Coralligenous communities linked to diapiric processes from the Spanish shelf of the Gulf of Cádiz

Comunidades de coralígeno ligadas a procesos diapíricos de la plataforma española del golfo de Cádiz

J.L. Rueda (1), M.C. Fernández-Puga (2), M.J. Peñalver (2), J.T. Vázquez (1), M. Gallardo-Núñez (1), N. López-González (1), L.M. Fernández-Salas (3), R. Martos (2) & M.P. Mata (4)

(1) Centro Oceanográfico de Málaga, Instituto Español de Oceanografía, Puerto pesquero s/n, 29640 Fuengirola, Málaga. Spain. Email: jose.rueda@ma.ieo.es
(2) Facultad de Ciencias del Mar y Ambientales. Universidad de Cádiz. Avda República Saharaui s/n. 11510 Puerto Real, Cádiz, Spain
(3) Centro Oceanográfico de Cádiz, Instituto Español de Oceanografía, Puerto pesquero, Muelle de Levante s/n, 11006, Cádiz, Spain
(4) Instituto Geológico y Minero de España. C/ Rios Rosas 23, 28002 Madrid, Spain

Abstract: The Gulf of Cádiz (GoC) represents an important area of seepage activity and of biological diversity due to the tectonic activity and subsoil fluid mobility, as well as the confluence of Atlantic and Mediterranean water masses and organisms from both basins. Some circalittoral and bathyal areas of the GoC remain still unexplored and they could harbour interesting communities and species that may deserve protection. In summer 2013, a geological expedition carried out between San Fernando and Conil de la Frontera, at water depths between 40 and 55 m and 10 M from Cádiz detected complex coralligenous communities that may be linked to diapiric processes. These communities represent a well preserved 1170 habitat type (Reefs) of the Habitat Directive and also contain ca. 20 spp. of invertebrates that are included in European, National and Local (Andalusian) threatened species lists. The area should be included in the Natura 2000 network as it represents one of the few circalittoral coralligenous communities from Spanish waters of the GoC.

Key words: *Circalittoral, scleractinians, gorgonian, threatened species, Cádiz*

1. INTRODUCTION

Coralligenous habitats represent a hard substratum of biogenic origin, mainly produced by the accumulation of calcareous encrusting algae growing in dim light conditions (between 20-120 m depth), as well as of sessile fauna, such as scleractinians, octocorals, bryozoans and sponges (Ballesteros, 2006). This results in a complex but fragile habitat that contains different microhabitats (holes, crevices and sessile organisms inhabited by a rich fauna from different taxonomic groups, including threatened species. Coralligenous habitats are one of the most biodiverse habitats in European coasts (Ballesteros, 2006), and because of those mentioned factors, are protected by the Natura 2000 Networking Programme from the EU in the category of 'Reefs' (Code 1170). Nevertheless, nowadays most coralligenous habitats are threatened because they generally attract human activities (e.g. fisheries, diving) that may negatively impact their sensitive species (e.g. gorgonians, bryozoans).

The Gulf of Cádiz (GoC) is an important area of seepage activity with the presence of ca. 70 mud volcanoes related to hydrocarbon extrusion, salt tectonics and diapirism developed in a compressional system linked to the Nubia-Eurasia plate convergence. There is a high variety of geomorphic features widespread along the sea floor associated with fluid venting and migration, being mud volcanoes and diapirs the ones that have received more attention in past studies, especially in bathyal areas (IEO-MAGRAMA, 2012; Díaz del Rio *et al.*, 2014). Diapirs located at the continental shelf have received less attention in the past and no information is currently available on their role for promoting habitats that could be ecologically singular or complex and may increase the heterogeneity of the circalittoral bottoms of the GoC.

Recently, the project CADHYS (*Presencia de metano y gases hidratados en el margen continental del Golfo de Cádiz: estructuras submarinas derivadas y procesos de interacción con sedimentos arcillosos*, funded by Junta de Andalucía) has focused on fluid migration and venting processes occurring at the shelf of the GoC. The find of complex coralligenous habitats that are favoured by diapiric structures occurring just 10 miles southwest from Cádiz is presented in this study. The main objectives of this study are to characterize

these habitats and their biota, evaluate their importance for conservation and explore the importance of diapiric structures as inducers of shelf benthic heterogeneity in the GoC.

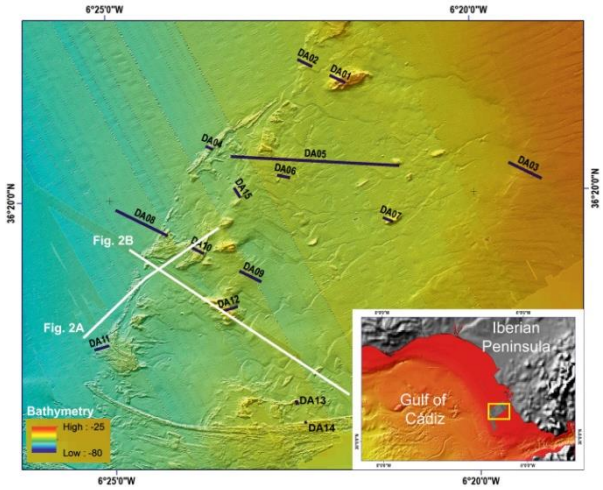

Fig. 1. Location of study area, benthic dredge samples (DA) and very high resolution profiles displayed in Fig. 2.

2. MATERIAL AND METHODS

The study area is located in the continental shelf of the Cádiz province, between San Fernando and Conil de la Frontera, at 40 and 55 m depth, and a distance of ca. 7.5 M from the coast and 10 M from Cádiz city. Bathymetric data and high resolution TOPAS profiles were obtained in CADHYS0410 and CADHYS0713 expeditions on board of R/V Odón de Buén and R/V Ramón Margalef respectively. In the CADHYS0713 sampling on the cap rock of the diapir and adjacent bottoms was achieved by using a benthic dredge (horizontal opening of 1 m and net with mesh size of 1 cm) during 5-30 minutes at a vessel speed of ca. 2 knots. The main and original purpose of the sampling was to carry out a geological characterization of the substrate types of these areas, but the fauna was then also studied in those samples for characterizing the habitats and associated biota. A total of 15 dredge samples were obtained and later on sieved using sieves of 10, 5 and 1 mm. Species above 10 mm were identified, photographed and quantified using rank abundances. Faunistic and geological material collected was preserved dry or with ethanol 70% until further processing in the laboratory.

A data matrix containing the rank abundance of all species per sample was subjected to cluster analysis and non-metric multidimensional scaling (MDS), in order to detect the main assemblages. Unweighted Pair-Group Method with Arithmetic Mean (UPGMA) was applied to link samples into clusters. Similarity Percentage analysis (SIMPER) was used to characterize the detected assemblages by assessing the species contribution to each of them. Different groups of samples were *a priori* compared using an analysis of similarities (ANOSIM) in relation to different sampled zones (cap rock *vs.* adjacent areas). All these multivariate analyses were executed using the PRIMER 6 (Plymouth Routines In Multivariate Ecological Research) software from Plymouth Marine Laboratory, UK.

The characterization of species was done according to their dominance (%D), mean rank abundance and frequency of occurrence (%F) in the samples. Species richness (S, spp . sample^{-1}) was also used to describe the assemblages detected in multivariate analyses and in relation to zones that were *a priori* established.

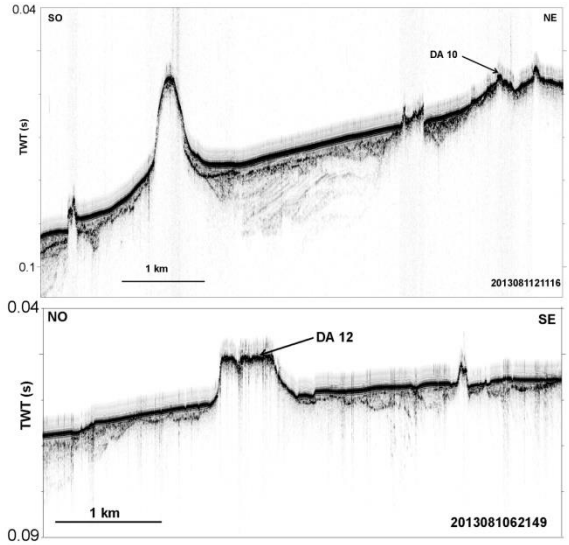

Fig. 2. Very High Resolution profiles displaying the diapir and outcroping cap rock as well as the location of some benthic drege samples (DA). Location in Figure 1.

3. RESULTS

The diapir sampled is located along the continental shelf and adjacent land and upper slope areas. Exhibit a NE-SW direction and outcrop locally along the continental shelf from 40 m depth, where the sedimentation is minor than in the shallower areas. This diapir is constituted by Triassic evaporites that continue uplifting from Pliocene to the present. The dredge samples were collected in outcrops that rise 6-7 m above the seafloor (Fig. 2).

A total of 163 spp. of more than 1 cm have been found so far in the samples, with 59 spp. being molluscs, followed by 36 spp. of cnidarians, 21 spp. of sponges and 14 spp. of echinoderms. A larger number of species is expected after further taxonomical study of the small fractions of the material (<10 mm) and of certain groups of invertebrates (e.g. small crustaceans, hydrozoans). Regarding total abundance, cnidarians represented the dominant group (35.6%), followed by molluscs (23.9%), sponges (13.6%), bryozoans (9.4%) and echinoderms (8.1%).

The species with high dominance and mean rank values included the coralligenous algae *Litophyllum*

stictaeforme, the sponges *Axinella damicornis* and *Axinella polypoides*, the cnidarians *Sertularella* sp., *Parazoanthus axinellae*, *Aglaophenia* sp., *Paramuricea clavata*, *Coenocyathus anthophyllites*, *Eunicella verrucosa* and *E. cavolinii*, the polychaete *Spiochaetopterus* sp., the echinoderms *Ophiothrix fragilis*, *Ophiopsilla* spp. and *Spatangus purpureus*, the decapod *Pilumnus* spp., the bryozoans *Myriapora truncata, Pentapora foliacea* and *Pentapora fascialis* and the molluscs *Chama gryphoides, Clausinella fasciata* and *Turritella turbona* (Fig. 3). The top-frequent species were the cnidarians *P. clavata*, *Dendrophyllia ramea*, *Sertularella* sp. and *Leptogorgia sarmentosa* (%F >70% in all cases), the sponges *A. polypoides* (73.3%) and *A. damicornis* (66.7%), the mollusc *T. turbona* (73.3%), the bryozoans *Cellepora* sp. (53.3%) and *P. foliacea* (46.7%) and the echinoderms *Ophiopsilla aranea* (53.3%) and *Ophiothrix fragilis* (46.7%), among others (Fig. 3).

Around 20 spp. are included in lists of threatened species such as the echinoderm *Centrostephanus longispinus* (Annex 4, Habitat Directive), the sponges *Axinella polypoides* (Catálogo Nacional de Especies Amenazadas, CNEA), *Spongia agaricina* (Libro Rojo de Invertebrados de Andalucía, LRIA) and *Tethya aurantium* (LRIA), the scleractinians *D. ramea* (LRIA) and *Phyllangia mouchezi* (LRIA), the gorgonians *P. clavata* (LRIA), *Eunicella verrucosa* (LRIA) and *Leptogorgia viminalis* (LRIA), the molluscs *Lithophaga lithophaga* (Annex 4, Habitat Directive), *Zonaria pyrum* (CNEA) and *Cymatium corrugatum* (LRIA), and the bryozoan *P. fascialis* (LRIA), among others (Fig. 3). Species of subtropical affinity from northwestern Africa also occur in these bottoms such as the gorgonians *E. gazella* (LRIA), *E. labiata* (LRIA) and *Elisella paraplexauroides* (LRIA), the latter displaying colonies of up to 1 m height (Fig. 3).

Multivariate analyses grouped the samples in relation to substrate type (cap rock *vs.* adjacent soft bottoms), with the largest S values for those benthic dredges collected on the cap rock (up to 72 spp. sample^{-1}). ANOSIM analyses detected significant differences in relation to the substrate type (R_{ANOSIM}=0.59, p<0.001) and the size of the outcropping cap rock (R_{ANOSIM}=0.26, p<0.05). SIMPER analyses in relation to substrate type indicated (1) a low intragroup similarity, being higher for the cap rock (37%) than for the soft bottoms (19%) and (2) a high between group dissimilarity (ca. 90%). The species that most contributed to these differences were *P. axinellae, A. damicornis, Sertularella* sp., *M. truncata, D. ramea, E. gazella* and *P. clavata* with higher abundances in the cap rock and *P. fascialis, T. turbona, Anomia ephippium, Suberites domuncula, Mysia undata* and *Arcopagia balaustina* displaying higher abundances in the surrounding soft bottoms.

4. DISCUSSION

Unlike the Mediterranean Sea, coralligenous bottoms in the Spanish margin of the GoC are very scarce (IEO-MAGRAMA, 2012; Díaz del Río *et al.,* 2014) and the ones found in this study may deserve to be included in the Natura 2000 Network. Coralligenous bottoms are included in the Habitat 1170 "Reefs" of the Habitat Directive. Moreover, the occurrence of threatened species, including some from Annex 4 of the Habitat Directive and from threatened species lists of national and local scope may also justify the inclussion of the area in the Natura 2000 Network.

Fluid venting generally induces acute changes on the seafloor and associated biota, as it has been observed on the slope bottoms of the GoC, where authigenic carbonates derived from methane anaerobic oxidation by archea may promote completely different habitats than those of gas saturated and non-saturated soft bottoms (Díaz del Rio *et al.*, 2014). Diapiric structures resulting from gas migration may also induce changes on seafloor morphology and substrate type due to the outcropping caprock developed on the crests of the diapirs, which may favour settlement and development of hard bottom species as found for mud volcanoes with authigenic carbonates. Fluid migration and fluid venting are common processes in the GoC, and diapirs may also induce a high habitat heterogeneity and biodiverse benthic communities as found for mud volcanoes. Further exploration using different sampling techniques may increase considerably the faunistic list and the characterization of vulnerable habitats and threatened species that may deserve protection under the Natura 2000 network.

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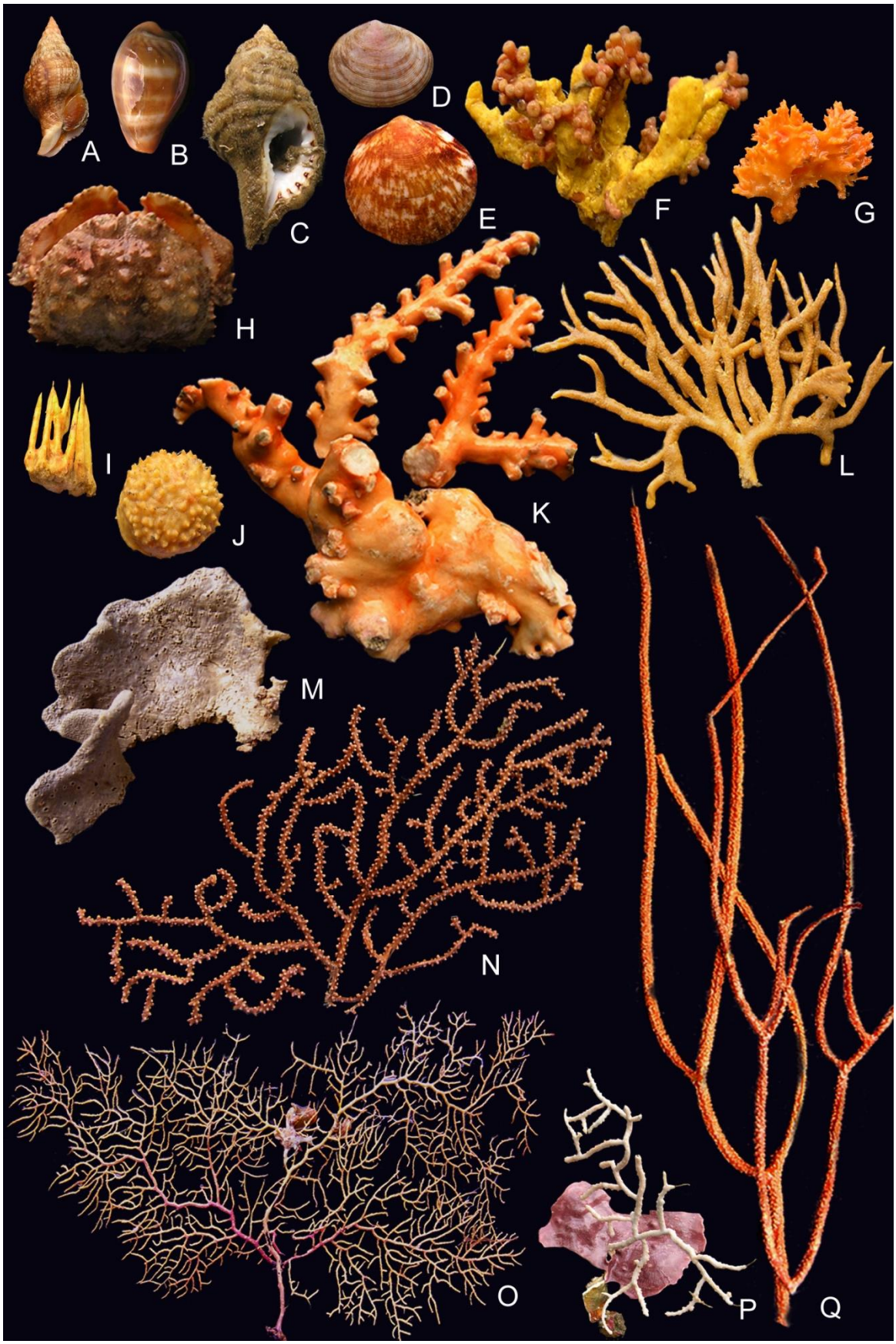

Fig. 3. Frequent and dominant species found on the coralligenous and adjacent bottoms of the studied area: (A) Buccinulum corneum*; (B)* Zonaria pyrum*; (C)* Cymatium corrugatum*; (D)* Arcopagia balaustina*; (E)* Glycymeris glycymeris*; (F)* Axinella damicornis *with* Parazoanthus axinellae*; (G)* Acanthella *sp.; (H)* Calappa granulata*; (I)* Ciocalypta *sp;(J)* Tethya aurantium*; (K)* Dendrophyllia ramea*; (L)* Axinella polypoides*; (M)* Spongia agaricina*; (N)* Eunicella labiata*; (O)* Leptogorgia sarmentosa*; (P)* Eunicella gazella*; (Q)* Elisella paraplexauroides.