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Inventory of benthic amphipods from fine sand community of the Iberian Peninsula east coast (Spain), western Mediterranean, with new records

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Recent sampling surveys (2004–2008) of the shallow (12–20 m) soft-bottom homogeneous fine-sand community have allowed the collection of 55 marine amphipod species (53 Gammaridea and 2 Caprellidea) along the 250 km of Iberian Peninsula east coast (Spain, Mediterranean Sea). Among the species recorded, one recently described is new to science, five were collected for the first time in the Spanish Mediterranean and 14 were recorded for a second time confirming their presence. Of these 20 species; six are considered to be endemic to the Mediterranean Sea, seven are also north-eastern Atlantic species, and the last seven have a wide geographical distribution in the Indo-Pacific or Arctic and the Atlantic Oceans. Finally, multivariate analyses of species distribution showed changes among locations according to the north–south axis and depth, parameters that highly influence the benthic communities.

Keywords: amphipods, Mediterranean, Spain, fine-sand

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INTRODUCTION

The Mediterranean Amphipoda fauna has a high richness, with more than 452 recorded species (Bellan-Santini *et al*., 1998), and has been widely studied; however, the knowledge of this order is not uniform throughout the entire Mediterranean. In this way, knowledge of the ecology and taxonomy of amphipod species on the Mediterranean coast of the Iberian Peninsula is still fragmentary (Jimeno & Turón, 1995; Bellan-Santini *et al*., 1998) and the central east coast has been studied relatively infrequently (Marti, 1989).

According to Jimeno (1993), there are 368 known species along the coast of the Iberian Peninsula, of which only 146 are reported from the Mediterranean side. Works on amphipods from this area have been mainly carried out on the Catalan coast (Castany *et al*., 1982; Bibiloni, 1983; Carbonell, 1984; Jimeno, 1993; San Vicente & Sorbe, 1999; Munilla & San Vicente, 2005; Cartes *et al*., 2007, 2009; Delgado *et al*., 2009) and the Andalucia coast (Conradi *et al*., 1995; Conradi & López-González, 1999; Sánchez-Moyano *et al*., 2007; Gonzalez *et al*., 2008; Guerra-García *et al*., 2009a, b; Izquierdo & Guerra-García, 2010; Guerra-García & Izquierdo, 2010). Other studies have been produced in the Balearic Islands (Cartes *et al*., 2003; Ortiz & Jimeno, 2003) and indeed, on the Iberian Peninsula east coast (Marti, 1989; Sánchez-Jerez *et al*., 1999; Vázquez-Luis *et al*., 2008, 2009), where this study was carried out (Figure 1); however, more studies on the distribution of amphipods are still required in order to increase the knowledge of species distribution and amphipod diversity of this area.

One of the communities more frequent in shallow soft-bottom non-vegetated areas from the western Mediterranean is the medium-to-fine sand community of *Spisula subtruncata* (Cardell *et al*., 1999). This community tends to colonize exposed or semi-exposed sublittoral habitats, from the beach environment to 30 m depth (Sardá *et al*., 1996, 2000; Cardell *et al*., 1999). Although this community generally contains low numbers of individuals and low values of biomass, a high abundance and diversity of amphipods had been reported (Bakalem *et al*., 2009).

The main objective of this paper was to report the status of the knowledge of the amphipod species inhabiting this widely distributed community on the eastern Spanish Mediterranean coast and to analyse changes in species composition among sampled locations.

MATERIALS AND METHODS

A total of 40 stations from ten different locations along approximatley 250 km of south-west coast of the Balearic

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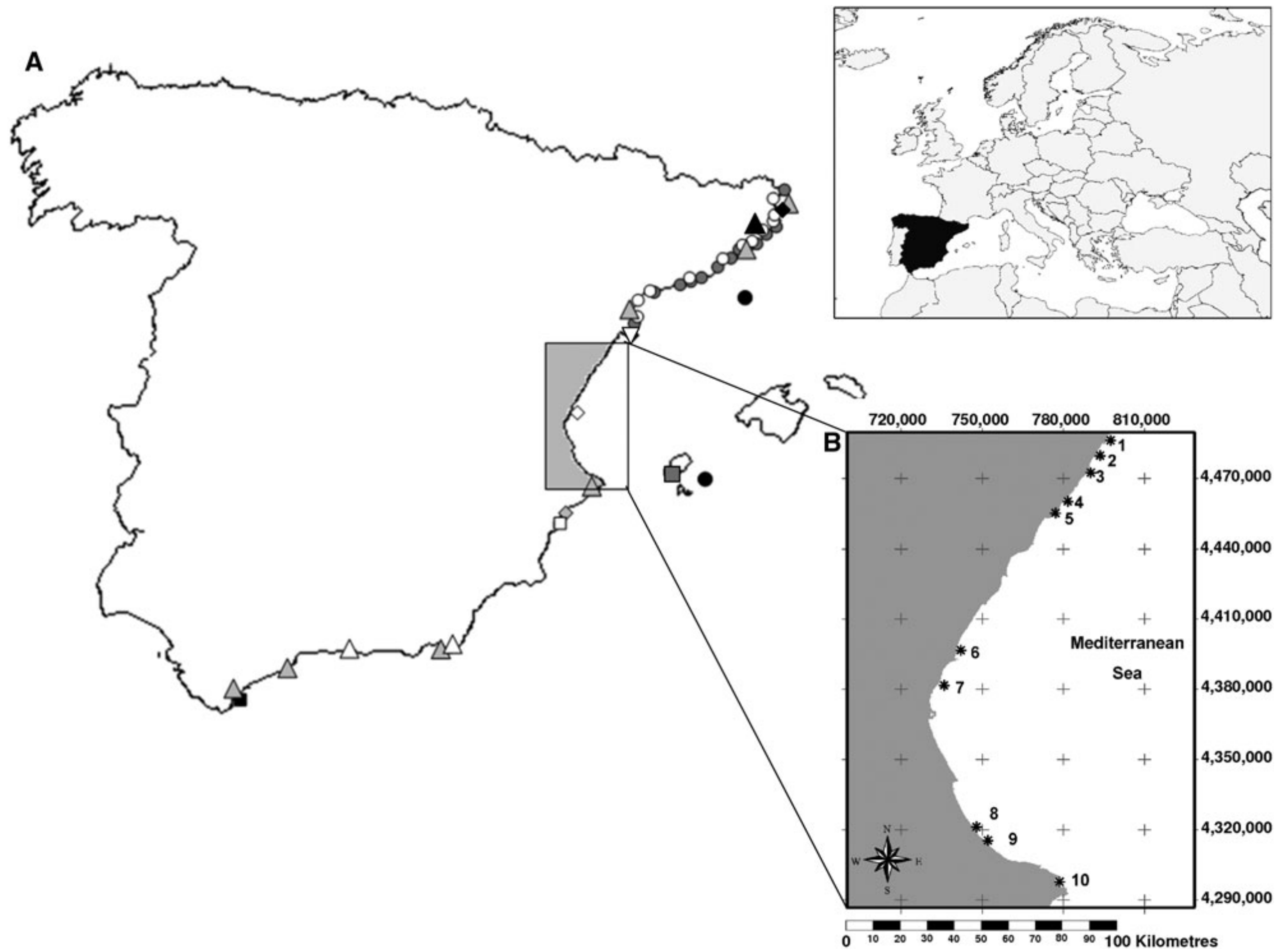

Fig. 1. (A) Locations from the literature about amphipods checked from the Spanish Mediterranean coast: ◆, Carbonell (1984); ▲, Bibiloni (1983); ◇, Marti (1989); ●, Jimeno (1993), Jimeno & Turón (1995); ◆, Sánchez-Jerez *et al.* (1999, 2000); ■, Conradi *et al.* (1995), Conradi & López-González (1999), Sánchez-Moyano *et al.* (2007), Guerra-García *et al.* (2009a); ○, San Vicente & Sorbe (1999); Munilla & San Vicente (2005); ▲, Guerra-García *et al.* (2009b), Guerra-García & Izquierdo (2010), Izquierdo & Guerra-García (2010); •, Cartes & Sorbe (1993, 1999), Cartes *et al.* (2003);▽, Cartes *et al.* (2007, 2009), Delgado *et al.*, 2009; ■, Ortiz & Jimeno, 2003; □, Vázquez-Luis *et al.* (2008, 2009); △, Gonzalez *et al.* (2008); (B) locations from this study: 1, Vinaroz; 2, Benicarló; 3, Peñíscola; 4, Alcossebre; 5, Torreblanca; 6, Canet d'en Berenguer; 7, Puebla de Farnals; 8, Gandia; 9, Oliva; 10, Javea.

Basin (Comunidad Valenciana, Iberian Peninsula east coast) were sampled (Figure 1). All locations were characterized by homogeneous fine-sand sediment (median sediment included between 0.125 μm and 0.25 μm) with a depth-range from 12.4 to 20 m (Table 1). For each location, four sites were sampled, keeping a constant depth in each location. All samples were collected in July during five consecutive years (2004 to 2008). Four Van Veen grab samples (400 cm^2) were obtained at each site. Three samples were sieved through a 0.5-mm screen, fixed in 10% formalin and preserved in 70% ethanol for the study of the amphipod assemblage. The other sample was used to characterize the sediment (granulometric analysis and organic content). Grain size analysis was assessed by standard sieve fractionation (Holme & McIntyre, 1984). Organic content of dry sediment was estimated as the loss of weight after ashing.

Table 1. Locations, geographical coordinates, depth (m) and physical characteristics of sediment of the stations of each location.

Location	Latitude	Longitude	Depth	% Mud	% Fine sand	% Medium sand	% Coarse sand	% Gravel	% Organic matter
1. Vinaroz	40°28.15′N	0°30.44′E	15.0	4.25	78.85	5.14	9.27	2.50	2.47
2. Benicarlo	40°24.55′N	0°27.70′E	14.0	7.56	73.55	5.68	6.79	6.43	1.61
3. Peñiscola	40°20.79′N	0°24.99′E	14.8	1.49	83.56	4.27	5.62	5.07	2.02
4. Alcossebre	40°14.45′N	0°18.55′E	12.4	1.03	74.34	14.01	5.64	4.98	1.56
5. Torreblanca	40°11.83′N	0°14.59′E	13.9	1.23	86.82	5.63	3.96	2.36	1.47
6. Canet d'en Berenguer	39°40.96′N	0°10.77′W	15.6	0.72	83.36	5.87	9.16	0.88	1.62
7. Puebla de Farnals	39°31.97′N	0°15.44′W	18.9	9.18	69.05	8.36	9.32	4.09	2.61
8. Gandia	39°0.15′N	0°8.31′W	16.5	1.76	88.91	4.50	3.32	1.50	2.02
9. Oliva	38°56.92′N	0°5.55′W	15.6	1.79	91.94	3.33	1.54	1.39	2.46
10. Javea	38°46.83′N	0°12.60′E	20.0	7.77	75.71	12.55	3.09	0.88	1.61

Amphipods were identified using the key of Mediterranean amphipod fauna established by Bellan-Santini *et al.* (1982, 1989, 1993, 1998), except for the genus *Bathyporeia*, which was identified using d'Udekem d'Acoz & Vader (2005). The taxonomy was validated using the ERMS referential for amphipod introduced by Bellan-Santini & Costello (2001) (http://www.marbef.org/data/erms.php, consulted on 25 May 2010). New records for the Mediterranean Spanish coast were checked using published available literature (Figure 1).

Non-parametric multivariate techniques were used to compare species composition among locations. All multivariate analyses were performed using the PRIMER v. 6 statistical package (Clarke & Warwick, 1994). Triangular similarity matrices were calculated through the Bray–Curtis similarity coefficient using abundance values that were previously square root transformed. Locations were classified into groups according to the cluster analysis of Bray–Curtis similarity coefficients. Similarities percentage analyses (SIMPER) of abundances were used to determine the species with higher percentage contribution in dissimilarity between groups.

The BEST procedure was used to determine the parameter (granulometry, organic matter %, depth and latitude) most correlated with species composition changes between sampled stations. Spearman correlation between similarity matrices of samples based on the abundances of benthic community and parameters was determined. Canonical correspondence analysis (CCA) was used to identify the relationships among the spatial distribution patterns of amphipods and environmental gradients. The CCA was conducted using the software CANOCO. The output is displayed as biplot, in which the plotted points for stations can be related to environmental gradients that are represented as arrows. The strength of the correlation of an environmental variable is reflected in the length of the arrow, and its association is reflected in the acuteness of the angle with the axis. Thus, the relationships among stations and environmental variables can be displayed on one plot.

RESULTS AND DISCUSSION

Taxonomic composition

A total of 55 species, belonging to 38 genera and 22 families, were identified. Among them, five species were first reported from the Mediterranean Spanish coast, 14 species were recorded for the second time and this study confirms their presence along the Spanish Mediterranean coast. A new species of *Medicorophium*, *M. longisetosum* sp. nov. (Myers *et al.*, 2010) was also described from this collection.

The species list is reported in Table 2, indicating when each species was previously cited and the bottom type where it was found. Some details on the new and second species records are given.

Order AMPHIPODA Latreille, 1816
Suborder GAMMARIDEA Latreille, 1803
Family AMPELISCIDAE Costa, 1957
Ampelisca sarsi Chevreux, 1888

This species is common on fine-sand shallow water (10–108 m depth) of the eastern Atlantic Ocean from the western part of the Channel, where it can form abundant populations, to the African coast of Senegal, and in the Mediterranean Sea where it was present in the Marseilles Gulf and in the Adriatic Sea (Bellan-Santini *et al.*, 1982; Bellan-Santini & Dauvin, 1988). It was also present along the Algerian coast in the Bou Ismail and Algiers Bays and the Bejaia Gulf from 13 to 120 m on diverse types of sediment from mud to coarse sand (Bakalem & Dauvin, 1995). *Ampelisca sarsi* was also recorded at 383 m from the Portugal coast (Marques & Bellan Santini, 1993). From the Spanish Mediterranean coast, *A. sarsi* was previously reported as a first record by Conradi & López-Gonzalez (1999) among *Bugula neritina* and *Mesophillum* in Algeciras Bay (Andalucían coast). This species has been recorded from Vinaroz to Puebla de Farnals and always in low abundances. A total of 64 individuals have been collected from 12.4 to 15.6 m.

Ampelisca spinifer Reid, 1951

It was observed in the eastern Atlantic Ocean from Ireland to the Liberia coast, and in the Mediterranean in the Marseilles Gulf, the Tyrrhenian Sea and the coast of Israel (Bellan-Santini *et al.*, 1982; Bellan-Santini & Dauvin, 1988). It was also recorded in Bou Ismail Bay in mud and muddy-gravel between 25 and 100 m depth (Bakalem & Dauvin, 1995). *Ampelisca spinifer* was not previously reported from the Spanish Mediterranean coast. A total of 37 specimens have been recorded in Vinaroz, Benicarlo, Peñíscola, Puebla de Farnals, Oliva and Javea, from 14 to 20 m in fine-sand bottom. Its ecology was previously established between 15 to 182 m depth on several types of sediment, from muddy to coarse sand but always in sediments with a large amount of mud (Bellan-Santini *et al.*, 1982; Bellan-Santini & Dauvin, 1988; Marques & Bellan Santini, 1993).

Ampelisca tenuicornis Liljeborg, 1855

It was observed in the eastern Atlantic Ocean from northern Norway to the Senegal coast, from 0 to 510 m depth; where it can form abundant populations in shallow muddy fine sand community (Bellan-Santini & Dauvin, 1988). *Ampelisca tenuicornis* was previously reported from the Mediterranean Spanish coast at the continental shelf of Ebro Delta (western Mediterranean) by Cartes *et al.* (2007, 2009). We have found a total of 1084 individuals from all studied locations (from 12.4 to 20 m), obtaining the highest abundances (956 ind/m^2) in Gandia during the year 2004. This species was found in sandy and muddy bottom in shallow waters in the eastern and western part of the Mediterranean Sea including the Algerian coast (Bellan-Santini *et al.*, 1982; Bakalem & Dauvin, 1995).

Family AORIDAE Stebbing, 1899
Autonoe spiniventris Della Valle, 1893

Despite being previously established as Mediterranean endemic (Bellan-Santini *et al.*, 1982), *Autonoe spiniventris* has since been observed by Martínez & Aderraga (2001) on the Atlantic coast (San Sebastian, Spain). This species is common in the Bou Ismail and Algiers Bays between 15 and 100 m depth from sand to muddy coarse sand (Bakalem & Dauvin, 1995). It was reported from the Spanish

Table 2. Amphipods species identified during present study. Asterisks indicate new records (*) and second records (**) for Spanish Mediterranean Coast. Literature and substratum where each species was found are indicated.

Families	Species	Recorded by	Substratum
Ampeliscidae	*Ampelisca brevicornis* (Costa, 1853)	III, V, XII	A, M, D
	Ampelisca diadema (Costa, 1853)	VI, XI, XII	A, D, V
	Ampelisca sarsi (Chevreux, 1888)**	VI	V, B
	Ampelisca spinifer (Reid, 1951)*	This study	A
	Ampelisca tenuicornis (Liljeborg, 1855)**	XV	M
	Ampelisca typica (Bate, 1856)	VI, VIII	A, M, D
Amphilochidae	*Amphilochus brunneus* (Della Valle, 1893)	VI, XV	A
Amphithoidae	*Amphithoe ramondi* (Audouin, 1826)	I, IV, V, VI, VII, VIII, XII, XIV, XVII	A, V, D, C
Aoridae	*Aora spinicornis* (Afonso, 1976)	IV, V, VII, IX, XVI	A, V
	Autonoe spiniventris (Della Valle, 1893)**	XII	A, V
	Microdeutopus versiculatus (Bate, 1856)	VI, IX, XII	A, M, D, V
	Tethylembos viguieri (Chevreuz, 1911)	I, VI	A, M, D, V
Argissidae	*Argissa stebbingi* (de Rouville, 1894)*	This study	A
Atylidae	*Atylus guttatus* (Costa, 1851)	I, IV, V, XII, XVI	A, V
	Atylus massiliensis (Bellan-Santini, 1975)	III, XII	A, V
Bathyporeiidae	*Bathyporeia lindstromi* (Stebbing, 1906)*	This study	A
	Bathyporeia guilliamsoniana (Bate, 1857)	V, VI, VIII, XII	A, V
	Bathyporeia borgi (d'Udekem d'Acoz & Vader, 2005)*	This study	A
Caprellidae	*Pariambus typicus* (Krøyer, 1844)	III, IX, XIV	A, V
	Phtisica marina (Slabber, 1769)	I, IV, V, VI, VII, X, XIV, XVI	A, V
Cheirocratidae	*Cheirocratus sundevalli* (Liljeborg, 1861)**	VI	A, M, D, V
Corophiidae	*Leptocheirus hirsutimanus* (Bate, 1862)**	VI	A, H
	Leptocheirus pectinatus (Norman, 1869)	VI, XIV	M, D, C
	Medicorophium longisetosum (Myers, de-la-Ossa-Carretero & Dauvin, 2010)	This study	A
	Medicorophium runcicorne (Della Valle, 1893)**	VI	M, D
	Monocorophium sextonae (Crawford, 1937)	IV, VI, VII, XVI	A, M, V, H
	Siphonoecetes sabatieri (de Rouville, 1894)	III, IV, XII	A, V
Dexaminidae	*Dexamine spinosa* (Montagu, 1813)	I, IV,VIII, X, XII, XIV	V, H
Eusiridae	*Apherusa alacris* (Krapp-Schickel, 1969)**	VI	V
Isaeidae	*Microprotopus maculatus* (Norman, 1867)	II, III, VIII, XII	A
Ischyroceridae	*Ericthonius punctatus* (Bate, 1857)	III, IV, V, VI, VIII, XVI	A, V
Leucothoidae	*Leucothoe inicisa* (Robertson, 1892)	II, VIII	A
	Leucothoe oboa (Karaman, 1971)**	VI	A, D, H
Lysianassidae	*Hippomedon massiliensis* (Bellan-Santini, 1965)**	VI	A, M, D, B
	Lepidepecreum longicorne (Bate & Westwood, 1861)**	V	V
	Lysianassa costae (Milne-Edwards, 1830)	VI, XII, XIV	A, M, D, V, B
	Orchomenella nana (Kroyer, 1846)	VI, XI	A
	Tryphosites longipes (Bate & Westwood, 1861)	VI, XI, XV	A, M
Megaluropidae	*Megaluropus massiliensis* (Ledoyer, 1976)	V, VI, VIII, XII	A, M, V
Melitidae	*Maera grossimana* (Montagu, 1808)	I, IV, V, VI	A, D, V
	Maera knudseni (Reid, 1951)**	V	V
	Elasmopus pocillamus (Bate, 1862)	I, IV, VII, X, XII, XIV, XVII	V
Oedicerotidae	*Monoculodes gibbosus* (Chevreux, 1888)**	XI	M
	Perioculodes longimanus (Bate & Westwood, 1868)	III, V, VI, VIII, XI, XV	A, M, D, V
	Synchelidium haplocheles (Grube, 1864)**	VIII	A
	Synchelidium maculatum (Stebbing, 1906)	XI	M
Photidae	*Gammaropsis maculata* (Johnston, 1828)	I, IV, VI, VII	A, M, D, V
	Megamphopus cornutus (Norman, 1869)	VI	A, M, D, V, B
	Photis longicaudata (Bate & Westwood, 1862)*	This study	A
	Photis longipes (Della Valle, 1893)	III, VI	A, M, D, V
Phoxocephalidae	*Harpinia crenulata* (Boeck, 187)	XI, XV	M
	Harpinia pectinata (Sars, 1891)	III, XI	A
	Metaphoxus fultoni (Scott, 1890)	I, V, VI	A, D, V
Urothoidae	*Urothoe pulchella* (Costa, 1853)	III, VI	A
	Urothoe elegans (Costa, 1853)**	XI	M

References: I, Carbonell (1984); II, Bibiloni (1983); III, Marti (1989); IV, Jimeno (1993); V, Sánchez-Jerez *et al.* (1999, 2000); VI, Conradi *et al.* (1995), Conradi & López-González (1999); VII, Ruffo & Krapp-Shickel, personal communication in Jimeno (1993) or Conradi & López-González (1999); VIII, San Vicente & Sorbe (1999), Munilla & San Vicente (2005); IX, Sánchez-Moyano *et al.* (2007); X, Guerra-García *et al.* (2009a, b); XI, Cartes & Sorbe (1993, 1999), Cartes *et al.* (2003); XII, Vázquez-Luis *et al.* (2008, 2009); XIII, Gonzalez *et al.* (2008); XIV, Ortiz & Jimeno (2003); XV, Cartes *et al.* (2007, 2009); XVI, Delgado *et al.* (2009); XVII, Izquierdo & Guerra-García (2010). Substratum: A, sands; M, mud or clayey bottom; D, detrital bottom; H, hard bottom; V, among algae or seaweeds; B, among *Bugula neritina* and *C. coraligene*.

Mediterranean coast among *Posidonia oceanica*, and *Cymodocea nodosa* from the Alicante coast (Vazquez-Luis *et al*., 2009). Its depth-range was established (Bellan-Santini *et al*., 1998) from 2 to 100 m in well-sorted sand bottoms and among photophilic algae. We have collected 5825 specimens from 12.4 to 20.0 m. It has been found in all locations, being especially abundant in northern locations (from Vinaroz to Torreblanca) and Canet d'en Berenguer, with a maximum density of 2125 ind/m² at Vinaroz in 2006.

Family ARGISSIDAE Walker, 1904
Argissa stebbingi de Rouville, 1894

This cosmopolitan species was previously recorded in the Atlantic Ocean, Indian Ocean and Japan Sea. In the Mediterranean Sea, it has been found from 11 to 370 m in various sediment types (Bellan-Santini *et al*., 1982, 1998; Grimes *et al*., 2009). From the Atlantic Iberian coast, *Argissa stebbingi* was previously reported in the Bay of Biscay (Bachelet *et al*., 2003) and as the synonym *A. hamatipes* in Portugal (Marques & Bellan-Santini, 1993) and San Sebastian coast (Martínez & Aderraga, 2001). Eleven individuals of this first record for the Mediterranean Spanish coast have been found from 13.9 to 16.5 m water depth, in Vinaroz, Peñíscola, Torreblanca and Gandia.

Family BATHYPOREIIDAE Bousfield & Shih, 1994
Bathyporeia borgi d'Udekem d'Acoz & Vader, 2005

It was described by d'Udekem d'Acoz & Vader (2005) from specimens of the Tyrrhenian and Adriatic Seas, reporting that *Bathyporeia nana* Toulmond, 1966 specimens recorded previously in the Mediterranean Sea are actually *B. borgi. Bathyporeia nana* was found in the western basin of the Mediterranean Sea (Bellan-Santini *et al*., 1989) in sandy beaches from the intertidal zone to about 10 m depth. Recently, *B. borgi* was reported on muddy-sand at a depth of 10 m from the Algerian coast (Grimes *et al*., 2009). We have found 338 specimens along all locations from 12.4 to 20 m.

Bathyporeia lindstromi Stebbing, 1906

This endemic Mediterranean species was known on sandy bottoms, in 20 to 30 m from Italy (Tyrrhenian Sea), Sardinia, Malta and the Israeli coast (Bellan-Santini *et al*., 1989, 1998; d'Udekem d'Acoz & Vader, 2005), and it has since been found on fine sand at a depth of 5 m from the Algerian coast (Grimes *et al*., 2009). We have collected two individuals in Oliva and Javea at a water depth of 15.6 and 20 m.

Family CHEIROCRATIDAE Ren, 2006
Cheirocratus sundevalli Liljeborg, 1861

This species was widely distributed in the Mediterrranean Sea, the Atlantic Ocean, the Black Sea and the Arctic Ocean from 8 to 157 m, being characteristically on sandy bottoms with loose-lying algae (Bellan-Santini *et al*., 1982, 1998; Marques & Bellan-Santini, 1993). It was also found on *Posidonia* meadows and various sediment types in the Bou Ismail Bay and Annaba Gulf from 8 to 90 m depth (Bakalem & Dauvin, 1995). On the Spanish Mediterranean coast, it was recorded for the first time by Conradi & López-Gonzalez (1999) in sand, mud and detrital bottoms as well as among *Halopteris scorparia* from the Andalusian coast in 5 to 30 m water depth. We have collected 28 individuals from Vinaroz, Benicarlo and Peñíscola in 14 to 15 m.

Family COROPHIIDAE Leach, 1814
Leptocheirus hirsutimanus Bate, 1862

It was observed along the north-eastern Atlantic Ocean and Mediterranean Sea from 7 to 350 m (Bakalem & Dauvin, 1995; Bellan-Santini *et al*., 1998). Its ecology was established as detritic and mud coastal bottoms and bathyal muds (Bellan-Santini *et al*., 1982, 1998) as well as gravelly and coarse sand (Marques & Bellan-Santini, 1993). *Leptocheirus hirsutimanus* was first recorded from the Mediterranean Spanish coast by Conradi & López-Gonzalez (1999) in medium sand, biodetrital and hard bottoms from the Andalucían coast. We have found 26 individuals in Puebla de Farnals at 18.9 m water depth.

Medicorophium runcicorne Della Valle, 1893

This species has only been reported from the Mediterranean and Black Seas in mud and mobile substrates and among algae from 15 to 105 m (Bellan-Santini *et al*., 1982, 1998; Bakalem & Dauvin, 1995). *Medicorophium runcicorne* was recorded for the first time from the Spanish coast by Conradi & López-Gonzalez (1999) in biodetrital, mud and clayey bottoms from the Andalucían coast. A total of 1304 individuals have been collected. It has been reported in all locations from 12.4 to 20 m water depth, obtaining the highest abundances in the locations of Gandia and Oliva (325 ind/m²).

Medicorophium longisetosum Myers, de-la-Ossa-Carretero & Dauvin, 2010

A total of 365 specimens were collected from all locations with a depth-range of 12.4 to 20 m. Numbers of specimens collected in the ten sampling sites varied from 211 individuals at Vinaroz to one specimen at Javea. The presence of this new species, which is habitual and relatively abundant, is the best example of the necessity for more taxonomic studies in this area. It was fully described in Myers *et al.* (2010).

Family EUSIRIDAE Stebbing, 1888
Apherusa alacris Krapp-Schickel, 1969

This Mediterranean endemic species was established inhabiting among seagrasses (*Zostera*) and fine and coarse sand bottoms from 3 to 25 m (Bellan-Santini *et al*., 1982, 1998). It was recorded for the first time in the Spanish Mediterranean coast by Conradi & López-Gonzalez (1999) among *Halopteris escorparia.* We have found 12 individuals in the locations of Alcossebre, Torreblanca and Oliva from 12.4 to 15.6 m in fine-sand bottoms.

Family LEUCOTHOIDAE Dana, 1852
Leucothoe oboa Karaman, 1971

This species was previously established as a Mediterranean endemic and its ecology was established in muddy bottoms from 14 to 400 m (Bellan-Santini *et al*., 1989, 1998), however, it was also reported from the Portuguese coast (Marques & Bellan-Santini, 1993) on gravelly and coarse sand bottoms from 52 to 97 m water depth. It was recorded in the Oran Gulf at a depth of 80 m on sandy mud and in the Oran Harbour on mud with shells (Grimes *et al.*, 2009). *Leucothoe oboa* was first recorded from the Spanish Mediterranean coast by Conradi & López-Gonzalez (1999) in hard and sand biodetrital bottoms. We have found it in sandy bottoms with specimens of *Leucothoe inicisa.* We have collected a total of 213 individuals from 12.4 to 20 m water depth. It has been found in all locations though always in low abundances (40 ind/m²).

Family LYSIANASSIDAE Dana, 1849
Hippomedon massiliensis Bellan-Santini, 1965

This Mediterranean endemic species was distributed on sandy and muddy bottoms from 4 to 350 m (Bellan-Santini *et al.*, 1989, 1998). It was also recorded from Bou Ismail Bay (10–88 m) from sand to muddy gravel (Bakalem & Dauvin, 1995). *Hippomedon massiliensis* was only recorded from the Spanish coast by Conradi & López-Gonzalez (1999) in sand, mud and detrital bottoms as well as among *Bugula neritina.* We have collected 228 individuals from 12.4 to 20 m depth, distributed in all locations but always in low densities (up to 40 ind/m²).

Lepidepecreum longicorne Bate & Westwood, 1861

This species was observed in the north-eastern Atlantic Ocean and Mediterranean Sea at depths ranging from 0 to 360 m (Bellan-Santini *et al.*, 1989, 1998; Bakalem & Dauvin, 1995). Its ecology is established in gravels and sand bottoms as well as abyssal and bathyal muds. *Lepidepecreum longicorne* was observed on the Spanish Mediterranean coast among *Posidonia oceanica* meadows along the Alicante coast and the Iberian coast, it was also previously recorded in Portugal (Marques & Bellan-Santini, 1993). We have found 46 specimens in northern locations (Vinaroz to Alcossebre), from 12.5 to 15 m water depth.

Family MELITIDAE Bousfield, 1973
Maera knudseni Reid, 1951

It is distributed in the Atlantic Ocean (West Africa) and the Mediterranean Sea (Bellan-Santini *et al.*, 1982). It was common in Bou Ismail Bay on mud and sandy-muddy gravel between 45 to 100 m depth (Bakalem & Dauvin, 1995). Its ecology was established in mud, muddy sands, coarse sands, fine gravel and detritic bottoms with a depth range from 10 to 68 m (Bellan-Santini *et al.*, 1982, 1998). *Maera knudseni* was previously observed in *Posidonia oceanica* meadows along the Alicante coast (Sanchez-Jerez *et al.*, 2000). We have found 18 individuals only in Puebla de Farnals at 18.9 m water depth.

Family OEDICEROTIDAE Lilljeborg, 1865
Monoculodes gibbosus Chevreux, 1888

This species was previously observed in the north-eastern Atlantic Ocean and Mediterranean Sea in soft bottoms from 10 to 360 m water depth (Bellan-Santini *et al.*, 1993, 1998). It was reported in the Bejaia Gulf and Bou Ismail Bay on various sediment types ranging from mud to coarse sand and at depths from 24 to 86 m (Grimes *et al.*, 2009). *Monoculodes gibbosus* was previously reported on the muddy bottoms of the deep slope in front of Barcelona (western Mediterranean) from 593 to 598 m water depth (Cartes & Sorbe, 1999). We have found 14 individuals from Vinaroz, Benicarlo, Peñíscola, Puebla de Farnals and Oliva in 14 to 15.6 m.

Synchelidium haplocheles Grube, 1864

It is known from the Mediterranean Sea, Atlantic Ocean and Indo-Pacific Ocean (Bellan-Santini *et al.*, 1993, 1998; Bakalem & Dauvin, 1995), living from 3 to 100 m water depth on well sorted sand and coastal terrigenous mud bottoms. *Synchelidium haplocheles* was previously recorded on beaches from the Catalonian coast (Munilla & San Vicente 2005). We have found 90 specimens at depths from 12.4 to 15.6 m in northern locations, Puebla de Farnals and Gandia.

Family PHOTIDAE Boeck, 1871
Photis longicaudata Bate & Westwood, 1862

This cosmopolitan species was observed in the Atlantic Ocean (from Norway to West Africa), the Indian Ocean and the Mediterranean Sea. Its ecology was established from infralittoral, among algae and *Posidonia* meadows, to bathyal (400 m), among mud and detritic bottoms (Bellan-Santini *et al.*, 1989, 1998; Bakalem & Dauvin, 1995). Although it was previously recorded from the Atlantic Iberian coast (Marques & Bellan-Santini, 1993; Matínez & Adarraga, 2001), *Photis longicaudata* was not previously reported from the Spanish Mediterranean coast. Two specimens have been collected in Torreblanca at a depth of 13.9 m.

Family UROTHOIDAE Bousfield, 1979
Urothoe elegans Costa, 1853

This species was observed in the Atlantic Ocean, Indian Ocean and Mediterranean Sea (western, Tyrrhenian, Adriatic, Israel and North Africa) associated with fine sediments distributed from 2 to 644 m (Bellan-Santini *et al.*, 1989, 1998; Bakalem & Dauvin, 1995). *Urothoe elegans* was previously reported on the muddy bottoms of the deep slope in front of Barcelona (western Mediterranean) (Cartes & Sorbe, 1993, 1999). We have found 143 individuals, in locations at Canet d'en Berenguer, Puebla de Farnals and Javea, from 15.6 to 20 m water depth.

Species distribution among locations

Cluster analyses based on species composition showed a segregation of stations according to the north–south axis (Figure 2). In this way, locations from north of the studied area (Groups A and B) obtained similarities among them higher than 60% and location 10 (Group F), which is sited south of studied area, showed more dissimilarity than other locations.

Changes among these locations were due to a decrease in abundance of species such as *Autonoe spiniventris*, *Perioculodes longimanus* or *Siphonoecetes sabatieri* from north to south. Whereas, other species abundance increased in locations 8 and 9, such as *Ampelisca typica*, *Ampelisca tenuicornis* or *Medicorophium runcicorne*, or from locations 6 to 9 *Urothoe pulchella*, or from locations 7 to 9 *Photis longipes* (Table 3).

The influence of geographical situations of each location in amphipod assemblage was reflected in BEST and CCA results.

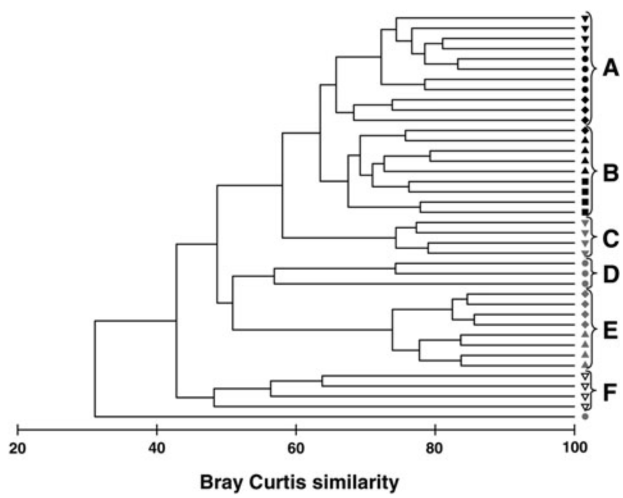

Fig. 2. CLUSTER analysis based on amphipod assemblage of stations (ind/m²), indicating each location (▼, 1; ●, 2; ◆, 3; ▲, 4; ■, 5; ▼, 6; ●, 7; ◆, 8; ▲, 9; △, 10) and groups established (A, B, C, D, E and F).

Latitude together with depth obtained the highest Spearman correlation (Rho: 0.609 and 0.606) with changes in species composition. The CCA showed that both parameters were related since the southern locations are slightly deeper than northern ones (Figure 3; Table 1). Both latitude and depth highly influence benthic communities and were related to other abiotic parameters such as hydrodynamic conditions, temperature, dissolved oxygen, granulometry and organic content. For instance, temperature, influenced by latitude and depth, affect most biological processes and act on growth rates, maturation or reproduction cycle. Despite the fact that species contributing to differences among locations displayed a wide bathymetric distribution, some of them could be less adapted to hydrodynamic processes than others (Bellan-Santini *et al.*, 1998). The fine sand communities, such as the study area, are always influenced by high hydrodynamism which can remove the surface layer (Cardell *et al.*, 1999), in such a way that local changes could change species abundances according to their capacity to shelter.

Table 3. Mean abundance of species contributing more in dissimilarities among groups established in CLUSTER analysis.

Species	Average abundance (ind m^{-2})					
	Group A	Group B	Group C	Group D	Group E	Group F
Ampelisca tenuicornis	20.45	10.19	41.67	52.78	635.42	22.92
Ampelisca typica	140.15	54.63	143.75	194.44	277.08	35.42
Autonoe spiniventris	778.79	535.19	560.42	72.22	52.08	25
Medicorophium runcicorne	100.76	47.22	47.92	16.67	337.5	2.08
Perioculodes longimanus	220.45	187.04	89.58	16.67	63.54	16.67
Photis longipes	96.21	27.78	95.83	438.89	382.29	85.42
Siphonoecetes sabatieri	180.3	91.67	0	22.22	8.33	39.58
Urothoe pulchella	25.76	25.93	137.5	258.33	121.88	87.5

Other parameters such as mud percentage or organic matter showed a weak correlation (Rho: 0.291 and 0.208), whereas percentages of other granulometric sizes showed the lowest correlations (Rho < 0.2) with amphipod species composition. Changes in these parameters were related to species differences among close locations. Despite the fact that sediments in the area were homogeneous and low changes in granulometry among locations were registered, grain size and organic content are factors that may be related to food availability and the ability to burrow (Oakden, 1984; Marques & Bellan-Santini, 1993); as a result light changes in sediment from close areas could produce changes in species composition.

BIOGEOGRAPHICAL CONSIDERATIONS

The present study recorded a total of 55 total species, but for a limited length of Spanish coast (250 km) and only for sandy bottoms. Among these species, 30 have a north-eastern Atlantic distribution and 17 have a wide distribution in Atlantic and Indo-Pacific or Arctic Oceans (Bakalem & Dauvin, 1995; Bellan-Santini *et al.*, 1998; Grimes *et al.*, 2009). Meanwhile, only eight species were considered Mediterranean endemics. Among these endemics, six are reported as first or second records on the Spanish Mediterranean coast; and among the north-eastern Atlantic species *Autonoe spiniventris* and *Leucothoe oboa* are known only along the Iberian coast (Marques & Bellan-Santini, 1993; Martínez & Aderraga, 2001). Among the 20 species recorded for the first or second time on the Mediterranean coast, only two species *Apherusa alacris* and the new species *Medicorophium longisetosum* were absent along the Algerian coast (Bakalem & Dauvin, 1995; Grimes *et al.*, 2009), and four species, namely the two same species for Algeria, plus the two *Bathyporeia* species, *B. borgi* and *B. lindstromi*, were absent from the French Mediterranean coast. This shows a good resemblance of the continental shelf amphipod fauna at the scale of the western part of the Mediterranean Sea.

A total of six species (>10% of the recorded species) was new for the Spanish coast, and among them a new species was described (Myers *et al.*, 2010). This proves the need to significantly increase the prospection of the amphipods from the Mediterranean Spanish coast. To give some comparative numbers, the French Mediterranean continental shelf accounts for 250 Gammaridea (Dauvin & Bellan-Santini, 2002). Nevertheless records depended on the sampling efforts among the regions, respectively 240 in the 'Provence-Alpes Côte d'Azur' region which included the Marseilles Gulf where numerous studies were made mainly through the expertise of Denise Bellan-Santini, 100 for the 'Languedoc–Roussillon' region at the frontiers with Spain, and only 78 species around Corsica (Dauvin & Bellan-Santini, 2002). Recent works on Algerian amphipods, including three orders, i.e. Caprellidea, Gammaridea and Hyperiidea (Bakalem & Dauvin, 1995; Grimes *et al.*, 2005), revealed that the fauna accounts for 298 species of the 451 species recorded in the mid-1990s for the whole Mediterranean fauna. Using these records, we expected that the total amphipod marine fauna (Caprellidea, Gammaridea and Hyperiidea) of the Mediterranean coast of Spain should include between 250 and 300 species. A first inventory of all

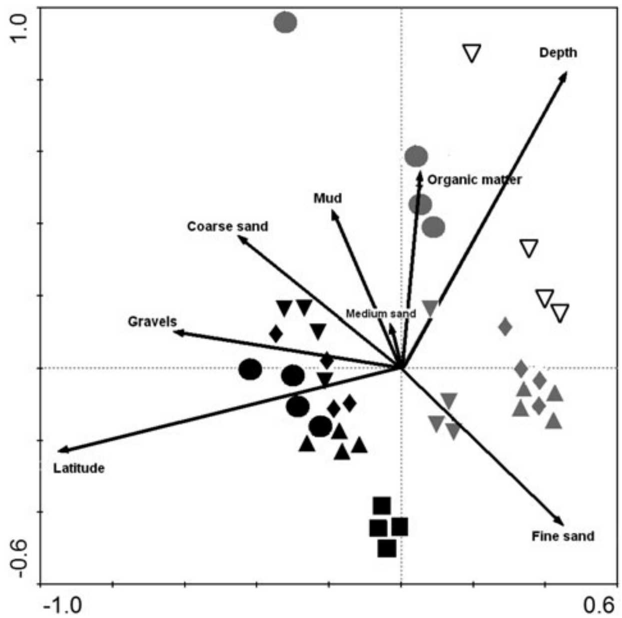

Fig. 3. Results of canonical correspondence analysis (CCA) biplots. Points correspond to samples from locations: ▼, 1; ●, 2; ◆, 3; ▲, 4; ■, 5; ▼, 6; ●, 7; ◆, 8; ▲, 9; △, 10. Arrows indicate environmental variables. CCA axis I and CCA axis II had eigenvalues of 0.184 and 0.142, respectively.

species collected in this area should be completed from published works particularly those of J.M. Guerra-Garcia on caprellids (Guerra-García *et al.*, 2000, 2001a,b, 2002, 2009a,b). Moreover, the higher percentage of endemics among first or second records indicates the need for more sampling studies in order to increase distribution knowledge of Amphipoda species from the Spanish Mediterranean coast.

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