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# First record of the starfish *Luidia atlantidea* Madsen, 1950 in the Mediterranean Sea, with evidence of persistent populations

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**Abstract:** The starfish *Luidia atlantidea*, an echinoderm known hitherto from infralittoral and circalittoral bottoms of the northwestern African coasts, is reported for the first time in the European margin and in the Mediterranean Sea. A total of 31 specimens of different sizes (disc diameters from 0.8 to 2.9 cm) were collected from the mechanized dredges fleet targeting four commercial bivalves (*Acanthocardia tuberculata, Callista chione*, *Chamelea gallina*, *Donax trunculus*) between February and July 2013 in the northern Alboran Sea (southern Spain). Most individuals had broken arms due to the collecting gear. The specimens were generally collected in low numbers, at shallower depths (1-11 m) than the bathymetric range reported for this species along the northwestern African coasts (10-80 m). The data provided here, and supported by old specimens collected between 1980-1990, suggests that local populations of *L. atlantidea* occur in shallow infralittoral soft bottoms of the northern Alboran Sea. This constitutes a new extended northeastern limit for the distribution of *L. atlantidea* and increases the known number of *Luidia* species in the Mediterranean Sea.

**Résumé :** *Premier signalement de l'étoile de mer* Luidia atlantidea *Madsen, 1950 en Méditerranée, et indices de populations persistantes.* L'étoile de mer *Luidia atlantidea*, un échinoderme connu précédemment sur les fonds infralittoraux et circalittoraux du nord-ouest de l'Afrique, est signalé pour la première fois sur la marge européenne, en Méditerranée. Un total de 31 spécimens de différentes tailles (diamètre de disques entre 0.8 et 2.9 cm) a été recueilli par les dragues mécanisées de la flottille ciblant quatre espèces de bivalves d'interêt commercial (*Acanthocardia tuberculata, Callista chione*, *Chamelea gallina*, *Donax trunculus*) entre février et juillet 2013 dans le nord de la Mer d'Alboran (sud de l'Espagne). La plupart des individus étaient démembrés en raison du mode de prélèvement. Ces spécimens ont été récoltés à des profondeurs plus faibles (1-11 m) que celles indiquées pour cette espèce le long des côtes africaines (10 à 80 m). Ces données, corroborées par des spécimens prélevés entre 1980 et 1990, suggèrent l'existence de populations locales de *L. atlantidea* sur les fonds meubles infralittoraux peu profonds du nord de la Mer d'Alboran. Ceci constitue une extension pour la distribution connue de *L. atlantidea* et constitue une nouvelle signalisation pour la Mer Méditerranée.

*Keywords:* Asteroidea ● Echinoderm ● Alboran Sea ● Fisheries ● Soft bottoms ● Infralittoral

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## Introduction

The Alboran Sea represents a biodiversity hot-spot within Europe and the Mediterranean Sea, due to the confluence of fauna and flora from different areas such as the Atlantic Ocean and the Mediterranean Sea (García Raso et al., 2010; Robles, 2010). In this small basin, endemic species have also been found as well as species that are mainly distributed in northwestern Africa but display in the Alboran Sea their only populations within European waters (García Raso et al., 2010; Rueda et al., 2010). Moreover, alien species have also been detected in the last decades, but they still represent a very low number in this basin when compared to those occurring in the eastern Mediterranean Sea (Zenetos et al., 2010). Studies on the benthic and demersal fauna of the Alboran Sea have increased in the last decades, but recent information regarding specific groups (e.g. Echinoderms, Sipunculids, Bryozoans) is still very scarce when compared to others (e.g. Fish, Molluscs, Decapods, Macroalgae) (Reina-Hervás, 1987; García Muñoz et al., 2008; Rueda et al., 2009; García Raso et al., 2010; Urra et al., 2011, 2012, 2013a & b; Mateo-Ramírez & García Raso, 2012).

Previous studies on the echinoderm fauna from the Alboran Sea have dealt with the composition of echinoderm assemblages in specific coastal locations (Rodríguez & Ibáñez, 1976; Rodríguez, 1980; Salas et al., 1988) or in the entire basin, including the bathyal zone (Sibuet, 1974; Pérez-Ruzafa & López-Ibor, 1988; Ocaña & Pérez-Ruzafa, 2004). The Atlantic biogeographical relationships of the echinoderm fauna of the Alboran Sea are especially perceptible in the northern part of the basin (Sibuet, 1974). Regarding Asteroidea, ca. 25 spp. have been listed so far, representing a higher number of species when compared to other Mediterranean areas (Pérez-Ruzafa & López-Ibor, 1988). Some genera are represented by a high number of species (e.g. *Astropecten*) whereas others are only represented by one or two species (e.g. *Peltaster, Odontaster, Tethyaster, Luidia*). The genus *Luidia* Forbes, 1839, currently included in the Family Luidiidae Sladen, 1889 and the Order Paxillosida Perrier, 1884, is nowadays represented by *Luidia ciliaris* (Philippi, 1837) and *Luidia sarsii* Düben & Koren, in Düben, 1845 in this basin and in the Mediterranean Sea. The former generally displays 7 arms and occurs shallower (5-80 meters) than *L. sarsii* which displays 5 arms and inhabits circalittoral and bathyal bottoms (> 50 meters) (Koehler, 1969; Clark & Downey, 1992). A third species, namely *Luidia atlantidea* (Madsen, 1950), occurs in shallow bottoms (10-80 meters) in the Atlantic coasts of northwestern Africa (Madsen, 1950; Clark & Downey, 1992; Entrambasaguas, 2008), but no records for this species have been found so far in the European margin or in the Mediterranean Sea.

In this study we indicate the presence of persistent populations of *L. atlantidea* in different locations of the northern Alboran Sea based on individuals collected by artisanal fisheries during 2013 and also from student collections deposited in the Departamento de Biología Animal of the Universidad de Málaga (Spain) between 1980 and 1990. This study has been carried out within the project REMAN-REMARAN (Instituto Español de Oceanografía and Junta de Andalucía) which focuses, among other topics, on the characterization of discards of artisanal fisheries targeting four commercial bivalves of the northern Alboran Sea such as *Acanthocardia tuberculata* (Linnaeus, 1758), *Callista chione* (Linnaeus, 1758) *Chamelea gallina* (Linnaeus, 1758) *and Donax trunculus* Linnaeus, 1758.

## Material and Methods

*Luidia atlantidea* individuals from different sizes (disc diameters from 0.8 to 2.9 cm) were collected between February and July 2013 using mechanized dredges in shallow infralittoral soft bottoms (generally less than 15 m depth) of the northern Alboran Sea (Fig. 1). The dimensions and mesh size of these dredges were different regarding the different commercial bivalves targeted, being of ca. 100 cm width with a mesh size of 20 mm for the striped venus (*C. gallina*) and the wedge clam (*D. trunculus*) and with a mesh size of 55 mm for the smooth clam (*C. chione*) and the rough cockle (*A. tuberculata*). The lengths of the tines ranged between 40 (for *C. gallina* and *D. trunculus*) and 220 mm (for *C. chione* and *A. tuberculata*). A total of 139 hauls performed by different artisanal fishing vessels were analysed, which generally spanned for ca. 15 minutes and had a trawled distance of ca. 200 meters.

Commercial bivalves were separated from the discard samples and the remaining species were counted and weighed to the nearest 0.1 g. Furthermore all *L. atlantidea* specimens were separated from the discard samples, measured, photographed, and fixed in 70% ethanol or preserved dried. Individuals of this species have been deposited in the invertebrate reference collection of the Centro Oceanográfico de Málaga from the Instituto Español de Oceanografía (IEO, Spain). Another set of 3 individuals were collected by students of the Universidad de Málaga between 1980 and 1990 in different coastal areas of Málaga and identified until this study as *Luidia sarsii*. These latter starfishes were deposited in the invertebrate reference collection of the Departamento de Biología Animal of the Universidad de Málaga (UMA). Material of *Luidia* spp. deposited in collections of museums (Museo Nacional de Ciencias Naturales, Madrid, Spain) and research institutions within Spain (IEO, Centro Oceanográfico de Cádiz) have been examined in order to detect the presence of *L. atlantidea*.

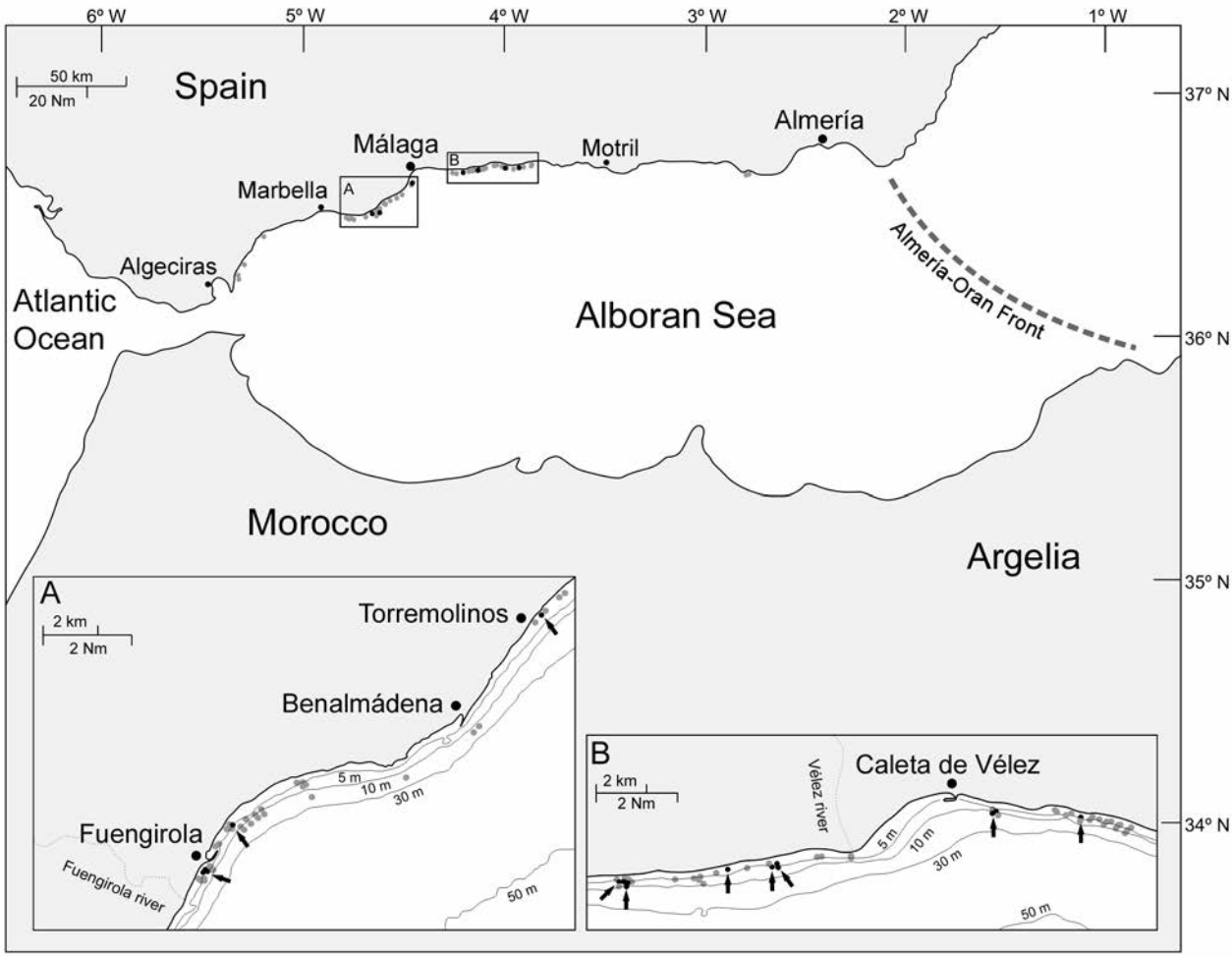


**Figure 1.** *Luidia atlantidea.* Location map of artisanal shellfish hauls with (black circles and arrows) and without (grey circles) individuals in the northern Alboran Sea (western Mediterranean Sea).

## Results

A total of 31 specimens of *L. atlantidea* were found in 22 of 139 hauls performed with the mechanized dredges at depths between 0.9 and 11.6 m. Most individuals were collected in captures targeting *C. gallina* (27 individuals of *L. atlantidea* collected), followed by those targeting *D. trunculus* (2 indiv.) or *C. chione*/*A. tuberculata* (2 indiv.). The *L. atlantidea* specimens were mainly collected in fine sand with pebbles and/or bioclasts, where this starfish generally occurs together with the dominant molluscs *Glycymeris nummaria* (Linnaeus, 1758), *Mactra stultorum* (Linnaeus, 1758), *Nassarius reticulatus* (Linnaeus, 1758) and the four commercial bivalves targeted by artisanal fisheries, as well as the dominant decapods *Portumnus latipes* (Pennant, 1777), *Liocarcinus vernalis* (Risso, 1816) and *Atelecyclus undecimdentatus* (Herbst, 1783), among other species. In all samples, *L. atlantidea* displayed a very low abundance (generally < 2 individuals per haul) and dominance (< 1% from the total discarded).

Regarding coastal areas, most individuals were collected close to La Caleta de Vélez (20 individuals), followed by Fuengirola (11 individuals) (Fig. 1). Individuals were mainly collected between 3.5 and 5.5 m depth (87% individuals), and rarely collected shallower (0.9-2.2 m) (6.45%) or deeper (7.5-11.6 m) (6.45%). In the studied period, the frecuency of occurrence of *L. atlantidea* in shellfish discards is ca. 17% of the trawls performed.

The collected individuals of *L. atlantidea* displayed five long arms flattened dorso-ventrally, with a main line of paxillae arranged longitudinally at the margins of the ambulacros in the abactinal side, and followed by two rows of paxillae that are less marked and thick than the primary more marginal ones (Fig. 2). The actinal surface contains numerous pedicellariae arranged in the central part of the ambulacros, forming two rows of long pedicellariae

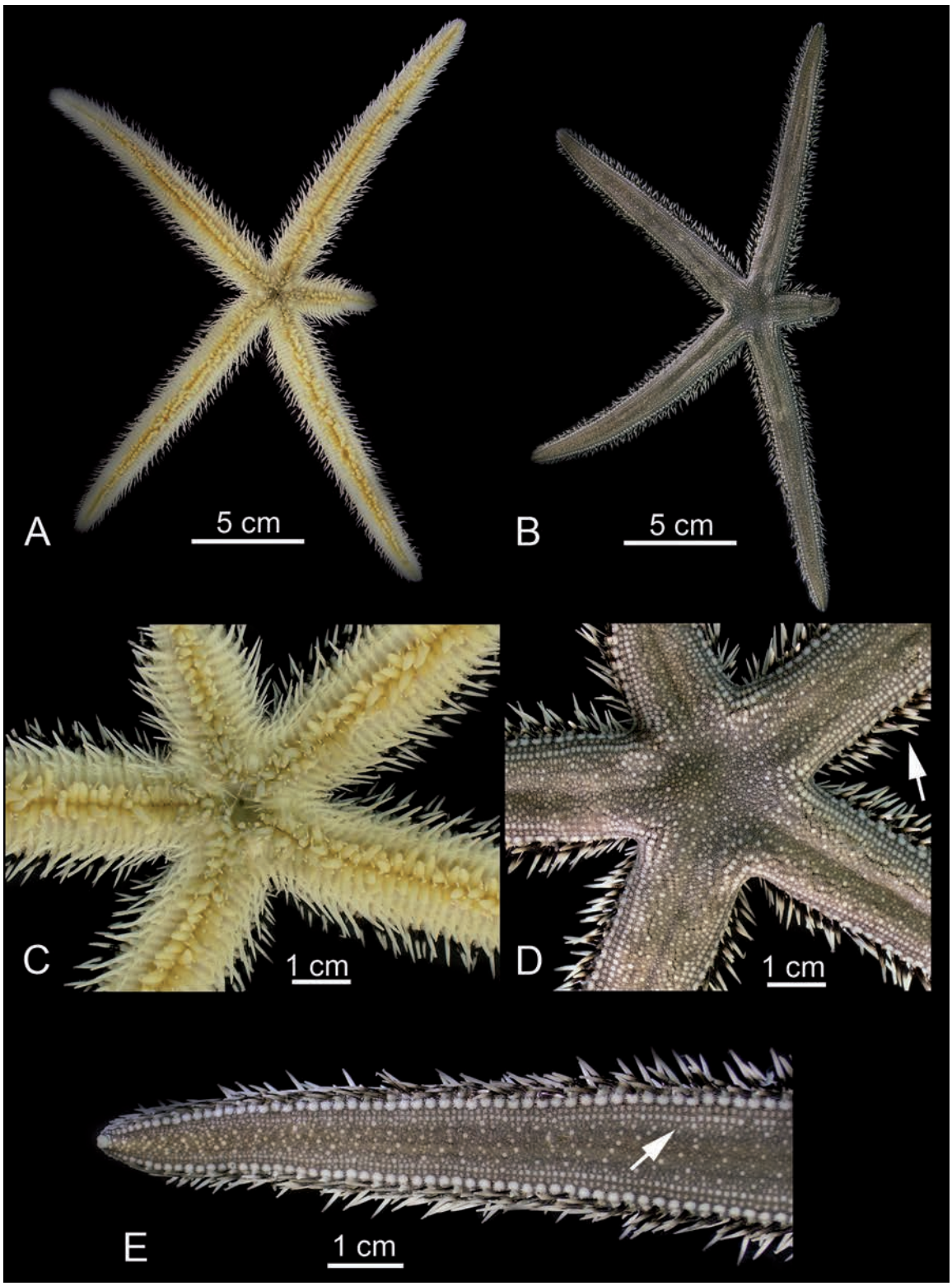


**Figure 2.** *Luidia atlantidea.* External morphological features of collected individuals. **A-C.** General view of actinal side. **B-D.** Abactinal side of an individual regenerating one arm. **E.** Detail of the abactinal side of one arm showing the marginal spines that are black with white tips as well as the main line of paxillae arranged longitudinally at the margins of the arm and followed by two rows of paxillae that are less marked and thick than the primary one. Arrows display the taxonomic details that enable the identification of the species such as the black and white marginal spines and the 3 rows of paxillae

surrounded by other smaller and finer ones. The marginal areas of the arms are covered by 3 to 4 rows of large marginal spines that are black with white tips (Fig. 2). All specimens of *L. atlantidea* were extremely fragile (generally displaying broken arms after being trawled), with a grey color at the abactinal side and yellow-white at the actinal side (Fig. 2). Some individuals displayed arms that were regenerating, which represents an advantage for recovery after physical disturbances (e.g. trawling) (Fig. 2).

## Discussion

The reported records of *L. atlantidea* in the northern Alboran Sea occur at a depth range that is somehow shallower than the one observed for this species along the coasts of northwestern Africa (10-80 m) (Clark & Downey, 1992). The presence of several individuals of *L. atlantidea* of different sizes in different parts of the northern Alboran Sea and with records spanning several decades indicate that local populations of this species are rather common and persistent in infralittoral bottoms of this part of the Mediterranean Sea. In fact, more individuals (ca. 25 ind.) of *L. atlantidea* were collected by fishermen in following months and years (from summer 2013 to spring 2014) along the coasts of Málaga (Urra, pers comm). Moreover, a large individual with unbroken arms was collected by UMA postgraduate students in March 2015 in El Rincón de la Victoria (Málaga, Spain) and deposited at the invertebrate reference collection of the Centro Oceanográfico de Málaga (IEO, Spain) (Rueda, pers comm). The previously known distribution of *L. atlantidea* ranged from the Atlantic coasts of Morocco to Zaire, including Cape Verde Islands (Madsen, 1950; Clark & Downey, 1992; Entrambasaguas, 2008). In the Mediterranean Sea, the species has not been previously found (Cherbonnier, 1956; Tortonese, 1965; Koehler, 1969; Sibuet, 1974; Rodríguez, 1980; Zavodnik, 1982; Pérez-Ruzafa & López-Ibor, 1988; Ocaña & Pérez-Ruzafa, 2004) and no records are also available for Portugal (de Jesus & da Fonseca, 1999). Moreover, Tortonese (1980) reported six Atlantic species only found in northwestern Africa and the Aboran Sea, but *L. atlantidea* was not listed in that study. Thus, the *L. atlantidea* specimens from the present study may represent the first record for this species in the Mediterranean Sea and in the European continental margin.

Another seven subtropical species (i.e. species with a large part of their range in West Africa, at least south to Senegal) have been found in the estudied discard samples, including the gastropod molluscs *Mesalia varia* (Kiener, 1843), *Bivetiella cancellata* (Linnaeus, 1767), *Cymbium olla* (Linnaeus, 1758), *Tectonatica sagraiana* (d'Orbigny, 1842), *Sinum bifasciatum* (Récluz, 1851) and *Natica vittata* (Gmelin, 1791), as well as the decapod crustacean *Albunea carabus* (Linnaeus, 1758). Most of the specimens were collected in captures targeting *C. gallina* and *D. trunculus*. Populations of these subtropical species in the Mediterranean Sea seem to be mostly restricted to the Alboran Sea (Rueda et al., 2009 & 2010; Urra et al., 2011), indicating the importance of this area for marine biodiversity due to the confluence of fauna from different regions (Lusitanian, Mediterranean, Mauritanian).

Individuals of *L. atlantidea* were always collected in soft-bottoms (mainly fine sand with pebbles and/or bioclasts) but the species seems to prefer mud, sand with calcareous algae, muddy sand, broken shell bottoms, sand with stones and fine sand bottoms (Clark & Downey, 1992). In the Alboran Sea, *L. atlantidea* generally occurs within the 'sables fins bien calibrés' (SFBC, well sorted fine sands) biocoenoses of Pérès & Picard (1964), as reflected by the most dominant species collected (e.g. *Donax* spp., *C. gallina*, *G. nummaria*, *A. tuberculata*, *P. latipes*, *L. vernalis*, among others) and the predominance of bivalves overall. Other echinoderms occurring in these bottoms, some of them displaying high abundance values, are the asteroids *Astropecten irregularis* (Pennant, 1777) and *Astropecten aranciacus* (Linnaeus, 1758), the ophiuroids *Ophiura ophiura* (Linnaeus, 1758) and *Acrocnida brachiata* (Montagu, 1804) as well as some species of holothurians (*Leptosynapta* cf. *inhaerens*) and irregular echinoids (*Echinocardium* cf. *mediterraneum*). In studied areas where populations of *L. atlantidea* occur, ophiouroids and infaunal echinoids are dominant components of the benthic community and may provide enough food sources for this starfish, which could have similar food requirements as *L. sarsii* or *L. ciliaris* (Fenchel, 1965; Brun, 1972).

The description of the collected *L. atlantidea* in the northern Alboran Sea is very similar to that given by Madsen (1950) and later on by Clark & Downey (1992), who provided a useful key for the 11 Atlantic species of *Luidia*. According to the authors, this species has 15 to 19 consecutive lateral paxillae corresponding to ten superomarginal ones that are usually square in shape, with central paxillar spinelets that are distinctly coarser than peripheral ones and adambulacral plates with three large spines, and sometimes a smaller fourth spine or enlarged spinelet that is proximal to the most lateral. Moreover, they indicated that this starfish species has two large inferomarginal spines and two valves on actinal pedicellariae, which can be very numerous and usually present on the furrow face of each oral plate. The same authors pointed out that the color patterns are generally dark grey with a white stripe along the superomarginal paxillae in the abactinal side and white in the actinal side, with marginal spines that are dark basally with their tips white.

In the Alboran and Mediterranean Sea, two species of the genus *Luidia* have only been found so far (Tortonese, 1965; Koehler, 1969; Sibuet, 1974; Rodríguez, 1980; Tortonese, 1980; Zavodnik, 1982; Pérez-Ruzafa & López-Ibor, 1988; Clark & Downey, 1992; Ocaña & Pérez-Ruzafa, 2004). The infralittoral species *L. ciliaris* is very different from *L. atlantidea* and *L. sarsii* because it generally displays 7 arms (rarely 8) (Tortonese, 1965; Koehler, 1969). In contrast, *L. sarsii* generally occurs at larger depths (very rarely at depths below 45 meters) but could be confused with *L. atlantidea* since both starfishes have 5 arms with large marginal spines on the ambulacros and both of them are extremely fragile (Tortonese, 1965; Koehler, 1969; Nataf & Cherbonnier, 1973; Clark & Downey, 1992). Nevertheless, these two species differ in the shape of the superomarginal paxillae (being roundish-square in *L. atlantidea* and elongate in *L. sarsii*), in the number of consecutive lateral paxillae (15-19 in *L. atlantidea* and 17-20 in *L. sarsii*) and in the color pattern of the arms, disc and spines (generally dark grey with black and white marginal spines in *L. atlantidea*, and brownish yellow, reddish or orange and marginal spines darker in *L. sarsii*) (Nataf & Cherbonnier, 1973; Clark & Downey, 1992). In contrast to *L. sarsii*, the specimens of *L. atlantidea* also display central paxillar spinelets that are coarser and also have a greater frequency of pedicellariae (Clark & Downey, 1992). Clark & Downey (1992) already pointed out that *L. sarsii* overlaps with *L. atlantidea* in northwestern Africa, displaying both species very similar characters, but some of the above mentioned characters (i.e. elongated superomarginal paxillae), as well as the pale colour pattern of live or freshly-preserved specimens of *L. sarsii* and its different bathymetric distribution, may help in distinguishing these two very similar species in areas where both species occur. Considering these different taxonomical characteristics and the low probability of occurrence of *L. sarsii* at shallow infralittoral depths (generally collected at deep circalittoral and bathyal bottoms in annual MEDITS surveys in the Alboran Sea, Gil de Sola & García, pers. comm.), it could be concluded that the collected specimens of this study are *L. atlantidea*. Material from other echinoderm collections was examined such as that of Museo de Ciencias Naturales de Madrid (Spain) and IEO-Cádiz. In both collections, the deposited and examined *Luidia* only belonged to *L. ciliaris* and *L. sarsii*, probably because most *Luidia* specimens of those collections were collected at circalittoral and bathyal bottoms of the Gulf of Cádiz and Alboran Sea where *L. atlantidae* does not generally occur. This then may indicate that three species of *Luidia* occur simpatrically in the northern Alboran Sea as observed previously in the northwestern African coasts (Nataf & Cherbonnier, 1973; Clark & Downey, 1992).

It is difficult to explain the main reason revealing the presence of local and persistent populations of *L. atlantidea* in the northern Alboran Sea. One possible explanation is that the oceanographic dynamics of this basin, with a constant flux of Atlantic surficial waters entering the Mediterranean Sea, through the Strait of Gibraltar, may promote larval transport from northwestern Africa to the Alboran Sea. This may have favored the maintenance of populations of common northwestern African species of different phyla in this area of southern Europe over the last centuries (Rueda et al., 2010). Muñóz et al. (2015) have recently shown that Atlantic surficial waters from the Gulf of Cádiz and northern Africa may reach the coasts of Málaga in less than two weeks, which represents a shorter time than that of the larval metamorphosis in *Luidia* spp. (Clark & Downey, 1992). Considering this, local populations observed in the northern Alboran Sea could be treated as sinks supported by the spill over from source populations located in northwesten African coasts. On the other hand, if *L. atlantidea* individuals of the Alboran Sea are well established and have the possibility to breed, it would be likely to find more populations in other localities in the northeastern and especially in the southern Alboran Sea. Pedrotti & Fenaux (1996) found that echinoderm larval populations were more abundant and biodiverse in areas of the Alboran Sea that are more influenced by the Atlantic waters and near the African coasts due to the Alboran sea anticyclonic gyre currents, so larval transport of *Luidia* could also display a similar trend. Another explanation for the presence of persistent populations of *L. atlantidea* could be related to a recent colonization from southern populations due to global warming as it has been observed for other species that are common at lower latitudes (Azzurro, 2008; Lejeusne et al., 2010). A third explanation could be related to the fishing activity of the trawling fleet from southern Spain (e.g. Málaga, Cádiz, Huelva) in northwestern African fishing grounds (e.g. Morocco) during the last decades (Balguerías et al., 1990; Ramos et al., 2000). This could have promoted an input of specimens of *L. atlantidea* as well as other species in the Alboran Sea as part of discards remaining on trawling boats until harbour arrival. This has been the introduction pathway for a new alien gastropod from western Africa that nowadays occurs in Málaga harbour (Luque et al., 2012). Finally it is important to highlight that individuals of *L. atlantidea* are very similar to *L. sarsii* and this could have promoted misidentification of *Luidia* individuals collected in infralittoral and shallow circalittoral bottoms of the Alboran Sea during the last centuries.

## Conclusion

The occurrence of *Luidia atlantidea* in Mediterranean waters and the European margin is reported for the first

time. A total of 31 specimens were collected in artisanal fisheries during six months (February-July 2013) and 3 specimens were found in the invertebrate reference collection of the Universidad de Málaga and collected by students during 1980-1990 in the northern Alboran Sea. Other individuals have been collected by fishermen and students in similar locations from summer 2013 to winter 2015. This may indicate the presence of local and persistent populations of *L. atlantidea* in this part of the Mediterranean Sea, and suggests that *Luidia* species inhabiting Alboran waters could have been misidentified in the last decades. This would indicate that three species of *Luidia* occur simpatrically in the northern Alboran Sea. The reasons behind the expansion of the northeastern distribution range of *L. atlantidea* are difficult to explain but could be mainly related to larval dispersal by Atlantic surficial waters entering the Mediterranean Sea, or past fisheries activities of the Spanish fleet in northwestern Africa that could have brought individuals as part of discard remains.

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