*, 1989). In Portugal found alive from the tidal flat to the high marsh in the lower Tejo and lower Sado estuaries, in autumn/winter and spring/summer conditions (approximate salinity range of 19.0–34.1‰ and temperature 13.8–21.7°C, in sediment interstitial water). It seems to prefer very large estuaries, with almost lagoonal dynamics. No nodal forms have been found until now.

Cytherois fischeri (Sars, 1866)

A common and widespread brackish species, tolerating salinities from 4–35‰, known in the Mediterranean, western Europe, to Scandinavia in the north (Athersuch *et al.*, 1989) and Morocco in the south (Nachite *et al.*, 2010). In Portugal found alive from the tidal flat to the lower part of the low marsh (much more abundant on the tidal flat) in the lower Minho, lower Tejo, lower Sado and lower Mira estuaries, in autumn/winter and spring conditions (approximate salinity range of 10.3–37.0‰ and temperature 13.7–19.7°C, in sediment interstitial water).

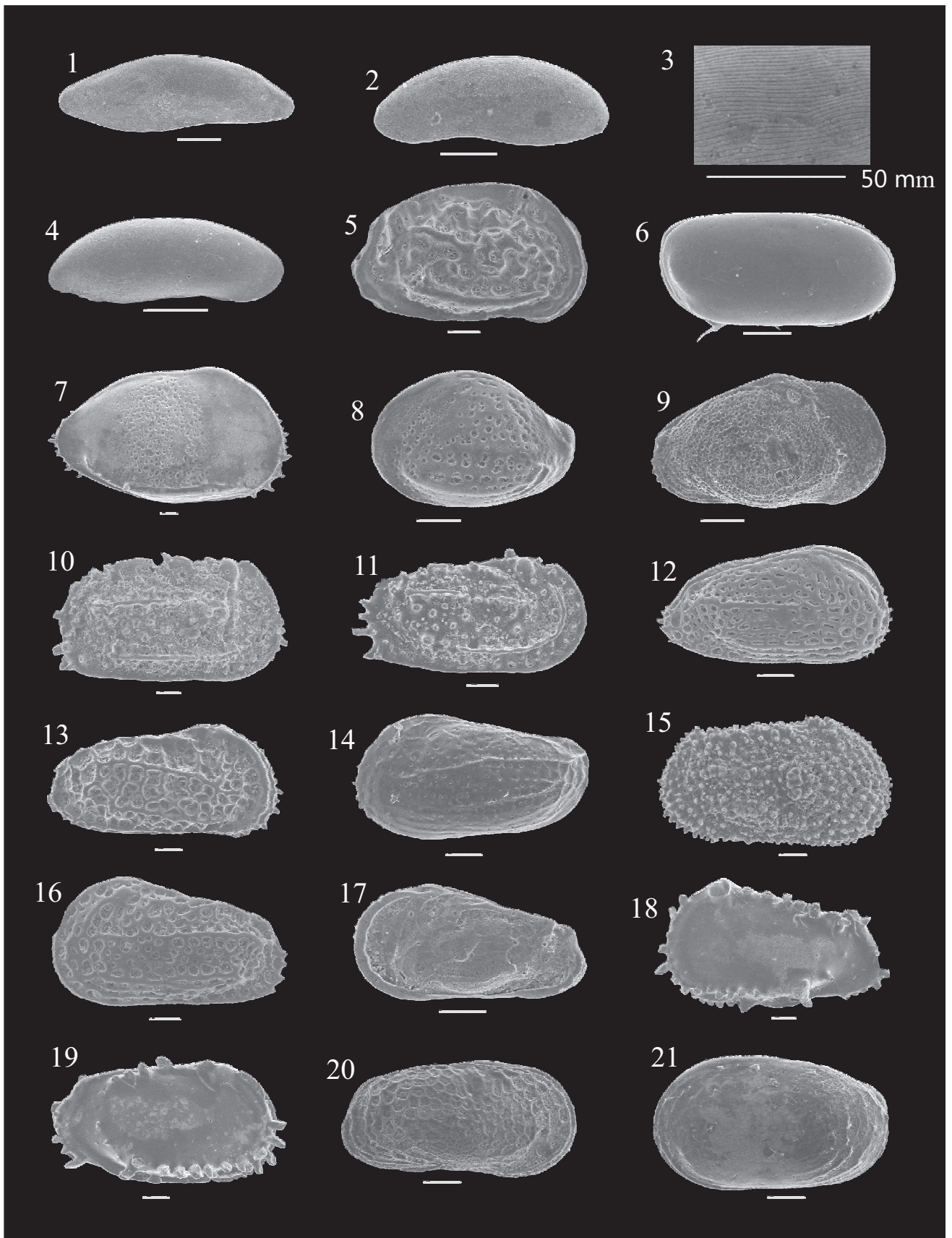
Cytherois cf. *stephanidesi* Klie, 1938

A brackish species found associated with algae and fine sediment, in salinities of 0–20‰, known in the Mediterranean and western Europe (Athersuch *et al.*, 1989). In Portugal found alive in the lower Minho and mid Lima estuaries, from the tidal flat to the low marsh (where it is much more abundant), in autumn and spring conditions (approximate salinity range of 1.1–22.9‰ and temperature 12.4–21.4°C, in sediment interstitial water).

Hemicytherura videns (G. W. Müller, 1894)

A marine, littoral, phytal species, known from the Mediterranean to western Europe (northern limit of its distribution appears to be in France – Yassini, 1969) and NW Morocco (Nachite *et al.*, 2010). The Portuguese specimens which present small variation in fossal patterns, particularly in the central part,

Explanation of Plate 7. LV, left valve; RV, right valve; C, carapace; f, female; m, male; j, juvenile; aut., autumn; spr., spring. Scale bar 100 µm.
fig. 1. *Neocytherideis subulata* (Brady, 1868), RV, external; Lima-NSR, P6 (spr.). **fig. 2.** *Procytherideis* cf. *foveolata* (G. W. Müller, 1894), RV, external; Pederneira, S2-3.98. **fig. 3.** *Procytherideis* aff. *subspiralis* (Brady, Crosskey & Robertson, 1874), RV, external, j; Mira-MAS, P1 (spr.). **fig. 4.** *Sahnicythere retroflexa* (Klie, 1936), C, left view, f; Mira-MAS, P1 (spr.). **fig. 5.** *Paracytheridea depressa* G. W. Müller, 1894, LV, external, ?m; Mira-MAS, P1 (aut.). **fig. 6.** *Paracytheridea triquetra* (Reuss, 1850), LV, external; Mira-MAS, P1 (aut.). **fig. 7.** *Tuberculoocythere infelix* (Bonaduce, Ciampo & Masoli, 1976), LV, external; site 13 (POP 0108). **fig. 8.** *Bradystoma bradyi* (Sars, 1928), RV, external, m; Mira-PMF, P1 (aut.). **fig. 9.** *Brunneostoma* aff. *cuneatum* Schornikov & Keyser, 2004, C, left view; Mira-MAS, P1 (spr.). **fig. 10.** *Cytherois fischeri* (Sars, 1866), C, right view, f; Mira-MAS, P1 (aut.). **fig. 11.** *Cytherois* cf. *stephanidesi* Klie, 1938, C, right view, ?j; Minho-PR, P3 (aut.). **fig. 12.** *Lanceostoma* aff. *tenerifense* Schornikov & Keyser, 2004, RV, external; Mira-MAS, P1 (spr.). **fig. 13.** *Paradoxostoma* aff. *abbreviatum* Sars, 1866, RV, external, f; Mira-MAS, P1 (spr.). **fig. 14.** *Paradoxostoma* cf. *atrum* G. W. Müller, 1894, LV, external; Mira-MAS, P1 (spr.). **fig. 15.** *Paradoxostoma ensiforme* Brady, 1868, RV, external, m; Mira-MAS, P1 (spr.). **fig. 16.** *Paradoxostoma incongruens* G. W. Müller, 1894, LV, external; Mira-MAS, P1 (aut.). **fig. 17.** *Paradoxostoma robinhoodi* Horne & Whittaker, 1985, RV, external, m; Mira-MAS, P1 (spr.). **fig. 18.** *Paradoxostoma sarniense* Brady, 1868, C, right view, f; Oeiras, rock pool PP2'Avm. **fig. 19.** *Paradoxostoma tenuissimum* (Norman, 1869), broken LV, external, ?f; site 14 (POP 0608). **fig. 20.** *Paradoxostoma trieri* Horne & Whittaker, 1985, C, left view, f; Oeiras, rock pool PP2'Avm. **fig. 21.** *Paradoxostoma* cf. *versicolor* G. W. Müller, 1894, RV, external; Mira-MAS, P1 (aut.).



were rarely found alive in the lower and mid Mira estuary, from the tidal flat to the low marsh, in autumn and spring conditions (approximate salinity range of 23.2–42.0‰ and temperature 15.1–17.2°C, in sediment interstitial water).

Heterocythereis albomaculata (Baird, 1838)

A common phytal, littoral and sublittoral marine species, often abundant in rock pools, known from the Mediterranean to northern Norway (Athersuch *et al.*, 1989) and NW Morocco (Nachite *et al.*, 2010). In France, Yassini (1969) reports the euryhaline nature of the species, with a salinity range of 26–34‰. In Portugal found alive in the lowest part of Laje River estuary (Tejo's tributary), associated with green algae, in spring conditions (approximate salinity 28.9‰ and temperature 15.8°C, at low tide) and in the sediment of an intertidal rock pool, in Santo Amaro de Oeiras beach (near Laje River mouth), in spring conditions (approximate salinity 36.2‰ and temperature 29.4°C, at low tide).

Krithe aff. *praetexta* (Sars, 1866)

K. praetexta is a marine sublittoral species, living on sand and mud at depths of 50–500 m, from the British Isles to Sweden and Norway (Athersuch *et al.*, 1989). The Portuguese species, closely related but with a less rounded posterior margin, was found alive in sites 5 (94.0 m depth) and 6 (100.0 m depth), western Algarve continental shelf, in spring conditions.

Leptocythere baltica Klie, 1929

A marine/brackish NW European species, occurring from the Bay of Biscay to the Baltic, usually on sand substrates, but also in British low marsh, within an approximate salinity of 25‰ (Horne & Boomer, 2000). In Portugal found alive in the lower Minho and lower Lima estuaries, on sand to silty sand substrates of the tidal flat and low marsh, in autumn and spring conditions (approximate salinity range of 12.6–19.7‰ and temperature 11.7–19.3°C, in sediment interstitial water).

Leptocythere ciliata Hartmann, 1957

A brackish species known from Germany (North Sea), also recorded in the British Isles by Horne (1980 – unpublished PhD thesis) and probably in NW Morocco (Nachite *et al.*, 2010, Pl. 2, fig. 15). In Portugal found alive in the lower Minho, lower and mid Lima, lower and mid (Trancão) Tejo, lower Sado and lower and mid Mira estuaries, from the tidal flat to the high marsh (more abundant on the low and high marsh), in autumn/winter and spring/summer conditions (approximate salinity range of 2.5–47.5‰ and temperature 10.2–23.0°C, in sediment interstitial water).

Leptocythere fabaeformis (G. W. Müller, 1894)

A brackish (highly euryhaline – 13–33‰), phytal/littoral marine species, known from the Mediterranean to western Europe,

whose northern limit of distribution is apparently in France (Yassini, 1969). In Portugal found alive only in the tidal flat of the lower Mira estuary, as subordinate species, in autumn and spring conditions (approximate salinity 33.6‰ and temperature 16.3°C, in sediment interstitial water).

Leptocythere lacertosa (Hirschmann, 1912)

A common NW European brackish species usually inhabiting estuaries on mud or fine sand substrate; its geographical distribution spans from the Baltic Sea to the NW Morocco coast (Nachite *et al.*, 2010). In Portugal found alive from the tidal flat to the high marsh (more abundantly on the tidal flat and low marsh) of the lowest part of Minho (very rarely), lower Tejo, lower Sado and lower and mid Mira estuaries, in autumn/winter and spring/summer conditions (approximate salinity range of 22.9–47.5‰ and temperature 13.6–21.7°C, in sediment interstitial water).

Leptocythere porcellanea (Brady, 1869)

A brackish NW European species usually living on mud substrates in estuaries and salt marshes from the Baltic to SW France (Horne & Boomer, 2000) and SW Spain (Ruiz *et al.*, 2000). It is the most abundant species found alive in Portuguese tidal marshes of the lower Minho, mid Lima, lower and mid (Trancão) Tejo, lower Sado and lower and mid Mira estuaries, from the tidal flat to the high marsh, in autumn/winter and spring/summer conditions. It is frequently the dominant species in the low and/or in the high marsh in the SW estuaries (approximate salinity range of 2.5–47.5‰ and temperature 11.6–21.6°C, in sediment interstitial water).

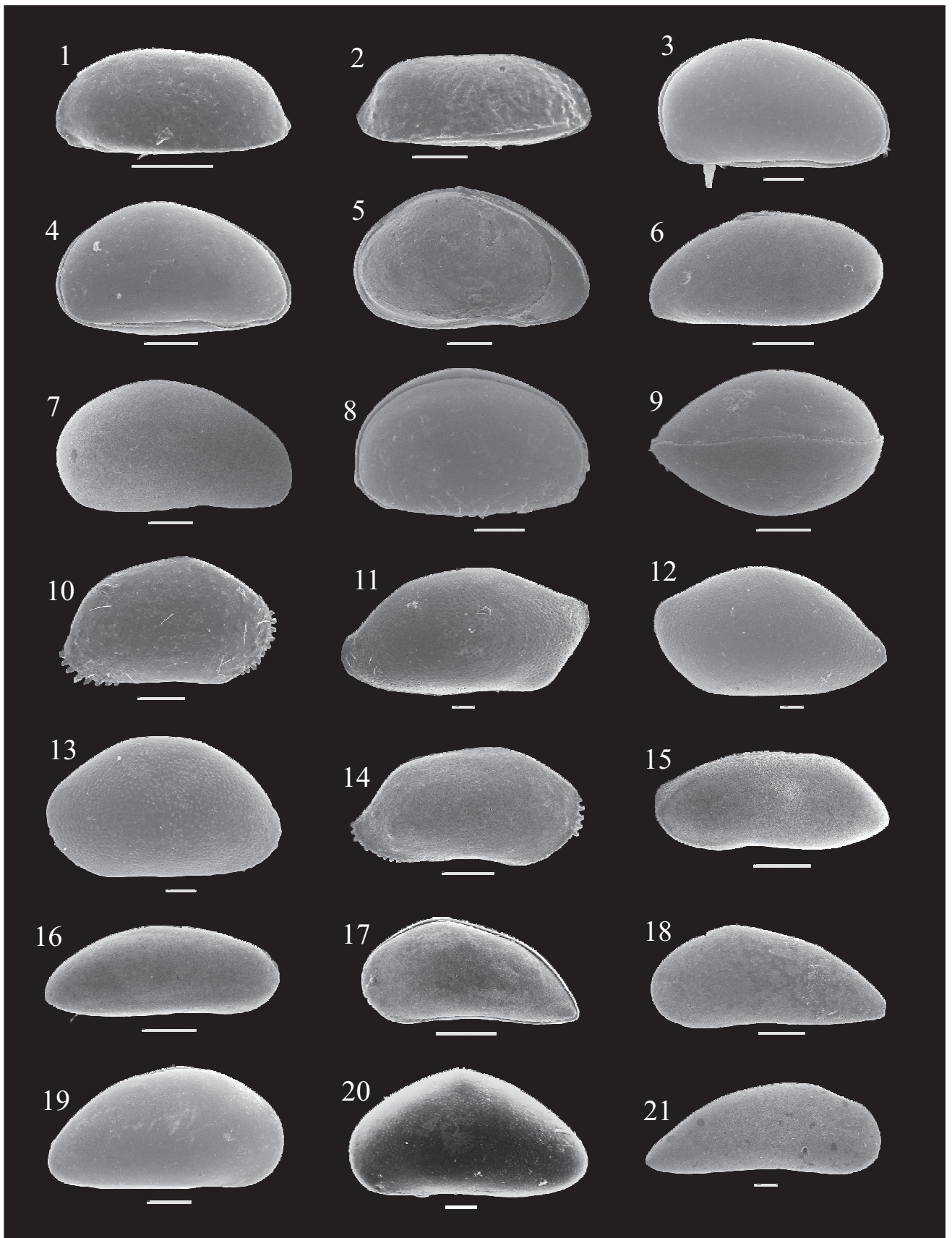
Leptocythere psammophila Guillaume, 1976

An outer estuarine species inhabiting sandy substrates from the Atlantic coasts of France to Iceland and the Baltic (Athersuch *et al.*, 1989) and NW Morocco (Nachite *et al.*, 2010); in the British Isles it was found in a low salt marsh, within a salinity range of 25–29‰ (Horne & Boomer, 2000). In Portugal found alive on sandy to silty sand substrates of the tidal flat of the lower Minho estuary, in autumn and spring conditions (approximate salinity range of 1.1–18.6‰ and temperature 18.5–21.4°C, in sediment interstitial water).

Leptocythere sp. A

Although showing affinities to some *L. lacertosa* in NW Europe it is best to leave this species in open nomenclature, pending further study; it is a brackish species found alive only in the lower Minho estuary, from the tidal flat to the low marsh, in autumn and spring conditions (approximate salinity range of 1.1–22.3‰ and temperature 13.8–21.4°C, in sediment interstitial water).

Explanation of Plate 8. LV, left valve; RV, right valve; C, carapace; f, female; m, male; j, juvenile; aut., autumn; spr., spring. Scale bar 100 µm. **fig. 1.** *Paracytherois acuminata* G. W. Müller, 1894, C, right view; Mira-MAS, P1 (aut.). **figs 2, 3.** *Paracytherois flexuosa* (Brady, 1867), C, left view; Mira-PMF, P2 (spr.); **3,** detail of ornamentation. **fig. 4.** *Paracytherois* cf. *mediterranea* Bonaduce, Ciampo & Masoli, 1976, RV, external; Mira-PMF, P2 (aut.). **fig. 5.** *Thaerocythere hoptonensis* (Brady, Crosskey & Robertson, 1874), RV, external; Lima-NSR, P2 (spr.). **fig. 6.** *Basslerites teres* (Brady, 1869), C, right view; site 9 (POP 0608). **fig. 7.** *Bosquetina tarentina* (Baird, 1850), RV, external, f; site 12 (POP 0108). **fig. 8.** *Buntonia sublatissima* (Neviani, 1906), LV, external; site 9 (POP 0108). **fig. 9.** *Buntonia textilis* Bonaduce, Ciampo & Masoli, 1976, RV, external, f; site 11 (POP 0108). **fig. 10.** *Carinocythereis carinata* (Roemer, 1838), RV, external, f; site 12 (POP 0608). **fig. 11.** *Carinocythereis whitei* (Baird, 1850), RV, external, ?; site 1 (POP 0608). **fig. 12.** *Celtia quadridentata* (Baird, 1850), C, right view, f; site 12 (POP 0608). **fig. 13.** *Costa runcinata* (Baird, 1850), RV, external, m; site 3 (POP 0608). **fig. 14.** *Falunia* cf. *sphaerulolineata* (Jones, 1857), LV, external; Mira-MAS, P1 (aut.). **fig. 15.** *Henryhowella sarsii* (G. W. Müller, 1894); RV, external; site 9 (POP 0108). **fig. 16.** *Hiltermannicythere emaciata* (Brady, 1867), LV, external, f; Melides, MB-16.275. **fig. 17.** *Ocultocythereis dohrni* (Puri, 1963), C, left view, ?m; Mira-MAS, P1 (spr.). **fig. 18.** *Pterygocythereis ceratoptera* (Bosquet, 1852), LV, external, f; site 6 (POP 0108). **fig. 19.** *Pterygocythereis jonesii* (Baird, 1850), RV, external, f; site 9 (POP 0108). **fig. 20.** *Rectobuntonia miranda* Bonaduce, Ciampo & Masoli, 1976, C, right view, m; site 11 (POP 0108). **fig. 21.** *Rectobuntonia rectangularis* (Ruggieri, 1954), LV, external; site 5 (POP 0608).



Leptocythere sp. B

Like *Leptocythere* sp. A, this species shows affinities to some *L. lacertosa* in NW Europe, but until further study it is best to leave it in open nomenclature; it is a rare brackish species found alive in the lower Minho and lower and mid Lima estuaries, from the tidal flat to the low marsh (particularly on the tidal flat), in autumn and spring conditions (approximate salinity range of 3.1–24.8‰ and temperature 11.6–20.2°C, in sediment interstitial water).

Loxococoncha elliptica Brady, 1868

A common brackish species usually associated with algae and mud, known from the Mediterranean to NW Europe (Horne & Boomer, 2000) and NW Morocco (Nachite *et al.*, 2010). In Portugal found alive in lower Minho, lower and mid Lima, lower and mid (Trancão) Tejo, lower Sado and lower and mid Mira estuaries, from the tidal flat to the high marsh, in autumn/winter and spring/summer conditions (approximate salinity range of 1.1–34.3‰ and temperature 10.9–21.7°C, in sediment interstitial water).

Loxococoncha malcomsoni Horne & Robinson, 1985

A rare brackish species, until now only known from the British Isles, living in salt marshes close to the tidal flat/low marsh limit, near marine salinity conditions (Horne & Boomer, 2000). In Portugal found alive in the lowest part of Mira and lower Sado estuaries, from the low to the high marsh, in autumn and spring conditions (approximate salinity range of 23.2–47.5‰ and temperature 14.4–17.2°C, in sediment interstitial water).

Loxococoncha rhomboidea (Fischer, 1855)

A common phytal, littoral/shallow sublittoral marine, NW European species (from Norway to Madeira and Canary Islands – Athersuch *et al.*, 1989), also found in salt marshes in slightly reduced salinities near the mouth of estuaries (Horne & Boomer, 2000); most Mediterranean records are doubtful, but some species from Cyprus and from the western part of the Mediterranean do appear to be *L. rhomboidea* (Athersuch & Whittaker, 1976). In Portugal very rarely found alive in the tidal flat of the lower Lima and lower Mira estuaries, in autumn and spring conditions (approximate salinity range of 24.8–33.8‰ and temperature 16.3–20.2°C, in sediment interstitial water).

Paradoxostoma sarniense Brady, 1868

A phytal, marine/brackish species (tolerant to salinities as low as 25‰) apparently only known previously from the British Isles and France (Athersuch *et al.*, 1989). In Portugal found alive on sandy substrate and red algae, in an intertidal rock pool near Laje River mouth, Santo Amaro de Oeiras beach, in spring conditions

(approximate salinity range of 35.5–36.2‰ and temperature 26–29.4°C, at low tide). Also found alive in the tidal flat of the lower Sado estuary, in autumn and spring conditions (approximate salinity range of 31.6–34.1‰ and temperature 13.8–18.7°C, in sediment interstitial water).

Paradoxostoma trieri Horne & Whittaker, 1985

A phytal, littoral marine species, apparently only known previously from the British Isles and France (Horne & Boomer, 2000); in the British Isles it also lives in salt marshes at the limit tidal flat/low marsh (Horne & Boomer, 2000). In Portugal found alive on sandy substrate, green and red algae, in an intertidal rock pool near Laje River mouth, Santo Amaro de Oeiras beach, in spring conditions (approximate salinity range of 35.5–36.2‰ and temperature 26–29.4°C, at low tide). Also found alive in the tidal flat of lower Sado and lower Mira estuaries, in autumn and spring conditions (approximate salinity range of 33.4–34.6‰ and temperature 15.9–17.6°C, in sediment interstitial water).

Rectobuntonia rectangularis (Ruggieri, 1954)

A marine sublittoral species known from the Mediterranean, found living at depths of 54–112 m, essentially on mud (Yassini, 1979, Pl. 4, figs 7 and 15, as *Buntonia subulata* Ruggieri, 1954). In Portugal found alive in sites 3 (96.5 m depth) and 5 (94.0 m depth), on western Algarve continental shelf, in spring conditions.

Semicytherura sella (Sars, 1866)

A shallow-marine/outer estuarine species, living on silty and sandy substrates, in NW Europe, including Norway and the Baltic Sea (Whittaker, 1974; Athersuch *et al.*, 1989). In Portugal rarely found alive on muddy substrate in the tidal flat of the lowest part of Mira estuary, in spring conditions (approximate salinity range 32.8–35.8‰ and temperature 17.7–18.9°C, in sediment interstitial water).

Semicytherura tela Horne & Whittaker, 1980

A littoral marine/brackish species found on algae in rock pools, in British Isles and France (Athersuch *et al.*, 1989). In Portugal, found alive (only one specimen) on sandy substrate in an intertidal rock pool near Laje River mouth, Santo Amaro de Oeiras beach, in a salinity of 35.5‰ and a temperature of 26°C, at low tide, in spring conditions.

Terrestricythere aff. *elisabethae* Horne, Smith, Whittaker & Murray, 2004

T. elisabethae was described in the British Isles from the high intertidal zone of a brackish creek with reeds and overhanging trees providing leaf litter (Horne *et al.*, 2004). The Portuguese species is possibly new and was found alive only in the high marsh of lower Tejo, lower Sado and mid Mira estuaries, in

Explanation of Plate 9. LV, left valve; RV, right valve; C, carapace; f, female; m, male; j, juvenile; aut., autumn; spr., spring. Scale bar 100 µm.

fig. 1. *Microxestoleberis nana* G. W. Müller, 1894, LV, external; Mira-MAS, P1 (aut.). **fig. 2.** *Microxestoleberis* cf. *pustulosa* Ciampo, 1986, RV, external; Mira-MAS, P1 (spr.). **fig. 3.** *Xestoleberis labiata* Brady & Robertson, 1874, C, right view, f; Mira-MAS, P1 (aut.). **figs 4, 5.** *Xestoleberis* cf. *nitida* (Liljeborg, 1853): **4**, C, right view, j; Mira-PMF, P1 (aut.); **5**, LV, internal, f; Mira-MAS, P1 (spr.). **fig. 6.** *Xestoleberis* aff. *parva* G. W. Müller, 1894, LV, external; Mira-MAS, P1 (spr.). **fig. 7.** *Xestoleberis rubens* Whittaker, 1978, RV, external, f; Mira-MAS, P1 (spr.). **figs 8, 9.** *Terrestricythere* aff. *elisabethae* Horne, Smith, Whittaker & Murray, 2004, C; Sado-TRO, P6 (aut.): **8**, right view; **9**, dorsal view. **fig. 10.** '*Bairdia*' *subcircinata* (Brady & Norman, 1869), RV, external, j; Lima-NSR, P1 (spr.). **fig. 11.** *Neonesidea* cf. *corpulenta* (G. W. Müller, 1894), RV, external; Lima-NSR, P3 (aut.). **fig. 12.** *Neonesidea longevaginata* (G. W. Müller, 1894), LV, external, j; Pederneira, S2-3.98. **fig. 13.** *Neonesidea* sp. 2 (Bonaduce, Ciampo & Masoli, 1976), LV, external; Pederneira, S2-3.98. **fig. 14.** *Triebelina raripila* (G. W. Müller, 1894), RV, external, j; Melides, MB-16.915. **fig. 15.** *Argilloecia* aff. *conoidea* Sars, 1923, LV, external, f; site 23 (POP 0108). **fig. 16.** *Argilloecia minor* (G. W. Müller, 1894), RV, external; site 14 (POP 0108). **fig. 17.** *Pontocypris* cf. *acuminata* (G. W. Müller, 1894), C, left view; Mira-PMF, P1 (spr.). **fig. 18.** *Pontocypris mytiloides* (Norman, 1862), LV, external; Mira-PMF, P1 (aut.). **fig. 19.** *Propontocypris* cf. *intermedia* (Brady, 1868), C, right view; Pederneira, S2-6.70. **fig. 20.** *Propontocypris pirifera* (G. W. Müller, 1894), LV, external; Lisboa, PC-18.80-18.81. **fig. 21.** *Paracypris polita* Sars, 1866, RV, external; site 23 (POP 0108).

autumn/winter and spring/summer conditions (approximate salinity range of 18.5–25.9‰ and temperature of 13.4–14.4°C, in sediment interstitial water).

Tuberoloxoconcha cf. *atlantica* Horne, 1989

T. atlantica is a marine, littoral, interstitial, western (Massachusetts, USA) and eastern (west Scotland) North Atlantic species (Horne, 1989). The Portuguese species, very similar but almost without ornamentation, was found alive only in the high marsh of lower Tejo and lower Mira estuaries, in autumn/winter and spring/summer conditions (approximate salinity range of 18.5–30.6‰ and temperature of 14.4–16.3°C, in sediment interstitial water).

Tuberoloxoconcha sp. 1

A new brackish species found alive only in the transition zone between low and high marsh of lower Minho estuary (Coura confluence), in autumn and spring conditions, within an approximate salinity range of 10.1–22.9‰ and temperature of 12.9–15.4°C, in sediment interstitial water.

Xestoleberis labiata Brady & Robertson, 1874

A shallow-marine species recorded previously only from the British Isles and France (Athersuch *et al.*, 1989). In Portugal found alive on sandy substrate, green and red algae, in an intertidal rock pool near Laje River mouth, Santo Amaro de Oeiras beach, in spring conditions (approximate salinity range of 35.5–36.2‰ and temperature 26–29.4°C, at low tide). Also found alive in the tidal flat of the lower Mira estuary, in autumn and spring conditions (approximate salinity range of 33.4–33.8‰ and temperature 16.0–16.3°C, in sediment interstitial water).

SUMMARY

A total of 178 brackish and marine ostracod species belonging to 75 genera has been found and identified in Portugal, most of them as empty valves. From those species, 17 are referred to as aff. or in open nomenclature; some of them are probably new. Eighteen species are recorded as fossil only and 73 have no fossil record in the area. Thirty species were found alive, most of them living in littoral areas; only 4 species were found alive in the western zone of the continental shelf of Algarve, and none was found alive in the continental slope.

Autochthonous fauna

The autochthonous fauna of the estuaries comprises 25 species, distributed in the high and low tidal marshes and in the tidal flat. Almost all the species are known in marginal-marine settings of the Atlantic coast of NW Europe – Spain, France, UK, Ireland, Belgium, The Netherlands and, for 10 of the species, even Norway, Sweden and the Baltic Sea (*Cyprideis torosa*, *Cytherois fischeri*, *Heterocythereis albomaculata*, *Leptocythere baltica*, *L. lacertosa*, *L. porcellanea*, *L. psammophila*, *Loxoconcha elliptica*, *L. rhomboidea*, *Semicytherura sella*) and also in both the Atlantic and Mediterranean coasts (9 species: *Basslerites teres*, *Callistocythere badia*, *Cyprideis torosa*, *Cytherois fischeri*, *C. cf. stephanidesi*, *Hemicytherura videns*, *Heterocythereis albomaculata*, *Leptocythere fabaeformis*, *Loxoconcha elliptica*). Two **phytal species** live in the lower estuaries, being found alive very rarely, but with very abundant empty valves in the tidal flat: *Hemicytherura videns* (also in the lower part of the low marsh) and *Loxoconcha rhomboidea*. The phytal *Paradoxostoma sarniense*, *P. trieri* and *Xestoleberis labiata* were found alive in

the tidal flat of the SW Portuguese estuaries, in a near-marine salinity range (31.6–34.6‰). *Heterocythereis albomaculata*, also a phytal species, was found alive associated with green algae, always submerged (even at low tide), in the lowest part of Laje river estuary, in the confluence with Tejo, in a salinity of 28.9‰. Five **brackish species**, preferring a muddy substrate and with a wide salinity tolerance can be found in all the three environments, **tidal flat, low and high marsh**: *Cyprideis torosa*, *Leptocythere ciliata*, *L. lacertosa*, *L. porcellanea* and *Loxoconcha elliptica*.

In the **tidal flat**, generally muddy, where the emersion time (time of subaerial exposure between tides) ranges between 12% and 70% and the salinity is highly variable, but no higher than 35‰, the number of species is high. Twenty species were found alive, from which eight are restricted to the tidal flat: *L. rhomboidea*, *P. sarniense*, *P. trieri*, *X. labiata*, *Basslerites teres*, *Leptocythere fabaeformis*, *L. psammophila* and *Semicytherura sella*. *Leptocythere psammophila* is associated with fine sand substrate. *Cytherois fischeri* is found both in the tidal flat and in the lower part of the low marsh, but it is much more abundant in the tidal flat. The most abundant species in the tidal flat are *L. elliptica*, *C. fischeri*, *L. porcellanea* and *Leptocythere* sp. A in the NW estuaries and *C. fischeri*, *L. elliptica*, *C. torosa* and *L. lacertosa* in the SW ones. The dominant species differs from one estuary to another and according to the location of the transect inside the estuary. In the tidal flat of the lower Lima and the lower Mira estuaries, empty valves of over 25 and 80 marine species, respectively, which do not live in these estuaries, were transported in by tidal currents.

In the **low marsh**, generally muddy, with emersion time around 75–90% and variable salinity (always lower in the NW estuaries, higher in the SW ones, where frequently it exceeds 35‰), fourteen species were found alive, all of them also found in the tidal flat and/or in the high marsh. The most frequent species in the low marsh are *L. porcellanea*, *L. ciliata* and *L. lacertosa*, present in almost all the estuaries and frequently dominant. In the NW estuaries, in addition to *L. porcellanea* and *L. ciliata*, *Cytherois* cf. *stephanidesi*, *Leptocythere* sp. A and *L. elliptica* are also well represented, particularly in the autumn. In the SW estuaries *L. porcellanea* and *L. lacertosa* are the dominant species, with *L. ciliata*, *L. elliptica* and *C. torosa* sometimes well represented. Among the other species also recorded alive in the low marsh are *L. baltica* and *Leptocythere* sp. B in the NW estuaries, *L. malcomsoni* in the SW ones, *C. murrayi* and *C. fischeri* in both; very rarely, *Tuberoloxoconcha* sp. 1 and *H. videns* occur, each one in one of the estuaries.

The **high marsh**, with a long emersion time (93–99.5%) and wide range of salinity values (frequently very low, reaching 2.5‰ in the NW estuaries and very high, reaching 45–50‰ in the SW estuaries), is often barren of ostracods. Besides the five very tolerant brackish species found in some high marshes (generally in the lower part), three other species have been recorded living there: *Tuberoloxoconcha* sp. 1 in the NW Minho estuary, characterized by low salinities at low tide and *Tuberoloxoconcha* cf. *atlantica* and *Terestricythere* aff. *elisabethae* in the SW estuaries. Though more abundant in the low marsh, *Loxoconcha malcomsoni* is also found inhabiting the lower part of the high marsh in two SW estuaries.

In the **marine littoral** settings, only two intertidal rock pools were studied, where six species were found living on algae or in sandy substrate, within a salinity around 35.5–36‰: *Callistocythere badia*, *Heterocythereis albomaculata*,

Paradoxostoma sarniense, *P. trieri*, *Semicytherura tela* (only in the substrate) and *X. labiata*.

Continental shelf and slope. On the continental shelf and slope 86 species were recognized, from which 10 were found only in the continental slope. Over 30% of the species are known, until now, both in the Atlantic Ocean and in the Mediterranean Sea, with at least 27 recorded only in the Mediterranean Sea and 19 only in the Atlantic Ocean. On the continental shelf the most common species, represented by abundant and complete populations (with all or almost all ontogenic stages, though all dead), are: *Costa runcinata*, *Palmoconcha guttata*, *Krithe* aff. *praetexta*, *Pterygocythereis jonesii* and *Henryhowella sarsii* (this species only abundant around or below –125m depth). *Rectobuntonia rectangularis*, *Celtia quadridentata* and *Cytheropteron* cf. *ruggierii* are not abundant but are frequently present. Only four species have very few specimens found alive: *Basslerites teres*, *Bosquetina tarentina*, *K.* aff. *praetexta* and *R. rectangularis*. *B. teres* is found alive as deep as 96.5m, but is more frequent in shallower water. In the continental slope no species were found alive. The assemblages are dominated by *K.* aff. *praetexta* and *H. sarsii* around –220m depth and by *Paracypris polita*, *K.* aff. *praetexta* and *K. keyi* around –500m depth.

Holocene

In the Holocene the ostracods characterize different environments and help to build a general evolutionary model of the studied marginal-marine regions since the Lateglacial (Cearreta *et al.*, 2003; Freitas *et al.*, 2003). This model includes several palaeoenvironmental stages, with the earliest and the latest being characterized by sediments barren in ostracods. The first stage (Lateglacial to Early Holocene), lacking ostracods, was interpreted as a high-energy fluvial environment, contemporaneous with a sea level significantly lower than present. In the second stage (Early Holocene), ostracods are present, at first represented by brackish forms (generally *C. torosa* and *L. elliptica*), progressively replaced by littoral and sublittoral marine species, the most abundant being: *Urocythereis britannica*, *Pontocythere elongata*, *Basslerites teres*, *Carinocythereis whitei*, *Semicytherura robertsi*, *S. sella*, *X. labiata*, *L. rhomboidea*, *Aurila convexa*. The maximum signal of marine influence in the sedimentary record is represented by the highest diversity in ostracods, including some deeper-water marine species, such as *Celtia quadridentata*, *Cytheropteron dorso-costatum*, *C. depressum*, *Roundstonia robertsoni*. This stage corresponds to the progressive development of an estuarine environment that further evolved to fully marine, due to the rapid sea-level rise during the Holocene transgression. A third stage (Middle and Late Holocene) is contemporaneous with a pronounced decrease in the rate of sea-level rise followed by stabilization of mean sea level. In this stage, brackish (and sometimes, rare freshwater) ostracods are once more present: *C. torosa* and *L. elliptica* if the marginal zone evolved to a barrier-lagoon system or *C. torosa*, *L. elliptica*, *Cytherois fischeri*, *L. porcellanea*, *L. lacertosa* (and many littoral marine/slightly brackish species) if the environment remained as an open estuary with marginal tidal marshes. The last stage (Late Holocene), lacking ostracods, corresponds to the terrestrialization of the former marginal marine systems, which became progressively shallower and smaller, due to significant input of terrestrial-sourced sediment settling in low energy depocentres and retained in alluvial fans and plains prograding and accreting over former intertidal space. In consequence, the environment resumed essentially freshwater and fluvial conditions that persisted until present.

CONCLUSIONS

To assist both monitoring of contemporary environmental change and to assist reconstruction of Holocene palaeoenvironments, we list and figure 30 living ostracod species from a range of marginal to marine environments in Portugal. In addition, we list and figure 148 species for which we have only the calcareous carapaces or valves, some of which appear to be restricted to the Holocene and are not known living in the area.

Knowledge of Recent Portuguese ostracods is fair for the western estuarine zones, but very incomplete for the marine littoral and sublittoral zones, where only two intertidal rock pools near Lisbon and a very small area from the continental shelf and slope in south Portugal have been studied. Holocene ostracods are relatively well known in the marginal-marine settings, particularly in the lagoons.

With this work, ostracod biogeographical patterns between NW European waters and the Mediterranean Sea are clarified, with some NE Atlantic species whose southern distribution limit was set in northern Spain (Bay of Biscay) now shown to live further to the south in Portugal. Most of the listed species are typical NE Atlantic forms, especially the Recent ones, found living or accumulated in the western Portuguese estuaries, but in Algarve, in the continental shelf and slope faunas, a Mediterranean influence is clearly stronger than in the other studied environments. In future research it will be very interesting to check whether this influence is also that important in the marginal littoral Algarve assemblages.

NOTE ADDED IN-PRESS

After manuscript acceptance, further work on the western Algarve continental slope revealed 19 more Recent ostracod species and eight more genera not previously reported in the main list. All were found on the continental slope, between 230 and 513 m depth; only 2 species were found alive. The discoveries modify some of the manuscript data (total number of species and genera, number of live species, etc) particularly the Abstract, which are not possible to change at this stage.

Genus *Monoceratina* Roth, 1928 *Monoceratina mediterranea* Sissingh, 1971 – continental slope (alive). Genus *Cytheropteron* Sars, 1866 *Cytheropteron* aff. *alatum* Sars, 1866 – continental slope, *Cytheropteron crassipinatum* Brady & Norman, 1888 – continental slope, *Cytheropteron rotundatum* Müller, 1894 – continental slope (alive). Genus *Eucythere* Brady, 1868 *Eucythere* cf. *curta* Ruggieri, 1975 – continental slope, *Eucythere pubera* Bonaduce, Ciampo & Masoli, 1976 – continental slope. Genus *Parakrithe* Van den Bold, 1958 *Parakrithe* aff. *robusta* Van den Bold, 1966 – continental slope. Genus *Pseudopsammocythere* Carbone, 1966 *Pseudopsammocythere* aff. *reniformis* (Brady, 1868) – continental slope. Genus *Loxoconchidea* Bonaduce, Ciampo & Masoli, 1975 *Loxoconchidea minima* Bonaduce, Ciampo & Masoli, 1976 – continental slope. Genus *Nipponocythere* Ishizaki, 1971 *Nipponocythere* sp. 1 – continental slope. Genus *Sagmatocythere* Athersuch, 1976 *Sagmatocythere* aff. *moncharmonti* (Ciampo, 1971) – continental slope. Genus *Echinocythereis* Puri, 1953 *Echinocythereis echinata* (Sars, 1866) – continental slope. Genus *Microxestoleberis* G. W. Müller, 1894 *Microxestoleberis* aff. *xenomys* (Barbeito-González, 1971) – continental slope. Genus *Platyleberis* Bonaduce & Danielopol, 1988 *Platyleberis profunda* (Breman, 1975) – continental slope. Genus *Anchistrocheles* Brady & Norman, 1889 *Anchistrocheles* cf. *tenera* (Breman, 1975) – continental slope. Genus *Bythocypris* Brady, 1880 *Bythocypris obtusata* (Sars,

1866) – continental slope. Genus *Macropyxis* Maddocks, 1990 *Macropyxis* cf. *adriatica* (Breman, 1975) – continental slope. Genus *Argilloecia* Sars, 1866 *Argilloecia* cf. *acuminata* G. W. Müller, 1894 – continental slope, *Argilloecia* cf. *robusta* Bonaduce, Ciampo & Masoli, 1976 – continental slope.

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