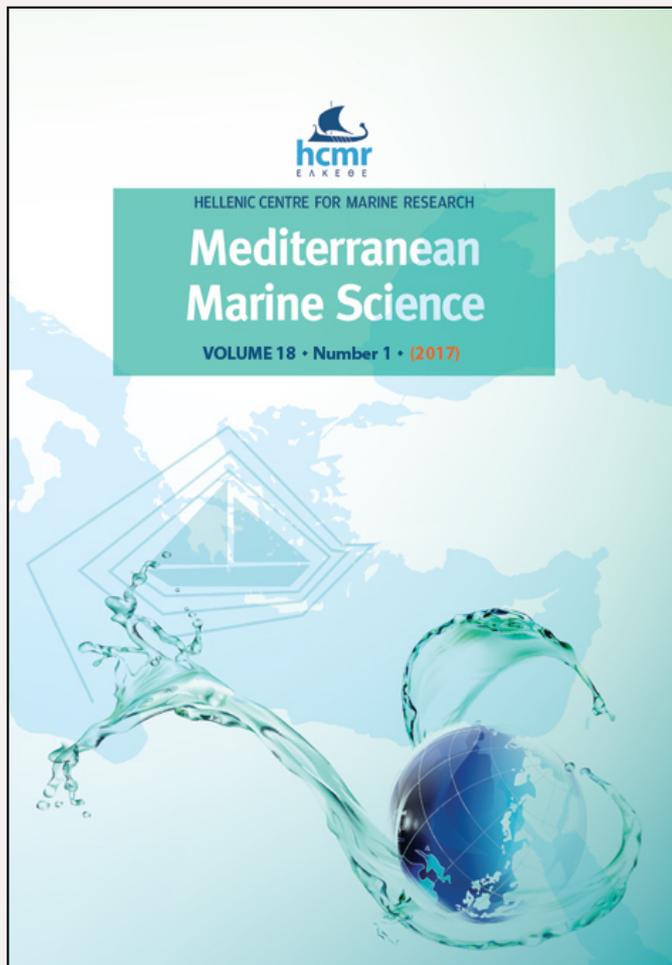


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A new *Cladocora caespitosa* population with unique ecological traits

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Abstract

The Mediterranean endemic scleractinian coral *Cladocora caespitosa* (L., 1767) has been recently included in the IUCN Red List as an endangered species. In this context, information on the species is urgently required to further assess its status and to determine its distribution area. This study reports on the main traits of a recently discovered *C. caespitosa* population in Formentera (Balearic Islands, W Mediterranean). Here, coral colonies live wrapped in *Cystoseira* forests thriving on rocky substrata (5 - 13 m depth), thus being a new example of the ability of *C. caespitosa* to build up extensive populations within algal communities. Even though coral cover reaches ~ 20 % on average, which is a remarkable figure for this species, colonies are generally small (~ 10 cm diameter on average), most probably due to partial exposure to waves and currents. The combination of hydrodynamics and the presence of algal forests in the studied site could be responsible for the high occurrence of a rare type of colony growth: free-living coral nodules or coralloliths. This population is highly interesting for future monitoring owing to its unique traits, the absence of necrosis signs related to past mortality events, and its location inside a marine reserve.

Keywords: *Cladocora caespitosa*, Scleractinia, coral cover, coralloliths, Balearic Islands, Mediterranean Sea.

Introduction

The endemic scleractinian coral *Cladocora caespitosa* (L., 1767) is the only zooxanthellate reef-building coral in the Mediterranean Sea. It is a long-lived, ecosystem engineer species whose large bioconstructions have become rare in the Mediterranean (Kružić & Benković, 2008; Kersting & Linares, 2012).

Cladocora caespitosa is capable of living in contrasting environments such as infralittoral communities, where it is able to develop extensive populations among the dense algal cover (e.g., Columbretes Islands; Kersting & Linares, 2012), or in the dim light conditions found in circalittoral coralligenous assemblages such as those in Bonassola and Riomaggiore, Ligurian Coast (Morri *et al.*, 1994), or Cap de Creus and Medes Islands, Catalan Coast (Kersting *et al.*, 2015). This plasticity is most probably related to the species' ability to up-regulate heterotrophy in order to compensate lowered autotrophy in low light conditions (Hoogenboom *et al.*, 2010; Ferrier-Pagès *et al.*, 2013), while its allelochemical defence mechanisms (Kersting *et al.*, 2014a) presumably contribute to its successful development among algal forests.

Cladocora caespitosa shows different types of spatial development and colony morphology, whose occurrence could be closely related to hydrodynamics (exposure to waves and currents), type of substrata and seafloor mor-

phology (Kružić & Benković, 2008; Kersting & Linares, 2012). Peirano *et al.* (1998) described two types of colony distributions: beds and banks. Beds are composed of a large number of distinct subspherical colonies, while banks are made up of large colonies, reaching several decimetres in height and covering several square meters in surface area. Mixed distributions of beds and banks can also be found.

In addition to general human pressures in coastal zones (e.g., habitat destruction and pollution), over recent decades this species has been continuously subject to mortalities caused by sea warming in several Mediterranean sites (Rodolfo-Metalpa *et al.*, 2005; Garrabou *et al.*, 2009; Kersting *et al.*, 2013; Kružić *et al.*, 2014; Jiménez *et al.*, 2016). Its accelerating decline and poor capacity to recover from disturbances (Kersting *et al.*, 2014b), has led to its recent inclusion in the IUCN Red List as an endangered species (Casado-Amezúa *et al.*, 2015). In this context, research on new *C. caespitosa* populations is even more important and highly needed to assess the status of the species in the Mediterranean Sea, and to move forward in its conservation. This study focuses on describing a new *C. caespitosa* site in the western Mediterranean Sea, and aims to contribute new information on the types of benthic communities this coral thrives in, its colony distribution patterns, coverage, and its morphological traits.

Materials and Methods

Study site

The small islet of S'Espardelló (38.787278° N, 1.483250° E) is located south of S'Espardell islet, to the northeast of Formentera and south of Eivissa (Balearic Islands, W Mediterranean Sea) (Fig. 1). The sea bottom closest to the islet is mainly rocky and harbours Mediterranean photophilic assemblages, primarily *Cystoseira* forests (*C. balearica* Sauvageau and *C. spinosa* Sauvageau) and seagrass *Posidonia oceanica* (L.) Delile meadows. All of the surveyed area lies within the no-take zone of the Freus d'Eivissa i Formentera Marine Reserve.

Sample design

Exploratory dives were undertaken in May 2016 around S'Espardelló islet to delimit the occurrence of *C. caespitosa*. Once the coral concentration zone was located, 16 random transects were performed in a survey area of 100 x 300 m, at a depth of 5-13 m. All transects were of 20 m in length along a constant (± 1 m) depth (Fig. 1). Information on depth and benthic community was first obtained for each transect, then line-intercept methodology was used to calculate coral cover, i.e., the coral area exactly under the measuring tape (width: 1 cm) was measured continuously along the 20 m transect and then normalised to the total transect area (0.2 m²). In addition, the following information was obtained for each coral colony intercepted along the transect: maximum and minimum diameters (D1 and D2, following Peirano *et al.*, 2001); morphological traits; and percentage of mortality, differentiating between recent and old necrosis on the basis of the occurrence of epibionts (Kersting *et al.*, 2013). Special attention was taken in order to record dead colonies or partially dead colonies covered by epibionts. Altogether, 787 colonies were recorded and measured.

Data analysis

Descriptive statistics were used to analyse the size-frequency distribution of the population (Sokal & Rohlf, 1995). Correlations analyses were performed between 1) coral cover (considering both fixed colonies and coralliths) and depth, and 2) the percentage of occurrence of coral nodules and the total number of colonies and cover among transects. All analyses were performed using STATISTICA 8 software.

Results

Cladocora caespitosa colonies occur mainly on the southeastern side of S'Espardelló islet, sheltered from storms from the N and NE (main storm directions in the area) by the islet and a mostly submerged rocky reef that extends to the SE (Fig. 1). Coral colonies occur at a depth of between 5 and 13 m, in rocky substrata among *Cystoseira* forests (Fig. 2) of both *C. balearica* and *C. spinosa*, the former being dominant in the shallowest parts (5 to 12 m) and the latter in the deepest parts (10 to 15 m).

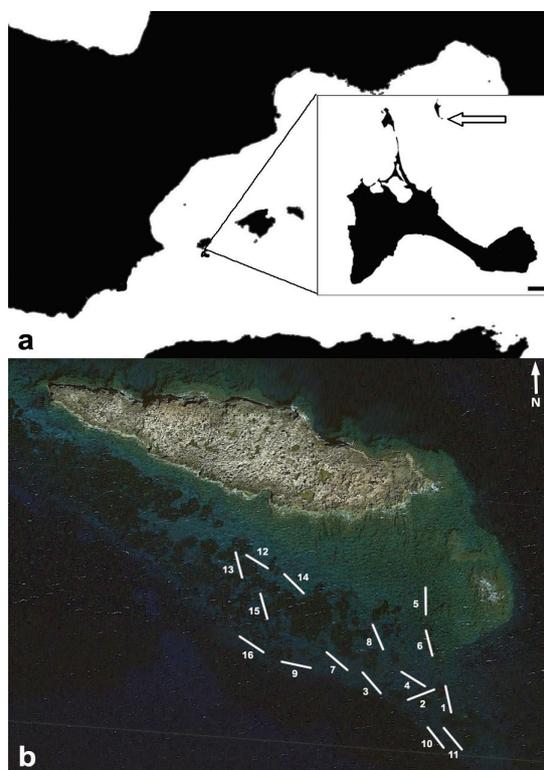


Fig. 1: (a) Western Mediterranean, Balearic Islands and Formentera (in frame). Arrow points to S'Espardelló islet. Scale bar: 2 km. (b) S'Espardelló islet and the surveyed transects (transect length: 20 m). Source: Google Maps.

Mean substrate coverage of *C. caespitosa* was $18.96 \pm 10.87\%$ (\pm SD here and hereafter, N = 16) and reached maximum values of 35.5% (Table 1). The size-frequency

Table 1. Average depth, coral cover and total number of *Cladocora caespitosa* colonies in the surveyed transects.

Transect	Avg. depth (m)	Coral cover (%)	N colonies
1	8	25.65	64
2	13	30.05	74
3	9	27.65	71
4	5	24.85	65
5	5	2.65	8
6	6	4.75	13
7	8	2.65	44
8	6.5	10.80	29
9	12.5	26.85	71
10	10	31.85	87
11	10	24.35	77
12	6.5	9.75	21
13	6.5	2.80	12
14	7.5	13.25	28
15	7	12.00	26
16	9	35.50	97



Fig. 2: (a) General view of *Cladocora caespitosa* colonies among *Cystoseira spinosa* in S'Espardelló. Scale bar: 5 cm. (b) Coral nodule or corallith. Scale bar: 1 cm.

distribution of this population was unimodal and non-normal (K-S, $d = 0.139$, $p < 0.01$) and average colony size (D1) was 10.27 ± 8.22 cm ($N = 787$) (Fig. 3). The skewness of the distribution was significantly positive ($g_1 = 2.11$; Sokal & Rohlf, 1995), which indicates the prevalence of small classes in the population. Colonies were mostly attached to the substrate, however, many free-living coral nodules or coralliths (*sensu* Glynn,

1974) were found in the transects (see Kersting *et al.*, 2016) (Fig. 2). Average corallith size (D1) was 4.38 ± 1.97 cm and their occurrence along the transects relating to the total number of colonies was 11.92 ± 6.57 %, i.e., about 1 in every 10 colonies was free-living, reaching maximum occurrence values of 18.6 %. A positive and significant association was found between coral cover and depth ($R = 0.70$, $p < 0.01$), while no significant cor-

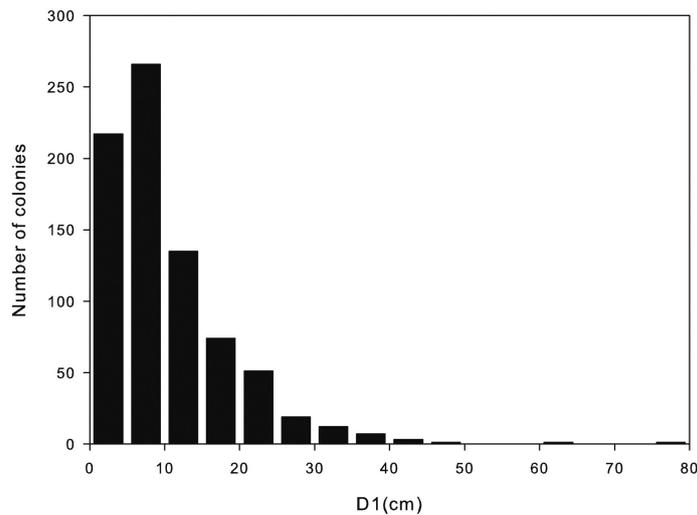


Fig. 3: Size-frequency distribution of *Cladocora caespitosa* colonies in S'Espardelló ($N = 787$).

relations between the overall occurrence of coralliths and the number of colonies ($R = 0.51$, $p = 0.19$) or cover ($R = 0.47$, $p = 0.23$) was found.

In relation to past mortality signs, average dead colony surface for the whole population was 5.44 ± 7.23 %, while it was of 6.85 ± 18.51 % when considering only coralliths. These values represent accumulated mortality and recent necrosis signs were not detected.

Discussion

Our findings, as well as past research undertaken on *C. caespitosa* (see introduction), show its capacity to thrive in contrasting environments, and provide a new example of coexistence of traditionally considered competitors, i.e., reef-building corals and macroalgae (e.g., McCook *et al.*, 2001), which comprise a unique community in the studied site. *Cladocora caespitosa* typically thrives among photophilic assemblages dominated by macroalgae of small sizes and seasonal dynamics (i.e., mainly Dictyotales; Kersting & Linares, 2012). However, this is the first time that a population is found within a macroalgal forest dominated by perennial species (*Cystoseira* spp.).

The shape of the size-frequency distribution in this population shares main traits with distributions given for other well developed *C. caespitosa* populations (e.g., Kersting & Linares, 2012), and with those of other Mediterranean long-lived invertebrates (e.g., Linares *et al.*, 2008), being positively skewed, i.e., with prevalent, small colony sizes. In *C. caespitosa* populations, the development of bigger colonies seems to be mostly impeded by hydrodynamics, and their occurrence is highly associated with sea-floor morphology and the equilibrium between sheltered conditions and water exchange, as previously highlighted in several studies (Kružić & Benković, 2008; Kersting & Linares, 2012). In accordance with this, the absence of bigger colonies and banks in S'Espardelló, despite the high colony occurrence and cover values reported, is probably related to limited shelter from waves and currents. In addition, decreased wave exposure with increasing water depth could explain the positive association found between coral cover and depth. On the other hand, we consider the combination of wave-induced currents and the presence of erect algae as the most probable explanation for the high occurrence of free-living coral nodules or coralliths. We hypothesize that small coral fragments, originating from either colony fragmentation by waves (i.e., asexual fragmentation) or by larval recruitment on dead coral rubble, as reported by Roff (2008) for the Great Barrier Reef, acquire spherical growth (i.e., living polyps growing in all directions) as the result of periodical wave-induced turnover inside the algal forest. In this regard, algal thalli would prevent coral nodules from rolling away by stopping them and thus setting a certain pace to the rolling movement. Moreo-

ver, algal cover probably protects polyps from further abrasion injuries, adding to the intrinsic capacity of this species to rapidly recover from tissue injuries (Casado *et al.*, 2015). The percentage of dead colony area recorded in coralliths was slightly higher than that of the attached colonies, thus showing little additional mortality related to the differing growth and life style. However, it must be highlighted that outside the area of protection of the algal forests, totally or partially dead coralliths accumulate in high numbers in rocky depressions (Kersting *et al.*, 2016).

This type of coral colony morphology, which has been reported as well in other seas (Glynn, 1974; Roff, 2008; Capel *et al.*, 2012; Hoeksema & Wirtz, 2013), is considered rare and has been reported in the Mediterranean Sea for the first time in S'Espardelló (Kersting *et al.*, 2016), adding interest to this *C. caespitosa* population. Mediation of biotic and abiotic factors in the origin of coralliths has been previously considered in other sites. Capel *et al.* (2012) considered the displacement of the coral fragments by the sand dollar *Clypeaster subdepressus* as an important source of rotatory movement. Growth of *Madracis decactis* coralliths (Glynn, 1974) seemed to be caused by fish frequently disturbing bottom sediments. Finally, coralliths from Heron Reef (Australia) resulted from the circumrotatory action induced mainly by currents (Roff, 2008).

Even though mass mortalities have impacted many *C. caespitosa* populations throughout the Mediterranean Sea, the studied site has remained free of severe mortality episodes. As mentioned in Kersting *et al.* (2013), mass mortality signs should be noticeable in *C. caespitosa* colonies for many years after the episodes. However, the average percentage of accumulated dead colony surface obtained in S'Espardelló was slightly over 5 %, not very different from the 3 % recorded in the Columbretes Islands before the outburst of the recurrent warming-related mortalities (Kersting *et al.*, 2013).

Coral cover in this site is remarkable in the current context of the species in the Mediterranean Sea, and can be considered similar to that reported in other sites with extraordinary development of the species (e.g., Columbretes Islands; Kersting & Linares, 2012). However, this population differs in other traits, such as the total extension, distribution or colony size. The abundance of *C. caespitosa* in S'Espardelló, the unique traits of this population, its protection inside an existing marine reserve and the absence of significant mortality signs, make this site highly interesting for future monitoring, especially in relation to warming-related mortalities.

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