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Geographic distribution of *Astroides calycularis* (Scleractinia: Dendrophylliidae) as a baseline to assess future human impacts on the Southern Iberian Peninsula

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Human activities have increasingly affected biodiversity in the Mediterranean Sea. Data on the distribution and abundance of species allows researchers to assess the possible degradation of wild populations. These data could act as a baseline to assess the magnitude of the effects of human activities on a bioindicator species. The distribution and relative abundance of the south-western populations of the endemic Astroides calycularis *in the South Iberian Peninsula were studied to establish a baseline for future studies. The rocky shoreline was studied at a depth range of 0–12 m, including more than 650 km of Spain's Andalusian coastline. The species was present in 135 of the 585 dive points sampled. ANOVA analysis showed differences in depth in the four provinces studied, and there was no interaction between the two factors. As human activities on the Mediterranean coast are reducing the* A. calycularis *populations, a baseline on marine populations is greatly recommended for monitoring, assessment, and management studies, especially for endangered or bioindicator species. This baseline could be useful as a reference tool to assess the effects of human activities on marine biodiversity, including global change.*

Keywords: *Astroides calycularis*, baseline, geographic distribution, abundance, endangered species, Mediterranean Sea

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INTRODUCTION

Human activities have increasingly affected biodiversity in the Mediterranean Sea. Most of this biodiversity can be found in or near shallow shore waters, and the anthropogenic uses that threaten this biodiversity include, among other activities: land usage, which causes habitat destruction; water pollution; changes in nutrients and sedimentation; loss of coastal habitats (e.g. Airoldi & Beck, 2007); fishing activities; changes in communities or habitat destruction (e.g. Coll *et al.*, 2010); diving, which affects benthic communities (Garrabou *et al.*, 1998; Wielgus *et al.*, 2002; Coma *et al.*, 2004; Linares *et al.*, 2010); and mass mortality events related to climate change, which has already been observed in Mediterranean benthic invertebrates in the last decades (Gaino & Pronzato, 1989; Bavestrello *et al.*, 1994; Cerrano *et al.*, 2000; Perez *et al.*, 2000; Rodolfo Metalpa *et al.*, 2000; Harvell *et al.*, 2002; Garrabou *et al.*, 2009; Vezzulli *et al.*, 2010; Crisci *et al.*, 2011; Kersting *et al.*, 2013). These impacts and the synergies among them can greatly affect the distribution and survival of species (e.g. Coll *et al.*, 2010, 2011; Micheli *et al.*, 2013a; Serrano *et al.*, 2013). Moreover, these threats may be endangering species that play a structural role in benthic assemblages, and their alteration may further threaten rich Mediterranean biodiversity (Cebrián *et al.*, 2011; Kersting *et al.*, 2013).

The evaluation of baseline conditions is the challenge to understand the causes of environmental change (Francour *et al.*, 1994). The use of historical baselines allows researchers to assess possible degradations in wild populations and to guide conservation and management initiatives for good ecosystem conditions (Sala *et al.*, 2012). In order to understand the effects of human impacts along the coastline, monitoring should be a routine activity (Coll *et al.*, 2010), but a reference point is necessary.

The endemic and endangered orange coral (*Astroides calycularis*) is an azooxanthellate scleractinian colony coral with a carbonate calcium exoskeleton (Zibrowius, 1980) that inhabits the rocky shore from the surface to 50 m depth (Rossi, 1971; Ocaña *et al.*, 2000), but is typically found in the shallow infralittoral zone (0–15-m depth), on vertical walls, or inside caves (Rossi, 1971; Zibrowius, 1978; Kružic *et al.*, 2002). It occupies both light and dark habitats and appears to prefer a highly hydrodynamic environment (Zibrowius, 1978; 1995; Kružic *et al.*, 2002). The population density can be locally high, with colonies covering up to 90% of the sea bottom (Goffredo *et al.*, 2011). It has a limited geographic distribution in the Mediterranean Sea, is present in Italy between the Sicilian and Messina Straits and in the Gulf of Naples, and is also present in the Iberian Peninsula, from the Strait of Gibraltar to Palos Cape (Murcia) (Zibrowius, 1980;

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López-González, 1993). It can be found in Malta, Tunisia, Algeria, Morocco, Ceuta (Spain), and Melilla (Spain). Moreover, it is also present in Atlantic waters in the Espartel Cape (Morocco) and La Caleta (Cádiz, Spain). These westernmost locations (Zibrowius, 1995; Bianchi, 2007) are probably attributable to currents dispersing larvae out of the Strait of Gibraltar (Ocaña *et al.*, 2000; Casado-Amezúa, 2012; Casado-Amezúa *et al.*, 2012). Inside the Iberian Peninsula, the highest densities can be found on the Andalusian shores (Alboran Sea), where it has recently been recognized as an important habitat for other species, which can vary depending on location and season (Terrón-Sigler *et al.*, 2014).

This orange coral has been affected, in particular, by the siltation that results from increasing coastal urbanization (Ocaña *et al.*, 2009) and by human activities in the littoral zone, which increase marine pollution and/or habitat destruction (Moreno *et al.*, 2008). Moreover, it has also been demonstrated that recreational activities like scuba diving have a negative effect on the coral populations, because colonies can be damaged or removed by fins, hands and other diving equipment parts (Moreno *et al.*, 2008). Nevertheless, *A. calycularis* is considered a key species with high biomass values in our study area (Cebrián & Ballesteros, 2004). Therefore, the aim of the present study is to establish a baseline of the distribution and abundance of *A. calycularis* in the south-western Mediterranean Sea (the Andalusian coast). This baseline might be useful to identify changes in their populations resulting from human impact, and it could be used by management administrators, scientists and marine protected area (MPA) managers.

MATERIALS AND METHODS

The survey was conducted in the rocky and shallow bottoms of the Andalusian coastline in 2011. The Andalusian coastline studied comprises the provinces of Cádiz, Málaga, Granada and Almería (Figure 1). Monitoring sites were established at a minimum distance of 0.5 nautical miles, depending on the presence of a rocky substrate. The area of study included three marine protected areas: the Natural Park of the Strait of Gibraltar (Cádiz), the Natural Reserve of Maro-Cerro Gordo Cliff (Málaga-Granada) and the Natural Park of the Cape of Gata-Níjar (Almería).

In order to study the distribution, a total of 195 monitoring sites were selected (59 in Cádiz, 37 in Málaga, 49 in Granada and 50 in Almería shorelines) according to the substrata-type preferences of the orange coral. Following Benedetti-Cecchi *et al.* (1996), we studied the species' abundance in terms of cover percentage, as observed visually by scuba divers. The percentage of species covered may be estimated for sessile species such as corals, sponges and encrusting bryozoans (Katsanevakis *et al.*, 2012). At each monitoring sites, two scuba divers carried out three dives at different range depths (0–3 m, 3–6 m and 6–12 m), meaning a total of 585 points were sampled. At each depth, the scuba divers localized the *A. calycularis* colonies (Figure 2) and took data relating to date, geographic position (ED 1950; WGS 84), depth and substratum type. Four random replicate samples were collected using a 1 × 1-metre quadrant to assess the relative abundance in percentage of coverage. All data were registered in a database to perform statistical and spatial distribution analyses.

Five hundred and eighty-five dives were performed for the study and a total of 2340 m^2 were visually estimated, obtaining data of the presence or absence of orange coral, its abundance, its depth, its geographic position and the sea-bottom composition in the four provinces studied. For abundance, the mean and standard error of the mean were calculated.

A multifactor analysis of variance (ANOVA) was used to test whether the relative abundance of *A. calycularis* was similar across provinces and depths, with the following factors: province as a fixed factor with four levels (Cádiz, Málaga, Granada and Almería); and depth as a fixed factor, orthogonal with province, including three levels (3, 6 and 12-m depth) where the species is typically found (Kružic *et al.*, 2002). For ANOVA analysis, considering that Málaga was the province with the lowest number of sites ($N = 37$), 37 sites were used as replicates for both factors, because a balanced ANOVA test is more suitable than an unbalanced ANOVA (Underwood, 1997). Prior to ANOVA, the heterogeneity of variance was tested via a Cochran test. Univariate analyses were conducted with GMAV5 (Underwood *et al.*, 2002). When statistical differences were detected, an *a posteriori* Student-Newman-Keuls (SNK) test was applied.

Geospatial data from *A. calycularis* abundance were interpolated by means of raster analyses using a gridding of 1 m^2 and were represented spatially. We only interpolated the six points closest to the abundance of orange coral (no further than 2 km between the presence points) and used the bathymetric line of 15 m of the marine cartography. Mean abundances were grouped into five categories (absent; scarce: >0–25% coverage; moderate: >25–50% coverage; abundant: >50–75% coverage; very abundant: >75% coverage) to perform SIG graphics in order to make the visualization of the map easier. ArcGIS 9.2 (http://www.esri.com/) software was used to represent and analyse the spatial distribution.

RESULTS

A rocky shore bottom was the most predominant substrata in all provinces, followed by a sandy bottom and, finally, a mixed bottom (66.7, 29.1 and 4.2% respectively). Cádiz showed the greatest coverage for the rocky bottom, followed by Granada, Almería and Málaga. The rocky substrata were predominant at 3 m in all provinces, followed by depths of 6 and 12 m (Figure 3).

Astroides calycularis was present in 135 of the 585 monitoring points studied (Figures 3 & 4). Figure 4 shows the different abundances found in the 135 monitoring points where *A. calycularis* was found. Cádiz had a mean coverage of 23.11%, with similar values at the different depths studied. However, Granada showed higher abundances, with a mean coverage above 40% and maximum values observed at the deepest points (49.89%).

Almería and Málaga were the provinces with the lowest mean coverage: 12.6 and 1.31% respectively. Neither province hosted any populations at 12 m. However, Málaga had similar population coverage at 3- and 6-m depths, while Almería showed a higher mean coverage at 3 m (15.43% for 3 m and 1.25% for 6 m).

ANOVA analysis showed significant differences between provinces and depths regarding the abundance of *A. calycularis* coverage, but there were no interactions between the two factors (Table 1). Regarding depth, the highest presence

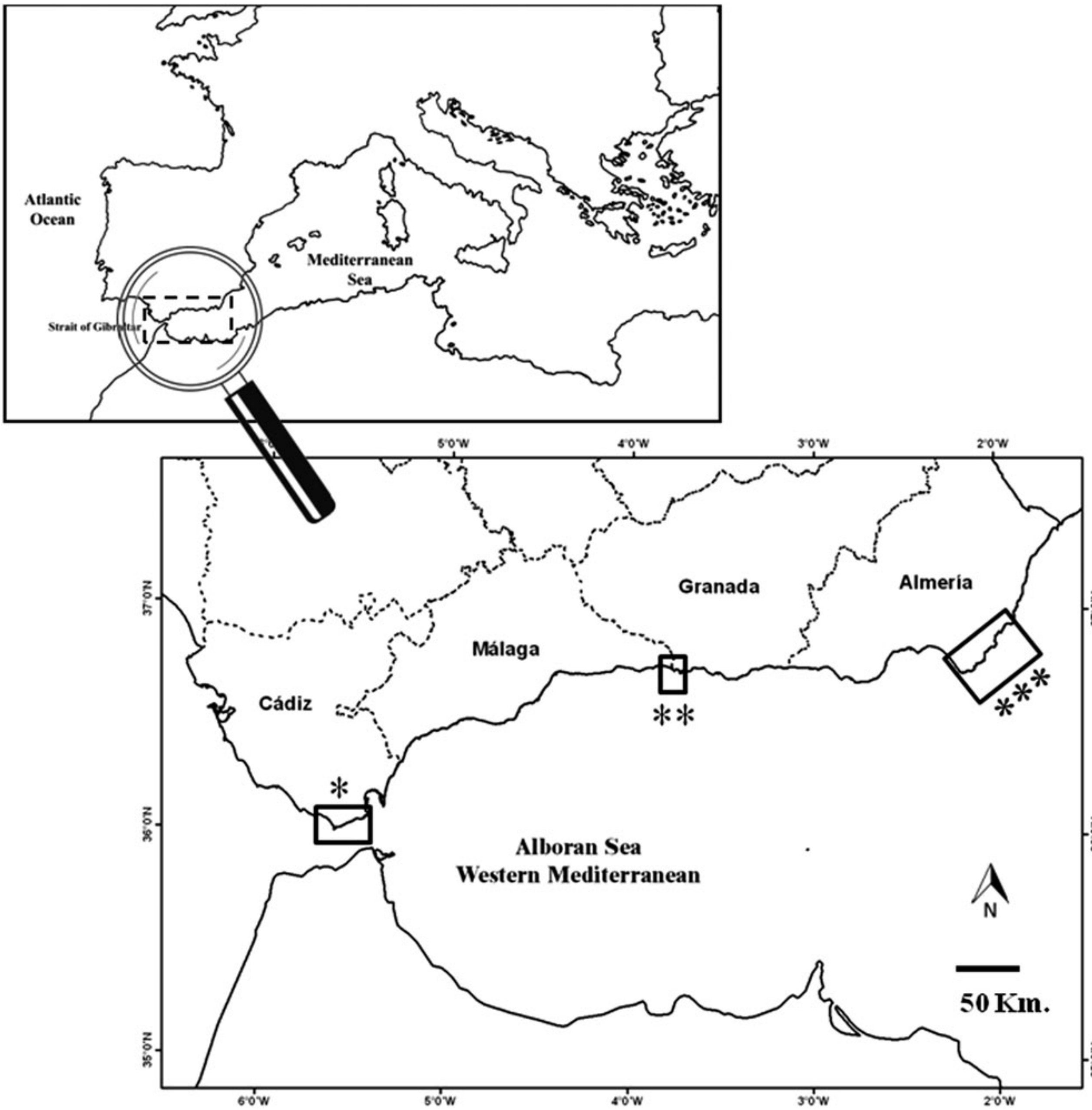

Fig. 1. Map of the study area (Andalusian coastal line; Spain). *Natural Park of the Strait of Gibraltar; **Natural Reserve of Maro-Cerro Gordo; ***Natural Park of Cape of Gata.

of *A. calycularis* was found at 3 m, with the presence decreasing at lower depths. The SNK test showed variation between provinces (Table 1), with a break between Cádiz, Granada, and the group formed by Málaga and Almería. This test also showed variation between depths, grouping 0–3 m with 3–6 m and 3–6 m with 6–12 m. Finally, complete data for all the points sampled are provided as a Supplementary Table (Appendix 1).

Raster analyses showed three areas where well-established populations could be found on the Andalusian coastline (Figure 5). The westernmost area was found to be in the Natural Park of the Strait of Gibraltar (Cádiz), which was also the biggest area. Here the population density was medium. Further east, a small area (which includes the Natural Reserve of Maro-Cerro Gordo) between Málaga and Granada had the highest abundance. The last area was found on the Castell de Ferro cliffs and the nearby area. This was not an MPA but had a high population density. The analysis showed that the population in the Natural Park of the Cape of Gata-Níjar was localized and had low density.

DISCUSSION

This study has established a current assessment of the distribution and abundance of *Astroides calycularis* populations in the Iberian Peninsula (in particular, the Andalusian coast). The purpose was to identify a population baseline for future studies. Previous studies in the region have only focused on species distribution (Zibrowius, 1980; López-González, 1993;

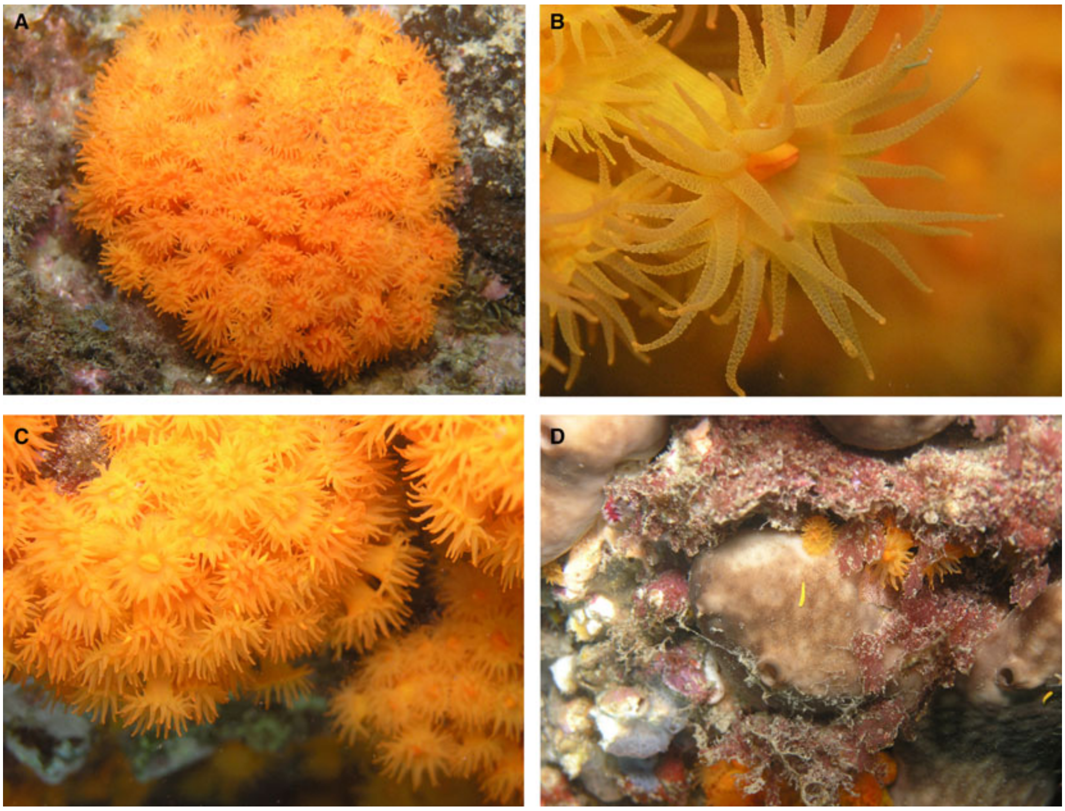

Fig. 2. The orange coral *Astroides calycularis*. (A) Colony from Granada coast. (B) Detail of a polyp extended. (C) Colony with some polyps with larvae in the tentacles. (D) Larvae on the sponge *Chondrosia reniformis*.

Ocaña *et al.*, 2000; Moreno *et al.*, 2008), and only a few have provided abundance data (Cebrián *et al.*, 2000; Moreno *et al.*, 2007). Furthermore, none have documented the entire Andalusian littoral zone, only some localities.

Our study area, the Alboran Sea, is a biodiversity hotspot in the Mediterranean Sea (Coll *et al.*, 2010). However, harbours and enclosures of medium-high to very-high impact (Micheli *et al.*, 2013a) create a fundamental problem of balancing human use with the conservation of nature (Micheli *et al.*, 2013b). In this area, urbanization appears to be a high threat to marine ecosystems (Malvárez García *et al.*, 2000; Costello *et al.*, 2010). This phenomenon increases pollution, local eutrophication, and water turbidity (Malvárez García *et al.*, 2000; Chapman, 2003; Mangialajo *et al.*, 2008).

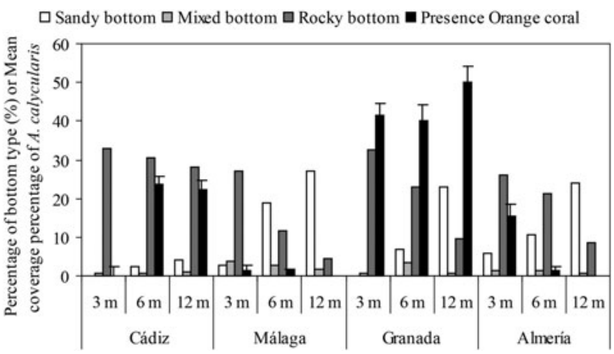

Fig. 3. Percentage of bottom type per provinces and depth and data of that *A. calycularis* appeared in the provinces; depths and abundance (mean coverage percentage and standard error of the mean).

Shallow marine assemblages (up to 10 m depth) can be considered good indicators of environmental change, because species living at shallow depths are particularly exposed to the impacts of coastal activities and thus tend to exhibit stronger responses to human pressure than assemblages from deeper habitats (Fraschetti *et al.*, 2002). Ocaña *et al.* (2009) already reported that *A. calycularis* is also affected by siltation caused by high coastal urbanization. The fragmented distribution of *A. calycularis* populations in the Andalusian shores has been clearly demonstrated and is certainly an effect of high urbanization. Interestingly, the three MPAs along the studied coastline enclosed the majority of the populations. Marine reserves have become a highly advocated form of marine conservation (Allison *et al.*, 1998). Given the high fecundity of many marine organisms, as well as evidence of limited larval dispersal distances, it is likely that reserves are able to maintain their own biodiversity while also servicing nearby non-reserve areas (Halpern & Warner, 2003). Many invertebrate populations located within the MPAs can act as source populations, as reported by some authors (e.g. Goñi *et al.*, 2003; Espinosa *et al.*, 2013).

On the other hand, orange coral populations are well established in some coastal zones, such as eastern Granada. These populations are far from urbanized areas and/or present difficulties in terms of access for recreational activities. This distribution pattern could support the hypothesis that *A. calycularis* is affected by urbanization stress and also, potentially, by high levels of siltation. Furthermore, orange coral could be considered a good indicator of well-oxygenated waters (García-Gómez, 2007; Casado-Amezúa, 2012). As a consequence, it can be concluded that the species is being increasingly affected

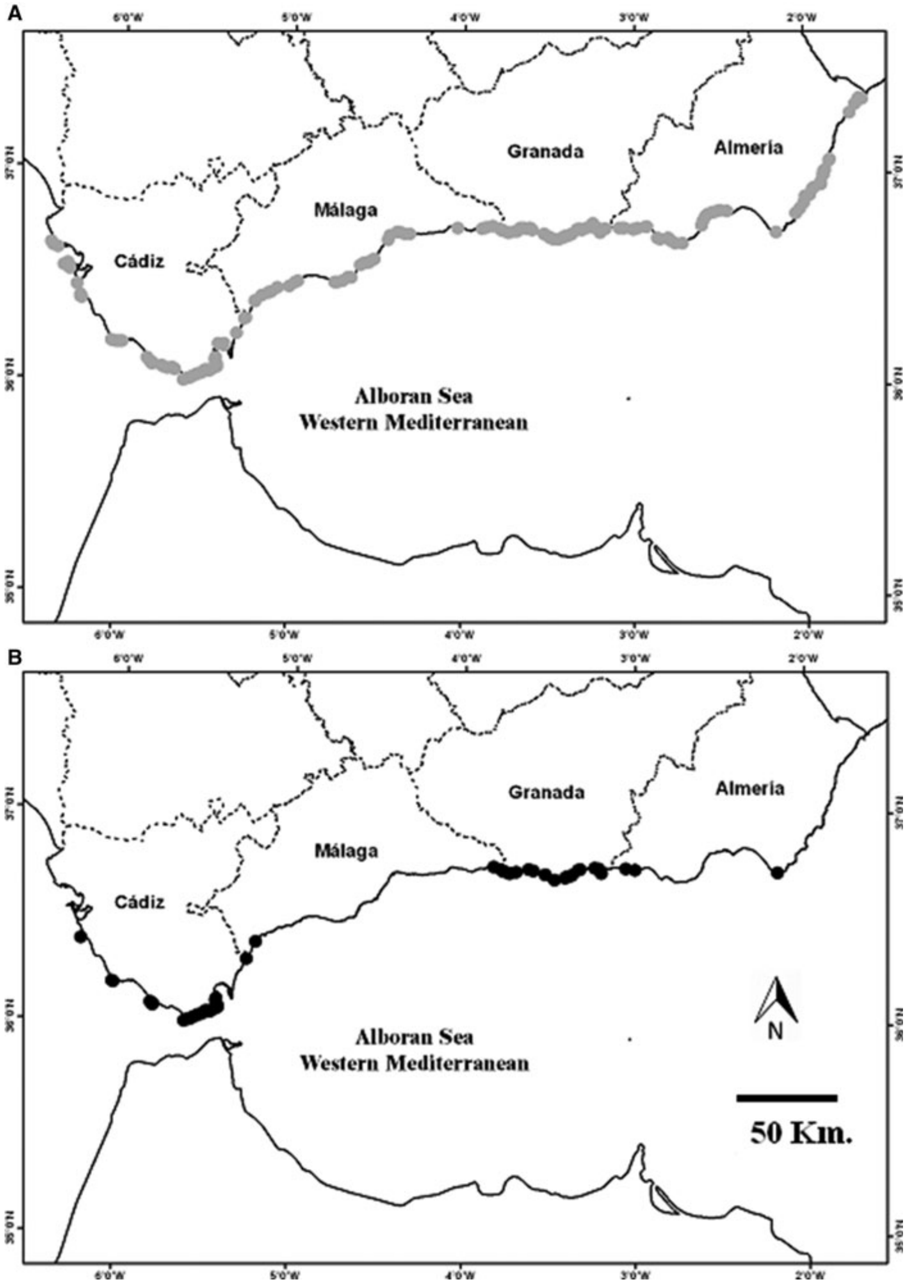

Fig. 4. Presence of *Astroides calycularis* along the shoreline studied. (A) grey circles show the points sampled; (B) black circles show the *A. calycularis* presence.

Table 1. Two-way ANOVA results for the influence of province and depth on the abundance of *Astroides calycularis*. Underlined provinces and depths corresponding with homogeneous groups based also on SNK test.

Source of variation	df	MS	F	*P*
Province	3	18,978	32,000	***
Depth	2	2983	5030	***
Pr × De	6	0.785	1323	n.s.
Residual	432	0.5917		
Total	443			
Cochran's C-test	C = 0.2178			
Transformation	None			

n.s. = not significant, $^{***}P < 0.01$

Ca Gr Ma Al 0–3 m; 3–6 m; 6–12 m

by coastal development. In fact, the extremely urbanized coastline of Malaga harbours scarce and isolated populations, suggesting that habitat fragmentation is a major threat to this species and could potentially lead to local extirpation of populations, thereby limiting the gene flow at different scales (Fauvelot *et al.*, 2009; Bulleri & Chapman, 2010).

It has already been demonstrated that recreational activities such as scuba diving or fishing can have negative effects on *A. calycularis* populations, because colonies can be damaged or removed by the impact of fins, hands and other diving equipment parts (Moreno *et al.*, 2008). Lloret *et al.* (2006) claimed that orange coral had a middle-level population in a dive-perturbation assessment. However, in Andalusian MPAs, scuba diving is allowed, and prohibitions of certain human activities are not totally effective (Linares *et al.*,

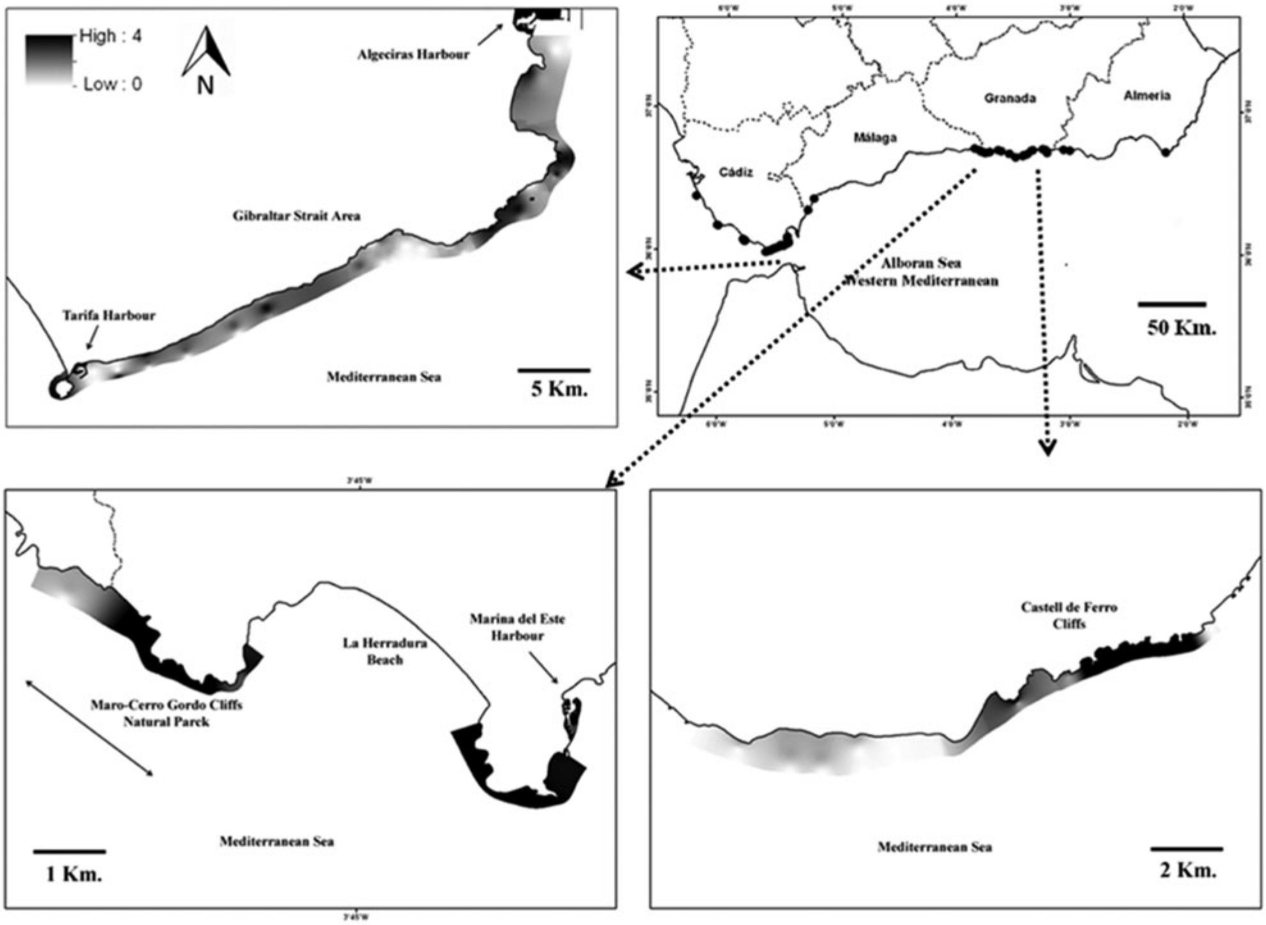

Fig. 5. Raster analyses of the three populations well-established on the Andalusian coastal line. Scale density: $0 =$ absence; $>0 < 1 =$ scarce; $>1 < 2 =$ moderate; $>2 < 3 =$ abundant; $>3 < 4 =$ very abundant.

2011). In this regard, some regulations such as a maximum number of divers per day could be applied, although the paucity of data and turnover rates for most organisms does not allow a quantitative estimate to be made of diver capacity (Sala *et al.*, 1996). These management measures could be greatly effective in preserving benthic invertebrate assemblages.

Moreno *et al.* (2007) reported *A. calycularis* abundances in some localities of the Andalusian coast. These authors observed the greatest abundances in Cádiz and Granada, reaching densities of 80–85%. We have already observed the highest abundance in these provinces, showing densities of 90–95%, but in Málaga the populations are localized inside MPAs. Nevertheless, these authors observed an abundance that reached 70% in only one locality – in an MPA of Almería. In the same locality, we only found a maximum density of 50%. These populations are isolated and should be monitored to understand their population dynamics and possible threats.

In the last decades, shallow bottoms have been monitored in several studies to evaluate mass mortality events of invertebrate populations in the Mediterranean (e.g. Cebrián *et al.*, 2011; Sala *et al.*, 2012; Serrano *et al.*, 2013). Following Goffredo *et al.* (2008), the demographic traits of coral populations may reveal relationships between the organisms and their environment and can be used to assess habitat stability and suitability. Therefore, the populations of this species should be studied in relation to the changes that could appear because of global changes.

Current observations suggest that an increase in the frequency of mass mortality events around the Mediterranean Sea is expected due to global climate change (Vargas-Yáñez *et al.*, 2008). In fact, Maldonado *et al.* (2010) have already observed mass mortality events in marine invertebrates along the Andalusian coastline. Mortality associated with these global phenomena can result from increases of 1–2°C above the mean sea temperature in the summer (e.g. Bensoussan *et al.*, 2010; Cebrián *et al.*, 2011). Therefore, knowledge of abundance and distribution of *A. calycularis* as a baseline would be of great interest. In this sense, monitoring programmes are an important tool (Calvo *et al.*, 2011) that will enable scientists to assess the orange coral populations and detect the possible impacts of human activities on the local, regional and global scale. In this way, environmental managers may be able to implement appropriate measures for species conservation.

Connectivity among environmental managers, researchers, NGOs, private agents and citizens is required. Setting up volunteer webs could be a good management tool when the species being studied covers large areas (Bramanti *et al.*, 2011). A simple qualitative and/or semi-quantitative sampling methodology will allow for routine collection of data about the targeted species' presence/abundance. These studies must be accompanied by temperature serial analyses by establishing control stations in MPAs or additional strategic localities. All of these data will show evidence of changes in coastal areas.

The knowledge of population dynamics through time and space is crucial, and therefore, baseline studies are also urgently required in order to implement management measures on the conservation, protection and restoration of endangered habitats and ecosystems.

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