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The amphipod assemblages of *Sabellaria alveolata* reefs from the NW coast of Portugal: An account of the present knowledge, new records, and some biogeographic considerations

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Abstract Amphipod assemblages associated with the biogenic reefs built by the honeycomb worm *Sabellaria alveolata* were studied at two sites (Praia da Aguda and Belinho) along the northwestern coast of Portugal. A total of 3909 specimens were collected, comprising 14 different amphipod species. A first record from the northeastern Atlantic coast was registered here for the species *Caprella santosrosai*, which was, up to now, recorded only along the Mediterranean coast of the Iberian Peninsula. A male specimen collected from the *Sabellaria*-reef located in Belinho allowed an update to the known distribution of *C. santosrosai*, thus altering its previous status as an endemic Mediterranean species. The most common species collected during the study were *Microdeutopus chelifer* ($n = 1828$), *Jassa ocia* ($n = 1426$), and *Hyale stebbingi* ($n = 452$). Forty-three percent of the total recorded species were encountered in both study sites, whereas the remaining 57 % were restricted to a single site (Belinho). The majority of the collected species (93 %) showed an Atlantic-Mediterranean distribution, confirming the close affinity between eastern Atlantic and Mediterranean amphipod assemblages and the role of the Portuguese coast as a transition zone through which numerous warm-water species, coming from North Africa and the Mediterranean Sea, could enter into the Atlantic and possibly get mixed with species coming from the North Sea and the Arctic, typically having affinity for colder waters.

Keywords Amphipoda · Taxonomy · Biodiversity · Biogenic reefs · *Sabellaria alveolata* · NW Portugal

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Introduction

The honeycomb worm *Sabellaria alveolata* (L.) is the most common reef-building species belonging to the Sabellariidae family. These polychaetes are widely distributed along the European Atlantic coast, from Ireland to the south of Morocco (Firth et al. 2015) and punctually in the Mediterranean Sea (Sparla et al. 1992; Gambi et al. 1996; Nicoletti et al. 2001). *S. alveolata* reefs normally grow parallel to the coastline and in the direction of main tidal currents (Dubois et al. 2006), and they usually develop in the intertidal or shallow subtidal habitat (De Grave and Whitaker 1997). Under suitable environmental conditions (i.e. moderate hydrodynamics, not too low salinity, availability of hard substrates), this reef-building polychaete can spread over hundreds of hectares (Holt et al. 1998). *S. alveolata* usually develops as an encrusting "ball-shaped" colony adhering to rocks or as large "platform" banks, with a specific infaunal assemblage for each structural type (Dubois et al. 2002). Some Atlantic amphipod species, e.g. *Melita palmata* (Montagu, 1804), for instance, can be much more abundant on platforms than on other evolution stages, whereas others, e.g. *Corophium volutator* (Pallas, 1766), were preferentially found on degraded reefs (Dubois et al. 2002). Such biogenic reefs are considered as a valuable

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marine habitat that should be protected by the designation of Special Areas of Conservation in the European Union (EU) (Annex I of the EC Habitats Directive), and their ecological importance is worldwide recognized. They typically provide extremely productive and diverse habitats due to their structural heterogeneity and three-dimensional complexity, which can enhance local biodiversity by making available new resources, including shelter and food, to associated species (Dayton 1971). Moreover, as tube-builders and suspension feeders, they can interfere with sedimentary processes (Noernberg et al. 2010) and play a key role in trophic webs (Dubois et al. 2003). According to Dubois et al. (2002, 2006), *S. alveolata* reefs host rich and unique assemblages consisting of species coming from both subtidal and intertidal areas and from both muddy and sandy substrates. *S. alveolata* reefs have been deeply investigated in the Bay of Mont Saint-Michel (France), which hosts the largest European *Sabellaria* formations (Gruet 1970, 1972; Dubois et al. 2002, 2003, 2006), and in the Mediterranean Sea (Sparla et al. 1992; Lo Brutto and Sparla 1993; Gambi et al. 1996; Nicoletti et al. 2001; La Porta et al. 2009; Iaciofano et al. 2015). Very few studies, however, have been conducted on *S. alveolata* reefs and their associated benthic infauna from the Portuguese coast (but see Sousa Diaz and Paula 2001; Plicanti et al. 2016). Amphipods could play a key role in biodiversity monitoring, due to their great abundance, their wide distribution across several habitats, and their high morphological, functional, and behavioral diversity (Lo Brutto et al. 2013; Scipione 2013). Even if their ecological role within Sabellarian reefs is still unexplored, amphipods seem to be an important component of crustacean assemblages associated with such reefs, as suggested by information available on the amphipod community associated with *S. alveolata* reefs from Atlantic France (Dubois et al. 2002) and the Mediterranean Sea (Sparla et al. 1992; Lo Brutto and Sparla 1993; Gambi et al. 1996; Nicoletti et al. 2001; La Porta et al. 2009; Iaciofano et al. 2015). In general, amphipod assemblages from the Portuguese coast have been widely investigated in the last decades. Several studies were carried out to describe their distribution and ecology across a range of geographical areas and environments, from estuarine systems to the continental shelf and submarine canyons (Marques and Bellan-Santini 1991, 1993; Lopes et al. 1993; Costa and Costa 1999; Maranhão and Marques 2003; Subida et al. 2005; Pereira et al. 2006; Duffy et al. 2012; Bessa et al. 2013). The goal of the present paper was to integrate the existing knowledge with the description of the amphipod community associated with *S. alveolata* reefs, providing the first species inventory of this important taxon and system from the NW Portuguese coast. The biogeographic distribution of recorded amphipod species was also investigated to confirm the possible role of the Portuguese coasts as a biogeographic bridge between warm-water species coming from the south and cold-water species coming from the north.

Materials and methods

The material was collected at two sites located about 60 km apart along the NW Portuguese coast (NE Atlantic): Praia da Aguda and Belinho. A rocky shore, interspersed within an almost continuous sandy beach, characterized each site. At both sites, *S. alveolata* formed tri-dimensional and complex reefs that developed as large "platform" banks (sensu Dubois et al. 2002) (Fig. 1). The two study sites were comparable for a number of main physical traits (i.e. orientation of the coastline, exposure to prevailing northwestern winds and waves, typically granitic horizontal, or gently sloping, substratum, tidal range). The sampling was performed during the daytime at

Fig 1 *Sabellaria alveolata* reefs from the study area. Structural types (i.e. "platform" banks, sensu Dubois et al. 2002) and details

low tide, between July 2012 and September 2012 in the low intertidal habitat. At each study site, sixteen areas (2.5 m × 2.5 m, some meters apart) were randomly selected. The fauna associated with *S. alveolata* was sampled by collecting eight replicate cores (7 cm in diameter, extended from the top of the reef until the rocky substratum) within each of the 16 areas (256 replicates collected in total). A cylindrical PVC tube was used to collect cores and all the sampled material was removed down to the basal crust with the help of a metal scraper. Samples from each replicate were put in ice for transportation to the laboratory, where they were weighted and preserved in 70 % ethanol until sorting. Before the analysis, each sample was washed and sieved through a 500-μm mesh. The retained amphipod fauna was sorted, counted, and identified to the species level. The raw abundance of each species in each replicate was divided by the wet weight of that replicate, obtaining the abundance value per gram of sample. The taxonomic identification was performed following Ruffo ed. (1982–1998), Barnard and Karaman (1991), Krapp et al. (1996), Vader and Krapp-Schickel (2012) and Guerra-García et al. (2013). Photos of some dissected appendages showing the most valuable diagnostic characters for each species are shown in Figs. 2 and 3. Voucher specimens for each species were deposited at the Zoological Museum of the University of Palermo (MZPA), under the catalogue numbers specified below.

Results

A total 3909 specimens were collected from 256 replicates. Most of them (98 %) were identified to the species level. Fourteen different amphipod species were detected. The remaining 2 % were identified to the genus level ($n = 73$; *Ampelisca* sp., $n = 2$; *Caprella* sp., $n = 7$, *Elasmopus* sp., $n = 20$; *Jassa* sp., $n = 43$; *Siphonoecetes* sp., $n = 1$) or were described as "not classified" ($n = 30$) due to inadequacy of data (e.g. too small or damaged material) that did not allow us to properly recognize some essential diagnostic traits. The seven immature *Caprella* sp. turned out to be problematic in terms of being morphotypes close to two other species, *Caprella dilatata* Krøyer, 1843 and *C. penantis* Leach, 1814, both very similar to each other. In the two sites, the most abundant species were *Microdeutopus chelifer* ($n = 1828$), *Jassa ocia* ($n = 1426$) and *Hyale stebbingi* ($n = 452$). These three species showed a greater mean abundance in Belinho than in Praia da Aguda (Fig. 4).

Systematics

Suborder GAMMARIDEA
Family DEXAMINIDAE Leach, 1814
Genus *Dexamine* Leach, 1814
Dexamine spiniventris (Costa, 1853)

Material examined

Total of six specimens. Praia da Aguda, zero specimens. Belinho, six specimens. Museum code: MZPA-AMPH-0009.

Geographical range

Within the Mediterranean Sea, records of *Dexamine spiniventris* are known from France (Chevreux and Fage 1925; Bellan-Santini and Ledoyer 1973), Greece (Ledoyer 1969; Myers 1969), Italy (Costa 1853; Heller 1866; Della Valle 1893; Cecchini 1928; Cecchini and Parenzan 1935; Fischetti 1937; Ruffo 1938), Turkey (Geldiay et al. 1971; Kocatas 1976), and Algeria (Chevreux 1911). The species has been recently recorded along the Atlantic coast of the Iberian Peninsula (Guerra-García et al. 2012).

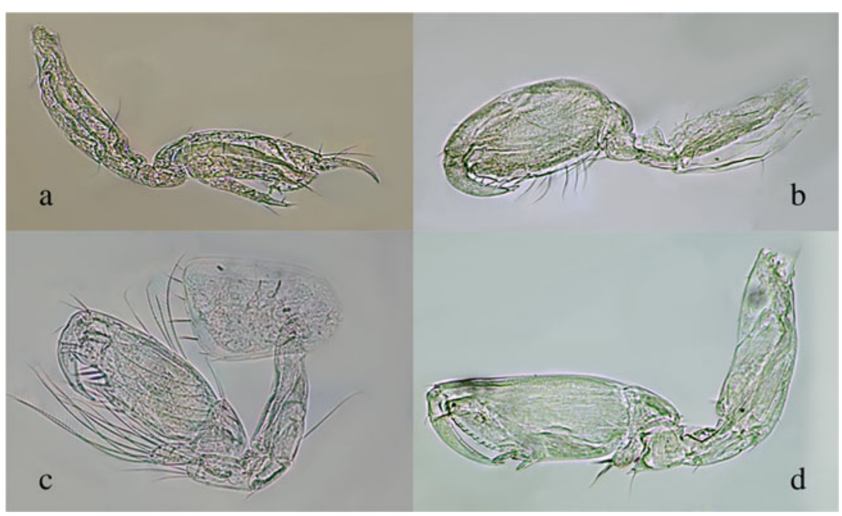

Fig 2 Some diagnostic characters. Second gnathopod of **a** *Perioculodes aequimanus*; **b** *Ischyrocerus inexpectatus*; **c** *Microprotopus longimanus*; **d** *Stenothoe monoculoides*

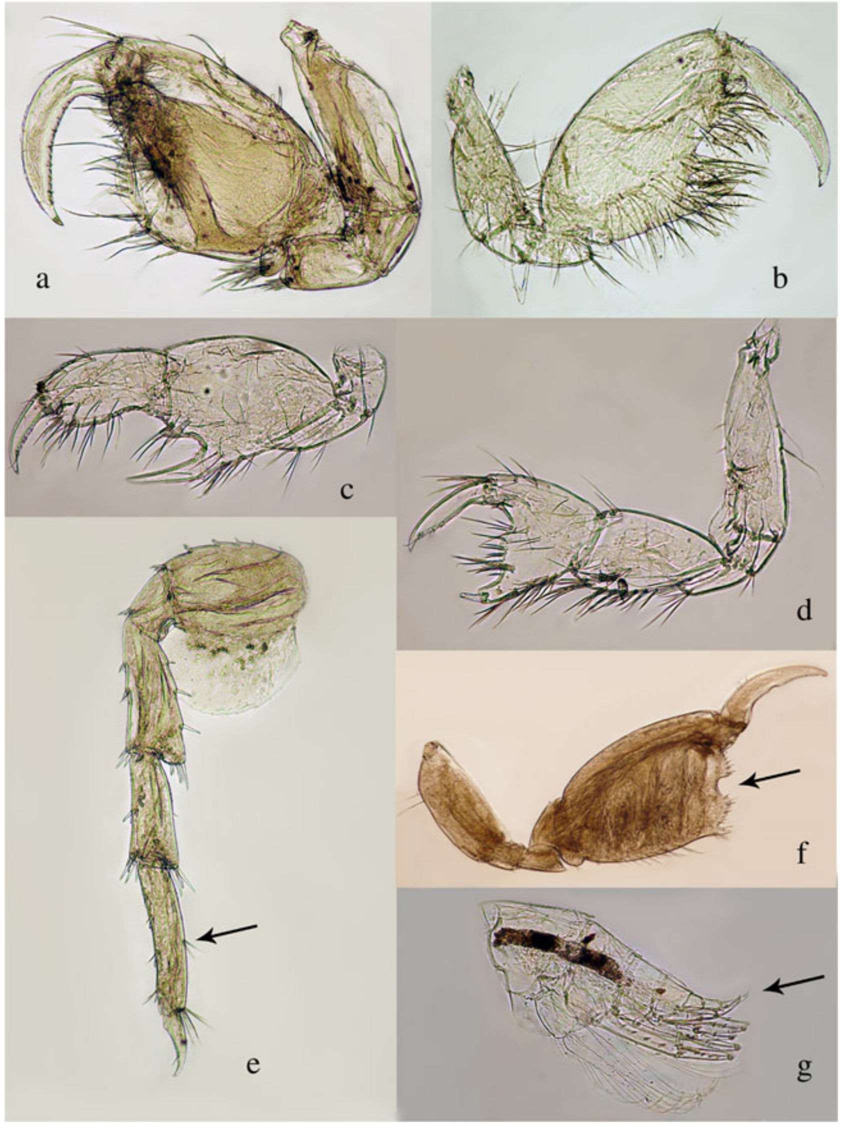

Fig 3 Some diagnostic characters. Second gnathopod of **a** *Ampithoe helleri*; **b** *Jassa ocia*; **d** *Microdeutopus chelifer*; **f** *Quadrimaera inaequipes*; first gnathopod of **c** *Microdeutopus chelifer*; seventh pereopod of **e** *Hyale stebbingi*; third uropod of **g** *Photis longicaudata*

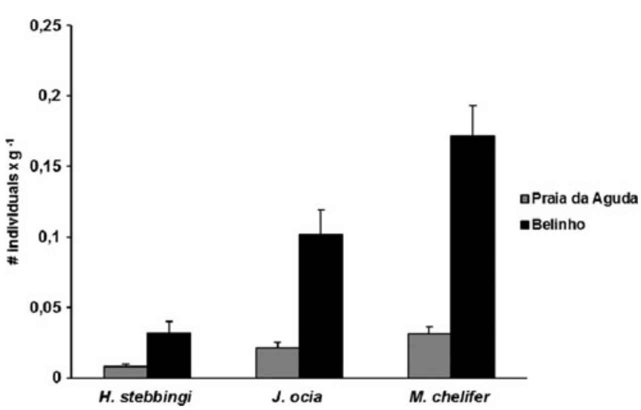

Fig 4 Mean (+SE) abundance of the most common species, *Hyale stebbingi*, *Jassa ocia*, and *Microdeutopus chelifer*, sampled in the two study sites: Praia da Aguda and Belinho

Ecology

Dexamine spiniventris is generally associated with vegetal biotopes (algae and phanerogams), in littoral or deep environments (Bellan-Santini and Ledoyer 1973). It has been described as a nocturnal species (Macquart-Moulin 1968).

Suborder GAMMARIDEA

Family DEXAMINIDAE Leach, 1814

Genus *Guernea* Chevreux, 1887

Guernea coalita (Norman, 1868)

Material examined

Total of eight specimens. Praia da Aguda, zero specimens. Belinho, eight specimens. Museum code: MZPA-AMPH-0010.

Geographical range

Within the Mediterranean Sea, records of *G. coalita* are known from France (Bellan-Santini and Ledoyer 1973), Corsica Island (Chevreux and Fage 1925), Italy (Della Valle 1893), Turkey (Kocatas 1976), Tunisia, and Algeria (Chevreux 1911). Within the Atlantic Ocean, records of *G. coalita* are known from the Bay of Biscay (San Vicente and Sorbe 2001) and along the Atlantic coast of the Iberian Peninsula (Lourido et al. 2008; Guerra-García et al. 2012).

Ecology

Guernea coalita is usually common in motile substratum biotopes enriched with sand and detritus, whereas it is quite rare in vegetal biotopes (Bellan-Santini and Ledoyer 1973). It has been described as a nocturnal species (Macquart-Moulin 1968).

Suborder GAMMARIDEA
Family OEDICEROTIDAE Lilljeborg, 1865
Genus *Perioculodes* Sars, 1895
Perioculodes aequimanus (Korssman, 1880)

Material examined

Total of three specimens. Praia da Aguda, zero specimens. Belinho, three specimens. Museum code: MZPA-AMPH-0011.

Geographical range

Within the Mediterranean Sea, records of *P. aequimanus* are known from France (Ledoyer 1972, 1993), the Iberian Peninsula (Cartes and Sorbe 1999; Munilla and San Vicente 2005), the Aegean Sea (Ledoyer 1993; Baxevanis and Chintiroglou 2000; Antoniadou et al. 2004; Dağli et al. 2008), Italy (Ledoyer 1993; Sparla et al. 1993; Dondi et al. 2003), Cyprus (Kocatas et al. 2001), Israel (Sorbe et al. 2002), and Tunisia (Ledoyer 1993; Zakhama-Sraieb et al. 2009). Records of *P. aequimanus* are also known from the northeastern Atlantic Ocean (Esquete et al. 2010) and from the Red Sea (Sorbe et al. 2002).

Ecology

Perioculodes aequimanus is mainly found on sedimentary bottoms, varying from muddy sands to coarse sand and gravels, of sheltered shallow areas (Esquete et al. 2010). The species has been also described on the sponge *Dysidea fragilis* (Serejo 1998), red algae (Sparla et al. 1993), and artificial hard substratum (Baxevanis and Chintiroglou 2000).

Suborder GAMMARIDEA
Family STENOTHOIDAE Boeck, 1871
Genus *Stenothoe* Dana, 1852
Stenothoe monoculoides (Montagu, 1815)

Material examined

Total of 24 specimens. Praia da Aguda, 22 specimens. Belinho, two specimens. Museum code: MZPA-AMPH-0012.

Geographical range

Within the Mediterranean Sea, records of *Stenothoe monoculoides* are known from France (Chevreux and Fage 1925; Chardy 1972; Bellan-Santini and Ledoyer 1973), Italy (Fischetti 1937; Ruffo 1941; Ruffo and Wieser 1952; Krapp-Schickel 1971), Malta (Krapp-Schickel 1976a), former Yugoslavia (Ruffo 1946; Krapp-Schickel 1969), Greece (Myers 1969), Turkey (Kocatas 1976), Libya (Tigănus 1984), Tunisia, and Algeria (Chevreux 1911). Records of *S. monoculoides* are known along the Atlantic coast of the Iberian Peninsula (Lourido et al. 2008; Guerra-García et al. 2012) and from the North Sea (Gulliksen 1978; Bonsdorff 1983).

Ecology

Stenothoe monoculoides has been described as a littoral species, occurring at depths of 0–80 m.

Suborder SENTICAUDATA Lowry & Myers, 2013
Family CAPRELLIDAE Leach, 1814
Genus *Caprella* Lamarck, 1801
Caprella acanthifera Leach, 1814

Material examined

Total of 13 specimens. Praia da Aguda, one specimen. Belinho, 12 specimens. Museum code: MZPA-AMPH-0013.

Geographical range

Within the Mediterranean Sea, records of *Caprella acanthifera* are known from the Balearic Islands (Isern-Arus 1977), France (Haller 1879, 1880; Carausu 1941; Rancurel 1949; Costa 1960; Bellan-Santini and Picard 1963; Bellan-Santini 1969; Chardy 1972; Cavedini 1982), Monaco (Carausu 1941), Italy (Haller 1879, 1880; Mayer 1882; Monterosso 1915; Fischetti 1937; Krapp-Schickel 1971; Cavedini 1982), Malta (Cavedini 1982), former Yugoslavia (Heller 1866; Krapp-Schickel 1969; Cavedini 1982), and Turkey (Geldiay et al. 1971). The species has been also recorded in the Black Sea (Carausu and Carausu 1959) and along the Atlantic coast of the Iberian Peninsula (Guerra-García et al. 2012).

Ecology

Caprella acanthifera is mainly found between depths of 0 and 10 m, where it is typical of low hydrodynamism and detritus-enriched areas. It usually occurs in association with brown algae, sponges, hydroids (Krapp-Schickel and Vader 1998) or with *Bugula* bryozoan colonies (Caullery 1926).

Suborder SENTICAUDATA Lowry & Myers, 2013
Family CAPRELLIDAE Leach, 1814
Genus *Caprella* Lamarck, 1801
Caprella santosrosai Sánchez-Moyano, Jiménez-Martín & García-Gómez, 1995
(Fig. 5)

Material examined

Total of one male specimen. The material was collected in Belinho (41°34’52.5060” N, 08°48’25.1460” W) in July 2012. Museum code: MZPA-AMPH-0015.

Geographical range

Caprella santosrosai was found only on the Mediterranean side of the Strait of Gibraltar (Table 1) with low abundance (Sánchez-Moyano et al. 1995; Guerra-García and García-Gómez 2001; Sturaro and Guerra-García 2011). An additional record of the species was registered by Vázquez-Luis et al. (2009) based on specimens collected from *Caulerpa cylindracea* at the Cape of Santa Pola, Alicante (Mediterranean coast of the Iberian Peninsula).

Fig 5 *Caprella santosrosai* Sánchez-Moyano et al. 1995. Male

Ecology

Caprella santosrosai was described from bryozoans at the Gibraltar Harbour as a subtidal species (Sánchez-Moyano et al. 1995). It usually occurs in areas with high hydrodynamics (Guerra-García and García-Gómez 2001; Guerra-García 2001, 2011) at low abundances (Sánchez-Moyano et al. 1995; Guerra-García and García-Gómez 2001), on many different substrata in the Mediterranean Sea (Table 1), where it feeds on detritus (Guerra-García et al. 2014). The Atlantic specimen was found associated with *S. alveolata*, within the reef, at low tide, and close to continuous sandy beach. *Caprella santosrosai* is distinguished from other caprellid species inhabiting the Iberian Peninsula by a set of unique characters: a dorsal projection on the head, antenna 1 shorter than half of the body, pereonites 1–2 lacking projections, and P3–4 absent (Guerra-García et al. 2013).

Remarks

New record for the northeastern Atlantic Ocean.

Description

Head anteriorly round with dorsal projection posterior to the eye. Antenna 1 shorter than half of the body; antenna 2 with long setae. Pereonite 1 with small, unpaired postero-dorsal tubercle. Gnathopod 1 propodus palm with a pair of proximal grasping spines, dactylus serrate. Pereonite 2 with a pair of acute ventro-lateral projections from the coxa of the gnathopods. Gnathopod 2 is essentially about 1/2 of pereonite 2 and 2/3 of the propodus; the propodus is oval and 2/3 of the pereonite, palm densely setose with one proximal process and one poison tooth; dactylus also with numerous setae and serrate proximally. Pereonite 3 with paired antero-lateral and mid-lateral projections. Peraeopod 3–4 absent.

Suborder SENTICAUDATA Lowry & Myers, 2013
Family MICROPROTOPIDAE Myers & Lowry, 2003
Genus *Microprotopus* Norman, 1867
Microprotopus longimanus Chevreux, 1887

Material examined

Total of five specimens. Praia da Aguda, zero specimens. Belinho, five specimens. Museum code: MZPA-AMPH-0016.

Table 1 Mediterranean records of *Caprella santosrosai*

Habitat	Locality	Reference
Bryozoans	Algeciras Bay, southern Spain	Sánchez-Moyano et al. 1995
Anthozoan, sponge, and *Salmazina disteri* (tubicolous annelid)	Ceuta, North Africa	Guerra-García 2001
Hydroids	Ceuta, North Africa	Guerra-García and Takeuchi 2002
Cystoseira usneoides	Ceuta, North Africa	Guerra-García and García-Gómez 2001
Sphaerococcus coronopifolius	Ceuta, North Africa	Guerra-García et al. 2004
Caulerpa cylindracea	Cape of Santa Pola, eastern Spain	Vázquez-Luis et al. 2009

Geographical range

Within the Mediterranean Sea, *M. longimanus* has been recorded in Roquetas de Mar, Spain (Ruffo ed. 1982–1998). Within the Atlantic Ocean, records are known from France (Dauvin 1999).

Ecology

Microprotopus longimanus is mainly found at depths of 1–2 m, usually associated with green epiphytic algal species (Ruffo ed. 1982–1998).

Suborder SENTICAUDATA Lowry & Myers, 2013
Family ISCHYROCERIDAE Stebbing, 1899
Subfamily ISCHYROCERINAE Stebbing, 1899
Genus *Ischyrocerus* Krøyer, 1838
Ischyrocerus inexpectatus Ruffo, 1959

Material examined

Total of three specimens. Praia da Aguda, zero specimens. Belinho, three specimens. Museum code: MZPA-AMPH-0017.

Geographical range

The species has been recorded along the Mediterranean Sea in Italy (Ruffo 1959; Diviacco 1981), former Yugoslavia (Ruffo and Schickel 1967), Spain (Conradi et al. 2000), Greece (Ruffo 1959), Turkey (Bakir and Katağan 2014), and Morocco (Menioui and Ruffo 1989). Within the Atlantic Ocean, records of *I. inexpectatus* are known from Gran Canaria Island (Png-Gonzalez et al. 2014).

Ecology

Ischyrocerus inexpectatus usually inhabits algae in relatively wave-exposed conditions (Ruffo ed. 1982–1998). It seems to show a species-specific affinity with algal beds dominated by the green rhyzophytic alga *Caulerpa prolifera* (Png-Gonzalez et al. 2014).

Suborder SENTICAUDATA Lowry & Myers, 2013
Family ISCHYROCERIDAE Stebbing, 1899
Genus *Jassa* Leach, 1814
Jassa ocia (Bate, 1862)

Material examined

Total of 1426 specimens. Praia da Aguda, 337 specimens. Belinho, 1089 specimens. Museum code: MZPA-AMPH-0018.

Geographical range

Within the Mediterranean Sea, records of *Jassa ocia* are known from France (Poisson and Legueux 1926; Ruffo 1958; Bellan-Santini 1961, 1962a, b; Ledoyer 1968; Bellan-Santini and Ledoyer 1973), former Yugoslavia (Heller 1866), and Israel (Fishelson and Haran 1988), and recently from the Sabellarian reefs in the central Mediterranean where it was dominant (Iaciofano et al. 2015). Within the Atlantic Ocean, the species has been recorded in France (Dauvin 1999) and along the Atlantic coast of the Iberian Peninsula (Guerra-García et al. 2012).

Ecology

As are other species of the same genus, *J. ocia* is an important element of marine fouling communities. This species is able to quickly settle on any kind of hard substrate, thanks to its strong ability to build tubes and colonize available space (Sezgin and Katağan 2007).

Suborder SENTICAUDATA Lowry & Myers, 2013
Family PHOTIDAE Boeck, 1871
Genus *Photis* Krøyer, 1842
Photis longicaudata (Bate & Westwood, 1862)

Material examined

Total of one specimen. Praia da Aguda, zero specimens. Belinho, one specimen. Museum code: MZPA-AMPH-0019.

Geographical range

Within the Mediterranean Sea, records of *Photis longicaudata* are known from France (Chevreux 1911; Chevreux and Fage 1925; Ruffo 1958; Harmelin 1964; Febvre-Chevalier 1969; Bellan-Santini and Ledoyer 1973), Italy (Della Valle 1893; Chevreux and Fage 1925; Ruffo and Wieser 1952), Israel (Sorbe et al. 2002), and Algeria (Chevreux 1911; Falconetti 1970). Within the Atlantic Ocean, *P. longicaudata* has been recorded from the English Channel and France (Dauvin 1999). The species has been also recorded from the Caribbean Sea, Gulf of Mexico, and Venezuela (Miloslavich et al. 2010).

Ecology

Photis longicaudata has been described as an infralittoral species and it is usually common among algae. It can reach a bathyal distribution, up to 400 m depth (Ruffo ed. 1982–1998).

Suborder SENTICAUDATA Lowry & Myers, 2013
Family AORIDAE Stebbing, 1899
Genus *Microdeutopus* Costa, 1853
Microdeutopus chelifer (Bate, 1862)

Material examined

Total of 1828 specimens. Praia da Aguda, 376 specimens. Belinho, 1452 specimens. Museum code: MZPA-AMPH-0020.

Geographical range

Within the Mediterranean Sea, records of *Microdeutopus chelifer* are known from France (Chevreux and Fage 1925; Bellan-Santini and Ledoyer 1973), Italy (Fischetti 1937), and Greece (Myers 1969). Within the Atlantic Ocean, records are known from the English Channel and France (Dauvin 1999) and from the Atlantic coast of the Iberian Peninsula (Guerra-García et al. 2012).

Ecology

Microdeutopus chelifer has been described as an infralittoral species, rarely extending into the subtidal environment deeper than 2 m. The species is common in shallow and sheltered waters, with a high detritus accumulation. In the Mediterranean Sea, the species has been recorded among arborescent algae, like *Cystoseira* spp. On the Atlantic and English Channel coasts, it has been frequently found among algae in tide pools, but it has been also encountered in the shallow sub-littoral, among *Laminaria* holdfasts (Myers 1969).

Suborder SENTICAUDATA Lowry & Myers, 2013
Family AMPITHOIDAE Stebbing, 1899
Genus *Amphitoe* Leach, 1814
Ampithoe helleri Karaman, 1975

Material examined

Total of 30 specimens. Praia da Aguda, three specimens. Belinho, 27 specimens. Museum code: MZPA-AMPH-0021.

Geographical range

Within the Mediterranean Sea, records of *Ampithoe helleri* are known from France (Chevreux and Fage 1925; Bellan-Santini and Ledoyer 1973; Krapp-Schickel 1978; Muller 2004), Italy (Della Valle 1893; Ruffo 1941; Giordani-Soika 1950; Krapp-Schickel 1975, 1976b, 1978), Greece (Myers 1969), Malta (Krapp-Schickel 1978), Egypt (Schellenberg 1936) and Tunisia (Chevreux 191 l). The species has been also recorded along the Atlantic coast of the Iberian Peninsula (Guerra-García et al. 2012).

Ecology

Ampithoe helleri is an infralittoral species, usually associated with phanerogams, such as *Posidonia oceanica* and *Zostera hornemanniana* (Bellan-Santini and Ledoyer 1973), or with algal species with soft and floating thalli, such as *Cystoseira* spp. and *Halopteris* sp. (Krapp-Schickel 1969).

Suborder SENTICAUDATA Lowry & Myers, 2013
Family MAERIDAE Krapp-Schickel, 2008
Genus *Quadrimaera* Krapp-Schickel and Ruffo, 2000
Quadrimaera inaequipes (A. Costa, 1851)

Material examined

Total of six specimens. Praia da Aguda, zero specimens. Belinho, six specimens. Museum code: MZPA-AMPH-0022.

Geographical range

This species is widely distributed within the Mediterranean Sea. It has been recorded from the Balearic Islands (Chevreux 1911), France (Chevreux and Fage 1925; Charniaux-Legrand 1951; Bellan-Santini 1962c, 1969; Harmelin 1964; Macquart-Moulin 1968; Chardy 1972), Corsica island (Chevreux 1902), Italy (Costa 1857; Fischetti 1937; Karaman and Ruffo 1971; Krapp-Schickel 1971, 1976b; Karaman 1979), Malta (Karaman 1979), former Yugoslavia (Heller 1866; Ruffo 1946; Krapp-Schickel 1969; Karaman 1979), Greece (Ledoyer 1969; Myers 1969), Israel (Gottlieb 1960; Lipkin and Safriel 1971), Egypt (Schellenberg 1936), and Algeria (Chevreux 1911; Falconetti 1970). The species has been also recorded from the Caribbean Sea, Cuba, and Venezuela (Miloslavich et al. 2010).

Ecology

Quadrimaera inaequipes is an epifaunal, free-living species, usually living on plants (Scipione 2013).

Suborder SENTICAUDATA Lowry & Myers, 2013

Family HYALIDAE Bulycheva, 1957

Genus *Hylae* Rathke, 1837

Hyale stebbingi Chevreux, 1888

Material examined

Total of 452 specimens. Praia da Aguda, 109 specimens. Belinho, 343 specimens. Museum code: MZPA-AMPH-0023.

Geographical range

Within the Mediterranean Sea, records of *Hyale stebbingi* are known from France (Chevreux and Fage 1925; Bellan-Santini and Ledoyer 1973), Italy (Fischetti 1937; Ruffo 1941; Giordani-Soika 1950; Ruffo and Wieser 1952), former Yugoslavia (Heller 1866), and Algeria (Chevreux 1911). Within the Atlantic Ocean, records of *H. stebbingi* are known from the Iberian Peninsula (Guerra-García et al. 2012).

Ecology

Hyale stebbingi is usually found in vegetal biotopes, among algae and seagrasses (Ruffo ed. 1982–1998).

Discussion

In spite of their important ecological role within benthic ecosystems, amphipod assemblages associated with *S. alveolata* reefs have never been investigated along the Portuguese coast. In the present study, 14 amphipod species were recorded as associated with *S. alveolata* reefs in NW Portugal. In terms of species composition, this assemblage appeared considerably different compared to the more extensively studied ones from the Bay of Mont Saint-Michel, France. None of the amphipod species (*Corophium volutator*, *Melita palmata*, *Leucothoidae* sp., *Gammarus* sp. among the most common) that have been reported as associated with French Sabellarian reefs have been recorded in the present study. Instead, an affinity with the amphipod assemblage inhabiting Mediterranean Sabellarian reefs was documented, due to shared species like *Caprella acanthifera*, *Jassa ocia*, and *Quadrimaera inaequipes* (Iaciofano et al. 2015). The first record for the northeastern Atlantic coast was registered for *Caprella santosrosai*, which was until now considered endemic to the Mediterranean, having been found only on the Mediterranean side of the Strait of Gibraltar (Sturaro and Guerra-García 2011) and in the Cape of Santa Pola, in eastern Spain (Vázquez-Luis et al. 2009). Recently, however, Ros et al. (2014) have revised a previous Portuguese record of a single female with a cephalic projection that had been identified as *Caprella cf. scaura* by Marques and Bellan-Santini (1985), and argued that it was a probable misidentification ascribable to *C. santosrosai*. The present record would provide indirect support to the above consideration and delineate a new range of geographical distribution of the species, which therefore should lose its endemic Mediterranean status. In the present study, species with an Atlantic-Mediterranean distribution accounted for 93 % of the list. A close affinity between Atlantic and Mediterranean amphipod assemblages was suggested by previous research. Guerra-García et al. (2009), in particular, examined patterns of amphipod assemblage associated with intertidal articulated red algae (*Corallina elongata*) along the north–south and Atlantic-Mediterranean axes across the Strait of Gibraltar and collected 28 amphipod species, 64 % of which had an Atlantic–Mediterranean distribution. According to these authors, the Mediterranean-Atlantic axis could be considered as a relatively homogeneous area, not being characterized by clear changes in patterns of distribution of peracaridean assemblages. The palaeogeographic history of the Mediterranean Sea could be responsible for the analogy between the Mediterranean and Atlantic fauna of amphipods, assuming that a large proportion of the Mediterranean fauna is of Atlantic origin and relatively recent (Ruffo ed. 1982–1998). A biogeographic affinity between the Mediterranean and the eastern Atlantic regions has been observed also for other invertebrate groups, including Ascidians (Naranjo et al. 1998), Anthozoans (López-González 1993), and opisthobranch molluscs (Cervera et al. 2004). Moreover, due to its geographic position, the Portuguese coast could represent a region of contact between warm-water species coming from North Africa and the Mediterranean Sea and cold-water species coming from the North Sea and the Arctic (Ardré 1970, 1971; Pereira et al. 2006). For example, Pereira et al. (2006) reported clear geographic differences, with a sharp gradient from north to south, in patterns of distribution of epifaunal crustacean species associated with dominant macroalgal species along the Portuguese rocky coast. Such a gradient could be driven by a combination of physical and biological factors, including the availability of seston and grain-size of sands (Sparla et al. 1992), rafting of juveniles and adults (Guerra-García et al. 2009; Izquierdo and Guerra-García 2010), temperature, water currents, and wave exposure (Pereira et al. 2006), which are known to play a key role in driving the distribution of plant-associated epifaunal amphipods over large oceanic distances. It is worth mentioning that the herein amphipod records belong exclusively to the biogeographic Atlantic-Mediterranean category, and no subtropical or boreal Atlantic species were collected. Such an observation could support the idea of the Portuguese coast as a kind of "Mediterranean appendix", rather than a biogeographic bridge, and highlight the need to further revise some species that have until now been registered as cosmopolitan.

At a smaller scale, such as that comprising the two study sites, local factors could be responsible for the variability in amphipod abundance. Although examining their driving role was beyond the goals of the present study, these could include the influence of biotic interactions, physical habitat heterogeneity, and local variations in hydrodynamics affecting patterns of settlement and recruitment (e.g. Menconi et al. 1999; Coleman et al. 2002; Oliveira et al. 2014). For example, variability in the patterns of colonization of sessile organisms was also documented in other systems over similar scales, possibly due to variation in the availability of larvae (Raimondi 1990). In general, small-scale variability has emerged as a consistent property of benthic assemblages in marine coastal habitats (Fraschetti et al. 2005). The actual cause-effect relationships between sets of physical and biological processes and amphipod distributional patterns should be investigated in detail by means of specifically designed experiments. The present study contributes to improving collective knowledge on the biodiversity along the Portuguese coast, by providing the first species inventory of a numerically and ecologically important group of crustaceans from *S. alveolata* reefs and by delineating a new range of geographical distribution for the species *Caprella santosrosai*. Besides their taxonomic and biogeographic implications, the present findings may provide essential reference data for future studies aimed at assessing changes in biodiversity patterns due to natural and/or anthropogenic perturbations. These may include, inter alia, direct and indirect effects of climate change that are considered responsible for recent variations in the distribution of marine species during the last decade and that are predicted to become exacerbated in the future (Walther et al. 2002; Harley et al. 2006). For instance, climate- or non-climate-driven changes in physical factors, such as water current, sedimentation rate, temperature, impact of storms, and wave exposure, could play a relevant role in influencing *S. alveolata* reefs by causing variations in diversity and distribution patterns of the associated amphipod community whose ecological and societal consequences should be analyzed by future research.

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Compliance with ethical standards

Declarations None of the authors have any competing interests in the manuscript.

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