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ORIGINAL ARTICLE

An illustrated key to the soft-bottom caprellids (Crustacea: Amphipoda) of the Iberian Peninsula and remarks to their ecological distribution along the Andalusian coast

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Abstract The soft-bottom caprellids of the Iberian Peninsula are revised. Nineteen species have been reported so far, 42 % being endemic to the Mediterranean Sea. The lateral view of all of them is provided, together with an illustrated key for all the species. An ecological study was also conducted during 2007–2010 along the Andalusian coast to explore the relationships of caprellids with abiotic data. A total of 90 stations (0–40 m deep) were sampled and 40 contained caprellids. Along the Atlantic, caprellids were present in only 20 % of the stations, while along the Mediterranean coast, caprellids were present in the 75 % of the sampling sites. Furthermore, the abundance of caprellids was also higher in the Mediterranean coast. The dominant species was *Pseudolirius kroyeri* (present in 24 stations and showing the highest abundances with 1,780 ind/m^2), followed by *Phtisica marina* (22 stations) and *Pariambus typicus* (11 stations). According to CCA and BIO-ENV, sediment type, P, pH and oxygen were the parameters that better explained the distribution of caprellids. Although the three dominant species were found in all types of sediment, the univariate approach showed that *P. kroyeri* was significantly more abundant in fine sediments (silt–clay and very fine sands) than in gross sediments (coarse and very coarse sands). The majority of studies dealing with caprellids from the Iberian Peninsula have been focused on shallow waters and further efforts are needed to explore biodiversity of deeper areas.

Keywords Caprellidae · Soft bottoms · Atlantic · Mediterranean · Depth · Sediment type

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Introduction

Caprellids (Crustacea: Amphipoda) are small marine crustaceans which inhabit algae, hydroids, ascidians, anthozoans, bryozoans, sponges, seagrasses and sediments (McCain 1968; Guerra-García 2001). They feed on suspended materials, prey on other organisms or graze on epibiotic fauna and flora (Caine 1974; Guerra-García et al. 2002a; Thiel et al. 2003). In general terms, they can be considered as detritivores (Guerra-García and Tierno de Figueroa 2009). Caprellids are an important prey for many coastal fish species (Caine 1987, 1989, 1991) and have also been found to be useful bioindicators of marine pollution and environmental stress (Guerra-García and García-Gómez 2001; Ohji et al. 2002; Takeuchi et al. 2004; Guerra-García and Koonjul 2005; Guerra-García et al. 2010a).

Although the knowledge of the ecology and taxonomy of amphipod species on the coasts of the Iberian Peninsula has traditionally been considered fragmentary (Jimeno and Turón 1995; Bellan-Santini and Ruffo 1998), an increasing effort has been made during the last decade to understand the biodiversity of caprellids in intertidal and shallow waters of Spanish and Portuguese coasts (Guerra-García et al. 2010b), especially in the Strait of Gibraltar. However, most of the studies have been focused on algae (Guerra-García et al. 2009, 2010b; Guerra-García and Izquierdo 2010) and the knowledge of the caprellids from soft bottoms is still very scarce. The information available so far is restricted to taxonomical papers including descriptions of new taxa (Guerra-García et al. 2001a, b), inventory of species (de-la-Ossa-Carretero et al. 2010) or community structure of caprellids on seagrasses (González et al. 2008). In spite of the caprellid species *Phtisica marina* Slabber, 1769 or *Pariambus typicus* (Krøyer, 1844) are among the dominant taxa in shallow sediment communities of the Iberian Peninsula (Sánchez-Mata 1996; Estacio 1996; Lourido et al. 2008; Sánchez-Moyano and García-Asencio 2010), very little is known about their ecology and distribution.

Consequently, the main aim of the study was to review recent literature in order to provide an illustrated key to all caprellids species reported so far in soft bottoms of the whole Iberian Peninsula. Additionally, an extensive sampling survey was conducted to statistically explore the patterns of ecological preferences (mainly depth and sediment type) and spatial distribution of the dominant species.

Materials and methods

Fieldwork was carried out along the Andalusian coast (Fig. 1). A total of 90 stations were chosen to encompass the broadest possible range of natural environmental conditions. We selected undisturbed sites with low human impact to avoid the effect of anthropogenic influence on the natural ecological patterns of species. In fact, the selected stations are considered as reference undisturbed monitoring sites for the extensive research programme on sediment communities from the Andalusian coasts (southern Spain) conducted by the *Agencia de Medio Ambiente y Agua* and supported by the *Consejería de Medio Ambiente* of the Andalusian Government. This project is in the context of the European Water Framework Directive (WFD) and it is focused on the environmental control of the littoral zone based on the macrofaunal communities and their relationships with the abiotic variables.

As a part of the monitoring programme of the above-mentioned project, all the stations were sampled during the summers of 2007, 2009 and 2010. At each station, four replicate samples (three for biological analysis and one for sediment analysis) were taken with a 0.05-m^2 van Veen grab. Each biological replicate was sieved in seawater through a mesh of 0.5 mm, fixed with 4 % formalin and stained with Bengal rose. All caprellids were sorted and identified to species level. For sediment analysis, organic matter percentage was obtained as weight loss by ignition at 450 °C for 24 h and granulometry was assessed following the protocols of Buchanan and Kain (1984). Phosphorous was measured using UV–visible spectrophotometry, and total nitrogen was assessed via Kjeldahl digestion. For water analysis, a water sample per station was obtained close to the bottom by a vertical Alpha Van Dorn-style bottle. Salinity, temperature, pH and dissolved oxygen were measured with a CTD SBE 10 plus. ClhA was also measured with UV–visible spectrophotometry.

To assess the ecological patterns of the dominant caprellids, univariate and multivariate analyses were conducted. To explore the relationships among abiotic data and the caprellid assemblages, a canonical correspondence analysis (CCA) was applied. The abundance data were transformed with the squared root and the Bray–Curtis similarity index was used. Relationships between multivariate biological structure and environmental data were also examined using the BIO-ENV procedure. Multivariate

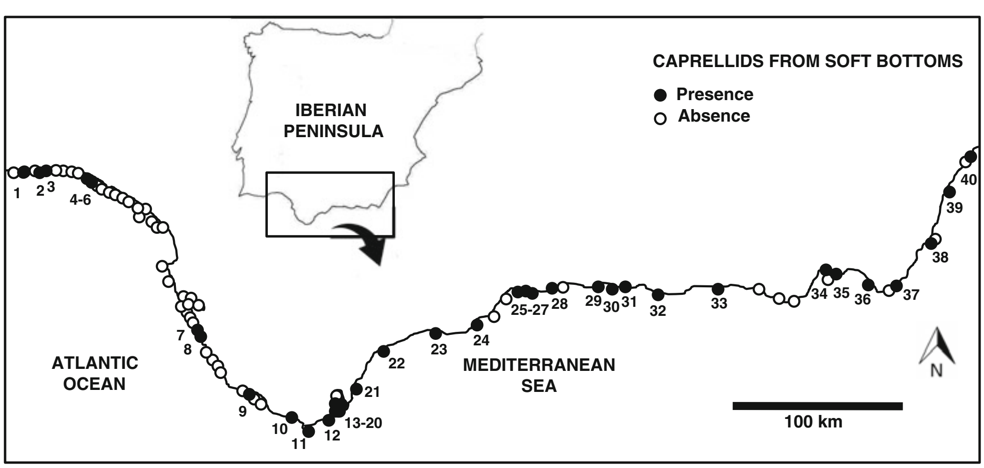


Fig. 1 Study area showing the sampling stations

analyses were carried out using the PRIMER v.6 package (Clarke and Gorley 2001). To test whether the caprellids' abundance of the main species was similar across depths and sediment types, we used an analysis of variance (ANOVA) with the following factors: 'Depth', a fixed factor, with two levels: 0–15 m and 15–30 m deep; 'Sediment type', a fixed factor and orthogonal, with two levels: gross sediment (gravels and coarse–very coarse sands) and fine sediment (fine–very fine sands and silty and clay); and 'Site', a random factor and nested with 'Sediment type' and 'Depth', with three random sampling sites. From each site, three samples ($n = 3$) of sediment were considered. For this univariate approach, a total of 12 sites were randomly selected of the total 25 stations with caprellids along the Mediterranean coast. Taking into account that in the Atlantic coast there were not enough sites containing caprellids for a balanced statistical design, we only used data of the Mediterranean coast. Prior to ANOVA, heterogeneity of variance was tested with Cochran's *C* test. Data were transformed with $\ln(x + 1)$ if variances were different at $P = 0.05$. When variances remained heterogeneous, untransformed data were analysed, as ANOVA is a robust statistical test and is relatively unaffected by heterogeneity of variances, particularly in a balanced design (Underwood 1997). In such cases, special care was taken in the interpretation of results, and to reduce type I errors, the level of significance was reduced to <0.01. Univariate analyses were conducted with GMAV5 (Underwood et al. 2002).

Results

Soft-bottom caprellids from the Iberian Peninsula

Table 1 includes all the species that have been reported so far in soft bottoms of the Iberian Peninsula, including seagrasses and *Caulerpa* meadows associated with sediments. The following references have been consulted during the review: Mayer (1882, 1890), Cavedini (1981), Krapp-Schickel (1993), Laubitz and Sorbe (1996), Bellan-Santini and Ruffo (1998), Krapp-Schickel and Vader (1998), Estacio (1996), Guerra-García (2001, 2004), Guerra-García et al. (2000, 2001a, b, c, 2002b, 2008, 2010b), Bachelet et al. (2003), González et al. (2008), Lourido et al. (2008), Moreira et al. (2008), Vázquez-Luis et al. (2009), Cacabelos et al. (2010), de-la-Ossa-Carretero et al. (2010), Sánchez-Moyano and García-Asencio (2010, 2011).

Of the 19 species found, 8 species (42 %) are Mediterranean endemic. Only 2 species, *P. spinipoda* and *L. cachuchoensis*, can be considered as deep-sea species, although *C. equilibra*, *P. marina* and *P. phasma* have a wide depth range. *Caprella caulerpensis*, *L. cachuchoensis*, *P. major* and *P. spinipoda* have been recorded in muddy sediments (silt and clay), whereas *C. rapax*, *C. pseudorapax*, *C. sabulensis*, *L. elongatus* and *P. onubensis* seem to prefer coarse sands. *P. typicus*, *P. marina*, *P. kroyeri* and *P. phasma* have been found in sediments of different granulometry. *Caprella grandimana*, *C. hirsuta*, *C. santosrosai* and *D. schieckei* usually inhabit algae instead of sediments; however, they have been also recorded in *Caulerpa* meadows associated with soft bottoms. Other species, such as *C. acanthifera*, *C. equilibra*, *P. marina* and *P. phasma*, have been found in a variety of other substrates and are not exclusive of sediments.

Figure 2 includes the male lateral view of the 19 species. The following key is based on adult male specimens and it has been elaborated using characters that do not need dissection of mouthparts. Figure 3 provides a generalized caprellid body plan showing the terminology included in this key. Additionally, Fig. 4 graphically compiles the morphological details to be used in conjunction with the provided key.

1a	Pereopods 3 and 4 fully articulate	*Phtisica marina*
b	Pereopods 3 and 4 absent or reduced	2
2a	Head with acute dorsal projection	3
b	Head smooth	4
3a	Antenna 1 longer than half of the body, P3–4 very reduced. Dorsal projections on head and pereonites 1–2	*Pseudoprotella phasma*
b	Antenna 1 shorter than half of the body, P3–4 absent. Dorsal projection on head. Pereonites 1–2 lacking projections	*Caprella santosrosai*
4a	Antenna 2 very setose. Ventral projection between gnathopods 2	*Caprella equilibra*
b	Antenna 2 scarcely setose. Ventral projection among gnathopods 2 absent	5
5a	Propodus of gnathopod 2 setose	6
b	Propodus of gnathopod 2 not setose	7
6a	Propodus of gnathopod 2 dorsally with long setae. Antennae and pereopods with abundant short setae	*Caprella hirsuta*
b	Propodus of gnathopod 2 dorsally with short setae. Antennae and pereopods with scarce short setae	*Caprella grandimana*
7a	Eyes absent	8
b	Eyes present	9
8a	Triangular projection laterally on the head. Dorsal projections on the anterior end of pereonites 3–5	*Liropus cachuchoensis*
b	Head and pereonites 3–5 without projections	*Protoaeginella spinipoda*
9a	Distinct dorsal projections (rounded or acute) on pereonites 3–7	*Caprella acanthifera*
b	Dorsal projections absent or tiny	10

10a	Body very elongate >8 mm. Antennae >6 times (head + pereonite 1)	*Parvipalpus major*
b	Body <8 mm. Antennae <6 times (head + pereonite 1)	11
11a	Pereopod 5 reduced to 2 articles	12
b	Pereopod 5 with 7 articles	14
12a	Propodus of gnathopod 2 smooth, without medial or distal projections. "Abdomen" with developed pleopods carrying a strong setae	*Pseudolirius kroyeri*
b	Propodus of gnathopod 2 with medial or distal projection. "Abdomen" without developed pleopods	13
13a	Gnathopod 2 with distal projection	*Liropus elongatus*
b	Gnathopod 2 with medial projection	*Pariambus typicus*
14a	Pereopods 3 and 4 present, reduced to 2-articles	*Deutella schieckei*
b	Pereopods 3 and 4 absent	15
15a	Head with a short rostrum	*Parvipalpus onubensis*
b	Head without rostrum	16
16a	Suture between head and pereonite 1 present	17
b	Suture absent	18
17a	Head 'skull' like	*Caprella caulerpensis*
b	Head smooth and rounded	*Caprella sabulensis*
18a	Eyes reduced to 6–8 ocelles	*Caprella pseudorapax*
b	Eyes normal	*Caprella rapax*

Sampling survey along Andalusian coast

Caprellid assemblages

Of the 90 stations sampled along the coast, 40 contained caprellids (Table 2; Fig. 1). Along the Atlantic shore, caprellids were present only in 20 % of the stations, while along the Mediterranean coast, caprellids were present in 75 % of the sampling sites. Furthermore, the abundance of caprellids was also higher in the Mediterranean coast (Fig. 5). Seven species were identified from the samples: *Caprella acanthifera* Leach, 1814, *Caprella rapax* Mayer, 1890, *Caprella sabulensis* Guerra-García, Sánchez-Moyano and García-Gómez, 2001, *Pseudolirius kroyeri* (Haller, 1879), *P. marina* Slabber, 1769, *Pseudoprotella phasma* (Montagu, 1804) and *P. typicus* Krøyer, 1844 (Table 2). The dominant species was *P. kroyeri* (present in 24 stations and showing the highest abundances), followed by *P. marina* (22 stations) and *P. typicus* (11 stations). The remaining 4 species were occasional: *C. acanthifera* was only present in stations 30 and 40, *C. rapax* only in station 9, *C. sabulensis* in station 2 and 11, and *P. phasma* in stations 5 and 9. The highest abundance was measured for *P. kroyeri* with a mean value of 1,780 ind/m^2.

Abiotic data

Water depth at the stations ranged from 3 to 36 m (Table 2). A variety of sediment types was represented, with stations dominated by gravels (e.g. station 1 or 11), coarse and very coarse sands (e.g. stations 9, 12, 23, 30, 31, 33 or 35), medium sands (e.g. stations 28 or 36), fine and very fine sands (most of the stations) and silt and clay (e.g. stations 4, 5, 13, 17, 18, 20, 25, 26, 31, 32 or 34). The organic matter content was low in most of the stations; however, values higher than 6 % were measured in some stations of the Atlantic coast (Huelva and Cádiz) coinciding with the discharges of the main rivers. High P and N concentrations were also measured in stations of the Atlantic coast, but also in the Mediterranean site of Algeciras Bay (e.g. station 20). Regarding water samples, ClhA ranged from 0.10 to 4.73 mg/m^3, oxygen from 4.0 to 8.1 mg/l, salinity from 35.31 to 40.54 psu, temperature from 14.5 to 26.7 °C and pH from 7.54 to 8.40.

Multivariate approach

According with the results of the Table 2, the three dominant caprellids, *P. kroyeri*, *P. marina* and *P. typicus*, were present in a variety of depths and sediment types, showing that the three species are able to live in gravels, coarse sands, medium sands, fine sands or silt and clays. The BIO-ENV analysis produced the best correlation (0.21) for the combination of the variables Chl*a*, oxygen, salinity, pH, P and medium sands, but this correlation was very low. However, when the exploratory multivariate approach was conducted throughout the CCA, higher correlations were obtained (Fig. 6; Table 3). The first axis explained the 28.4 % of the total variance and correlated mainly with granulometry and pH. While *P. kroyeri* was mainly related with the percentage of the finest fractions (silts and clays) and higher values of pH, *P. typicus* and *P. marina* were associated with the gross fractions (gravels, coarse and medium sands) and lower values of pH. The second axis correlated with oxygen measured in the water column (bottom) and P measured in sediments. These two variables separated the species *P. typicus* from *P. marina*, being the first associated with more oxygenated stations, while the latter is able to live in stations with higher contents of phosphorous and lower oxygen concentrations.

Table 1 Caprellids collected from soft bottoms of the Iberian Peninsula

Name of species	Distribution	Depth (m)	Type of sediments	Other substrates
Caprella acanthifera Leach, 1814	M, A	0–90	MS–CS, *Cn*, *Po*, *Zm*	Al, Hy, As, An, Sp, Br
Caprella caulerpensis Guerra-García, Sánchez-Moyano and García-Gomez, 2002	E	5	SC with *Cp*, high OM (>10 %)	
Caprella equilibra Say, 1818	M, A, P, I	0–3,000	Sandy bottoms with *Cn*	Al, Hy, As, Sp, Br
Caprella grandimana Mayer, 1882	E	0–10	Sediments with *Cr*	Al
Caprella hirsuta Mayer, 1890	E	0–40	Sediments with *Cr*	Al, Hy, Eq
Caprella pseudorapax Guerra-García, Sánchez-Moyano and García-Gómez, 2001	E	20–30	MS–CS, low OM (<1 %)	
Caprella rapax Mayer, 1890	M, A	1–80	CS, *Po*	
Caprella sabulensis Guerra-García, Sánchez-Moyano and García-Gómez, 2001	M, A	20–30	MS–CS, biodetritic, low OM (<1 %)	
Caprella santosrosai Sánchez-Moyano, Jiménez-Martín and García-Gómez, 1995	E	0–40	Sediments with *Cr*	Al, Hy, An, Sp
Deutella schieckei Cavedini, 1982	E	0–10	Sediments with *Cp* and *Cr*	Al
Liropus cachuchoensis Guerra-García, Sorbe and Frutos, 2008	A	619–1,062	SC with medium OM (4–6 %)	
Liropus elongatus Mayer, 1890	E	25–30	Sandy bottoms, *Po, Pe*	
Pariambus typicus Krøyer, 1844	M, A	0–40	G, CS, MS, FS, SC, *Cn*, *Zm*, *Zn*	Eq
Parvipalpus major A. Carausu, 1941	M, A	0–924	Muddy sands to mud, *Po*	Al
Parvipalpus onubensis Guerra-García, García-Asencio and Sánchez-Moyano, 2001	A	20	CS, low OM (<2 %)	
Phtisica marina Slabber, 1769	M, A, P	0–660	G, CS, MS, FS, SC, *Cn*, *Po*, *Zm*, *Zn*	Al, Hy, As, An, Sp, Br, Eq
Protoaeginella spinipoda Laubitz and Sorbe, 1996	A	2,990–3,070	SC	
Pseudolirius kroyerii (Haller, 1879)	E	0–62	G, CS, MS, FS, SC	
Pseudoprotella phasma (Montagu, 1804)	M, A	0–2,450	G, CS, MS, FS, SC, *Cn*, *Po*, *Zm*, *Zn*	Al, Hy, An

Species collected from seagrasses and *Caulerpa* spp. growing on sediments are also included

References: Mayer (1882, 1890), Cavedini (1981), Krapp-Schickel (1993), Laubitz and Sorbe (1996), Bellan-Santini and Ruffo (1998), Krapp-Schickel and Vader (1998), Estacio (1996), Guerra-García (2001, 2004), Guerra-García et al. (2000, 2001a, b, c, 2002b, 2008, 2010b), Bachelet et al. (2003), González et al. (2008), Lourido et al. (2008), Moreira et al. (2008), Vázquez-Luis et al. (2009), Cacabelos et al. (2010), de-la-Ossa-Carretero et al. (2010), Sánchez-Moyano and García-Asencio (2010, 2011)

E Mediterranean endemic, *M* Mediterranean Sea; *A* Atlantic ocean; *P* Pacific Ocean; *I* Indian Ocean. *CS* coarse sand; *MS* medium sand; *FS* fine sand; *SC* silt and clay; *OM* organic matter; *Cn Cymodocea nodosa*; *Po Posidonia oceanica*; *Zm Zostera marina*; *Zn Zostera noltii*; *C Caulerpa*; *Cp Caulerpa prolifera*; *Cr Caulerpa racemosa*; *Pe Peysonnelia*; *Al* algae; *Hy* hydroids; *As* ascidians; *An*, antozoans; *Sp*, sponges; *Br* bryozoans; *Eq* equinoderms

Univariate design

To verify the influence of sediment type on the abundance of the dominant caprellid species (*P. kroyeri*, *P. marina* and *P. typicus*), a three-way ANOVA was conducted, including not only the sediment's granulometry, but also water depth as a factor. The abundance of each species was similar in shallow (0–15 m) and deep (15–30 m) stations (Table 4; Fig. 7). On the other hand, ANOVA results evidenced no significant differences in the abundances of *P. marina* and *P. typicus* between gross (gravels and coarse–very coarse sands) and fine sediments (fine–very fine sands and silts and clays), although *P. kroyeri* showed higher abundances in fine sediments (Table 4; Fig. 7), in spite of the differences among sites.

Discussion

Ecological remarks of soft-bottom caprellids

The present study reveals that the dominant caprellid species from shallow soft bottoms of southern Spain (*P. kroyeri*, *P. typicus* and *P. marina*) may inhabit different sediment types, from gravels to silts and clays. However, univariate analyses confirmed that *P. kroyeri* was significantly more abundant in fine–very fine sands and muddy sediments than coarse sands and gravels. This is in agreement with Krapp-Schickel (1993) who described the species as typical from muddy bottoms, sometimes commensal with pelagic *Salpa mucronata*. In spite of the high abundance of *P. kroyeri* shown by this study, the species has

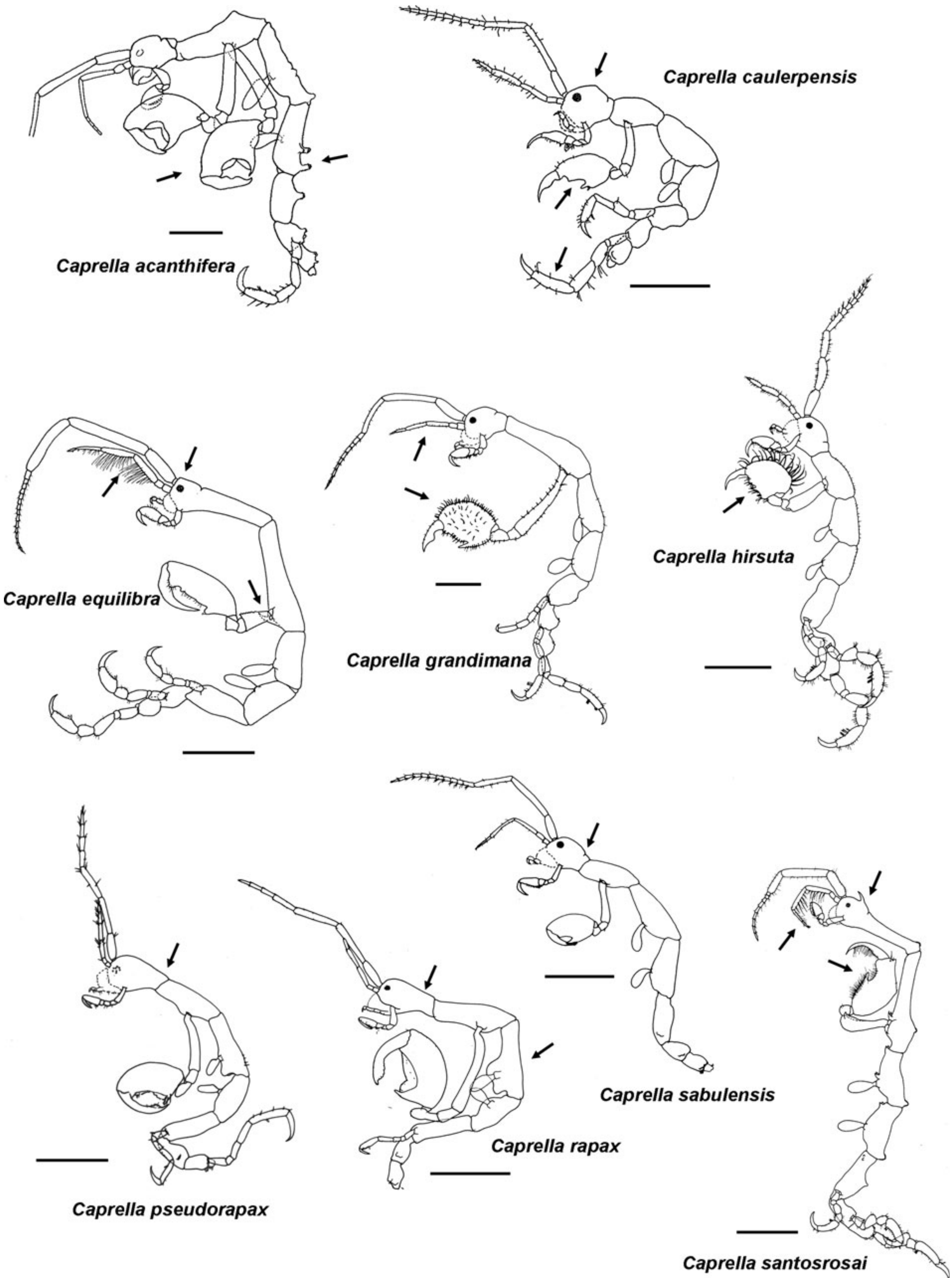


Fig. 2 Male lateral view figures of caprellids inhabiting soft bottoms of the Iberian Peninsula. Refigured from Krapp-Schickel (1993), Laubitz and Sorbe (1996), Guerra-García et al. (2000, 2001a, b, c, 2002b, 2008), Guerra-García and Takeuchi (2002), Riera et al. (2003). Scale bars 1 mm

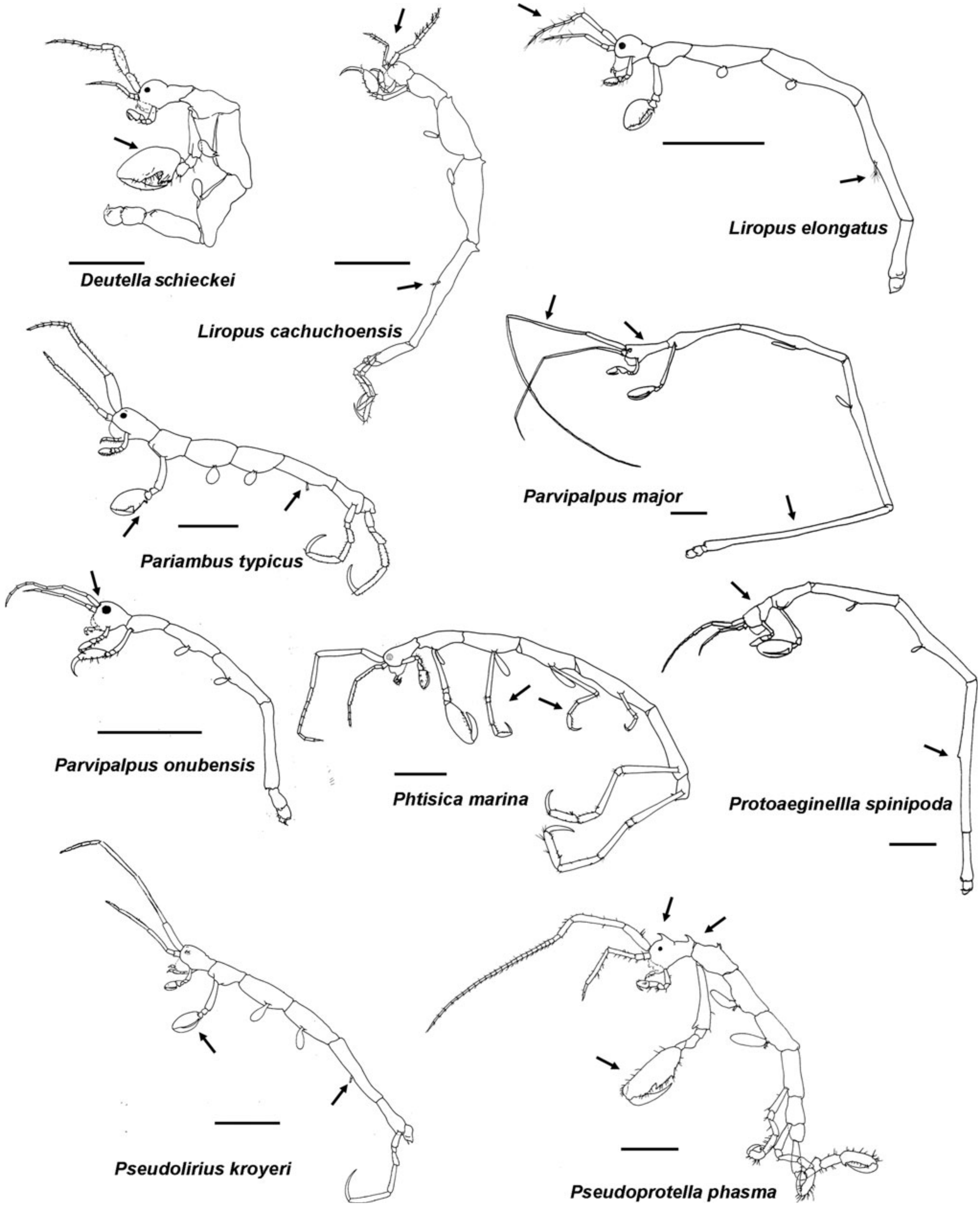


Fig. 2 continued

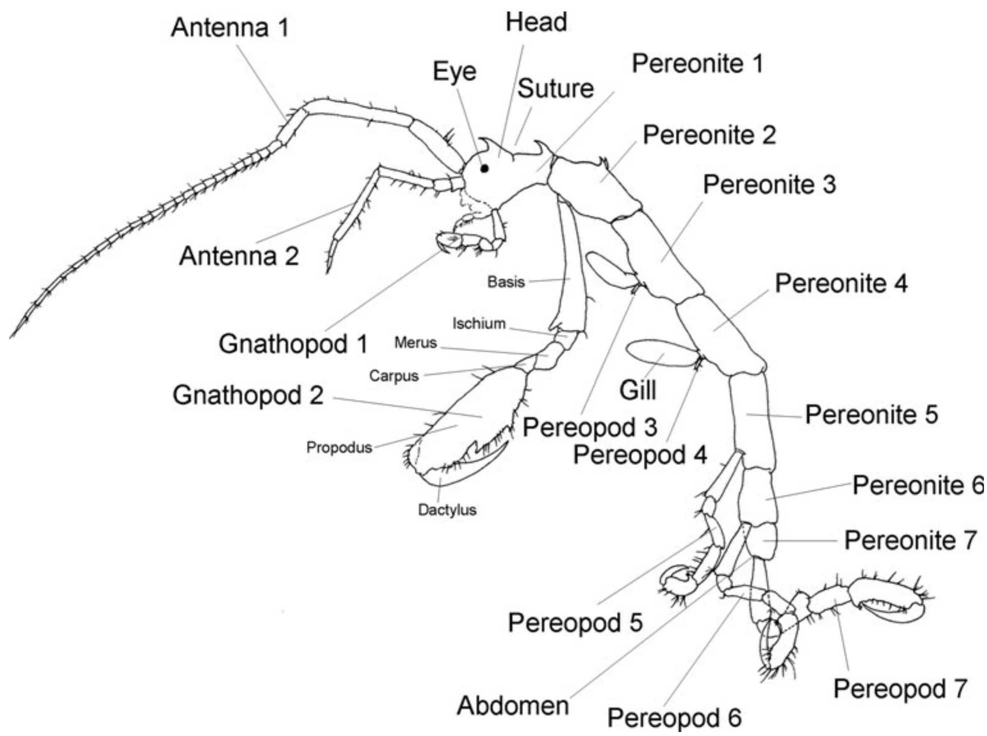


Fig. 3 Lateral view of a generalized caprellid (*Pseudoprotella phasma*) showing the different parts used in the key

been rarely reported along the Iberian Peninsula's coasts. Marti (1989) cited the species in Valencia Gulf, and Estacio (1996) found the species in sediments of Algeciras Bay, especially in fine sands and mud. The present study reveals that *P. kroyeri* is significantly more abundant than *P. typicus* along the Andalusian coasts. However, after consulting technical reports conducted by universities, public and private companies, *P. typicus* is usually the only species reported and *P. kroyeri* is rarely cited. Adult males of both species can be clearly distinguished by the gnathopod 2, but subadult males or juveniles have similar gnathopods, and examination of "abdomen" is necessary for a correct identification. Probably, both species have been misidentified in many of these reports, assigning all the specimens to *P. typicus*, and these mistakes could eventually be published as part of checklists, ecological or biogeographical papers. As a result, the abundance of *P. kroyeri* has been underestimated. For all these reasons, taxonomists are encouraged to provide illustrated keys to non-specialists, necessary to undertake correct identifications. Authorities and policy makers should also be aware of the importance of taxonomy as basic tool for properly conducting applied studies.

Phtisica marina and *P. typicus* are very common in soft bottoms along the Iberian Peninsula, inhabiting gravels, coarse sands, fine sands and muddy sediments (Sánchez-Mata 1996; Lourido et al. 2008; Sánchez-Moyano and García-Asencio 2010). Although the CCA conducted during the present study showed positive correlation of these two species with coarse sands and gravels, the three-way ANOVA did not show significant differences of abundance among substrates. Guerra-García and García-Gómez (2006) conducted a recolonization experiment of defaunated sediments and did not find clear differences in the preference patterns of these two species between the trays with coarse sands and fine sands. *P. marina* was slightly more abundant in coarse sands, while *P. typicus* reached highest densities in coarse sands after 30 days of recolonization but was more abundant in fine sands after 90 days. Although *P. typicus* has been found free-living on the sea floor, it has also been regularly found on asteroids, ophiuroids and echinoids, establishing a complex association of commensalism (Volbehr and Racor 1997).

The three dominant species found in the present study (*P. marina*, *P. typicus* and *P. kroyeri*) are used as bioindicators to evaluate the quality of coastal marine environments (de-la-Ossa-Carretero et al. 2012). Nevertheless, their sensitivity to pollution is not clear, since there is disagreement among the biotic factors used for their classification. *P. marina* is able to inhabit very polluted sediments (Guerra-García and García-Gómez 2004) or cling to seeweeds located in polluted waters (Guerra-García and García-Gómez 2001). According to the BENTIX classification, this species is tolerant to pollutants (Borja et al. 2000) and our data agree with this. However, this same species has been detected to be relatively sensitive to sewage discharges (de-la-Ossa-Carretero et al. 2012) and AMBI classification reported this species as sensitive (Simboura and Zenetos 2002). On the other hand,

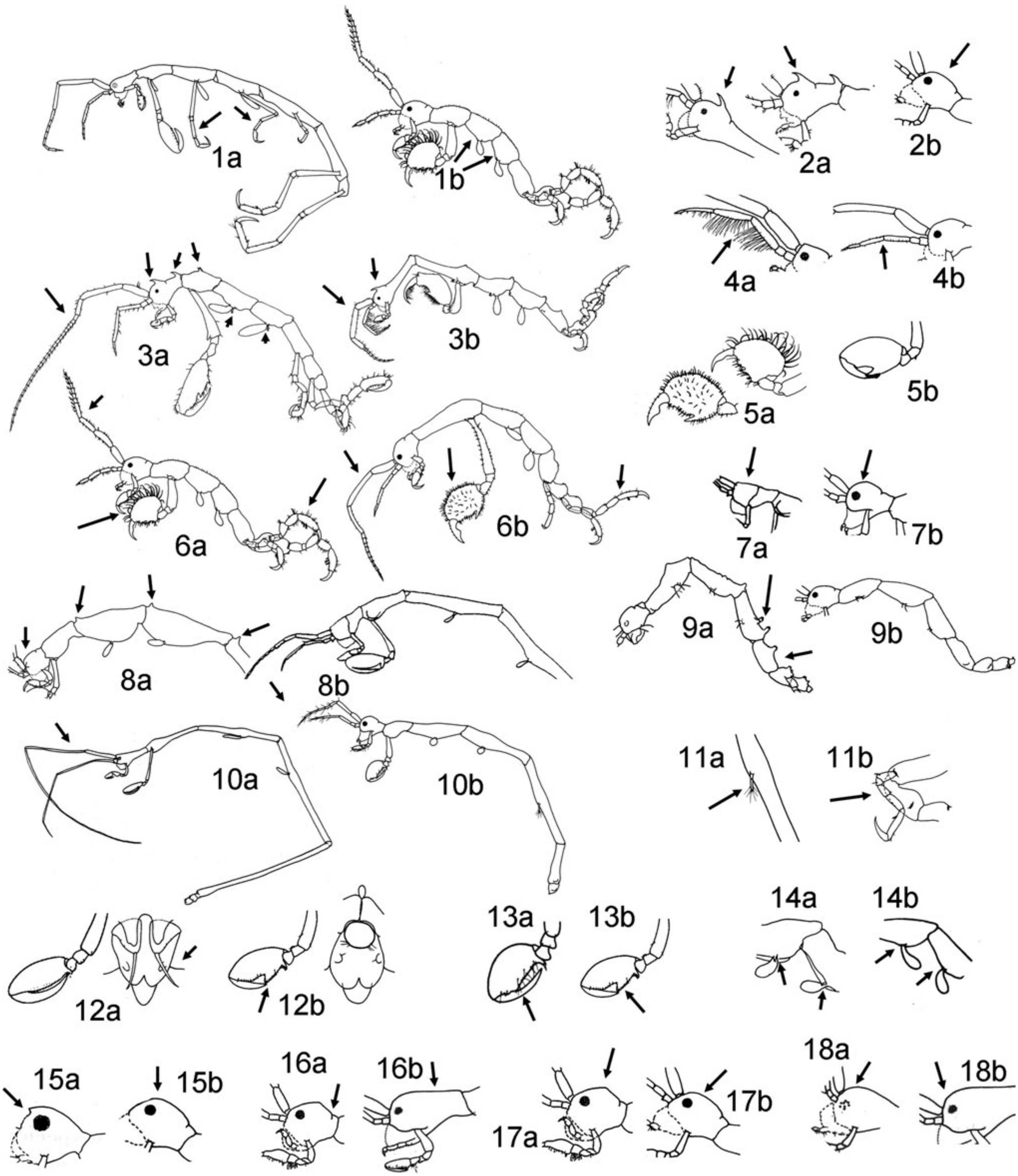


Fig. 4 Details of the main morphological characters to identify the soft-bottom caprellids of the Iberian Peninsula. Numbers (1–18) and letters (a, b) correspond to the options of the taxonomical key provided

P. typicus has been reported as a tolerant species by AMBI and BENTIX lists (Borja et al. 2000; Simboura and Zenetos 2002), although the species also shows sensitivity to the presence of sewage pollution (de-la-Ossa-Carretero et al. 2012). Our study showed higher abundances in sites with low levels of phosphorous in sediments.

Apart from these three dominant species, the remaining caprellids living in sediments are usually found in low

Table 2 Position, depth, water parameters measured at the water column bottom (chlorophyll *a*, oxygen, salinity, temperature) and sediment parameters (*P* total phosphorous, *N* total nitrogen, *OM* organic matter, *G* gravels, *CS* coarse and very coarse sands, *MS* medium sands, *FS* fine and very fine sands, *SC* silts and clays)

Station	Coordinates	Depth (m)	Years	Chl*a* (mg/m^3)	Oxy. (mg/l)	Salinity (psu)	Temp. (°C)	pH	*P* (mg/kg)	*N* (mg/kg)	OM (%)	Grain size					Caprellids
												G (%)	CS (%)	MS (%)	FS (%)	SC (%)	
1	7°19′25″W, 37°12′26″N	5	2009	1.79	7.1	36.85	20.0	8.11	6.7	6.5	3.8	55	10	2	7	26	Pm
2	7°12′01″W, 36°09′16″N	15	2009	1.22	6.9	36.40	18.3	8.02	12.8	38.0	2.1	7	10	19	53	11	Cs
3	7°10′02″W, 37°13′45″N	3	2009	2.53	4.2	40.54	24.0	7.47	41.0	48.0	5.2	–	–	–	–	–	Pm
			2010	2.62	4.0	40.11	26.2	7.65	43.0	8.5	2.9	1	1	1	45	52	Pk
4	7°00′33″W, 37°13′08″N	3	2009	4.73	4.3	37.12	23.2	7.64	316.5	86.8	6.7	22	2	1	7	68	Pm
5	6°58′36″W, 37°12′35″N	7	2009	2.46	5.7	37.21	23.3	7.80	64.0	38.0	3.8	1	1	1	18	79	Pp, Pm
6	6°53′11″W, 37°09′13″N	10	2009	4.10	6.9	36.78	25.0	7.94	37.0	6.8	10.9	55	1	0	0	44	Pm
7	6°15′28″W, 36°30′44″N	7	2009	3.53	6.8	37.33	25.5	8.26	24.4	125.0	9.9	1	6	6	46	41	Pm
8	6°13′19″W, 36°29′25″N	2	2009	3.13	6.8	37.47	25.7	8.26	20.4	129.0	10.1	–	–	–	–	–	Pm
9	5°58′19″W, 36°09′03″N	25	2009	0.59	7.4	36.82	20.9	8.30	15.0	10.0	1.3	12	77	4	5	2	Cr, Pp
10	5°41′42″W, 36°02′42″N	25	2009	1.25	7.4	36.91	18.7	7.54	11.4	63.0	1.3	1	2	2	92	3	Pt
11	5°33′05″W, 36°01′05″N	25	2009	0.72	8.0	37.58	16.5	8.25	7.4	75.0	4.4	42	40	4	12	2	Pt, Pk, Pm, Cs
12	5°28′28″W, 36°02′49″N	15	2010	0.79	6.9	37.00	19.2	8.20	14.5	100.0	2.4	2	47	36	14	1	Pt
13	5°25′53″W, 36°08′31″N	15	2010	2.40	6.9	36.87	20.9	8.19	19.7	6.8	2.1	1	1	2	38	58	Pk
14	5°25′46″W, 36°09′35″N	25	2009	0.72	8.1	37.34	18.1	8.22	13.1	49.0	0.9	4	2	1	87	6	Pk
			2010	2.20	6.9	36.89	20.4	8.19	10.7	9.1	0.9	1	2	3	80	14	Pk, Pm
15	5°25′32″W, 36°10′15″N	25	2010	0.81	7.4	37.40	15.5	8.10	13.9	61.0	2.7	0	1	2	63	34	Pk, Pm
16	5°25′27″W, 36°05′42″N	15	2009	0.81	7.8	37.48	18.3	8.19	12.6	57.0	1.7	5	2	3	89	1	Pk
			2010	1.20	7.1	36.91	20.1	8.20	19.2	124.0	2.0	1	2	5	88	4	Pk
17	5°24′32″W, 36°10′38″N	25	2010	0.23	6.9	37.60	14.7	8.08	28.0	89.0	5.8	12	15	4	23	46	Pk
18	5°23′23″W, 36°10′38″N	36	2009	0.85	7.1	38.36	14.2	8.19	14.3	46.0	2.0	11	0	2	42	45	Pk
19	5°22′39″W, 36°09′66″N	10	2009	0.72	8.0	37.58	16.5	8.25	7.4	75.0	0.9	1	2	6	86	5	Pk, Pt, Pm
			2010	0.75	7.2	36.88	20.0	8.22	11.7	9.6	2.4	0	1	4	87	8	Pk
20	5°21′33″W, 36°09′30″N	4	2010	0.98	7.1	36.82	21.6	8.21	9.5	229.0	6.0	9	18	9	23	41	Pk
21	5°18′48″W, 36°12′02″N	12	2009	1.57	7.5	37.52	17.0	8.14	9.8	45.0	0.9	1	3	2	92	2	Pk, Pm
			2010	0.49	7.0	37.47	21.8	8.25	14.0	27.8	1.2	1	1	1	93	4	Pk
22	5°08′23″W, 36°24′49″N	15	2009	0.97	7.7	37.37	17.4	8.11	12.1	49.0	4.1	1	1	0	82	16	Pk
			2010	0.52	6.9	37.49	22.9	8.23	12.2	16.4	1.1	1	1	1	86	11	Pk
23	4°52′33″W, 36°29′55″N	15	2007	0.55	7.8	37.38	16.2	–	9.6	–	–	13	47	7	26	7	Pm
			2010	0.45	7.0	37.41	23.3	8.26	19.6	2.1	0.9	4	7	4	51	34	Pk, Pm
24	4°36′31″W, 36°32′41″N	15	2009	0.36	7.2	37.60	21.3	8.14	13.2	12.4	1.6	1	3	5	83	8	Pk
			2010	–	7.0	37.44	17.6	8.37	16.0	68.0	1.4	0	4	5	83	8	Pk, Pm
25	4°26′21″W, 36°39′441″N	15	2007	0.72	8.0	36.82	18.9	8.40	11.3	39.4	2.0	0	0	0	36	64	Pk

Table 2 continued

Station	Coordinates	Depth (m)	Years	Chl*a* (mg/m^3)	Oxy. (mg/l)	Salinity (psu)	Temp. (°C)	pH	*P* (mg/kg)	*N* (mg/kg)	OM (%)	Grain size					Caprellids
												G (%)	CS (%)	MS (%)	FS (%)	SC (%)	
26	4°24′58″W, 36°42′24″N	15	2009	0.31	7.1	37.66	22.1	8.18	5.1	34.2	1.6	0	1	0	14	85	Pk. Pt
27	4°22′04″W, 36°42′45″N	35	2009	0.36	6.7	35.31	21.1	8.15	10.4	65.0	2.3	0	1	1	65	33	Pk, Pt, Pm
			2010	0.19	6.8	37.52	22.7	8.29	18.0	5.4	2.9	0	0	0	43	57	Pk
28	4°11′48″W, 36°42′10″N	15	2007	–	7.4	36.40	16.7	8.20	9.3	26.3	1.2	1	8	34	55	2	Pk
29	3°51′44″W, 36°44′47″N	25	2010	0.13	5.7	37.14	14.5	8.19	11.2	19.9	0.9	1	1	1	66	31	Pk, Pm
30	3°46′38″W, 36°44′02″N	25	2007	0.29	7.7	36.72	20.9	8.40	18.1	39.2	1.7	9	6	7	68	10	Pk
			2009	0.10	6.5	38.13	26.7	8.17	10.8	20.2	0.9	5	54	6	30	5	Pm, Ca
			2010	0.22	6.8	37.59	23.6	8.23	6.6	13.7	0.9	13	71	2	8	6	Pk, Pt
31	3°41′16″W, 36°43′35″N	25	2007	0.18	7.4	36.82	15.4	7.85	12.7	1.3	1.6	3	5	4	41	47	Pk
			2009	0.10	6.5	38.12	25.9	8.16	10.7	5.8	5.1	5	55	5	30	5	Pk
			2010	0.16	6.6	37.12	15.7	8.01	8.6	5.9	2.7	13	71	2	8	6	Pk
32	3°32′00″W, 36°43′06″N	15	2009	0.10	6.7	38.09	25.8	8.20	10.7	24.6	2.2	0	0	0	34	66	Pk
			2010	0.14	6.3	37.52	25.3	8.28	16.1	11.5	3.0	2	0	0	50	48	Pk
33	3°10′23″W, 36°44′39″N	25	2007	0.22	7.6	37.04	16.9	7.86	7.1	14.9	0.9	0	1	6	88	5	Pk
			2009	0.10	6.4	38.06	21.7	8.29	10.7	50.0	2.3	1	8	3	59	29	Pk, Pm
			2010	0.15	6.4	37.61	24.1	8.25	3.9	4.3	2.7	14	77	1	4	4	Pk, Pm
34	2°27′48″W, 36°49′46″N	10	2009	1.33	6.4	38.05	26.7	8.22	13.6	17.3	4.4	1	3	1	30	65	Pk
			2010	0.54	7.0	36.98	22.7	8.07	17.9	6.2	2.2	0	1	1	19	79	Pk, Pm
35	2°26′55″W, 36°48′28″N	15	2007	0.73	6.6	36.65	21.0	8.13	9.2	19.70	0.9	3	7	5	81	4	Pm
			2009	0.10	6.5	38.04	26.2	8.24	4.5	11.0	0.9	1	4	5	87	3	Pt
			2010	0.15	7.2	36.97	23.5	8.11	22.9	19.6	1.7	20	47	7	14	12	Pm
36	2°14′47″W, 36°46′06″N	25	2007	0.48	6.6	36.72	21.5	8.15	7.4	25.3	1.1	1	4	50	44	1	Pm
			2009	0.10	6.5	38.05	25.8	8.20	3.0	2.6	1.0	0	0	0	97	3	Pk
			2010	0.15	6.5	37.21	25.3	8.09	8.8	15.3	1.4	0	0	1	95	4	Pt, Pm
37	2°05′26″W, 36°45′14″N	35	2009	0.10	7.1	37.55	19.6	8.16	10.6	39.0	1.5	0	1	0	78	21	Pm
38	1°53′28″W, 36°59′07″N	15	2010	0.10	6.6	37.27	25.8	8.08	4.4	3.2	0.9	0	14	15	65	6	Pt
39	1°48′13″W, 37°11′04″N	29	2010	0.22	8.0	37.81	18.5	8.05	5.3	4.2	0.9	0	0	0	89	11	Pt
40	1°40′55″W, 37°19′11″N	25	2009	0.10	–	37.74	19.8	8.19	6.8	4.3	–	2	6	3	79	10	Ca, Pm

Caprellids found in each station are also included

Ca Caprella acanthifera; *Cr Caprella rapax*; *Cs Caprella sabulensis*; *Pk Pseudolirius kroyeri*; *Pm Phtisica marina*; *Pp Pseudoprotella phasma*; *Pt Pariambus typicus*

abundances, have narrow distribution areas or are poorly known due to the lack of ecological and biogeographical studies. Many of these species have very small sizes and are often overlooked during sorting, especially if the samples are not stained with Bengal rose, so further studies are necessary to properly characterise the ecological and geographical distribution of these species.

Caprellid diversity of the Iberian Peninsula

The caprellid fauna of the Iberian Peninsula (considering both soft and hard bottoms) consists of 35 species (Table 5). This number of species is high when compared with other Mediterranean and North Atlantic regions (Atlantic coast of USA and Canada: 30 species; North

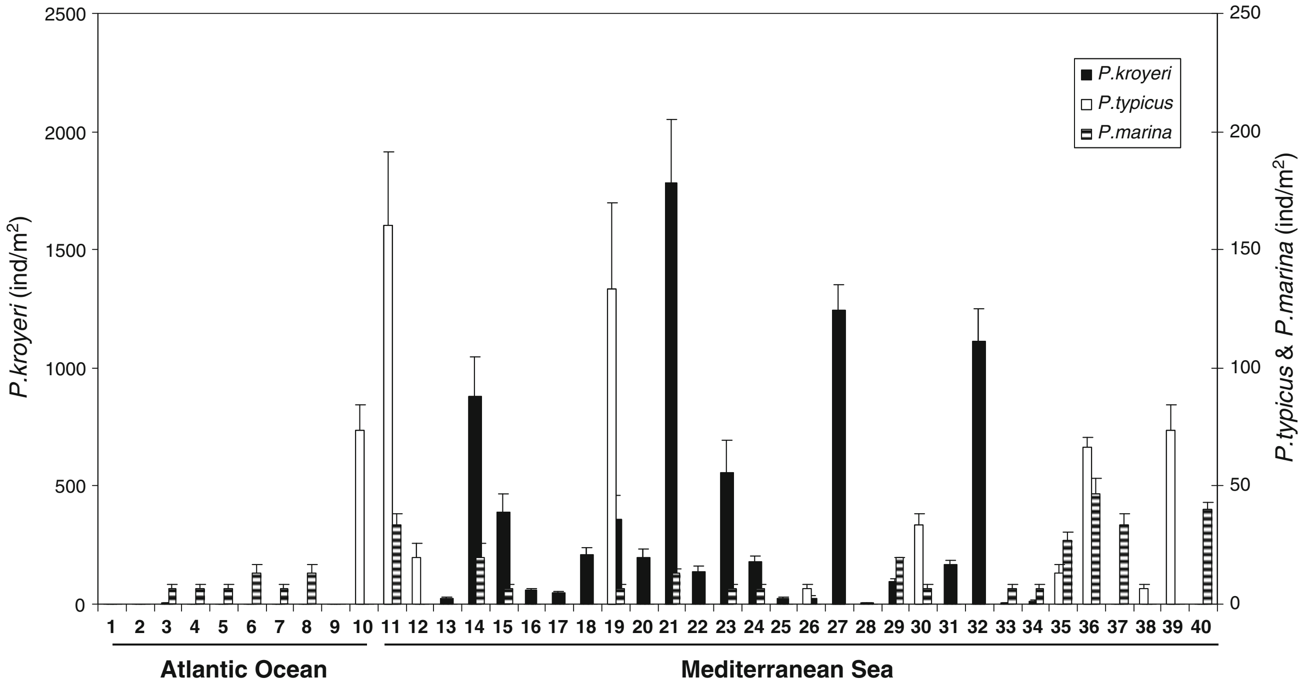
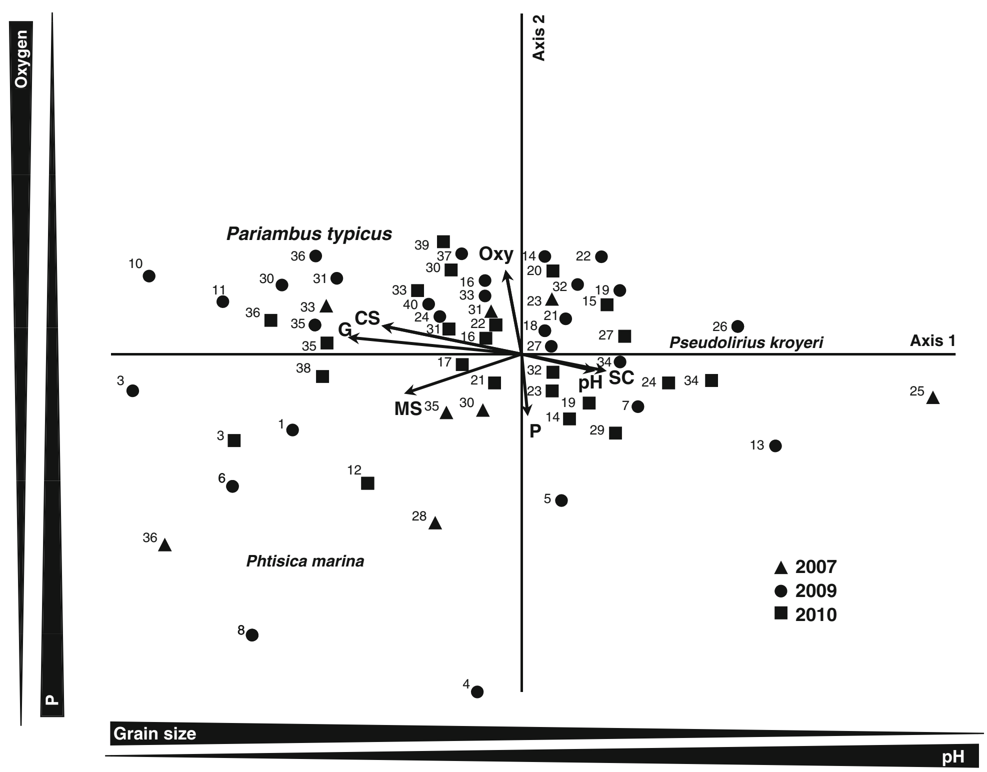


Fig. 5 Abundance (ind/m^2) of the three dominant caprellids species along the Andalusian coast

Fig. 6 Graphic representation of the stations, years, species and variables with respect to the first two axes of the canonical correspondence analysis (CCA). *Oxy* oxygen, *P* total phosphorous, *G* gravels, *CS* coarse and very coarse sands, *MS* medium sands, *SC* silts and clays



Atlantic (from 55°N): 33 species; British Isles: 13 species; Black Sea: 7 species; whole Mediterranean Sea: 41 species) (Guerra-García and Takeuchi 2002; Sturaro and Guerra-García 2012). In fact, if we examine the list of species for the Mediterranean Sea (see Sturaro and Guerra-García 2012), there are only 6 species (out of the 41 cited) that are not recorded so far in the Iberian Peninsula: *Caprella lilliput* Krapp-Schickel and Ruffo, 1987, *C.*

Table 3 Summary of the results of the CCA analysis

	Axis 1	Axis 2	Axis 3
Eigenvalue	0.37	0.13	0.01
Species-environment correlation	0.72	0.46	0.11
Percentage of species variance	28.40	9.90	0.01
Correlation with environmental variables			
Oxygen (mg/l)	–	0.26*	–
pH	0.27*	–	0.27*
P (mg/kg)	–	0.24*	–
G (gravels) (%)	−0.41***	–	0.39**
CS (coarse sands) (%)	−0.29*	–	−0.29*
MS (medium sands) (%)	−0.33**	–	–
SC (silt and clay) (%)	0.25*	–	0.27*

Only the variables that correlated with the first three axes were included

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

tavolarensis Sturaro and Guerra-García, 2012, *C. telarpax* Mayer, 1890, *Liropus minimus* Mayer, 1890, *Parvipalpus linea* Mayer, 1890 and *Pedoculina bacescui* A. Carausu, 1940. The Iberian Peninsula is of great interest from a zoogeographical point of view, receiving direct influence of Mediterranean and Atlantic Ocean, and being the boundary for the Mediterranean region (to the east), the Lusitanian region (to the north-east) and the Mauritanian region (to the south-east).

Of the 35 species recorded so far at the Iberian Peninsula, 19 species (54 %) have been collected from soft bottoms, indicating the importance of these ecosystems to host caprellids. For example, a recent survey of caprellids associated with macroalgae from intertidal and shallow waters (0–5 m) of the whole Iberian Peninsula (including 250 samples of 46 algal species) showed the presence of only 11 species (Guerra-García et al. 2010b). The soft-bottom caprellid fauna from the Iberian Peninsula has an important Mediterranean endemism component, with 42 %

Table 4 Results of the ANOVA (three-factor) for abundance of the dominant caprellid species

Source of variation	*df*	*P. kroyeri*			*P. marina*			*P. typicus*			*F* versus
		MS	*F*	*P*	MS	*F*	*P*	MS	*F*	*P*	
Depth (De)	1	4.45	1.23	0.2989	0.44	0.15	0.7078	0.02	0.01	0.9792	Si (De × Se)
Sediment type (Se)	1	45.24	12.54	0.0076**	2.77	0.94	0.3599	96.69	2.52	0.1510	Si (De × Se)
Site (De × Se)	8	3.60	5.28	0.0007***	2.94	1.38	0.2563	38.36	2.06	0.0817	Res
De × Se	1	0.01	0.01	0.9821	0.44	0.15	0.7078	0.02	0.01	0.9792	Si (De × Se)
Residual	24	0.68			2.14			18.61			
Cochran's *C* test		$C = 0.3127$			$C = 0.7403$ ($P < 0.01$)			$C = 0.5552$ ($P < 0.01$)			
Transformation		ln $(X + 1)$			None			None			

MS mean square, *P* level of probability, *df* degree of freedom

** $P < 0.01$; *** $P < 0.001$

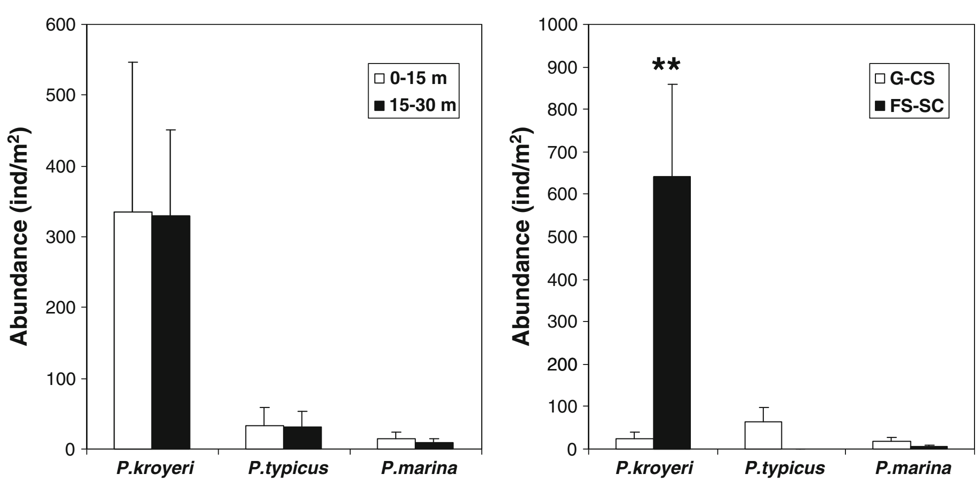


Fig. 7 Abundances (ind/m^2) (mean value ± SE) of the three dominant caprellids according to the depth (0–15 m vs. 15–30 m) and sediment type (gross vs. fine sediments). *G* gravels, *CS* coarse and very coarse sands, *FS* fine and very fine sands, *SC* silts and clays

Table 5 Caprellids recorded from soft and hard bottoms at the Iberian Peninsula

Name of species	Distribution
Caprella acanthifera Leach, 1814	M, A
Caprella andreae Mayer, 1890	M, A, P
Caprella caulerpensis Guerra-García, Sánchez-Moyano and García-Gomez, 2002	E
Caprella danilevskii Czerniavski, 1868	M, A, P, I
Caprella dilatata Krøyer, 1843	M, A
Caprella equilibra Say, 1818	M, A, P, I
Caprella erethizon Mayer, 1901	M, A
Caprella fretensis Stebbing, 1878	M, A
Caprella grandimana Mayer, 1882	E
Caprella hirsuta Mayer, 1890	E
Caprella linearis (Linnaeus, 1767)	A
Caprella liparotensis Haller, 1879	M, A
Caprella mitis Mayer, 1890	E
Caprella paramitis Guerra-García, Sánchez-Moyano and García-Gómez, 2001	E
Caprella penantis Leach, 1840	M, A, P, I
Caprella pseudorapax Guerra-García, Sánchez-Moyano and García-Gómez, 2001	E
Caprella rapax Mayer, 1890	M, A
Caprella sabulensis Guerra-García, Sánchez-Moyano and García-Gómez, 2001	M, A
Caprella santosrosai Sánchez-Moyano, Jiménez-Martín and García-Gómez, 1995	E
Caprella scaura Templeton, 1836	M, A, P, I
Caprella takeuchii Guerra-García, Sánchez-Moyano and García-Gómez, 2001	E
Caprella tuberculata Bate and Westwood, 1868	M, A
Caprella sp (armata-group) (see Krapp-Schickel and Vader 1998)	M, A
Deutella schieckei Cavedini, 1982	E
Liropus cachuchoensis Guerra-García, Sorbe and Frutos, 2008	A
Liropus elongatus Mayer, 1890	E
Pariambus typicus Krøyer, 1844	M, A
Parvipalpus major A. Carausu, 1941	M, A
Parvipalpus onubensis Guerra-García, García-Asencio and Sánchez-Moyano, 2001	A
Pedoculina garciagomezi Sánchez-Moyano et al. 1995	E
Phtisica marina Slabber, 1769	M, A, P
Protoaeginella spinipoda Laubitz and Sorbe, 1996	A
Pseudolirius kroyerii (Haller, 1879)	E
Pseudoprotella inermis Chevreux, 1927	M, A
Pseudoprotella phasma (Montagu, 1804)	M, A

References: Mayer (1882, 1890), Cavedini (1981), Marques and Bellan-Santini (1985), Krapp-Schickel (1993), Jimeno and Turón (1995), Sánchez-Moyano et al. (1995), Laubitz and Sorbe (1996), Bellan-Santini and Ruffo (1998), Krapp-Schickel and Vader (1998), Estacio (1996), Guerra-García and Takeuchi (2000), Guerra-García (2001, 2004), Guerra-García et al. (2000, 2001a, b, c, d, 2002b, 2008, 2010b, 2011), Bachelet et al. (2003), González et al. (2008), Lourido et al. (2008), Moreira et al. (2008), Vázquez-Luis et al. (2009), Cacabelos et al. (2010), de-la-Ossa-Carretero et al. (2010), Sánchez-Moyano and García-Asencio (2010, 2011)

E Mediterranean endemic, *M* Mediterranean Sea, *A* Atlantic Ocean, *P* Pacific Ocean, *I* Indian Ocean

of species being endemic to the Mediterranean (Table 1). This percentage is very similar to the percentage of caprellids' endemism in the Mediterranean (40 %) (Guerra-García and Takeuchi 2002; Sturaro and Guerra-García 2012) and only a little higher than the 37 % reported by Bellan-Santini and Ruffo (1998) for Mediterranean caprellids and gammarids combined. These values are higher than the 26.6 % calculated by Fredj et al. (1992) for all of the Mediterranean fauna taken together. Only three species (16 %), *Liropus cachuchoensis*, *Parvipalpus onubensis* and *Protoaeginella spinipoda*, are restricted so far to the Atlantic coast, being absent from the Mediterranean basin.

Only within the last 20 years, the 37 % of the species inhabiting sediments have been described (Table 1), indicating that soft bottoms had been scarcely explored in comparison with other ecosystems. However, most of the environmental monitoring programmes (urban and industrial outfalls, oil spills and other impacts) are usually focused on sediment communities and technical reports usually include lists of soft-bottom taxa together with the abiotic data. Consequently, identifying amphipods inhabiting sediments should be considered as a relevant tool, especially now that the WFD is focused on the environmental control of the littoral zone and giving priority to amphipods for this task. Unfortunately, there is a general lack of taxonomical tools for species identification, and non-specialists usually have problems to successfully identify their specimens. For the case of caprellids, identifications are more difficult when only females or juveniles are available, since most of the important characters for identification can be observed only in adult males. Furthermore, sediment samples are usually sieved after collecting, and caprellids easily loose the pereopods 5–7 during sieving (see Fig. 2) making identifications even more difficult. Often, similar species can be misidentified in technical reports or even in ecological papers that are eventually published. Additional efforts should be conducted to explore caprellid diversity in soft bottoms, especially biodetritics and sediments from deep sea, which have been scarcely explored. Undoubtedly, many new records and species will be found in these areas.

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