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Monitoring and assessment of rocky reefs and maërl communities in the Special Conservation Area “SCA - Underwater Valleys of the Mazarrón Escarpment” (SE Iberian Peninsula, Western Mediterranean)

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Rocky reef ecosystems and maërl communities have a great ecological importance. However, as most of these habitats are present in shallow water near shore, they are particularly vulnerable to the effects of human activities. The main goal of this research is to improve the knowledge on maërl communities and reefs within the Special Conservation Area (SCA) “Underwater Valleys of the Mazarrón Escarpment”, in southeast Spain. An intensive sampling of benthic habitats between 20 and 300 m depth by two coastal and two oceanographic surveys was conducted during 2022 and 2023. We made use of towed sledge and ROVs as main sampling methodologies, although some other benthic dredges were also utilized (shipek dredge, beam trawl and rock dredge). Results show a high taxonomic richness of megabenthic species. Currently approximately 400 taxa have been identified to the lowest possible taxonomic level, with a particular focus on the habitats of community interest “rocky reefs - 1170” (*Alcyonium acaule*, *Alcyonium palmatum*, *Leptogorgia sarmentosa*, *Cerianthus membranaceus* among others) and maërl communities (*Lithothamnion* spp., *Mesophyllum* spp., *Phymatolithon calcareum*, *Peyssonnelia rosa-marina* among others). Then we constructed an accurate habitat zoning and new bionomic cartography with a finer spatial resolution for the habitats of rocky reefs and maërl communities. Finally, we estimated a set of specific ecological indicators, which allow evaluating their conservation status, their monitoring over time as well as their spatio-temporal evolution.

KEYWORDS

benthic ecosystems, Good Environmental State, habitat 1170, Marine Protected Areas, Marine Strategy, rhodoliths

1 Introduction

Conservation of marine areas is essential for maintaining biodiversity and protecting ecosystems. Improving the current knowledge about biodiversity of benthic species and their distribution should be a major focus to develop an effective management, especially in Marine Protected Areas (MPAs) which play a key role in the protection of marine habitats.

Within a European context, the Marine Strategy Directive (EC, 2008) is the main planning instrument for the marine environment in the EU, establishing a framework to inform on specific monitoring for selected Special Conservation Areas (SCAs) as well as evaluating the Good Environmental State (GES), following a number of particular indicators. This work is carried out in the SCA of the Natura 2000 Network with official name “ZEC - ES62000048, Valles Submarinos del Escarpe de Mazarrón” (hereafter named in English as “SCA - Underwater Valleys of the Mazarrón Escarpment”), located off the southeast coast of the Iberian Peninsula in the Mediterranean Sea. This SCA was proposed due to the presence of ecologically-important habitats such as “Sandbanks permanently covered by shallow marine water”, “Posidonia meadows (*Posidonia oceanica*)” and “Reefs” through the Spanish Law 42/2007 (BOE, 2007) of December 13th on Natural Heritage and Biodiversity. This regulation also mandates that the types of natural habitats of community interest with a significant presence in the protected marine area are considered to be natural values subject to conservation. Specifically for our study area this includes the natural rocky reef habitat (habitat type 1170 according to EU Habitat Directive) and communities of maërl, biocenosis considered by the Convention of Barcelona with characteristic species *Lithothamnium coralloides* and *Phymatolithon calcareum* (BOE, 2007).

Reef habitats are one of the most valuable and biologically diverse ecosystems on the planet. In the Mediterranean, Templado and Calvo (2002) estimated that these communities can host up to more than 7,000 animal species, which would correspond to more than 70% of marine animal species. Several authors agree that many species use these habitats as breeding, feeding or refuge areas (Doherty, 1991; García-Charton et al., 2000; Houziaux et al., 2008; Templado et al., 2009). These habitats also provide food, coastal protection, and income from tourism and fishing (Costanza et al., 1997; Tubío Gómez et al., 2021).

This paper focuses on the monitoring and evaluation of rocky reefs and maërl communities in the SCA Underwater Valleys of the Mazarrón Escarpment, carrying out inventory, characterization and monitoring of the target habitats and species of community interest within the management plan of the SCA. Both rocky reefs and maërl habitats are considered “biodiversity hotspots”, which is why they are currently the subject of intensive studies and numerous conservation proposals (Templado et al., 2012).

Four specific sampling surveys have been launched for the different study habitats. The samplers used for biological characterization are based on two types of complementary methods for the study of benthic habitats: indirect biological prospecting methods, which are non-invasive and do not produce a physical impact on the substrate, and direct biological prospecting methods, which they are considered more traditional, invasive and produce

a physical impact on the substrate. As non-invasive methods, the Liropus ROV, Tasife photogrammetric sled, and Sibiu Pro miniROV were used, which allowed obtaining high-definition video images and exporting fixed plans in the habitats of interest.

Finally, this paper shows the detailed bionomic modeling and cartographies of the target habitats, based on the information collected in the oceanographic and coastal campaigns carried out in the study area, the catalog of characteristic species and key species associated with the target habitats and the updated inventory of species, as well as the assessment of the conservation status of the study habitats.

2 Materials and methods

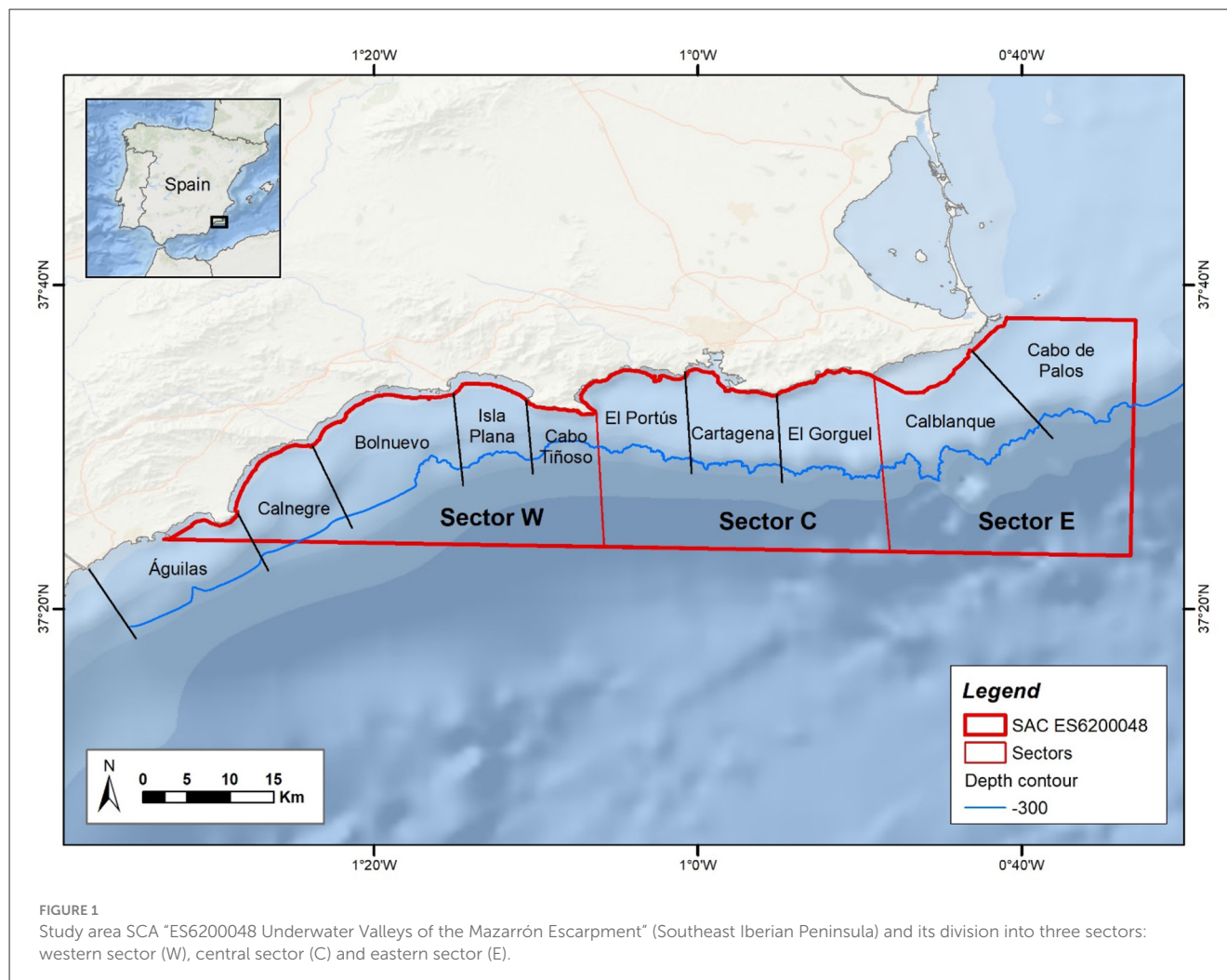
2.1 Study area

The SCA “Underwater Valleys of the Mazarrón Escarpment” includes the marine environment between the waters located south of the island of Fraile in the municipality of Águilas up to a distance from the coast of approximately 11.79 km to the south and in an easterly direction to the geographical longitude of Cape Palos, located in the municipality of Cartagena (Figure 1). It reaches a maximum width of 88 km at its southern outer limit as well as a maximum width at the easternmost part of 27 km, covering a total area of 154,081 ha and a bathymetric range of 20 to 2000 meters. This SCA is a very important geomorphological area, being in fact the area of the Mediterranean with the highest concentration of submarine canyons (BOE, 2016). The SCA is adjacent to other protected areas of natural interest, such as the Cabo de Palos-Islas Hormigas Marine Reserve (BOE, 1995).

This marine enclave has significant productivity and biodiversity due to the extraordinary oceanographic and physiological characteristics of the area (BOE, 2016). The proximity of this escarpment to the coast gives rise to a very small continental shelf. The slope begins between 100 and 200 m deep and it is characterized by having gentle slopes, between 2° and 5°, although occasionally they can exceed 10°, always associated with certain morphologies such as, for example, escarpments or terraces (Calvín, 1999; Templado et al., 2009).

Based on the geographical context of the area and for better planning of information collection, the study area has been divided into three sectors (Figure 1):

- West Sector (W): From the western limit of the SCA to Cabo Tiñoso. It is a coast with a southwest/northeast orientation that develops in a series of consecutive bays, from west to east it would be subdivided into the following five sections: Águilas, Calnegre, Bolnuevo, Isla Plana, and Cabo Tiñoso.
- Central Sector (C): Coastline from Cabo Tiñoso to Monte de las Cenizas. It is a west/east facing coast that develops in the following three sections: El Portús, Cartagena, and El Gorguel.
- East Sector (E): Coastline from Monte de las Cenizas to the Cabo de Palos lighthouse (eastern limit of the SCA). This coast has a southwest/northeast orientation that develops in the following two sections: Calbanque and Cabo de Palos.



2.2 Data sampling

Four specific sampling surveys have been launched for the collection of samples from the different study habitats. Due to the different vessel needs for access to the given study area, two LITMA surveys were carried out in semi-rigid inflatable boats to sample littoral environment from 20 to 125 m depth, while two ZECMA surveys were directed to the coastal environment up to 300 m depth. ZECMA oceanographic surveys were carried out in the research vessels of the IEO-CSIC, R/V Ramón Margaleff, and R/V Ángeles Alvariño. The LITMA and ZECMA surveys have been essential scientific activities to acquire new information in the area of study. Both indirect and direct sampling methods were utilized. The indirect samplers (Tasife photogrammetric sled, ROV Liropus and miniROV) are non-invasive and they do not produce a physical impact on the substrate, whilst direct samplers (shipek dredge, rock dredge, and beam trawl) are invasive prospecting methods, which they are considered more traditional, and produce a physical impact on the substrate. In total, 286 sampling operations were carried out, in addition to active acoustic sampling for geomorphological characterization (Table 1), with 6 different benthic samplers (Figures 2a–f).

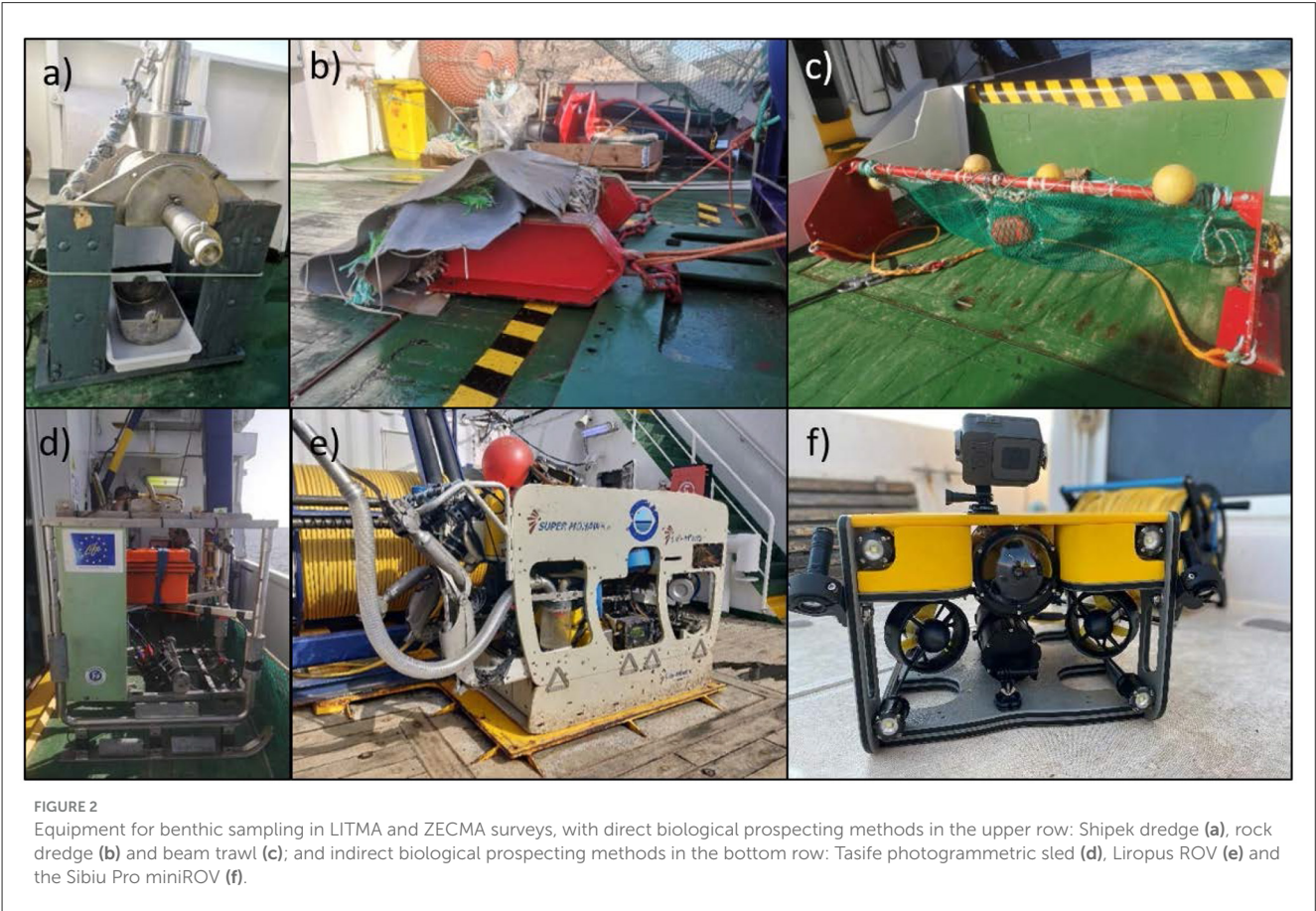
Regarding the littoral surveys, two LITMAs were carried out: LITMA-21 (at December 2021) and LITMA-22 (between October and November 2022). The general objective of these two campaigns has been to collect information in the bathymetric stratum closest to the coast, from 20 to 150 m approx., by sampling by video with miniROV (Figure 2f) from an inflatable boat. The work area has included the entire coastal perimeter of the SCA, between the towns of Águilas and Cabo de Palos in the Region of Murcia. Data collection was carried out through systematic sampling in radials perpendicular to the coast, locating four stations in each radial to prospect the different depth strata. This systematic sampling design has made it possible to have a total coverage of the study area with a total of 30 radials and 120 miniROV transects (Table 1).

The objective of the ZECMA surveys was to collect data for the geomorphological, sedimentary, and biological characterization of the benthic habitats of rocky reefs and maërl bottoms in the SCA area. ZECMA-0222 was carried out between February 15–27, 2022 at the R/V Ramón Margalef and ZECMA-0723 was carried out between July 10–19, 2023 at the R/V Ángeles Alvariño.

The equipment used on board for benthos sampling and geomorphological characterization was diverse (Figure 2). Rock dredge, shipek dredge, beam trawl, and TASIFE sled were used in

TABLE 1 Number of sampling sites in the SCA “Underwater Valleys of the Mazarrón Escarpment”, by type of survey, type of sampler and sector.

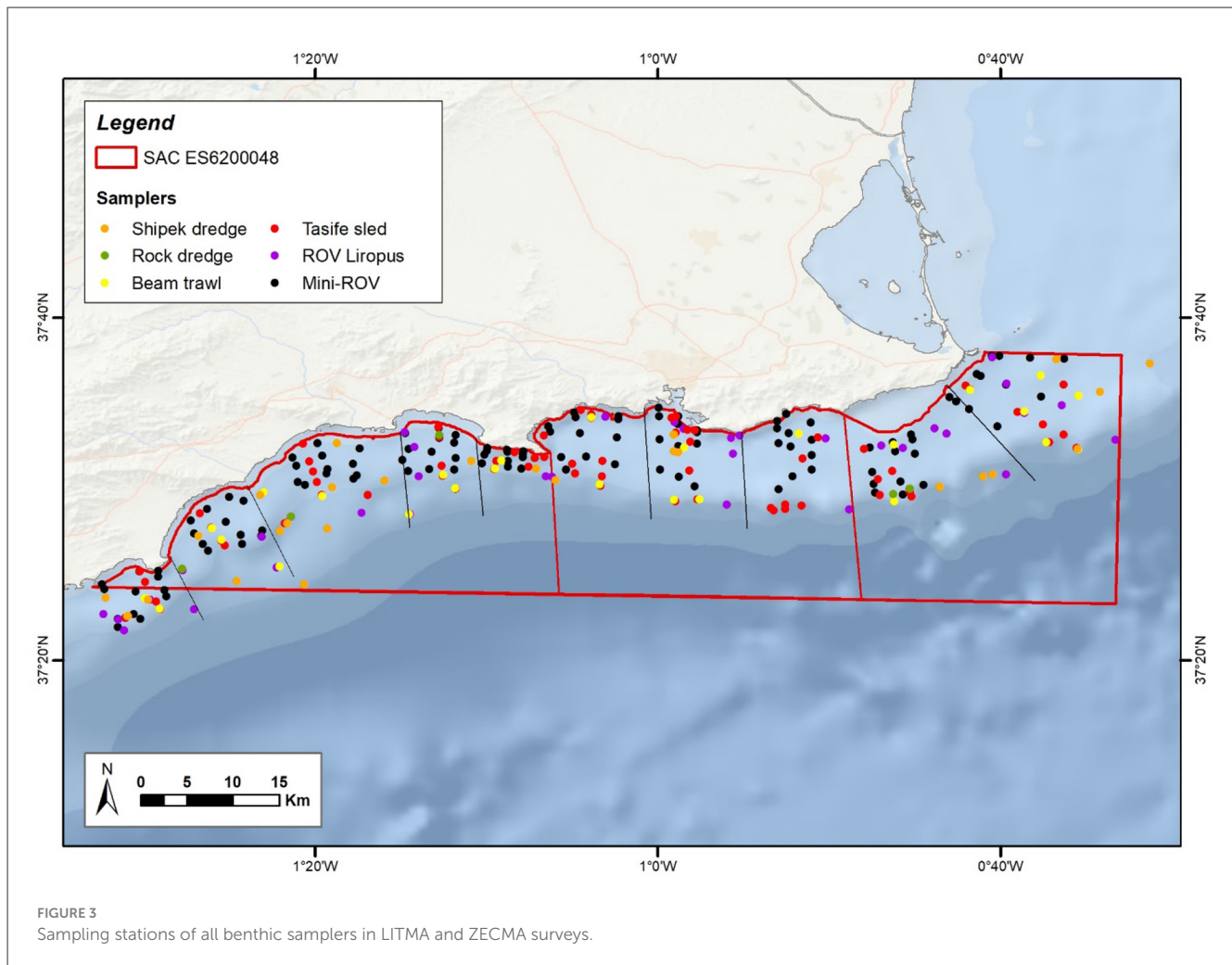
Sector	ZECMA					LITMA	Total
	Shipek dredge	Rock dredge	Beam trawl	Tasife sled	ROV Liropus	Mini-ROV	
West	15	3	14	30	18	60	140
Center	5	0	5	25	9	36	80
East	7	2	8	15	10	24	66
Total	27	5	27	70	37	120	286



ZECMA-0222 for the sampling directed at benthic organisms by a stratified sampling by depths and sectors following bathymetric categories: 20–50 m, 50–75 m, 75–100 m, 100–150 m, and greater than 150 m depth. The greatest sampling effort of this campaign has focused on the sampling carried out with the Tasife sled, which makes it possible to cover a large area by means of semi-intensive visual tracking. The high-resolution information obtained in ZECMA-0222 made it possible to accurately determine the most convenient locations (stations) with the highest probability of finding maërl or rocky habitats (habitat 1170). Hence, during ZECMA-0723, through preferential sampling, and using the Liropus ROV we obtained high quality videos as well as physical samples in these selected locations. Table 1 details the sampling intensity for each benthic sampler in the different sectors into which the study area has been divided. The geographical location of every station for each sampler can be seen in Figure 3.

2.3 Image processing and analysis

A detailed viewing of the videos obtained with the Tasife sled, ROV Liropus, and MiniROV Sibiu Pro SIFE was carried out in the laboratory, using the VLC media player software. The speed of the video has been modified according to the complexity of the transect, viewing at a speed of 0.33x in those videos with greater richness to rising at a speed of 1x in the habitats poorest in diversity. In these viewings, the identified taxa (at the lowest possible taxonomic level) and their abundances have been recorded. In the case of certain taxa, such as algae, surface coverage was considered instead of abundance. In all cases, the complete video recording of every transect was viewed, which implies different transect sampling duration; Tasife sled sampling (ZECMA-0222) were exactly 20 min long, miniROV (LITMA-21 and LITMA-22) between 20 and 27 min and ROV Liropus (ZECMA-0723) videos



lasted between 12 and 173 min. Figure 4 shows different examples of organisms observed during the different surveys.

VLC media player was also used to estimate the maërl coverage. In all the videos, the entire recording was viewed, estimating the maërl coverage by framing the screen into grids and measuring every 15–30 s approximately, thus having a characterization of the variation of maërl throughout the transect (Figure 5). This

grid system has also been used for counting animal species in each frame. Figure 5 shows an example of *Mesophyllum* sp. in the transect RV019 (ZECMA-0723, Calblanque, East sector) in which a coverage of 11% was determined taking into account the percentage of coverage analyzed for each of the 16 grids and calculating the average value of the total of them in the observed image.

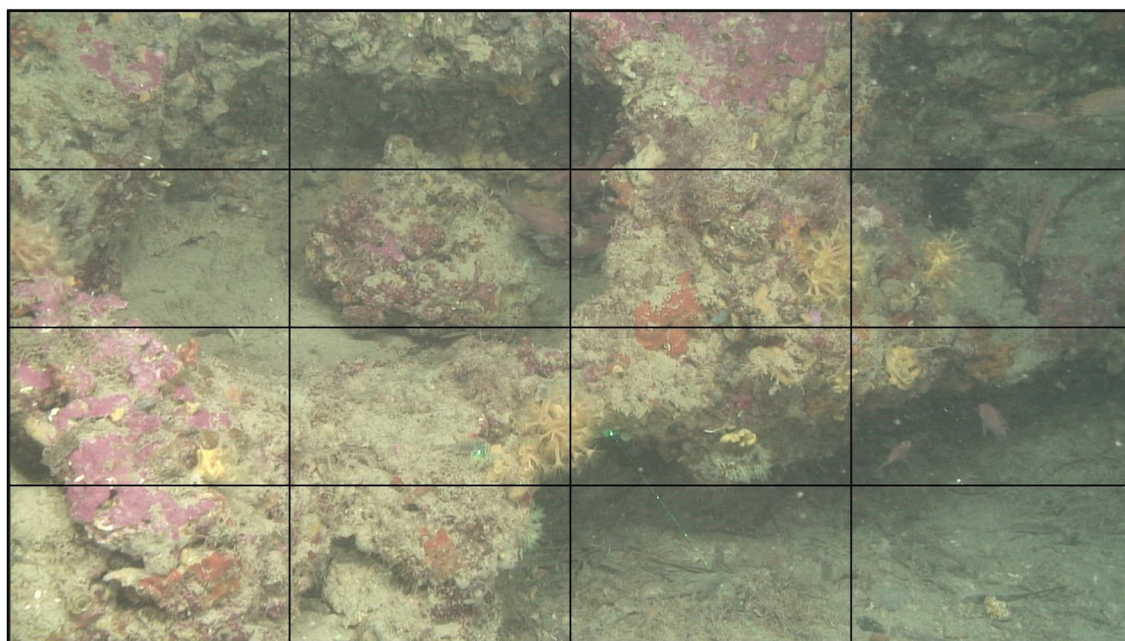


FIGURE 5
Mesophyllum sp. (coralline cover) in the transect RV019 (ZECMA-0723, Calblanque, East sector), with screen grid to calculate the total coverage in the observed image.

2.3.1 Inventory of benthic species and facies

A faunal list and inventory of benthic species was recorded for the study area. This included the identification for every particular species of their level of vulnerability according to international agreement such as EU Habitats Directive, Barcelona, and Berne Conventions as well as the degree of conservation established by the International Union for Conservation of Nature (IUCN). The code AphiaID from the World Register of Marine Species (WORMS, www.marinespecies.org) was used for referencing every species.

On the other hand, the [EUNIS marine habitat classification review \(2022\)](https://www.eea.europa.eu/data-and-maps/data/eunis-habitat-classification-1/eunis-marine-habitat-classification-review-2022/eunis-marine-habitat-classification-2022) was used to characterize the different facies of benthic habitats (<https://www.eea.europa.eu/data-and-maps/data/eunis-habitat-classification-1/eunis-marine-habitat-classification-review-2022/eunis-marine-habitat-classification-2022>). This is a wide recognized system used to categorize and describe the different types of marine habitats in Europe based on objective criteria.

2.4 Modeling of benthic reefs habitats and maërl in the SCA

Here we follow consistent methodologies already reported in previous studies for Natura 2000 Network areas ([de la Torre et al., 2020, 2022](#); [Rueda et al., 2019](#); [Sánchez et al., 2022](#)). We used a total of 189 sets from the Tasife photogrammetric sled and the miniROV, as these two video samplers are considered equivalent in data collection.

We focused on the most relevant species to identify every specific habitat, considering those species as indicators or

structuring species ([Table 2](#)). This final list of structuring species was based on particular criteria for each one of our target habitats. Regarding maërl, data on the presence of all species of calcareous red algae that form rhodoliths were selected. For reefs (habitat 1170), two criteria were taken into account to select the indicator species of this habitat. The former is biogenic concretion-forming species, understood as any type of concretion originating from living or dead animals, which provide a habitat for both epibiont and endobiont species ([Templado et al., 2009](#)), among which are the mollusc *Neopercnodonte choclear*, the bryozoan *Pentapora fascialis*, and the polychaete *Filograna implexa*. The latter is those species that need a hard substrate to fix themselves and therefore their presence in the environment indicates obviously a rocky substrate. This group includes species of the phyla Annelida (*Protula* sp.), Bryozoa (*Reteporella grimaldii*), Chordata (*Diazona violacea*, *Halocynthia papillosa*, etc.), Cnidaria (*Alcyonium acaule*, *Eunicella cavolini*, *Eunicella gazella*, etc.), Porifera (*Axinella damicornis*, *Axinella polypoides*, *Crambe crambe*, etc.), Chlorophyta (*Codium bursa*), and Ochrophyta (*Dictyota dichotoma* and *Zonaria tournefortii*).

A dissimilarity matrix was built using the Jaccard similarity index, based on absence-presence data. The distance matrix was calculated by the UPGMA algorithm. Several dissimilarity values were tested to group the sets into an adequate and coherent number of groups, with ecologically homogeneous characteristics. All these analyses were made using version 4.3.2 of R software.

2.4.1 Bionomic modeling and mapping

Bathymetry and reflectivity data came from previous research in the study area from other surveys carried out within the

TABLE 2 List of selected structuring species.

Taxon	Filum	Class	Rank	N	Min. depth	Max. depth
<i>Alcyonium acaule</i>	Cnidaria	Anthozoa	Species	19	38.83	80.12
<i>Axinella damicornis</i>	Porifera	Demospongiae	Species	11	32.78	113.05
<i>Axinella polypoides</i>	Porifera	Demospongiae	Species	11	46.10	126.71
<i>Axinella verrucosa</i>	Porifera	Demospongiae	Species	4	60.18	91.91
<i>Caryophyllia</i> sp.	Cnidaria	Anthozoa	Gender	5	60.00	79.87
<i>Codium bursa</i>	Chlorophyta	Ulvothyceae	Species	18	28.55	94.90
<i>Crambe crambe</i>	Porifera	Demospongiae	Species	14	46.10	91.69
<i>Diazona violacea</i>	Chordata	Ascidacea	Species	6	53.50	73.59
<i>Dictyota dichotoma</i>	Ochrophyta	Phaeophyceae	Species	7	43.05	62.15
<i>Dysidea avara</i>	Porifera	Demospongiae	Species	5	32.78	63.29
<i>Eunicella cavolini</i>	Cnidaria	Anthozoa	Species	10	43.33	78.94
<i>Eunicella gazella</i>	Cnidaria	Anthozoa	Species	19	40.10	96.58
<i>Eunicella verrucosa</i>	Cnidaria	Anthozoa	Species	8	55.60	81.31
<i>Filograna implexa</i>	Annelida	Polychaeta	Species	58	23.00	144.02
<i>Haliclona</i> sp.	Porifera	Demospongiae	Gender	8	51.59	144.02
<i>Halocynthia papillosa</i>	Chordata	Ascidacea	Species	18	33.75	81.31
<i>Hymedesmia paupertas</i>	Porifera	Demospongiae	Species	4	43.33	146.16
<i>Leptogorgia sarmentosa</i>	Cnidaria	Anthozoa	Species	14	39.17	81.31
<i>Neopycnodonte cochlear</i>	Mollusca	Bivalvia	Species	56	36.75	145.69
<i>Paramuricea clavata</i>	Cnidaria	Anthozoa	Species	4	63.07	81.31
<i>Pentapora fascialis</i>	Bryozoa	Gymnolaemata	Species	65	28.55	94.90
<i>Pentapora foliacea</i>	Bryozoa	Gymnolaemata	Species	8	60.18	103.17
<i>Protula</i> sp.	Annelida	Polychaeta	Gender	28	48.45	145.69
<i>Pycnoclavella communis</i>	Chordata	Ascidacea	Species	5	54.92	90.26
<i>Reteporella grimaldii</i>	Bryozoa	Gymnolaemata	Species	11	42.44	90.26
Corallinales	Rhodophyta		Phylum	40	23.00	91.49
<i>Zonaria tournefortii</i>	Ochrophyta	Phaeophyceae	Species	4	50.86	80.07

N is the number of sets with the presence of each taxon (species that appear in 3 sets or less have been eliminated).

framework of the Marine Strategies Directive (EC, 2008). Layers of environmental variables were generated, using the 3D Analyst and Benthic Terrain Modeler (BTM) extensions of the ArcGIS program (Walbridge et al., 2018). Layers generated were: slope (in degrees), aspect (in degrees, from 0° to 360°, which was subdivided into two components: east component and north component), roughness, and BPI (Bathymetric Position Index) at two different scales: fine scale (BPI fine) and wide scale (BPI broad).

Spearman's correlation analysis was carried out and highly correlated variables were removed (correlation coefficient greater than 0.7, according to Dormann et al., 2013). The value of VIF (Variance Inflation Factor) was calculated for the selected environmental variables, which allows quantifying the intensity of the multicollinearity between the variables (Fox and Monette, 1992).

Cartographies of the target habitats have been generated using habitat distribution models, with the exception of some of the morphotypes included within rocky reefs (habitat 1170), due to the scarcity of available points of presence.

Generalized additive models (GAM; Hastie and Tibshirani, 1990) have been developed, which allow modeling nonlinear relationships between the predictor variables and the response variable. As we are working with presence/absence data per set, a binomial distribution has been used in the model, with a logit link function, to relate the presence of the different habitats with the environmental variables selected at the study scale (bathymetry, reflectivity, roughness, north component, east component, BPI broad and BPI fine). The GAM model was made with the R mgcv package (Wood, 2017).

The complete model used for the analysis of the habitats was:

$$\text{Phi} = \beta i + s(\text{bathymetry}) + s(\text{reflectivity}) + s(\text{roughness}) + s(\text{north}) + s(\text{east}) + s(\text{BPI_broad}) + s(\text{BPI_fine}) + \varepsilon i$$

where Phi represents the probability of presence for each habitat i , βi is the intercept, s is an isotropic smoothing function, and εi represents the error.

For each modeled habitat, the explanatory variables to be included were selected, using the R MuMIn package (Bartón, 2023), by means of the forward/backward step technique, based on the Akaike AIC information criterion (Akaike, 1973). To avoid overfitting the models, the number of smoothed functions was limited to 5.

For the selected models, the normality and homoscedasticity of the waste were checked, as well as the existence of outliers. Likewise, the spatial autocorrelation of the residuals was verified by means of variograms and the Moran index (Moran, 1950).

The predictive capacity of each model was tested using the cross-validation technique. The presence-absence database for each of the modeled habitats has been separated into presence and absence data, and each group has been randomly divided into three groups, using two groups to generate the model and one to evaluate it, repeating this procedure 10 times. With these data, two statistics have been calculated, using the R Dism package (Hijmans et al., 2023): the area under the ROC AUC curve (Fielding and Bell, 1997), and Cohen's kappa coefficient (Cohen, 1960). In both statistics, the values range between 0 and 1, with those close to 1 being the models with the best predictive capacity.

As a result, predictive cartographies were generated for each of the modeled habitats, which offer probability values of presence that vary between 0 and 1. These cartographies were transformed into binary presence/absence cartographies using prevalence threshold, defined as the point at which the prevalence predicted by the model equals the observed prevalence (Freeman and Moisen, 2008). This threshold serves to determine a minimum probability value above which the presence of the species or habitat is considered.

2.5 Ecological indices for the assessment of the target habitats

The assessment of the degree of conservation of rocky reefs (habitat 1170) and maërl in the SCA was carried out on the basis of a series of ecological indices that make it possible to determine their current ecological status and to warn of possible future changes in them through their comparison over time (EC, 2008). Based on the density values of the determining species of each identified community, the following ecological indices will be estimated, used as descriptors of habitat status in each case and which, according to the expert's criteria, will serve to categorize the aforementioned indicators of habitat conservation status. These seven ecological indices are mandatory under the Marine Strategy Framework Directive (EC, 2008) and they are the following:

- HB-Bio, Percentage of area occupied by biogenic substrate. We estimated both potential habitat and current area covered by each of the target habitats, with its bathymetric range.

- HB-div, Diversity. This index made use of the Shannon Diversity Index, which is defined as $H' = -\sum (p_i \ln p_i)$, where p_i is the relative abundance of species i .
- HB-est, Structuring Species Quantification. This index refers to the main species that builds or structures a particular habitat. We estimated the percentage of presence for those given species.
- HB-RangBat, Bathymetric Range. The bathymetric range in which the habitats of interest were found.
- HB-RangGeo, Geographic Range. The habitat geographical distribution is shown by mapping the results of the modeling of the target habitats for the SCA.
- HB-riq, Specific Richness. We estimated here the specific richness (S), defined as the total number of species found in a given habitat, ecosystem, or area.
- HB-TSC, Typical Species Composition. The typical species of each habitat were identified, using as a criterion that they appear in more than 30% of the sets belonging to the group.

3 Results

3.1 Inventory of benthic species and facies

A total of 575 benthic species, comprising 15 different phyla, were identified in the study area. Figure 6 shows some of the species found and Supplementary Table 1 shows the complete inventory. Among all these 575 species, three of them are mentioned as figures for protection in the EU Habitat Directive; 89 species are included in the IUCN Red List (8 as Dd: Data deficient, 73 as Lc: Least concern, 4 as Nt: Near threatened, and 4 as V: Vulnerable); 10 species are listed in the Barcelona Convention (Annexes II and III) and 6 species are listed in the Berne Convention (Annexes I, II, and III).

Figure 6 shows some representative species recorded during the surveys. Figure 6a shows a colony of the Mediterranean tube anemone *Cerianthus membranaceus* on a rock bottom half-buried by sandy mud, at a depth of 184 m; Figure 6b shows on the right two colonies of the hexacoral anthozoan *Parazoanthus axinellae*, the bryozoan *Myriapora truncata* (also known as false coral) in the central area, and a specimen of the solitary sea squirt *Halocynthia papillosa* on the left upper corner. These community was found on rock substrate with half-buried rhodophyceous algae at a depth of 64 meters; Figure 6c shows the yellow gorgonian *Eunicella cavolini* together with several specimens of the sponge *Dysidea avara* and the bryozoan *Pentapora fascialis* on muddy bottoms with burrows bioturbation, at a depth of 83 m; Figure 6d shows specimens of the yellow coral *Dendrophyllia cornigera*, at a depth of 184 meters. This coral is included in the Red List of the International Union for Conservation of Nature (IUCN) as well as in Annex II of the Barcelona Convention.

3.2 Modeling of rocky reefs (habitat 1170) and maërl in the SCA

For rocky reefs, the grouping of the sets by the dissimilarity matrix and the subsequent ordering by distances resulted in 8

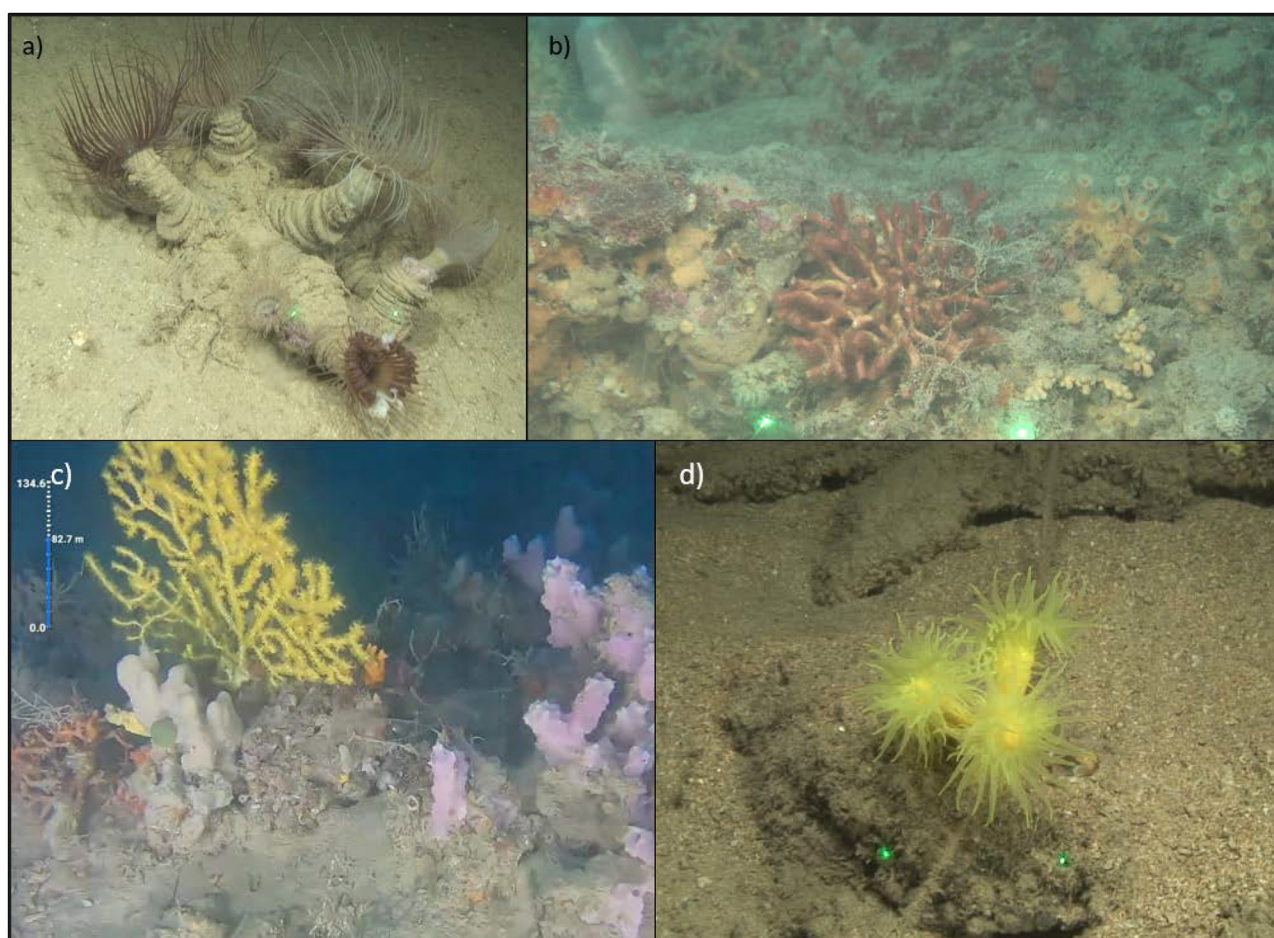


FIGURE 6

Representative taxa recorded during surveys: (a) colony of the Mediterranean tube anemone *Cerianthus membranaceus*; (b) hexacoral anthozoan *Parazoanthus axinellae* and bryozoan *Myriapora truncata* (central area) and *Halocynthia papillosa* (left upper corner); (c) yellow gorgonian *Eunicella cavolini* with several specimens of the sponge *Dysidea avara* and the bryozoan *Pentapora fascialis*; (d) yellow coral *Dendrophyllia cornigera*.

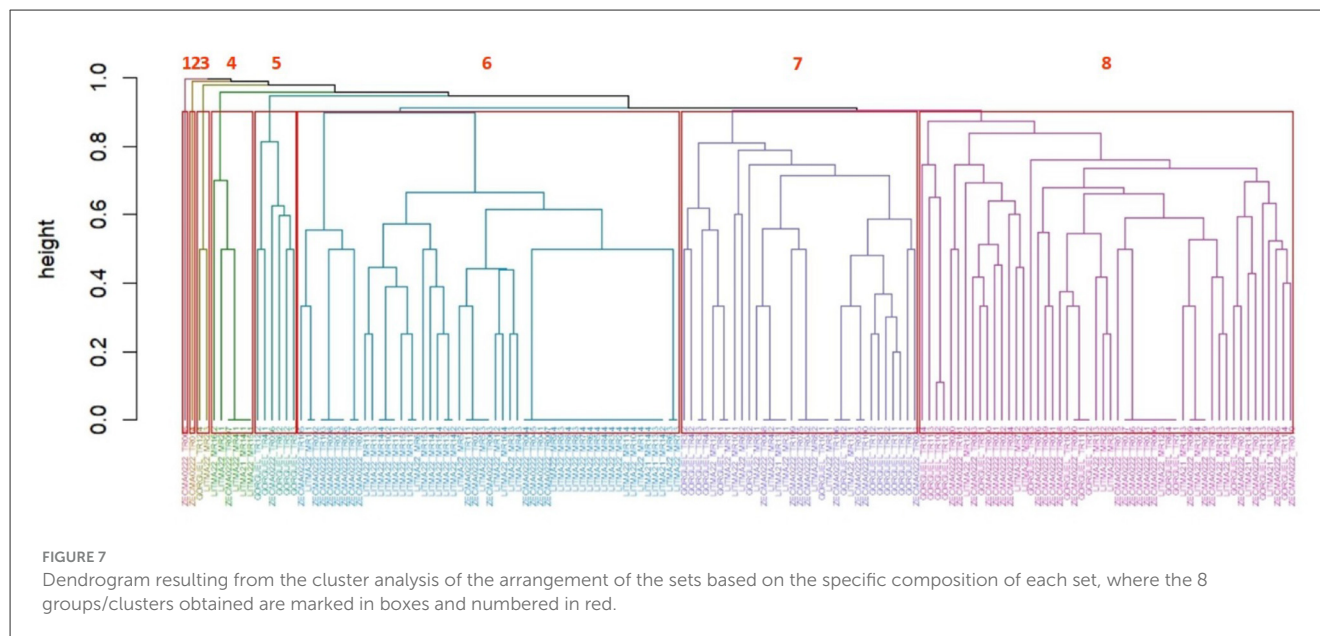
groups of homogeneous characteristics (Figure 7). This clustering of the sets allowed us to distinguish a number of different facies (hereafter also called morphotypes) within the rocky reef habitat, defined by the characteristic species of each group/cluster (Table 3).

Five main morphotypes were apparent (cluster 4, cluster 5, cluster 6, cluster 7, and cluster 8), whilst the remaining 3 clusters include 4 sets that cannot be grouped into any of the other groups due to their specific composition.

- Cluster 4 (hereafter named as Rocky dominated by *Halocynthia papillosa*) also groups 6 casts, which cover depths between 38 and 65 meters deep. They are located in casts near the coast, mainly in the area of Cabo de Palos (Figure 8). The characteristic species of this group is the sea squirt *Halocynthia papillosa* (Supplementary Figure 1).
- Cluster 5 (hereafter named as Rocky dominated by *Leptogorgia sarmentosa*), it encompasses only 6 sets, at depths between 39 and 81 meters, grouped mainly in the Cartagena area (Figure 8). The characteristic species of this group is the cnidarian *Leptogorgia sarmentosa*, accompanied mainly by

other cnidarians such as *Eunicella verrucosa* and *Paramuricea clavata* (Supplementary Figure 2).

- Cluster 6 (hereafter named as Aggregations of *Neopycnodonte cochlear*), this groups 53 sets, located at depths between 37 and 146 meters depth. It is mainly located in the western sector, and in the eastern sector in the Cabo de Palos area (Figure 8). The characteristic species of this group is the bivalve mollusc *Neopycnodonte cochlear*, also a biogenic concretion-former (Templado et al., 2009), which is mainly accompanied by the polychaete *Protula* sp. and the bryozoan *Pentapora fascialis* (Supplementary Figure 3).
- Cluster 7 (hereafter named as Rocky dominated by *Pentapora fascialis*), which includes 33 sets, is mainly located in the sets at shallower depths, between 29 and 80 meters deep (Figure 8). It covers both the infra and the circalitoral floor. For this reason, we can find the presence of photophilic algae such as *Codium bursa* and *Dictyota dichotoma*. The species that defines the group is the bryozoan *Pentapora fascialis*, which forms biogenic concretions (Templado et al., 2009) (Supplementary Figure 4).



- Cluster 8 (hereafter named as Rocky dominated by *Filograna implexa*), it is composed of 52 sets, at depths between 23 and 144 meters. It is located in all sectors, although it is concentrated in certain areas such as Águilas, Cabo Tiñoso, Cartagena, Calblanque, and Cabo de Palos (Figure 8). It is a group with a high diversity of target species, where the presence of the polychaete *Filograna implexa*, which is a species that forms biogenic concretions, stands out (Templado et al., 2009) (Supplementary Figure 5).

Regarding maërl habitat, 40 transects showed presence of maërl-forming species, at depths between 23 and 91 meters along the SCA (Supplementary Figure 6). They were particularly abundant both in Águilas section in the western area and Calblanque section in the eastern area, although they are also notable in other areas such as Cabo Tiñoso and Cartagena (Figure 8).

Table 4 synthesizes the benthic habitats identified in this analysis, naming them by a simplified acronym, their bathymetric range, and the typical species of each habitat.

3.2.1 Spatial modeling of habitat prediction and bionomic mapping

Regarding environmental variables, the oceanic shelf occupies a significant part of the surface of the protected area and most of the area is at depths of less than 300 meters (Figure 9). The area has a mostly south and east aspect, with reflectivity values mainly between -20 and -30 , with low slopes and roughness and a predominance of flat areas. Correlation analysis showed slope was highly correlated with the roughness ($\rho = 0.89$) and bathymetry layer ($\rho = -0.73$), so slope layer was been eliminated. The VIF

(Variance Inflation Factor) values for the selected layers was valid (<3) in all cases.

GAM models were applied to the 4 habitats with sufficient number of presence data (maërl and morphotypes 1170-RPf, 1170-RFi, and 1170-ANc). and Kappa statistics were estimated (Table 5). Goodness of fit of AUC statistic was considered outstanding for maërl and 1170-RPf (values upper 0.9), excellent for 1170-ANc (between 0.8 and 0.9) and acceptable for 1170-RFi (between 0.7 and 0.8) (Hosmer and Lemeshow, 2005). For Kappa values goodness of fit varies from excellent for maërl (upper 0.75), fair to good agreement for 1170-RPf and 1170-ANc (between 0.4 and 0.75) and poor agreement for 1170-RFi (values below 0.4) (Fleiss, 1991).

It is worth noting the good result obtained in the maërl biocenosis model, with high values in the validation, and 74% of the deviance is explained, and of Habitat 1170-RPf (Rocky dominated by *Pentapora fascialis*), with 50% of the deviance explained (Table 5). The results of the Habitat 1170-ANc model (*Neopycnodonte cochlear* aggregations) can be considered good, with almost 30% of the deviance explained, and medium-high validation values. The results of the modeling of Habitat 1170-RFi (Rocky dominated by *Filograna implexa*) have not been as good as expected, but they are considered to be acceptable and consistent with the current knowledge of the study area (complete outputs and diagnostics from the GAMs models can be found in Supplementary material, Supplementary Figures 7–10, and Supplementary Table 2).

Bionomic maps of the predicted distribution of each of the target habitats were generated (Figure 10). We applied the prevalence threshold to obtain presence/absence maps. In the case of the different morphotypes rocky reefs, once the binary presence/absence layers were obtained, they were combined to generate a single spatial distribution for the whole rocky reefs habitat 1170. The spatial prediction of reefs is distributed throughout the SCA within the studied bathymetric range (Figure 10 upper), except in the central sector (El Portús, Cartagena and El Gorguel) where some gaps appear. Regarding maërl habitat

TABLE 3 Groupings of morphotypes within rocky reefs (habitat 1170), where the number of sets grouped in each cluster is indicated, as well as the percentage of sets with the presence of each species in each cluster.

	1	2	3	4	5	6	7	8
Number of sets	1	1	2	6	6	53	33	52
Taxa								
<i>Alcyonium acaule</i>					16.7	7.5	30.3	7.7
<i>Axinella damicornis</i>				16.7			6.1	15.4
<i>Axinella polypoides</i>					16.7	3.8		15.4
<i>Axinella verrucosa</i>								7.7
<i>Caryophyllia</i> sp.						1.9	3.0	5.8
<i>Codium bursa</i>						9.4	36.4	1.9
<i>Crambe crambe</i>					16.7		9.1	19.2
<i>Diazona violacea</i>						5.7		5.8
<i>Dictyota dichotoma</i>							21.2	0.0
<i>Dysidea avara</i>							3.0	7.7
<i>Eunicella cavolini</i>								19.2
<i>Eunicella gazella</i>				33.3	33.3	5.7		23.1
<i>Eunicella verrucosa</i>					66.7			7.7
<i>Filigrana implexa</i>						5.7	15.2	96.2
<i>Haliclona</i> sp.		100.0					3.0	11.5
<i>Halocynthia papillosa</i>				100.0	16.7		18.2	9.6
<i>Hymedesmia (Hymedesmia) paupertas</i>	100.0				16.7			3.8
<i>Leptogorgia sarmentosa</i>					100.0		3.0	13.5
<i>Neopycnodonte cochlear</i>				16.7		83.0	3.0	19.2
<i>Paramuricea clavata</i>					50.0			1.9
<i>Pentapora fascialis</i>					33.3	32.1	90.9	30.8
<i>Pentapora foliacea</i>							3.0	13.5
<i>Protula</i> sp.					16.7	37.7		13.5
<i>Pycnoclavella communis</i>			50.0				3.0	5.8
<i>Reteporella grimaldii</i>			100.0			5.7	6.1	7.7
<i>Zonaria tournefortii</i>								7.7

spatial prediction (Figure 10 bottom), it is present through the whole study area, with the exception of Gorguel section, and the most abundant patches in the eastern (Aguilas) and the western areas (Calblanque and Cabo de Palos).

3.3 Ecological indices

We estimated a series of ecological indices to assess the state of the target habitats off the protected area (Table 6).

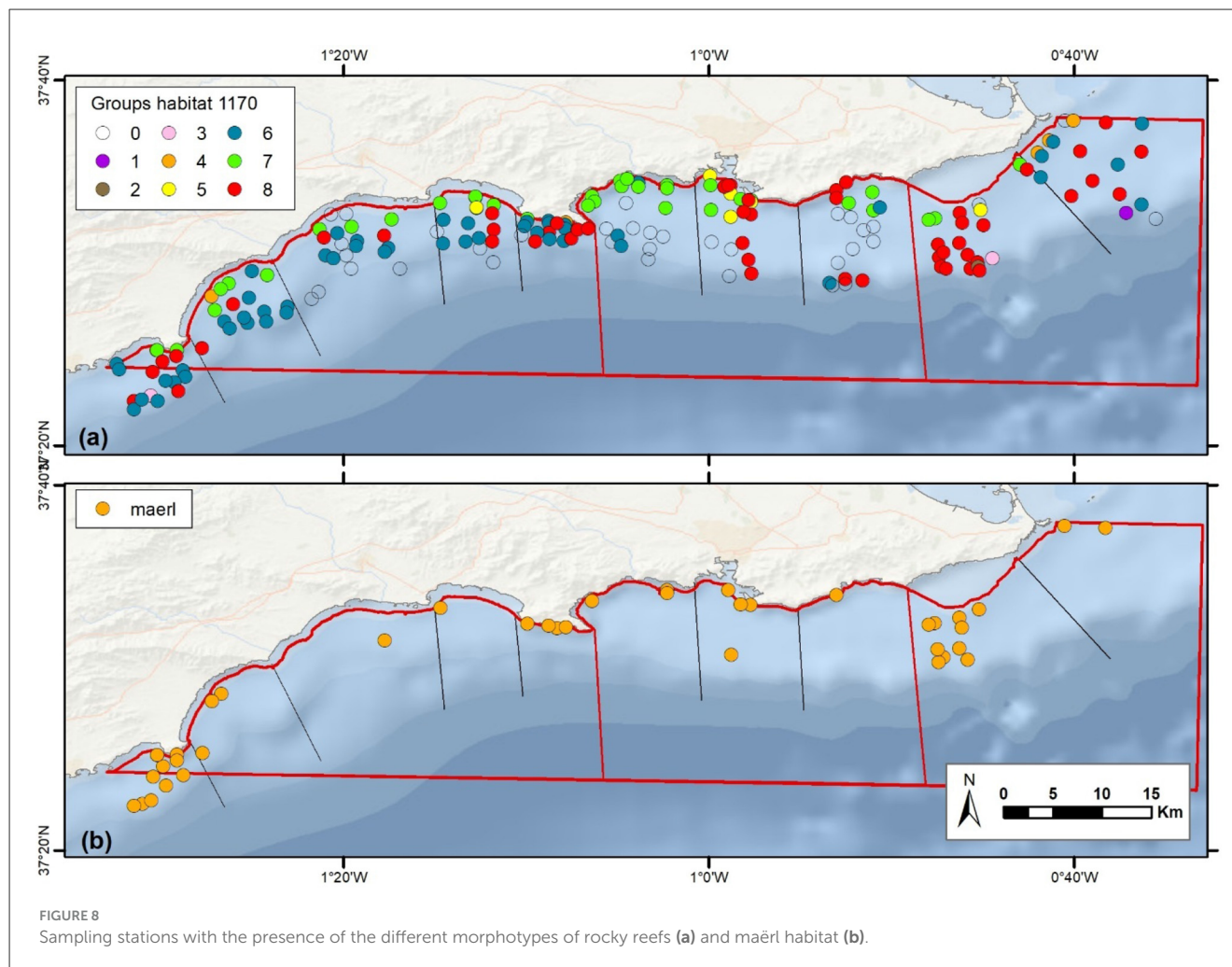
3.3.1 HB-Bio: percentage of area occupied by biogenic substrate

Areas of potential habitats for every target habitat were estimated. For maërl seabeds, the results obtained indicate that

the percentage of occupation of the potential habitat is around 13% of the surface of the SCA in the bathymetric range studied, which in this case coincides with the distribution of the habitat, since the maximum depths up to which maërl biocenosis have been located in the Mediterranean are around 180 m deep (Basso, 1996). For reefs, the percentage of occupation of the SCA within the bathymetric range studied (up to 300 m depth) is 68%. Of the three morphotypes within rocky reefs habitat 1170, Rocky dominated by *Filigrana implexa* (1170-RFi) is the one that occupies the largest area (42%).

3.3.2 HB-div: diversity

Shannon- diversity index was estimated for the rocky reefs habitats (Table 6). Rocky dominated by *Filigrana implexa* (1170-RFi) is the 1170 habitat with the highest biodiversity index values



($H' = 3.22$). In the case of maerl bottoms, although the species present in the SCA have been identified using the physical samplers, it was not possible to have a complete taxonomic identification to allow an appropriate and unbiased calculation of the diversity index, so we consider this index is not applicable with the current available data.

3.3.3 HB-est: structuring species quantification

The main structuring or constructing species of each of the identified habitats were identified as well as the percentage of occurrence of these species with respect to the total number of video sets analyzed has been obtained (Table 6). In the case of maerl biocenosis, the most common species obtained were *Phymatolithon calcareum*, *Lithothamnion* sp., *Lithophyllum racemus*, *Peyssonnelia rosa-marina* and *Mesophyllum* sp., although as it is not possible to carry out a complete taxonomic characterization at the species level, an approximation has been made level Order Corallinales (Phylum Rhodophyta).

Regarding the structuring species of habitat 1170 and their different morphotypes, *Pentapora fascialis* is the most common species and has been identified in 34.4% of the video sets analyzed. However, this value does not present great differences with respect

to the other two structuring species of habitat 1170, *Filograna implexa*, and *Neopycnodonte cochlear*, which have been found in 30.7% and 29.6% of the sets respectively (see also Table 2 on list of selected structuring species for reefs habitats).

3.3.4 HB-RangBat: bathymetric range

Presence of maerl were found at depths between 23 and 91 meters (Table 6). Regarding rocky reefs, these habitats were found between 23 and 146 meters deep (Table 6). The rocky habitat dominated by *Filograna implexa* is the habitat for which a greater bathymetric range has been identified, between 23 and 144 meters deep, always taking into account the sampled bathymetric range (20–300 m).

3.3.5 HB-RangGeo: geographic range

In terms of geographical range, the two target habitats cover the entire geographical range of the SCA, although their geographical distribution is different within the SCA (Figure 10). The maerl seabed is concentrated in specific locations within the SCA, mainly in Águilas, Calnegre, Calblanque, and Cabo de Palos, where the potential area occupied by this habitat is larger. Rocky reefs (habitat

TABLE 4 Benthic habitats identified, specifying the number of video sampling sets (miniROVs and sleds) as well as the most abundant species in every group and depth of the sets.

Group	Benthic habitat identified	Acronym	N sets	Typical species	Mean depth (m) (min–max)
Maërl	Maërl	Maërl	40	<i>Lithophyllum racemus</i> , <i>Liagora viscida</i> , <i>Lithothamnion</i> sp., <i>Mesophyllum</i> sp., <i>Peyssonnelia</i> sp., <i>Phymatolithon calcareum</i> , <i>Spongit</i> <i>fruticulosa</i>	55.18 (23.00–91.49)
Hab 1170 - Cluster 4	Rocky dominated by <i>Halocynthia papillosa</i>	1170-RHp	6	<i>Halocynthia papillosa</i> , <i>Eunicella gazella</i>	50.31 (37.91–64.60)
Hab 1170 - Cluster 5	Rocky dominated by <i>Leptogorgia sarmentosa</i>	1170-RLs	6	<i>Leptogorgia sarmentosa</i> , <i>Eunicella verrucosa</i> , <i>Paramuricea clavata</i>	65.34 (39.17–81.31)
Hab 1170 - Cluster 6	Aggregations of <i>Neopycnodonte cochlear</i>	1170-ANc	53	<i>Neopycnodonte cochlear</i> , <i>Protula</i> sp., <i>Pentapora fascialis</i>	76.21 (36.75–145.69)
Hab 1170 - Cluster 7	Rocky dominated by <i>Pentapora fascialis</i>	1170-RPf	33	<i>Pentapora fascialis</i> , <i>Alcyonium acaule</i> , <i>Codium bursa</i>	49.25 (28.55–80.12)
Hab 1170 - Cluster 8	Rocky dominated by <i>Filograna implexa</i>	1170-RFi	52	<i>Filograna implexa</i> , <i>Pentapora fascialis</i> ,	72.55 (23.00–144.02)

1170) are distributed throughout the SCA within the bathymetric range studied, except in the central sector where some gaps appear.

3.3.6 HB-riq: specific richness

Table 6 shows the estimated specific richness values for the habitats associated with rocky reefs, with the Rocky habitat dominated by *Filograna implexa* with the highest value of specific richness ($S = 25$). As in the HB-div: Diversity index, it was not possible estimate HB-riq and we consider this index is not applicable with the current available data.

3.3.7 HB-TSC: typical species composition

Typical species for each target habitat were identified, also considering the different morphotypes of rocky reefs (Table 4). In the case of maërl there is a high heterogeneity of the typical species, and although further taxonomic studies in detail are necessary, the species identified have been *Lithophyllum racemus*, *Liagora viscida*, *Lithothamnion* sp., *Mesophyllum* sp., *Peyssonnelia* sp., (*Peyssonnelia rosa-marina* and other *Peyssonnelia*), *Phymatolithon calcareum*, and *Spongit* *fruticulosa*. For every rocky reef habitat, the typical species identified for 1170-RPf have been *Pentapora fascialis*, *Alcyonium acaule*, and *Codium bursa*, for 1170-RFi *Filograna implexa* and *Pentapora fascialis*, and for 1170-ANc *Neopycnodonte cochlear*, *Protula* sp., and *Pentapora fascialis*.

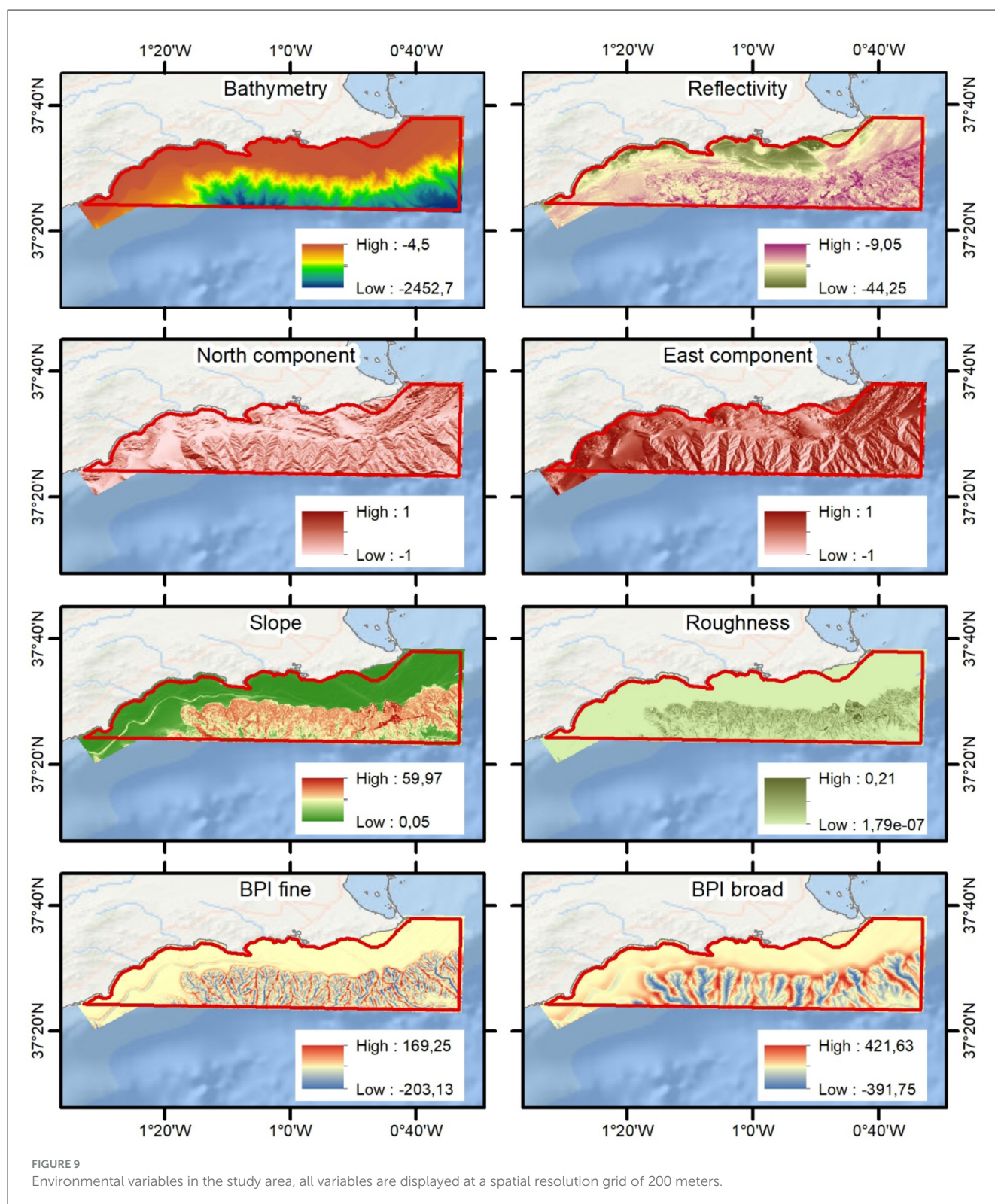
4 Discussion

A good environmental state of the benthic habitats is essential to foster and maintain all ecological relationships and marine food webs present both at the sea bottom and the water column. We need to increase the knowledge on some particular benthic

species and habitats to improve marine management, addressing their inventory, characterization, and monitoring within the conservation management plan in a coherent and coordinated manner. This research focused on two main benthic habitats of the SCA “Underwater Valleys of the Mazarrón Escarpment”, reefs (habitat 1170) and maërl bottoms. Both target habitats are of high ecological importance as they offer shelter, food, and substrate for many marine species and they are considered by the Barcelona Convention and Berne Convention of interest for their conservation.

According to Templado et al. (2009), reefs can be defined as all those compact hard substrates that outcrop on the seabed, whether of biogenic or geological origin, and can present a whole bathymetric zonation of benthic communities, including concretions of biogenic origin. It should be noted that this definition covers both a biogenic and non-biogenic component. The maërl seabed, also called rhodoliths, is a marine benthic community composed mainly of calcareous free-living red algae that form extensive beds in sedimentary soils (Picard, 1965). According to Templado and Calvo (2002), maërl-forming species form a perennial and heterogeneous habitat, they are heterogeneously distributed in the photic zone (Ballesteros, 1989; Foster, 2001; Barberá et al., 2003, 2017; Kamenos et al., 2004) forming very complex communities both structurally and functionally, which gives them intermediate characteristics between loose and hard substrates (Bordehore et al., 2003; Templado et al., 2009; Gofas et al., 2014). Apart from the diversity of substrate-forming species, various organisms such as bryozoans and small encrusting sponges settle on it, creating microcosms of great diversity (Ramos-Esplá et al., 1993, 2000; Giménez-Casaldueiro et al., 2011).

In recent years, various studies have been carried out to expand our knowledge of the marine ecosystems of the Murcian coast.



These studies have been carried out mainly on behalf of the Environmental Administration of the Autonomous Community of Murcia (Calvín, 1999, 2001; Ballester Sabater, 2003), and most have been conducted between the coastline and a depth of 50 m (Pérez-Ruzafa and Honrubia, 1984; Soto, 1992; García-Charton

and Pérez-Ruzafa, 2001). This has made it possible to highlight their richness, map the coastline based on biocenoses, and develop conservation proposals and monitoring projects, among other activities (Ballester Sabater, 2003). However, very little work has been done in circalittoral or bathyal habitats (Soto, 1990), which

TABLE 5 GAM model obtained for each habitat.

Habitat	Formula	Deviance explained	AUC	Kappa
Maerl	$\text{Phmaerl} = \beta_{\text{maerl}} + s(\text{bathymetry}) + s(\text{BPI_broad}) + s(\text{east}) + s(\text{north}) + s(\text{reflectivity}) + s(\text{roughness}) + \epsilon_{\text{maerl}}$	73.8%	0.98 ± 0.02	0.89 ± 0.03
1170-RPf	$\text{Ph1} = \beta_1 + s(\text{bathymetry}) + s(\text{BPI_broad}) + s(\text{BPI_fine}) + s(\text{north}) + s(\text{reflectivity}) + \epsilon_1$	49.8%	0.94 ± 0.02	0.74 ± 0.07
1170-RFi	$\text{Ph2} = \beta_2 + s(\text{bathymetry}) + s(\text{reflectivity}) + s(\text{roughness}) + \epsilon_2$	13.4%	0.70 ± 0.07	0.30 ± 0.09
1170-ANc	$\text{Ph5} = \beta_5 + s(\text{bathymetry}) + s(\text{BPI_broad}) + s(\text{east}) + s(\text{reflectivity}) + s(\text{roughness}) + \epsilon_5$	28.4%	0.86 ± 0.03	0.59 ± 0.05

The selected formula, the deviance explained by each model, and the AUC and Kappa values, expressed as the mean and standard deviation, are specified.

are more inaccessible due to their greater depth and require much more economic and technical resources for their research.

The maërl beds of the SCA are characterized by the presence of the typical species *Liagora viscida*, *Lithothamnion* sp., *Mesophyllum* sp., *Lithophyllum racemus*, *Peyssonnelia* sp., *Phymatolithon calcareum*, and *Spongites fruticulosa*. They develop at depths from the lower infralittoral to the upper circalittoral, between 23 and 91.5 m and at an average depth of 55.2 m. In the case of maërl beds, the results obtained indicate that the percentage of potential habitat occupancy is around 13% of the SCA surface area in the bathymetric range studied, which in this case completely coincides with the habitat distribution. In terms of geographic range, maërl covers the entire geographic range of the SCA, although these communities are often distributed in patches and they are more abundant in specific locations such as Águilas, Calnegre, Calblanque, and Cabo de Palos, where the potential area occupied by this habitat is greater. These results also confirm the areas where maërl habitat had been previously reported: Águilas (Soto, 1990; Sanz-Lázaro et al., 2011; Aguado-Giménez and Ruiz-Fernández, 2012), Cabo Cope and Calnegre (Soto, 1992), Calblanque (Ruiz Fernández et al., 2011), and Cabo de Palos (Ruiz Fernández et al., 2009).

Rocky reefs (Habitat 1170) is subdivided within the SCA into five morphotypes: 1170-RPf Rocky dominated by *Pentapora fascialis*; 1170-RFi Rocky dominated by *Filograna implexa*; 1170-RLs Rocky dominated by *Leptogorgia sarmentosa*; 1170-ANc Aggregations of *Neopycnodonte cochlear*; and 1170-RHp Rocky dominated by *Halocynthia papillosa*. These habitats have been located between 23 and 146 m depth. The morphotype Rocky dominated by *Filograna implexa* (1170-RFi) is the habitat morphotype for which the greatest bathymetric range has been identified, between 23 and 144 m depth, always considering the bathymetric range sampled (20–300 m). For the whole habitat 1170, the percentage of SCA occupancy within the studied bathymetric range (up to 300 m depth) is 68%. Of the three morphotypes modeled within habitat 1170, Rocky habitat dominated by *Filograna implexa* (1170-RFi) occupies the largest area (42%) and has the highest biodiversity index values ($H' = 3.22$). Regarding its geographic range, habitat 1170 (reefs) is distributed throughout the SCA within the studied bathymetric range, except in the central sector where some gaps appear.

Regarding structure and specific functions, marine biodiversity is a fundamental natural asset for generating marine ecosystem services, understood as the benefits that humans derive from ecosystems. These services play a crucial role in supporting the

economic prosperity and social well-being of human communities (Costanza et al., 1997; Naidoo et al., 2008; Tubío Gómez et al., 2021). Understanding the ecosystem services provided by SCA ES6200048 “Underwater valleys of the Mazarrón escarpment” is essential for protecting and managing them sustainably.

According to Bellido et al. (2021), bottom trawling is the only widely used gear that has a direct impact on benthic habitats in this area. The spatial distribution of fishing effort in the bottom trawl modality is fairly constant between years since it is associated with a specific substrate type, although interannual variability in intensity is observed. The areas with the highest fishing effort are concentrated close to the continental slope in the Mazarrón Escarpment, as well as in the northern part of the Gulf of Alicante pockmark field (Bellido et al., 2021). These areas with a high fishing density are characterized by flat bottoms with soft sediments, preferred for bottom trawling. To protect and promote the regeneration of fishery resources, there are two artificial reef zones partially included in the SCA and 24 anchorages to prevent seabed deterioration. Shellfish harvesting for the bivalve clam is also carried and there are three aquaculture facilities in the area, with high production of seabream, sea bass, croaker, and bluefin tuna.

In order to analyze the future prospects of the SCA, in addition to knowing the current nature of the target habitats, it is necessary to know in detail the pressures currently suffered by the area, its intensity, duration and impact, as well as both the present and future risks and threats that the protected area may suffer. In the case of maërl beds, due to the low growth rate of the species that form it (0.5–1.0 mm/year; Blake and Maggs, 2003), they have a limited capacity to respond to disturbances (Grall and Hall-Spencer, 2003; Hall-Spencer et al., 2010). In fact, several alterations in maërl beds caused by anthropogenic activities have been described, such as impacts from extractions, for example, soil conditioning and beach replenishment (Grall and Hall-Spencer, 2003) or sediment resuspension (Barberá et al., 2003), residual discharges (Barberá et al., 2003; Aguado-Giménez and Ruiz-Fernández, 2012), fisheries (Hall-Spencer et al., 2003; Hall-Spencer and Moore, 2000; Bordehore et al., 2003), coastal construction (Barberá et al., 2003), etc. Marine species can also be directly affected by climate change, through increases in temperature, changes in salinity, increases in acidity and rising sea levels, as well as indirectly, through changes in the availability of their prey and/or habitat (BOE, 2016).

As it is a protected marine area, the pressures and threats should be of low risk, ideally of low intensity. Likewise, the status of the management measures applied in the area, their degree of

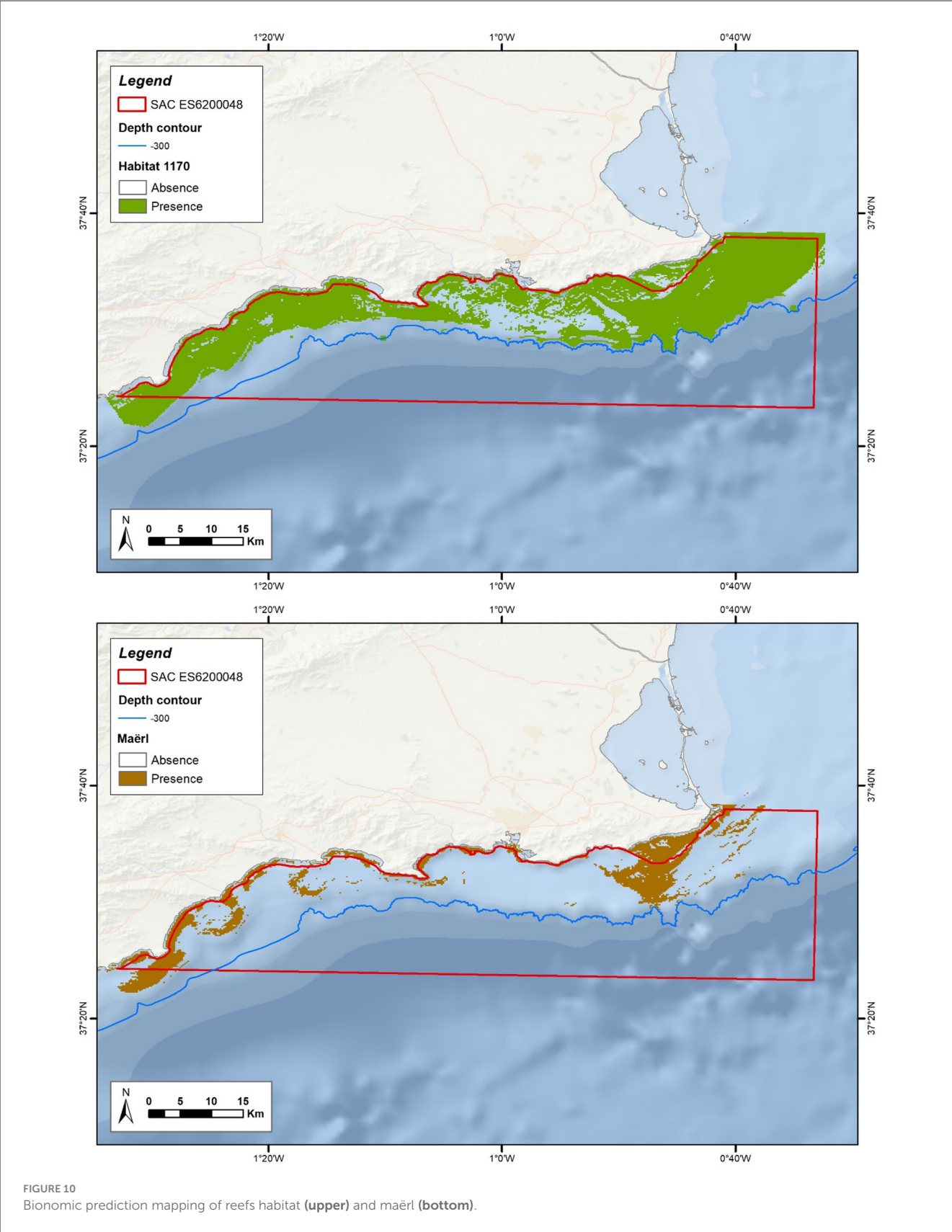


TABLE 6 Ecological indices calculated to assess the state of both target habitats.

Habitat	HB-Bio		HB-div	HB-est		HB-RangBat		HB-riq
	Area (ha)	Occupancy percentage*	Shannon	Structuring species	Presence (%)	Min depth	Max depth	Specific richness
Maërl	10,698.2	13.6	Not applicable	Corallinales	21.2	23.00	91.49	Not applicable
Habitat 1170	53,676.1	68.0	3.26	**	**	23.00	145.69	26
1170-RPf	14,684.5	18.6	2.77	<i>Pentapora fascialis</i>	34.4	28.55	80.12	16
1170-RFi	33,086.3	41.9	3.22	<i>Filograna implexa</i>	30.7	23.00	144.02	25
1170-ANc	30,965.6	39.2	2.40	<i>Neopycnodonte cochlear</i>	29.6	36.75	145.69	11

*Estimated percentage in the bathymetric range sampled (from the lower limit of the SCA to 300 m depth). **Habitat 1170 is a combination of different rocky habitat morphotypes, see Table 4 for structuring species for the entire habitat 1170.

implementation, compliance and monitoring of sanctions must be studied in detail. These aspects, which correspond to more advanced stages of knowledge, they were not the goal of this study. However, this work provides a complete background knowledge that will be essential for subsequent studies where an assessment of the future prospects of the target habitats maërl and rocky reefs in the SCA can be efficiently addressed.

The functioning of the mechanisms and structure of communities and habitats, as well as the resources they provide, is essential for the medium- and long-term well-being of society. However, this functioning can be altered by human action (Díaz et al., 2006; Carpenter et al., 2009). The adequate availability and updating of scientific and technical knowledge of marine habitats allows the competent authorities to design, develop and implement management measures to ensure the conservation of these marine ecosystems, integrating them into existing sectoral policies. Both regional and local marine spatial planning are needed, where the management of resources is balanced to allow their optimization, including restrictions on activities in certain areas to avoid extreme situations, to finally achieve social and economic objectives in an open and planned manner (Ehler and Douvère, 2009; Gretta et al., 2017).

Data availability statement

The datasets presented in this article are not readily available because the authors do not have permission to share data. Requests to access the datasets should be directed to Instituto Español de Oceanografía, ieo@ieo.csic.es.

Author contributions

JB: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. BT: Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Validation, Visualization,

Writing – original draft, Writing – review & editing. AM: Data curation, Formal analysis, Investigation, Methodology, Software, Validation, Visualization, Writing – original draft, Writing – review & editing.

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Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

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