Spatio-temporal macrofaunal assemblages associated with the endangered orange coral *Astroides calycularis* (Scleractinia: Dendrophylliidae)

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ABSTRACT: The orange coral *Astroides calycularis* is internationally protected due to its narrow distribution, its sensitivity to environmental changes and anthropogenic disturbance. Spatio-temporal macrofaunal assemblages associated with *A. calycularis* were studied along the southern coast of the Iberian Peninsula. A total of 878 invertebrate specimens were collected, comprising 81 species. At the 3 depths studied (0, 5 and 10 m), crustacean species were dominant in terms of abundance, followed by annelids and molluscs. Macrofaunal densities were higher in October and May, and lower in August and September. *Janira maculosa* (isopod), *Lembos* spp. (gammarid) and *Stenothoe cavimana* (gammarid) were the most abundant species, present in almost all depths and months. ANOVA analyses by month reflected significant differences in species richness and Shannon-Wiener diversity, but no differences among depth ranges and no interaction between time and depth. PERMANOVA analyses showed significant differences in the associated macrofauna for time and depth, but no interaction was observed between these factors. These results indicate the ecological relevance of this Mediterranean scleractinian coral as a habitat for many macrofaunal groups. Furthermore, the conservation of this endangered species contributes to the preservation of high marine biodiversity.

KEY WORDS: *Astroides calycularis* · Corals · Habitat · Associated macrofauna · Biodiversity · Conservation · Mediterranean Sea

INTRODUCTION

The Mediterranean Sea comprises less than 1% of the World Ocean (Defant 1961, Bianchi 2007) but harbours between 4 and 18% of the world's marine species, depending on the groups considered (Fredj et al. 1992, Bianchi & Morri 2000). Coll et al. (2010) listed approximately 17 000 marine species that are known to occur in the Mediterranean, although this number could be much higher. This marine biota includes a high number of endemic species (Roberts 1978, Giaccone 1999, Airoldi & Beck 2007), with endemics comprising more than one-quarter of all Mediterranean species (Tortonese 1985, Fredj et al. 1992, Giaccone 1999). Ten biogeographic sectors have been described in this temperate sea (Bianchi & Morri 2000). One of them, the Alboran Sea (Western Mediterranean), is a biodiversity hotspot due to its ecological importance as a result of the influx of Atlantic species and the physicochemical conditions of the area (Coll et al. 2010).

Despite the biodiversity found on hard substratum, there is relatively little information compared to studies conducted on soft substrata (Chintiroglou et al. 2005). Nevertheless, research regarding differences in distribution patterns on hard substratum have

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shown that the distribution and abundance of organisms differs among depths (Balata et al. 2006), and that the structure of benthic assemblages may change seasonally (Coma et al. 2000, Piazzi et al. 2004, Balata et al. 2005). Accordingly, bioconstructor species play an important role, increasing habitat complexity and biodiversity (e.g. Bianchi & Morri 1996, Porras et al. 1996, Cocito 2001). In the Mediterranean Sea, *Cladocora caespitosa* (a shallow-water zooxanthellate scleractinian coral), *Lophelia pertusa* and *Madrepora oculata* (a deep-water azooxanthellate scleractinian corals) are recognized as the main bioconstructors (see Kružić 2014). The fauna associated with these species has been the subject of some research (Koukouras et al. 1998, Antoniadou & Chintiroglou 2010, D'Onghia et al. 2010, Mastrototaro et al. 2010, Calcinai et al. 2013, Kružić et al. 2013); however, none of these studies have assessed the spatio-temporal variability of the macrofaunal assemblages associated with temperate corals.

Astroides calycularis (Pallas, 1766) is an azooxanthellate scleractinian colony coral with a carbonate calcium exoskeleton (Zibrowius 1980, 1983). It inhabits rocky shores from the surface to 50 m depth (Rossi 1971, Ocaña et al. 2000) but is typically found in the shallow infralittoral zone (0 to 15 m depth), on vertical walls or inside caves (Cinelli et al. 1977, Zibrowius 1978, Kružić et al. 2002). It occupies both light and dark environments and appears to prefer a high hydrodynamism (Cinelli et al. 1977, Zibrowius 1978, 1995, Kružić et al. 2002). Population density can be locally high; throughout our study site coverage of up to 90% can be found (Terrón-Sigler et al. 2008). *A. calycularis* is endemic to the Mediterranean Sea, present in Italy between the Sicilian and Messina Strait and the Gulf of Naples, and in the Iberian Peninsula from the Strait of Gibraltar to Palos Cape (Murcia). It is also found in Malta, Tunis, Algeria, Morocco, Ceuta and Melilla (Spain), and it also occurs in Atlantic waters in Espartel Cape (Morocco) and La Caleta (Cádiz, Spain) as the most westerly populations (Zibrowius 1983, 1995, Bianchi 2007), probably due to the currents dispersing larvae out of the Strait of Gibraltar (Ocaña et al. 2000, Casado-Amezúa 2012, Casado-Amezúa et al. 2012).

A. calycularis is protected by national and international organisations as an endangered species (i.e. the Bern and Barcelona Conventions and CITES). Nevertheless, its relevance as a habitat for macrofaunal community has never been studied. Therefore, the aim of this study was to show the role of *A. calycularis* as a possible habitat for macroinvertebrate fauna.

MATERIALS AND METHODS

This study was conducted in Marina del Este beach (Granada coast, Andalusia, Spain) from August 2010 to July 2011 (Fig. 1). Colonies were collected monthly by SCUBA diving at 3 depths: 0, 5 and 10 m, selected as higher populations of this species occur in this depth range along the Andalusian coast (Terrón-Sigler & León-Muez 2009). We chose a site with a rocky substrate with similar coverage of *Astroides calycularis* (between 50 and 75% cover) at the 3 depths. Cebrián & Ballesteros (2004) described the zonation of the rocky benthic communities in this area, and concluded that depth was the main axis of variation. These authors observed differences among communities between lower depths (25 m) and the shallow infralittoral zone (5 m).

A total of 67 *A. calycularis* colonies were collected at 3 different depths: 22 colonies at 0 m, 23 colonies at 5 m and 22 colonies at 10 m. Colonies were covered *in situ* with plastic bags before they were removed in order to retain all associated fauna. The samples were fixed in 4% formalin and subsequently placed in 70% ethanol in the laboratory. The colonies were washed, the macrofauna sieved using a 0.5 mm mesh size, and the specimens collected were sorted and identified to species level where possible. We expressed the density of the macrofauna as the number of individuals per volume (1000 ml) of colony. Volume of *A. calycularis* colonies was estimated as the difference between the initial and final volume when placed into a graduated cylinder with a fixed amount of water (see Pereira et al. 2006). Moreover, colony length (L_c, major axis of the colony) and colony width (W_c, minor axis of the colony) were measured, and colony area (A_c) was calculated using the formula for an ellipse ($A_c = \pi[L_c \times W_c] / 4$), according
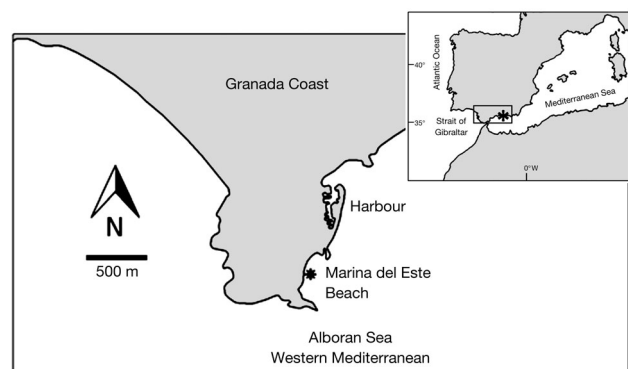

Fig. 1. Study site showing Marina del Este beach (Andalusia, Spain), where the colonies of *Astroides calycularis* were collected

to Goffredo et al. (2011). The number of polyps and biovolume were also studied. We selected colony area as the main biometric parameter because it is a more accurate and representative measure of colony size than colony length (Bak & Meesters 1998, Meesters et al. 2001, Vermeij & Bak 2002, Nozawa et al. 2008, Goffredo et al. 2011).

All collected colonies reached in total 989 ml of biovolume, with a mean of 15 ml colony^{-1}. To standardize individual abundance since colonies had different biovolumes, we calculated abundance for 1000 ml of coral volume, and estimated a mean of 1223 individuals based on a colony volume of 1000 m.

The abundance of the associated macrofauna was calculated for each colony, and the total number of species (S) and Shannon-Wiener diversity (H') (Shannon & Weaver 1963) were obtained. To test whether S and H' of macroinvertebrate assemblages were similar across depth and time, we used a multifactor ANOVA with time and depth as factors (orthogonal to each other and fixed), with 6 levels for time (February, March, April, May, June and July) and 3 levels for depth (0, 5 and 10 m); 3 replicates were collected for both factors. Prior to ANOVA, the heterogeneity of variance was tested via Cochran's C-test. Univariate analyses were conducted with GMAV5 (Underwood et al. 2002). When statistical differences were detected, *a posteriori* Student-Newman-Keuls test was applied.

A permutational multivariate ANOVA (PERMANOVA) was used to test differences in associated macrofaunal assemblages across depth and time, both as fixed factors. Data were square-root transformed and a similarity matrix was calculated using the Bray-Curtis index. The percentage similarity procedure (SIMPER) was then used to calculate the contribution of each species to the dissimilarity between depths and months. Multivariate analyses were carried out using the PRIMER v6 + PERMANOVA package (Clarke 1993).

RESULTS

Biometric analyses

Colony length, width, biovolume and number of polyps all correlated positively with colony area, whose variation explained 72.5

to 94.4% of the variance. Colony length, width, biovolume and colony area all correlated positively with the number of polyps, whose variation explained 63.3 to 73.0% of the variance (Fig. 2).

Colony length, width, biovolume and number of polyps were also positively correlated with colony area for all depths. However, this correlation was greater for deeper sites: variances were 50.5 to 89.9% at 0 m, 75.2 to 90.8% at 5 m and 79.0 to 97.3% at 10 m. The highest correlation was between length and width of the colony, and colony area at each depth, but these correlations were stronger for deeper sites: 89.1 to 89.9% at 0 m, 90.3 to 90.8% at 5 m and 96.5 to 97.3% at 10 m. The weakest correlation was between colony area and number of polyps at 0 m (explained 50.5% of the variance).
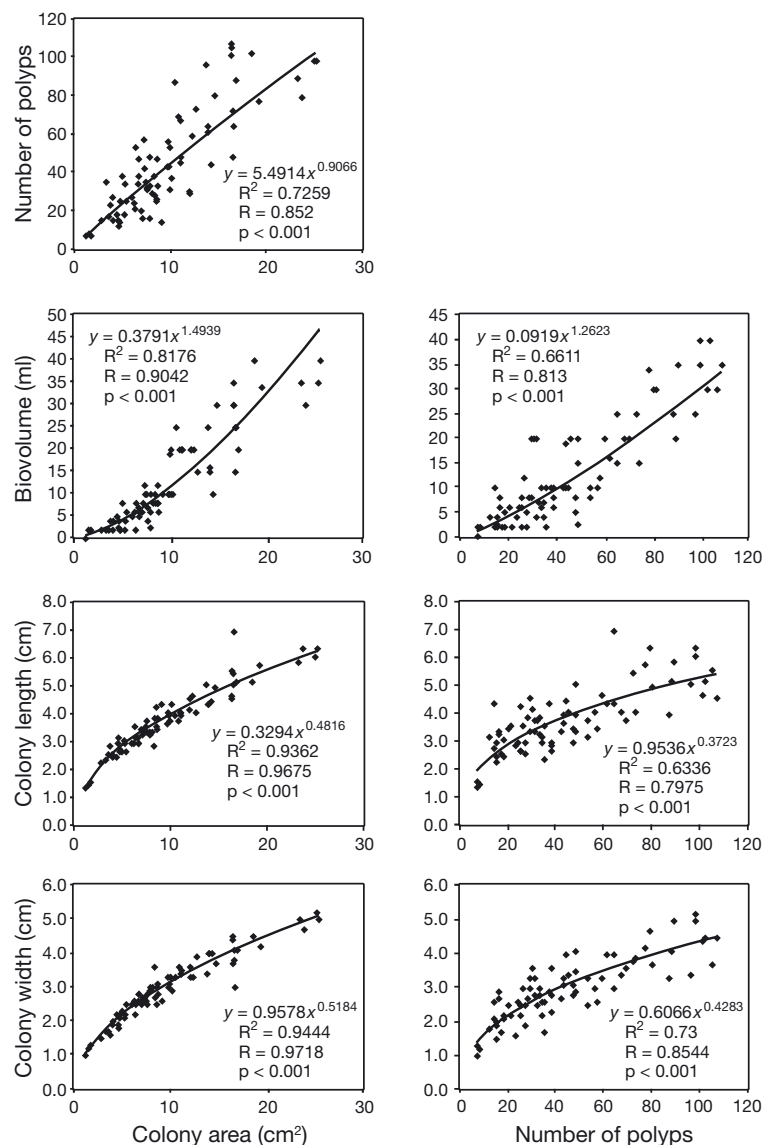

Fig. 2. Biometric analyses based on pooled data for all depths

Within colony area, biovolume, length and colony width were positively correlated with the number of polyps in all cases, differences in which explained 41.0 to 62.4 % of the variance at 0 m, 61.5 to 75.2 % at 5 m and 64.3 to 82.2 % at 10 m. Again, the correlations were stronger for deeper sites. Overall, colony area had a better positive correlation with the other variables than the number of polyps in the colony (Fig. 2).

Associated fauna

Invertebrate community structure

A total of 81 species were identified out of 878 invertebrate specimens that were sorted and examined (Table 1). Of these, almost 80 % were crustaceans, followed in importance by annelids (more than 16 %), molluscs (2.85 %), echinoderms (2.85 %), cnidarians (0.11 %) and platyhelminths (0.11 %). In this study, 38 different species of crustaceans were identified: 14 species of gammarids, 7 decapods, 6 caprellids, 4 isopods, 4 tanaids, 2 cumaceans and 1 barnacle. The most abundant crustacean group was gammarids (more than 68.5 %), followed by isopods (20.8 %). In fact, almost 90 % of the crustacean specimens belonged to these 2 taxa. The most common species collected were *Stenothoe cavimana* and *Lembos* spp. (gammarids) and *Janira maculosa* (isopod). These species comprised almost 77 % of the crustacean abundance associated with *Astroides calycularis* colonies.

From the annelid group, 27 polychaete species belonging to 4 orders were identified (Table 1). The most representative order in terms of number of species and specimens was Phyllodocida, with 16 species, the dominant species of which were *Nereis zonata* and *Syllis* spp. Both species represented 41 % of the specimens belonging to this order. The order Sabellida was second in terms of abundance, with 7 species and 15.6 % of the specimens identified; *Vermiliopsis infundibulum* was the most abundant species. In the order Eunicida, 3 species were identified that contributed 12.1 % to the annelid total; *Lumbrineris coccinea* was the dominant species. The order with the lowest species number was Spionida, with only 1 species identified.

The 9 species of molluscs identified consisted of bivalves (3 species), gastropods (5 species) and polyplacophorans (1 species); the bivalve *Gregariella semigranata* was the most common (Table 1).

Echinoderms, cnidarians and platyhelminths were rare and represented only 1.1 % of the specimens identified. The specimens of the abovementioned groups were all juveniles.

Abundance

In colonies harvested at 0 m depth, we found 245 specimens, with a mean of 892 ind. l^{-1} (24.2 %) in terms of density for the whole volume estimated at this depth. Crustacean species dominated (77.4 % of the total group), and 3 species accounted for more than 56 % of the crustacean specimen total; *S. cavimana* (gammarid), *J. maculosa* (isopod) and *Lembos* spp. (gammarid). The second group in terms of density was the annelids (21.2 %), with 1 dominant species: *Perinereis cultrifera* (almost 6 % of the total specimen density). Molluscs, cnidarians and echinoderms represented only 1.3 % of the total.

At 5 m depth, we identified 408 specimens and estimated their abundance to be 957 ind. l^{-1} (26 % of the total). The crustacean group was dominant, constituting 78.9 % of the fauna at 5 m depth, with 3 principal species in terms of density: *S. cavimana* (gammarid), *Lembos* spp. (gammarid) and *J. maculosa* (isopod). These species comprised 57.9 % of the total invertebrate assemblage. Annelids constituted 15.7 % of the total density, but there were no dominant species among the 20 annelid species identified, with all species having equal representation. Molluscs and echinoderms accounted the remaining 5.5 %.

At the deepest site (10 m), we found a total of 260 specimens, representing 1832 ind. l^{-1} (49.8 % of the total). Crustacean species accounted for 61.4 % of this assemblage, including *Lembos* spp. (gammarid), *J. maculosa* (isopod) and *S. cavimana* (gammarid). Although one crustacean species, *Microdeutopus armatus*, reached 1000 ind. l^{-1}, this species appeared only in 1 sample. The remaining groups were molluscs (28.5 %), annelids (9.3 %), echinoderms (0.5 %) and platyhelminths (0.1 %).

In summary, we observed the greatest abundance at greater depth. At all 3 depths, crustaceans were the dominant group, with *Lembos* spp. (gammarid), *J. maculosa* (isopod) and *S. cavimana* (gammarid) being the most abundant species. After crustaceans, annelids and molluscs appeared at all depths and were the most important fauna. Nevertheless, these taxa showed approximately the same proportion at each depth. Finally, echinoderms, cnidarians and platyhelminths were clearly present but did not appear at all depths.

On a monthly basis, the density of specimens was similar, although some months (i.e. October and

Table 1. Mean abundance (ind. l^{-1}) of the macroinvertebrate species associated with *Astroides calycularis*

	2010			2011							Depth (m)		
	Aug	Sep	Oct	Jan	Feb	Mar	Apr	May	Jun	Jul	0 m	5 m	10 m
ARTHROPODA													
Isopoda													
Janira maculosa	167	–	300	150	79	37	61	101	90	187	79	76	160
Munna sp.	–	–	–	–	–	–	–	–	–	19	–	7	–
Paragnathia formica	–	–	100	–	–	16	–	–	4	14	17	8	3
Stenosoma capito	–	–	–	–	–	–	–	–	–	2	–	1	–
Amphipoda													
Gammaridea													
Amphilochus spencebatei	–	–	–	–	–	–	–	–	22	–	–	–	9
Apocorophium acutum	–	–	–	–	–	–	56	–	–	–	–	–	23
Autonoe spiniventris	–	–	–	–	–	–	–	7	47	2	–	11	12
Elasmopus pocillimanus	–	–	–	–	37	–	6	–	–	–	17	–	–
Eusiroides dellavallei	–	–	–	–	–	–	14	–	–	–	6	–	–
Lembos spp.	–	–	33	–	79	154	233	1304	–	381	41	177	658
Lembos websteri	–	–	–	50	64	30	11	–	22	2	6	20	33
Leucothoe spinicarpa	–	–	33	17	33	–	17	–	–	4	–	28	–
Liljeborgia dellavallei	–	–	–	–	–	–	6	–	7	–	5	–	–
Liljeborgia psaltrica	–	–	100	–	–	–	–	19	17	13	8	21	4
Maera sp.	42	–	–	–	–	–	–	–	–	–	8	–	–
Microdeutopus armatus	83	–	367	–	–	–	–	–	–	–	–	19	45
Stenothoe cavimana	–	–	633	100	267	517	222	354	244	132	389	300	108
Stenothoe monoculoides	–	–	–	100	37	–	–	–	–	3	1	13	15
Caprellidea													
Caprella sp.	–	–	–	–	6	–	–	–	–	–	–	2	–
Caprella acanthifera	42	–	–	–	–	–	22	–	6	–	–	18	–
Caprella grandimana	–	–	–	–	–	–	–	–	–	3	–	–	1
Caprella penantis	–	–	–	–	–	14	–	–	–	–	6	–	–
Pseudoprotella phasma	–	–	–	17	–	–	17	–	–	–	–	–	9
Phtisica marina	–	–	–	–	22	–	–	19	–	15	8	9	5
Cumacea													
Cumella limicola	–	–	–	–	–	–	–	–	4	9	–	2	2
Cumella pygmaea	–	–	33	–	–	–	–	–	–	–	–	4	–
Tanaidacea													
Apseudes sp.	–	–	–	–	–	–	–	3	–	6	–	2	1
Apseudes talpa	–	–	167	–	–	–	–	–	–	–	–	–	23
Leptochelia dubia	42	–	–	17	–	–	–	59	–	18	36	1	4
Tanais dulongii	–	–	33	–	–	–	44	37	–	–	36	–	2
Decapoda													
Alpheus glaber	–	–	–	–	–	–	–	–	–	5	–	2	–
Anapagurus laevis	–	–	33	–	–	–	–	–	–	–	–	4	–
Galathea nexa	–	–	33	–	4	–	–	–	–	–	–	4	2
Pilumnus hirtellus	–	–	33	33	–	14	6	4	–	7	14	7	1
Periclimenes sp.	–	–	–	–	–	–	–	–	4	–	–	1	–
Processa edulis	–	–	67	17	48	–	–	–	–	–	15	13	2
Pasiphaea sivado	–	–	–	–	–	–	–	–	–	5	–	2	–
Cirripeda													
Balanus sp.	–	–	–	–	8	–	–	–	–	–	2	–	2
Chelicerata													
Pycnogonida indet	–	–	–	–	–	–	–	–	3	–	–	1	–
MOLLUSCA													
Bivalvia													
Arca noae	–	–	–	–	–	–	–	3	–	–	–	1	–
Gregariella semigranata	–	–	–	–	–	–	–	1111	31	17	3	4	467
Modiolus barbatus	42	–	–	–	–	–	–	–	–	–	–	7	–
Gastropoda													
Coralliophila sp.	–	–	–	–	–	–	–	7	3	7	–	4	3
Diodora gibberula	–	–	–	–	–	–	–	–	3	–	–	1	–
Nassarius sp.	–	–	–	–	–	–	–	7	–	3	–	3	1
Nassarius incrassatus	–	–	–	–	–	–	–	–	94	–	–	–	39
Nassarius reticulatus	–	–	–	–	–	–	–	–	28	2	–	1	11
Polyplacophora													
Chiton sp.	–	167	–	17	–	–	–	–	–	–	–	24	–

Table 1 (continued)

	2010			2011							Depth (m)		
	Aug	Sep	Oct	Jan	Feb	Mar	Apr	May	Jun	Jul	0 m	5 m	10 m
CNIDARIA													
Actinia sp.	–	–	–	17	–	–	–	–	–	–	2	–	–
PLATYHELMINTHES													
Turbellaria indet.	–	–	–	–	–	–	–	–	–	3	–	–	1
ANNELIDA													
Eunicida													
Lumbrineris coccinea	–	–	–	–	–	–	–	28	11	34	2	18	10
Hilbigneris gracilis	–	–	–	–	–	–	–	–	–	3	–	–	1
Scoletoma sp.	–	–	–	–	6	–	–	–	–	2	–	3	–
Phyllodocida													
Glycera sp.	–	–	–	33	45	67	56	–	6	–	41	2	32
Glycera tesselata	–	–	167	–	–	–	–	–	–	–	–	–	23
Lepidonotus clava	–	–	–	–	4	19	–	9	–	3	–	7	7
Neanthes irrorata	–	–	33	–	–	–	–	–	–	–	–	4	–
Nereis sp.	–	–	–	–	–	–	–	–	–	2	–	1	–
Nereis zonata	–	–	–	–	–	–	–	19	19	60	16	8	15
Perinereis sp.	–	–	–	–	–	22	–	–	–	2	–	9	–
Perinereis cultriífera	42	167	–	–	4	–	28	–	4	–	25	9	11
Pholoe minuta	–	–	–	–	–	–	–	–	11	3	–	–	6
Phyllodoce sp.	–	–	–	–	–	–	–	–	3	2	–	2	–
Platynereis dumerilii	–	–	33	17	10	36	11	7	7	5	21	17	–
Syllis spp.	–	–	167	–	28	16	11	37	19	8	32	11	27
Syllis gracilis	42	–	33	33	–	–	–	–	–	16	17	3	4
Syllis hyaline	–	–	33	–	–	–	–	–	–	3	5	–	1
Syllis variegate	–	–	–	–	–	–	–	–	3	3	–	1	1
Websterinereis glauca	–	–	–	–	–	–	–	4	16	9	10	–	1
Sabellida													
Branchiomma sp.	–	–	–	–	–	–	–	–	–	3	–	–	1
Hydroides pseudouncinatus	–	–	–	–	–	–	11	–	–	–	–	4	–
Protula tubularia	–	–	–	–	11	–	–	–	–	–	–	4	–
Sabella sp.	–	–	–	–	–	–	–	–	56	7	3	–	23
Serpula sp.	–	–	–	–	–	19	–	–	–	6	–	7	2
Serpula concharum	–	–	–	–	26	–	–	–	–	–	–	9	2
Vermiliopsis infundibulum	–	167	67	50	–	22	11	–	–	–	18	30	2
Spionida													
Spionidae sp.	–	–	–	–	–	–	–	–	–	6	–	1	1
ECHINODERMA													
Ophiuroidea													
Amphiura sp.	–	–	–	–	6	–	–	–	–	–	–	2	–
Ophiura ophiura	–	–	–	–	–	–	28	4	–	12	2	4	13
Holothuroidea													
Holothuroidea indet.	–	–	–	–	–	–	11	–	–	–	5	–	–
Equinoidea													
Paracentrotus lividus	–	–	–	–	–	–	–	–	–	3	–	–	1

May) showed higher densities, whereas densities in August and September were lower. *Lembos* spp. (gammarid), *J. maculosa* (isopod) and *S. cavimana* (gammarid) were present in almost all months in a similar proportion.

Species richness (*S*) and Shannon-Wiener diversity (*H'*)

Monthly counts of *S* and *H'* showed significant differences (Table 2), increasing considerably in July (Fig. 3) to values double those of the other months. No differences were detected for *S* and *H'* in terms of depth, but the greatest value was achieved at 5 m depth (*S* = 6.22 ± 1; *H'* = 1.3 ± 0.13) (Table 2, Fig. 3). Additionally, there was no recorded interaction between time and depth (Table 2).

PERMANOVA analyses showed significant differences in invertebrate assemblages associated with *A. calycularis* colonies for time and depth (p < 0.001), although no interaction was observed between these factors (Table 3).

Table 2. Results of the 2-factor ANOVA for Shannon-Wiener diversity and species richness for the macrofauna assemblage associated with *Astroides calycularis*. NS: not significant; ***p < 0.001

Source of variation	df	Species richness (S)			Shannon diversity (H')		
		MS	F	p	MS	F	p
Time	5	2,9025	12,10	0.0000***	1,3708	5,85	0.0005***
Depth	2	0,4771	1,99	0.1516	0,2186	0,93	0.4030
Time × Depth	10	0,3019	1,26	0.2896	0,3745	1,60	0.1471
Residual	36	0,2399			0,2345		
Total	53						
Cochran's C-test		C = 0.2673 NS			C = 0.1653 NS		
Transformation		Sqrt			None		
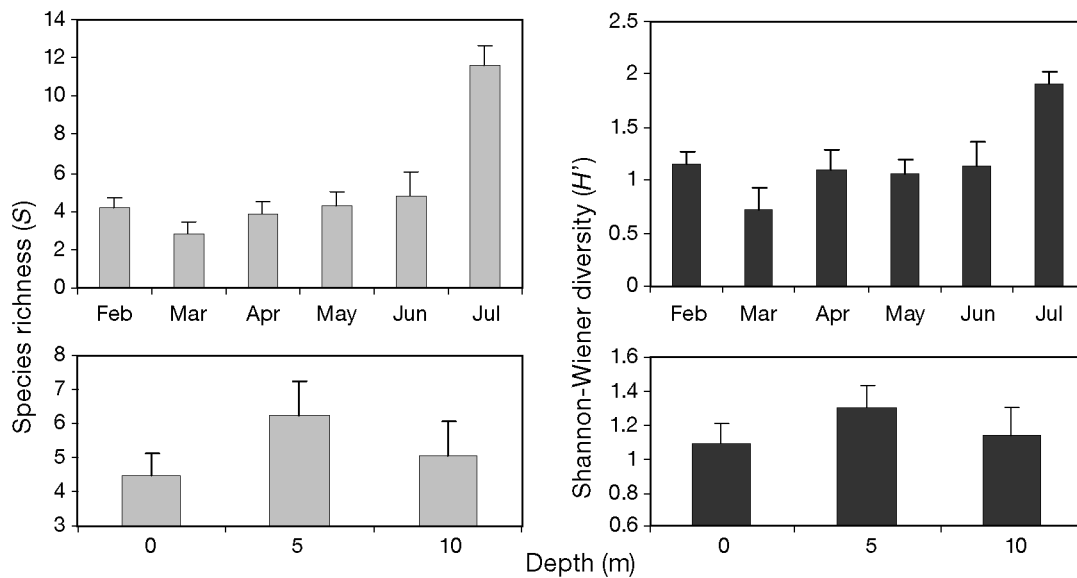
Fig. 3. Temporal and bathymetric changes in species richness and Shannon-Wiener diversity of macrofauna associated with *Astroides calycularis*, monthly and by depth. Data are mean + SE

DISCUSSION

To our knowledge, there have been no spatio-temporal studies on invertebrate communities associated with scleractinian corals in the Mediterranean Sea, despite the fact that information concerning these associated assemblages is crucial towards understanding the trophic web connections and health of marine ecosystems and habitats. Although there have been studies regarding species associated with scleractinian corals in the Mediterranean Sea (Koukouras et al. 1998, Castellanos et al. 2003, Richter & Luque 2004, Conradi et al. 2006, Taviani et al. 2009, Antoniadou & Chintiroglou 2010), these studies have contributed little towards our knowledge of the associated communities' spatio-temporal patterns. This is the first spatio-temporal study concerning the entire macroinvertebrate community associated with

Astroides calycularis (Scleractinian; Dendrophylliidae). Knowledge of this species and its associated community composition will provide information about ecosystem health, as well as Mediterranean habitats and species (García-Gómez 2007).

Biometric analyses

Goffredo et al. (2011) reported positive correlations between colony length, width or the number of polyps and colony area, and between colony length, width or area and the number of polyps on colonies of *A. calycularis* in Italy at 7 to 10 m depth. Colony area and polyp number explained 74.7 to 91.6% and 68.7 to 90.9% of the variance, respectively, in that study. In our study, we record similar results, with 72.5 to 94.4% and 63.3 to 73.0% of the variance, respec-

Table 3. Results of PERMANOVA analysis for macrofauna assemblages associated with *Astroides calycularis*, based on Bray-Curtis dissimilarities of square root transformed data. NS: not significant; *p < 0.001

Source of variation	df	MS	F	p
Time	9	5760,9	2,1953	0.001*
Depth	2	6740,8	2,5687	0.001*
Time × Depth	16	2968,9	1,1314	0.155
Residual	36	2624,1		
Total	63			
Transformation		Sqrt		

tively. We also show that these correlations are stronger at greater depths (0 < 5 < 10 m). Similar to Goffredo et al. (2011) with the same species, and to findings of other authors who studied different scleractinian corals (e.g. Vermeij & Bak 2002, Nozawa et al. 2008), we report that colony area, as a representative colony size parameter throughout the coral's life history, is a good parameter for wildlife managers interested in understanding the dynamics of coral populations. Moreover, we demonstrate that it is necessary to take into account the depth of colonies, because colony area changes according to physical (e.g. hydrodynamic, depth, sedimentation) or biological (e.g. symbiosis, competition, and predation) conditions (Zibrowius 1980, Chevalier & Beauvais 1987).

Associated fauna

In the Mediterranean Sea, *Cladocora caespitosa* is the only shallow-water scleractinian coral that may be considered as an ecosystem engineer (Peirano et al. 1999, Morri et al. 2001), forming large colonies with considerable interstitial space that provides habitat for a high diversity of associated fauna (Koukouras et al. 1998). Indeed, in the Eastern Mediterranean, studies of *C. caespitosa* have demonstrated high zoobenthos biodiversity associated with this coral, with up to 242 associated macrobentic species (Koukouras et al. 1998, Antoniadou & Chintiroglou 2010). Globally, annelids are the dominant species associated with these colonies, followed by molluscs and crustaceans. These studies concur that the associated assemblages are probably differently structured among individual colonies and banks. In the present study, we found 81 macroinvertebrate species associated with *A. calycularis* and noted clear differences between depth and season, with crustaceans being the dominant species, followed by annelids and molluscs. Similarly, *C. caespitosa* showed

crustacean dominance in shallow waters while polychaetes were dominant in deeper waters (Koukouras et al. 1998). Moreover, in one study regarding the epifaunal assemblages associated with 2 gorgonians (*Eunicella gazelle* and *Leptogorgia lusitanica*) from the south of the Iberian Peninsula, the dominant group was arthropods (mainly crustaceans), followed by molluscs and annelids (Carvalho et al. 2014).

In the Western Mediterranean Sea, many studies have focused on macrofaunal assemblages associated with algae. Seaweeds have an important role as a spatial complex within the substratum, creating a 3-dimensional habitat that increases species richness and diversity relative to unvegetated habitats (Dean & Connell 1987). Other studies have described the associated fauna that inhabits algae throughout the Alboran Sea (Mediterranean area), and all have shown the prevalence of crustaceans over other groups such as annelids, molluscs and echinoderms (Sánchez-Moyano & García-Gómez 1998, Sánchez-Moyano et al. 2000, Izquierdo & Guerra-García 2011, Pacios et al. 2011, Guerra-García et al. 2006, 2009a, 2012), as also occurs in *A. calycularis*. Guerra-García et al. (2011) identified 41 crustacean species on *Asparagopsis armata*, whereas for *Corallina elongata*, one of the most important algae in the intertidal ecosystem (Pérez-Cirera & Maldonado 1982, Guerra-García et al. 2006), a total of 78 crustacean species were found (Izquierdo & Guerra-García 2011). We found 39 crustacean species, a value similar to those reported for algae. Guerra-García et al. (2011) indicated that the different faunal composition on 4 species of algae might be due to the differences in algal morphology. *C. elongata* and *A. armata* are native and invasive seaweeds, respectively, in the Mediterranean Sea that cohabit with *A. calycularis* in our study area and maintain a high diversity of peracarid crustacean assemblages (Pacios et al. 2011, Guerra-García et al. 2012). The most common associated species hosted by *C. elongata* are *Caprella penantis* (caprellid) and *Stenothoe monoculoides* (gammarid), among others (Guerra-García et al. 2010). Alternatively, *A. armata* hosts *Aora spinicornis*, *Apherusa bispinosa*, *Dexamine spiniventris* (gammarids) and *Dynamene magnitorata* (isopod) as dominant species (Pacios et al. 2011, Guerra-García et al. 2012). *Janira maculosa* (isopods), *Lembos* spp. (gammarid) and *Stenothoe cavimana* (gammarid) are the dominant species associated with *A. calycularis* colonies. Therefore, peracarid species were different from those reported on both seaweeds, and only the genera *Stenothoe* (gammarid) is common between *A. calycularis* and *C. elongata*. Thus, macrofaunal assemblages appear to be host-

dependent. Furthermore, the bright orange colour of the 2 dominant species observed in *A. calycularis* (*J. maculosa* and *S. cavimana*) suggests a relationship between the coral and its associated species. The nature of this relationship (obligated/facultative, see Castro 1976 or trophic/cryptic) still needs to be clarified.

On the other hand, both *Stenothoe* spp. and *Lembos websteri* were associated with *C. caespitosa*, but neither was dominant. *Leucothoe spinicarpa* and the genera *Lilgeborgia*, *Microdeutopus* and *Maera* were common in both scleractinian species, being dominant in the *C. caespitosa* colonies from shallow waters (Koukouras et al. 1998).

Several species from genera *Gnathia* (isopods) have been described in association with *A. calycularis* in the south side of Alboran Sea, some of them being very abundant (Castellanos et al. 2003); however, this genus did not appear in our study. A plausible hypothesis would be that the authors could have mixed species from adjacent substrates with those associated with *A. calycularis* as a result of the methods used to collect them. They removed the colonies directly, without using plastic bags to isolate the associated assemblages. Alternatively, the genus *Gnathia* is absent or rare on samples of many seaweeds (*Stypocaulon*, *Asparagopsis* and *Corallina*) along the north side of the Alboran Sea (Guerra-García et al. 2009b, Izquierdo & Guerra-García 2011, Pacios et al. 2011, Soler & Guerra-García 2011). Therefore, it can be expected that this genus would also be absent from *A. calycularis* colonies in this area.

Some genera of decapods were found associated with *A. calycularis* in the present study (*Anapagurus*, *Galathea*, *Pilumnus*, *Periclemenes* and *Alpheus*). All of these genera have been reported from coralligenous assemblages in the Alboran Sea (García-Muñoz et al. 2008). In the Eastern Mediterranean Sea, the genera *Galathea*, *Pilumnus*, *Periclemenes* and *Alpheus* were associated with *C. caespitosa*, but no single genus was dominant (Koukouras et al. 1998).

Annelids were the second most important group within the macrofaunal assemblages associated with the orange coral. Nevertheless, there were no dominant species; only *Perinereis cultrifera* (polychaete) reached a high abundance at 0 m depth. In the Chafarinas Islands, López (1995) identified polychaetes in dead colonies of *A. calycularis*, but no type of relationship was reported. Annelids are generalist habitat species, and it is the physical and/or environmental factors (e.g. depth) of an area that influence their preference to settle in different substrata. However, polychaetes were dominant in deeper colonies of *C.*

caespitosa, common species being *Hydroides pseudo- uncinatus*, *Lepidonotus clava*, *Lumbrineris coccinea* and *Syllis gracilis* (Koukouras et al. 1998).

Scleractinian corals act as structural engineers (Jones et al. 1994), contributing to an increase in habitat complexity and surface topography, which promotes biodiversity by mediating competition or predation (Menge 1976, Holt 1987, Hixon & Menge 1991, Coker et al. 2009). The symbiotic associations with corals provide many benefits for invertebrate assemblages; corals provide a large surface area on and in which they can live, as well as refuges from predation, food in the form of coral tissue, mucus and its associated detritus and a hard skeleton used as a substratum by specialised burrowers (Castro 1988). Taking this into account, the molluscs, echinoderms, platyhelminths and cnidarians found associated with *A. calycularis* might use the coral skeleton as a refuge against potential predators, although these groups are less abundant. Richter & Luque (2004) observed *Epitoniem dendrophylliae* (Gastropoda: Mollusca) feeding on *A. calycularis.* However, this taxon is a rare species in shallow waters (Gofas et al. 2011), and consequently *E. dendrophylliae* did not appear in the present study, where depth ranged from 0 to 10 m.

Univariate analyses (species-independent), showed that macrofaunal composition associated with *A. calycularis* colonies differed through time, with a greater diversity in summer. This pattern has been previously observed in macrofaunal assemblages associated with seaweeds in the Mediterranean Sea (e.g. Guerra-García et al. 2010) and might be because some temperate species show peak abundances in summer and marked declines in winter (Keith 1971, Thom et al. 1995, Ashton 2006). Alternatively, the number of species and diversity did not show differences with depth. However, the PERMANOVA (species-dependent) detected that faunal assemblages changed with time and depth. Factors such as seawater temperature and wave action might be a seasonal reason for the vertical distribution of associated macrofauna (Neto 2000). In fact at 0 m, hydrodynamism is greater due to strong wave action, whereas at deeper sites the impact of this factor is greatly reduced, as demonstrated by Cebrián & Ballesteros (2004) in the same area. It has been pointed out that wave action affects patterns of distribution in the associated macrofauna in the intertidal zone (Chavanich & Wilson 2000). Oxygen concentration might be an additional factor that affects the patterns of macrofaunal assemblages associated with seaweeds (Guerra-García & Izquierdo 2010). Additionally, weather conditions, competition or preda-

tion might determine the associated macrofauna. More information concerning these factors and their interaction with macrofaunal assemblages is necessary.

The macrofaunal community composition of *A. calycularis* was previously unknown. This study has shown that this endangered and seascape-forming coral from the Western Mediterranean Sea maintains a diverse associated community that changes spatially and seasonally. Although more research is required, this study has provided important information about the potential role of *A. calycularis* in the trophic foodwebs of the Mediterranean Sea rocky shore. Moreover, knowledge of macrofaunal assemblages is essential as a baseline to evaluate disturbances due to natural and/or anthropogenic factors. In this context, this information is crucial to the future conservation framework of the endangered coral *A. calycularis*.

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