Abundance and distribution of the rapid expansive coral Oculina patagonica in the Northern Alborá n Sea (Western Mediterranean)

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Abundance and distribution of the rapid expansive coral *Oculina patagonica* in the Northern Alborán Sea (Western Mediterranean)

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We describe for the first time the distribution and abundance of Oculina patagonica *along the coasts of the Northern Alborán Sea (Andalusia Region, Southern Iberian Peninsula), which corresponds to the southernmost region of the known distribution range of the coral. After surveying 693 km of the Andalusia coastline, along three different depths, we showed that* O. patagonica *was restricted to the eastern shores of the Alborán Sea. It was only present in 7 out of 195 sampling stations in the eastern region along the studied coasts and at the depth range of 0–3 m. Moreover, we observed that the distribution of the species along the northern coasts of the Alborán Sea might be related to substrate availability and sea surface temperature. In the localities in which its presence was described, the annual mean sea water temperature was in the range of 18–21°C. In relation to substrate availability, it must be noted that the distribution of hard substrata – ideal for* O. patagonica *settlement and growth – along the sampling area, is not uniform in the study area; this might affect the continuity of the distribution of the species. Local studies such as this one are of importance as a starting point for delineating the species' relationship with its habitat, population boundaries and population ecology. Given the fast expansion of this species along the Mediterranean coasts, this study could serve as a basis for continuous monitoring of the spread of the species and its long-term effects on the ecosystem.*

Keywords: *Oculina patagonica*, Alborán Sea, distribution, abundance, expansion

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INTRODUCTION

A fundamental issue in marine ecology is explaining the patterns of a species' distribution and abundance, together with the processes that are associated with these patterns (Eriksson & Jakobsson, 1998; Magurran *et al.*, 2011). For this, local studies on species spatial distribution are needed as a starting point for delineating a species' relationship with its surroundings biotic and abiotic factors, population boundaries and population ecology (Gage, 2004).

The Mediterranean is considered to be a biodiversity hot-spot with a high level of endemism, as well as an assortment of temperate and subtropical elements (Coll *et al.*, 2010). This is mainly related to its narrow connection to the Atlantic Ocean, its west–east orientation and is geological history (Boudouresque, 2004). Thus, the current biological diversity of the Mediterranean is due to the interactions between ecological factors, as well as the historical processes that shaped the Mediterranean Basin throughout the course of history (Templado, 2014). Within the generally high diversity found in the Mediterranean Sea, some studies suggest that the Alborán Sea, the westernmost basin of the Mediterranean Sea, is a regional hot-spot of biodiversity (e.g. the Alborán Sea) because of the coexistence of species from three marine biogeographic provinces (Mediterranean, Lusitanian and Mauritanian regions) and because of the endemic species restricted to this zone (Coll *et al.*, 2010; Aguilar *et al.*, 2011).

Oculina patagonica (De Angelis D'Ossat 1908) is a zooxanthellate scleractinian coral that can only be found in the Mediterranean Basin. In particular, it has been found in abundance in the Western Mediterranean Basin in Italy (Rodolfo-Metalpa *et al.*, 2006), the Gulf of Lyon (Zibrowius, 1974) and the coasts of the Iberian Peninsula, mostly in the south-eastern and eastern coasts (Zibrowius, 1980; Zibrowius & Ramos, 1983; Ramos, 1985; Fine *et al.*, 2001; Serrano *et al.*, 2013; Rubio-Portillo *et al.*, 2014). In the Eastern Mediterranean Basin, it has been cited in abundance on the coasts of Lebanon (Bitar & Zibrowius 1997), Israel (Fine *et al.*, 2001) and Greece (Salomidi *et al.*, 2013). In less abundance, colonies have been found in Algeria, Tunisia (Sartoretto *et al.*, 2008) and Turkey (Çinar *et al.*, 2006). *Oculina patagonica* has been cited as a species that is non-native to the Mediterranean Sea (Zibrowius, 1983). Transoceanic transport of planula of the species via the

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Strait of Gibraltar to the Western Mediterranean has been considered to be the most probable means of introduction (Zibrowius, 1974). Nevertheless, the origin of the species is still dubious. The unsolved situation exists in that the original description of *O. patagonica* is based on fossil materials from Holocene deposits on the temperate coast of South America. However, nowadays, no living specimens are to be found in Patagonia (Serrano *et al.*, 2013).

Oculina patagonica is commonly found on rocky foreshores and in caves with water depths of 0–10 m. It is present in artificial habitats, although, it can be found in natural habitats as well (Ramos-Esplà, 1985; García-Raso *et al.*, 1992; Fine *et al.*, 2001). This coral has been recorded in natural substrate where the population densities were generally scarce (Fine *et al.*, 2001; Sartoretto *et al.*, 2008; Coma *et al.*, 2011). However, recently, a rapid expansion of the coral's populations has been recorded, and the coral has been cited as the main component of a natural community (Sartoretto *et al.*, 2008; Coma *et al.*, 2011; Salomidi *et al.*, 2013; Serrano *et al.*, 2013; Rubio-Portillo *et al.*, 2014). *Oculina patagonica* has the ability to live and reproduce under varying and diversified environmental conditions, such as a wide range of water temperatures, salinity, UV radiation, turbidity and strong wave energy (Fine *et al.*, 2001). Therefore, it has been considered as an 'opportunistic dominant settler' that overgrows the calcareous structures of serpulids, vermetids, barnacles, etc. It also competes with algae and other soft organisms at its growing edge (Sartoretto *et al.*, 2008). This coral has been cited as rapidly expanding along the Iberian coasts (Coma *et al.*, 2011). Therefore, local studies are of importance in order to establish the habitat preferences of the species, as well as its abundance and habitat acquisition characteristics.

Because of all these aspects, the main objective of our survey was to assess the distribution and abundance of *O. patagonica* in the Northern Alborán Sea (Andalusia Region, Southern Iberian Peninsula). This area, together with the coasts of Morocco (Northern African coasts, Southern Alborán Sea), comprises the southernmost region of the Mediterranean Sea in which the species lives.

MATERIALS AND METHODS

The survey was performed along the rocky shores of the Andalusia coasts (Southern Iberian Peninsula, Northern Alborán Sea). The sampling area covered a total of 693 km of coastline between the province of Cádiz (36°38.38′N 06°24.71′W) and the province of Almería (37°21.181′N 1°39.303′W). In order to estimate the abundance and distribution of *Oculina patagonica* (Figure 1), we sampled a total of 195 sites, spaced at a distance of 1 km from each other (Figure 2). Of these sites, ten were artificial substrate (breakwater) and 185 were natural habitats. We designed a systematic and stratified sampling technique, following Benedetti-Cecchi *et al.* (1996), by using 1×1 m^2 quadrats, which were launched four times at three different depths: 0–3, 3–6 and 6–12 m. Therefore, we considered a total of 585 sampling stations. At each station, the presence and/or abundance of the species, the date, substrate composition and geographical location were recorded. When colonies of *O. patagonica* were present, we estimated their abundance by visual observations of the percentage of coral coverage in the grid of quadrats (25×25 cm^2) in the sampling station; we also quantified the number of colonies found at each quadrat. Each time, two SCUBA divers independently performed the visual estimations in order to reduce the sampling bias.

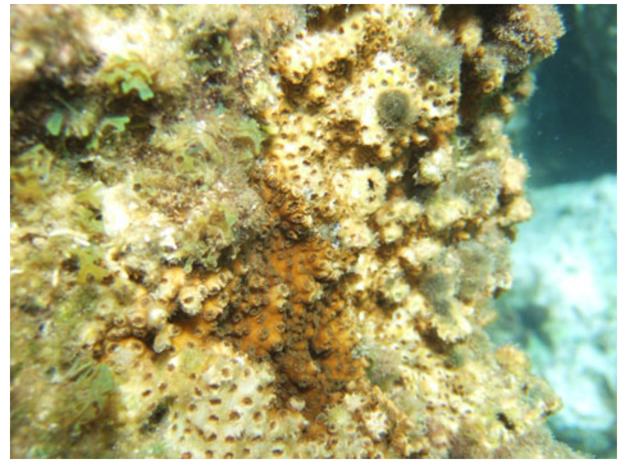

Fig. 1. *Oculina patagonica* on the Almería coastal line (natural habitat). Source: María del Mar Otero Villanueva (IUCN).

RESULTS AND DISCUSSION

In this manuscript, we describe the first survey of the distribution and abundance of *Oculina patagonica* along the entire coast of the Northern Alborán Sea (Andalusia Region, Southern Iberian Peninsula), which corresponds to the southernmost region of the known distribution range of the coral. In this area, previous studies have focused on the local presence of the species and/or abundance (CMA, 2012; Serrano *et al.*, 2012), but these studies only focused on some localities of the Andalusia region. Concerning other regions along the known distribution range of the species in the Mediterranean, studies have been performed on the coasts of Catalonia and Valencia (north-east and east of the Iberian Peninsula, respectively) (Serrano *et al.*, 2013; Rubio-Portillo *et al.*, 2014), as well as the Murcia coast (Algerian basin, south-east Iberian Peninsula) (Coma *et al.*, 2011).

From the 693 km of the Andalusian coastline surveyed, *O. patagonica* was only present in 7 out of 195 sampling sites (Figure 2). These sites were located in the provinces of Granada and Almería, in the easternmost regions along the Andalusian coasts and at the depth range of 0–3 m. Therefore, it is possible to conclude that *O. patagonica* is restricted to the eastern shores of the Alborán Sea.

The distribution patterns of *O. patagonica* on the northern coasts of the Alborán Sea seem to depend mainly on hard substrate availability, as well as the sea surface temperature, which might play a secondary role in the distribution patterns of the species. In the stations in which the coral was found as present, the annual mean sea water temperature was in the range of 18–21°C. Considering the availability of hard substrate, it should be noted that the distribution of rocky shores along the sampling area is not uniform. Given the need of the planulae of *O. patagonica* for a hard substrate in which it can settle down, the discontinuity found in rocky substrates is an important factor to take into consideration for the distribution patterns of the species. Even though rocky shore

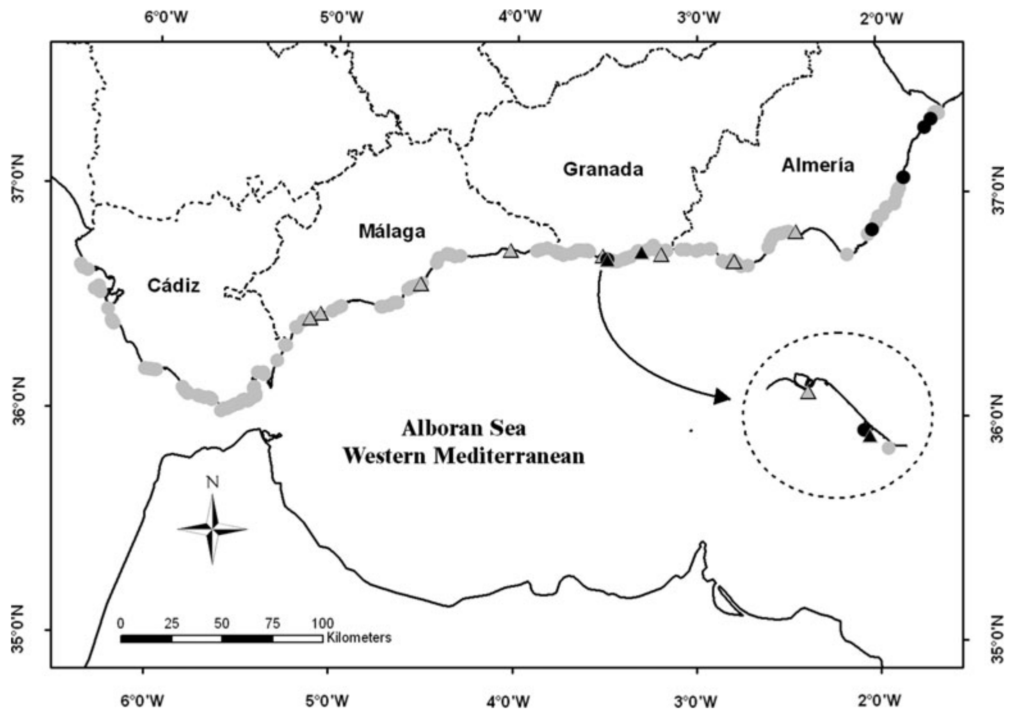

Fig. 2. Cartography of *Oculina patagonica* presence along the shoreline that we studied. The grey circles show the sampling points for natural habitat; the grey triangles show the sampling points for artificial substratum; the black circles show the *O. patagonica* presence in natural habitats; and the black triangles show *O. patagonica* presence in artificial substratum.

bottoms were the most predominant substrata in all provinces, we observed the presence of sandy bottom and mixed bottoms (66.7, 29.1 and 4.2% across the whole sampling region, respectively, as shown in Figure 3). The area of Cádiz (westernmost side of the study area) showed the greatest coverage of rocky bottoms, followed by Granada, Almería (easternmost sides of the study area) and, in a lesser extent, Málaga. Therefore, there is a continuum on the eastern side of the Andalusia coasts (Almeria and Granada areas) that might facilitate the settlement of planulae in hard substrates. Mixed and sandy bottoms predominate the central area of Malaga, separating this region from the rocky shores on the western shores of the sampling area (Cadiz area). Rocky substrates were predominant at 3 m, in all provinces, followed by depths of 6 and 12 m (Figure 3).

We found *O. patagonica* in two stations with artificial substrate (breakwater as a sandy shore defence), while the presence points corresponded with natural substrates (vertical and horizontal rocky shore). When the species was present, the colonies' abundance ranged between 5.25 ± 3.1 and 0.25 ± 0.5 colonies m^{-2}, while the coverage surface ranged

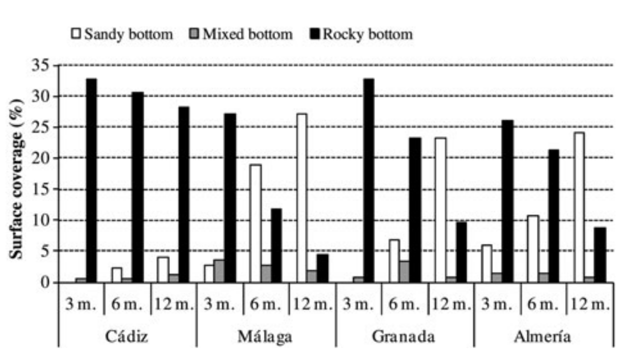

Fig. 3. Percentage of bottom type per provinces and depth.

between 5 and 30%. Both measurements were higher in Almería than those quantified on the Granada coastal line (Table 1). Therefore, both localities seem to correspond to the limit of distribution of the species in the Northern Alborán Sea. A decrease in species abundance and its distribution limits is a common feature in marine invertebrates and other passive dispersal species (Holt, 2003; Astanei *et al.*, 2005; Casado-Amezua *et al.*, 2012). In contrast to other studies, most of the substrates for *O. patagonica* were found to correspond with natural rocky surfaces, whilst there were only two localities with artificial substrates in which the species was found (breakwater as a sandy shore barrier). *Oculina patagonica* has the characteristics of an opportunistic species (Serrano *et al.*, 2013), inhabiting many natural sites and harbours along hundreds of kilometres of coastline in south-east Spain. However, it has been observed that a high capacity of this species settles on artificial harbours and polluted areas (Zibrowius, 1992). Therefore, artificial substrata might be another factor that supports dispersal (Serrano *et al.*, 2013). This has already been observed by Rubio-Portillo *et al.* (2014); these authors asserted that a harbour could be a focal point of dispersion in the Valencia Region. Local studies on the Andalusian coasts showed that the species may colonize artificial reefs (CMA, 2012). We also found the presence of this species on artificial reefs, although, the species was in a lower abundance. This could be because the two stations that correspond to artificial reefs in which the species was found corresponded with the westernmost distribution range of the species, not only on the Andalusian coasts but also in the Mediterranean Sea.

Whilst high coverage and abundance of *O. patagonica* has been observed in artificial habitats, coverage of natural substrata is generally low (Fine *et al.*, 2001; Sartoretto *et al.*, 2008; Coma *et al.*, 2011). However, recently, it has been reported in communities in which *O. patagonica* is the dominant species

Table 1. Sampling sites where colonies of *Oculina patagonica* were found (Gr, Granada; Al, Almería), the substrate type, geographic location (ED 50; WGS84), number of colonies per square meter (including average and standard deviation (SD)) and coverage percentage.

Point	Substrate	Latitude	Longitude	Colonies m^{-2} (average ± SD)	Coverage (%)
Gr 20	Breakwater	36°42.149′N	3°29.540′W	0.25 ± 0.5	8
Gr 28	Natural	36°42.093′N	3°24.429′W	0.25 ± 0.5	5
Gr 40	Breakwater	36°44.315′N	3°18.598′W	0.5 ± 0.58	10
Al 31	Natural	36°49.961′N	2°01.486′W	1 ± 0.82	12
Al 44	Natural	37°03.870′N	1°51.103′W	5.25 ± 3.1	30
Al 45	Natural	37°17.135′N	1°43.764′W	2 ± 0.82	25
Al 46	Natural	37°19.512′N	1°41.663′W	1.75 ± 1.71	25

(Serrano *et al.*, 2012), as it has been observed in Torre Pirulico, south-east Spain (37°4′70″N 1°50′59″W). These communities may act as a focus for local dispersion. This local dispersion may have happened in Almería's littoral zone, where these populations were observed, and close to this area, where we have observed the highest abundance in natural substrates (point Al_194 – 37°03.870′N 1°51.103′W). Coma *et al.* (2011) revealed a local-scale pattern of an increase in the abundance of coral colonies as a consequence of the opportunistic capacity of the species to colonize different types of substrata. Furthermore, these authors asserted that sea urchins' abundance, as grazers of macroalgae and, thus, creators of empty habitats, can play an important role regarding the expansion of this opportunistic species.

Routine monitoring programs are required for people to gain better knowledge of the population dynamics of any species (Bramanti *et al.*, 2011; Calvo *et al.*, 2011). In the case of *O. patagonica*, these programmes would be useful for detecting a possible widening of the species distribution at local or regional scales. Given the uncertain origin of the species, this is also helpful for disentangling ecological and taxonomical issues and, even more so, for a better understanding of the long-term effects that this opportunistic species has on the ecosystem. These studies must be accompanied by temperature serial analyses and control stations in MPAs or additional strategic localities. All of the data collected in this study, together with long serial data, can be evaluated and provides evidence for changes in coastal areas.

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