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A combined approach to assessing the conservation status of Cap des Trois Fourches as a potential MPA: is there a shortage of MPAs in the Southern Mediterranean?

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Abstract

The Mediterranean basin is recognized as one of the most diverse regions on the planet, but is being threatened by overexploitation and habitat loss. Furthermore, the Strait of Gibraltar and adjacent Alboran Sea have been identified as representing an important habitat for many threatened or endangered species. In this context, one vehicle for marine conservation is the creation of marine protected sites, although Mediterranean Marine Protected Areas (MPAs) are neither large nor representative enough to form an effective network of protection. An inventory of the benthic communities and habitats of conservation interest has been carried out in Cap des Trois Fourches, an ecological and biogeographical site of interest. Univariate and multivariate analyses showed differences for marine communities among habitats and localities, indicating a great diversity in marine assemblages but an absence of a spatial gradient in marine α-diversity. The Trois Fourches area showed a high environmental quality and hosted several endangered species. Habitats of conservation concern, such as marine caves, seagrass meadows and coralligenous assemblages, were detected and studied. The scientific data recorded provide sound support for the establishment of a new MPA in Trois Fourches, taking into account that the findings match the scientific criteria required for declaration as a protected area. The benefits for connectivity at the Mediterranean scale and the local economy are discussed.

Keywords: Coastal, littoral, Marine Protected Areas, conservation evaluation, biodiversity, invertebrates, benthos, fish.

Introduction

The Mediterranean basin is recognized as one of the most diverse regions on the planet, representing a 'hot spot' of marine biodiversity (4 to 18% of known marine species: Bianchi & Morri, 2000; Coll *et al*., 2010) and endemism (almost 25% of the species present: Boudouresque, 2004). This high biological diversity is related to the specific geomorphological and hydrographical features of the Mediterranean basin, its geological history and its position as an interface between temperate and tropical biomes, allowing it to host both cold- and warm-affinity species (UNEP/MAP-RAC/SPA, 2010). Mediterranean biodiversity is being reduced today by global threats, including anthropogenic pressures, alien species and climate change. These pressures are currently being increased in the Mediterranean, occurring at a speed that is particularly significant (Lejeusne *et al*., 2010). Consequently, key coastal habitats are being lost globally 2–10 times faster than those in tropical forests (Lotze *et al*., 2006), producing a major erosion of marine biodiversity. In this context, the ecological and conservation relevance of the Western Mediterranean basin and, specifically, the Alboran Sea has been pointed out by several authors (Templado *et al*., 2006; Coll *et al*., 2010). Furthermore, the Strait of Gibraltar, with the adjacent Alboran Sea and African coast have been identified as important habitats for many threatened or endangered species (Coll *et al*., 2010).

In contrast, the present situation indicates that Mediterranean coastal areas are inadequately protected, planned and managed. Although marine protected sites have received much interest recently as a vehicle for marine conservation (Allison *et al*., 1998), the present Marine Protected Areas (MPAs) are neither large nor representative enough to form an effective network of protection in the Mediterranean (Amengual *et al*., 2008). On the other hand, it is difficult to establish the current situation at local scales (α-diversity) in Mediterranean coastal areas (Coll *et al*., 2010). In most cases reserve design and site selection have in fact involved little scientific justification (Fraschetti *et al*., 2002). In this context, it is necessary to undertake field studies and explore those zones of biological interest to collect data in order to address this issue.

Additionally, the Mediterranean Sea suffers from a heterogeneous distribution of MPAs, an issue that makes it difficult to achieve conservation goals. Although great effort has been undertaken in this regard, the Southern Mediterranean has a shortage of MPAs, with several countries in Northern Africa having only one MPA each (see Portman *et al*., 2012).

A majority of the studies focused on fish populations have measured an important increase in abundance, biomass and fecundity (García-Chartón *et al*., 2008). Nevertheless, few studies have addressed the effects of protection on benthic species (Fraschetti *et al*., 2002). However, hard-bottom subtidal benthic assemblages can be the ideal target for studying and supporting the implementation of MPAs. Shallow marine assemblages (up to 10 metres depth) can be considered as good indicators of environmental change because species living at shallow depths are particularly exposed to the impacts of coastal activities and thus tend to exhibit stronger responses to human pressure than do assemblages from deeper habitats (Fraschetti *et al*., 2002).

Seagrass beds form another marine habitat of great interest, representing one of the most important habitats that can be found on the soft bottoms of coastal areas around the world (Den Hartog, 1970; Templado, 2004). This importance derives from the fact that seagrasses have a greater richness and density of animals than the adjacent unvegetated areas (Heck *et al*., 1995; Guidetti, 2000; Nakamura & Sano, 2005), offer protection against predators (Heck, 1981), reduce the effects of hydrodynamism (Fonseca & Koehl, 2006) or enhance the recruitment of several species (Wilson, 1990). Additionally, seagrasses are good indicators of changes in marine ecosystems and can be used in monitoring programmes (Dauvin, 1997), taking into account that they contribute to climate change mitigation through their role as a carbon sink (Duarte *et al*., 2013). Therefore, the study of these habitats is encouraged in the context of coastal area management.

Finally, knowledge of the distribution of endangered species is one of the major challenges in marine conservation. In this sense, the Mediterranean Sea shows high concentrations of endangered and endemic species. A good example is *Patella ferruginea*, the most endangered marine macroinvertebrate in the western Mediterranean (Ramos, 1998), which is included in several directives both at European and State level (MMAMRM, 2008).

García-Chartón *et al.* (2008) point out that site selection criteria for the establishment of new MPAs should be based on sound scientific information, in order to ensure that MPA objectives can be achieved; it is crucial that the criteria used to designate MPAs include environmental quality issues, the importance of the site for reproduction of overexploited or protected species, the presence of high biodiversity, and as many habitat types as possible. Additionally, connectivity between MPAs must be guaranteed in order to achieve conservation objectives, for which the size of MPAs and the distance between them is one of the main factors. In this context, there is a reasonable scientific consensus that networks of intermediate-sized reserves will be more effective than fewer large reserves in the marine environment. Considering size, Shanks *et al*. (2003) suggest that reserves that are *ca.* 4–6 km across should be able to capture most short-range dispersing species, whereas a size ranging from 10–100 km^2 has been proposed by several other studies (Boudouresque, 1996; National Research Council, 2001). Considering distance, some authors (Boudouresque, 1996; Shanks *et al*., 2003) estimated that reserves spaced *ca.* 20 km apart should support long-range dispersing species, such as the Mediterranean Monk Seal *Monachus monachus*, in encountering protected habitats frequently enough to ensure sustainability of populations and stocks. Furthermore, the choice of site and the design of MPAs is frequently based on opportunity rather than on ecological criteria (García-Chartón and Pérez-Ruzafa, 1999; Lasiak, 1999).

In light of the previous remarks, the aim of this study was to undertake a combined approach to characterizing the marine biodiversity in Cap des Trois Fourches (Northern Morocco), an area of high biological and biogeographical importance. In this context, singular habitats such as marine caves and seagrasses were located in order to collect fundamental scientific information, supporting an ecosystem-based management approach within a conservation context. We were specifically interested in evaluating the suitability of Cap des Trois Fourches as a potential MPA in the Southern Mediterranean.

Material and Methods

Study area

Cap des Trois Fourches is located in the Alboran Sea in the Southern Mediterranean, Northern Morocco (Fig. 1). This area is recognized by the Moroccan government as a site of biological and ecological interest (SBEI) (AEFCS, 1996) and as a RAMSAR site of international importance (Bazairi *et al*., 2011), although it is not a protected area. It is a site of high aesthetic value, unique in the Mediterranean. Its ecological values are related to some species that are remarkable in a global context (Monk Seal *Monachus monachus*, Audouin's Gull *Larus audouinii*, Loggerhead turtle *Caretta caretta*, Giant Limpet *Patella ferruginea*) (Bazairi *et al*., 2011).

The Trois Fourches SBEI, with an area of 5000 ha, occupies the extremity of the Cap des Trois Fourches and is limited to the east by Tibouda and to the west by Cala Charrana. It encompasses several environments of high biological value. Rocky impervious cliffs, some islets and sand or gravel beaches dominate the coast.

Fieldwork was carried out in September 2012, within the framework of the MedMPAnet project. The aim of the survey was to collect data in order to evaluate the

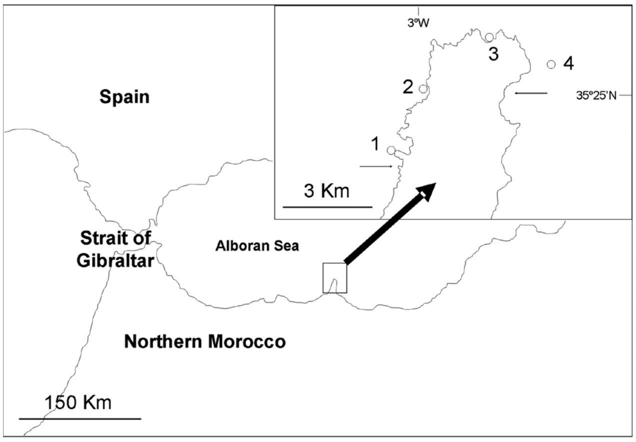

Fig. 1: Map of the study site. White circles indicate sampling localities. Arrows indicate the limit of the protected area (Site of biological and ecological interest as designed by Moroccan authorities). 1: Charrana, 2: Zona Oeste, 3: Cala Faro, 4: Farallones.

suitability of the area as a potential MPA on the Mediterranean Moroccan coast. Four localities of high ecological value were selected from along the coastline, according to the available bibliographic information (González García, 1994; Bueno del Campo & González García, 1996; González García *et al*., 2005).

Rocky shore communities

The whole coastline of the study area was surveyed using a 6m rubber inflatable boat with 60 HP engine as the survey platform. A bathyscope was used to assess the dominant communities along the coastline in the range of 0–10 m depth, and scuba diving was undertaken for detailed exploration of benthic assemblages, such as caves, seagrass beds and rocky shores. Three different sites were randomly selected per locality and a 10 m-transect was placed parallel to the coast at each site in order to study quantitatively the marine benthic communities associated with rocky substrata. Three different photographs were taken along the transect using 25x25 cm quadrats and a Nikon D80 camera, AF-S Nikkor 18–70 zoom lens, Ikelite DSLR underwater housing (8-inch dome port) for the Nikon D80 and one underwater flash Ikelite Substrobe DS 200. The auxiliary lens B+W 67 NL-4 was used for correcting distorted images. The quadrats were placed at the beginning, in the middle and at the end of the transect. This procedure was repeated for three different habitats at each site: upper midlittoral (+0.5 m above zero tidal level), lower midlittoral (0–0.5 m above zero tidal level) and sublittoral (5–10 m below zero tidal level). Deeper assemblages, such as coralligenous ones, were qualitatively prospected by means of scuba diving in Farallones, where this habitat can be found, according to previous local information.

Photographs were digitally analysed using Adobe Photoshop 6.0©. A digital network of 25 squares was superimposed onto the photographs and adjusted using the *distortion* tool. The coverage of each species was then measured.

Finally, all specimens of the endangered species *Patella ferruginea* found at each transect were measured with a calliper, to the nearest mm, along the longitudinal axis (Guerra-García *et al*., 2004).

Assessment of fish assemblages

A census of fish species was undertaken at each location. A linear transect of 10 min and 2 m width was surveyed by a scuba diver at 10 m depth, and the number of individuals per species was recorded following a method adapted from De Girolamo & Mazzoldi (2001). In the case of very abundant species, an arbitrary value of 1000 specimens was assigned for statistical analyses, taking into account that the most abundant species that could be counted consisted of 132 specimens.

Study in marine caves

Previous surveys conducted along 20 km of the coastline, embracing the entire Northern and Eastern shores of Cap des Trois Fourches, revealed the existence of more than ten caves suitable for *Monachus monachus*, of which four were recognized as optimal for reproduction in the area (Bayed *et al*., 2005).

During the present survey, the western coastline of the site was surveyed to search for further suitable caves. Swimming or snorkelling methods were used to explore every opening in the rocks at sea level.

The caves considered in this study to be potential terrestrial habitat (resting or breeding site) for the Mediterranean Monk Seal were those having an aquatic corridor leading to a cave beach or rocky platform, and which were poorly illuminated with a certain degree of protection from direct wave action (Karamanlidis *et al*., 2002).

Detection and study of seagrasses

A survey to find seagrasses in the area of Trois Fourches was conducted. Previous local studies of the area were used (González-García, 1994) in order to detect potential sites that might harbour this type of habitat. Once the sites were selected on the western side of Cap des Trois Fourches, linear transects, established along the coast at a depth at which seagrasses might be found (10–12 m), were surveyed by means of scuba diving. When a seagrass meadow/patch was detected, general data about its extension and morphology were collected using a circular search. Furthermore, to study the seagrass, 20 quadrats of 25x25 cm were randomly located to measure *in situ* the number of shoots and leaves per shoot following the standard methodology (Boström & Bonsdorff, 1997; Krause-Jensen *et al*., 2000; Middelboe *et al*., 2003; González-Correa *et al*., 2005).

Data analysis

Mean and standard deviation of coverage for each species were calculated at each sampling site, as well as the

Shannon–Wiener diversity index (Shannon & Weaver, 1963) and the total number of species (S). Two different statistical approaches (univariate and multivariate) were used to identify potential changes in community structure, based on the null hypothesis of no change in community structure composition among localities, habitats and sites.

To test whether the species richness and diversity of marine communities were similar across localities, habitats and sites, a multifactorial analysis of variance (ANOVA) was used with the following factors: 'Habitat' (Ha), a fixed factor and orthogonal, with three levels (*upper midlittoral, lower midlittoral* and *sublittoral*); 'Locality' (Lo), a fixed factor and orthogonal, with four levels (*Charrana, Zona Oeste, Cala Faro* and *Farallones*), and 'Site' (Si), a random factor and nested with 'Locality', with three random sites. Three samples (n = 3) were considered for each site. Prior to the ANOVA, homogeneity of variance was tested with Cochran's C-test. When the ANOVA indicated a significant difference for a given factor, the source of difference was identified using the Student–Newman–Keuls (SNK) test. Coverage parameters for seagrasses were also analysed by means of a one-way ANOVA. Analyses with balanced data were conducted with GMAV5 (Underwood *et al*., 2002). An unbalanced one-way ANOVA was undertaken, using SPSS© 15.0, to test differences in size and densities of *Patella ferruginea* among localities.

Permutational multivariate analysis of variance (PERMANOVA) was used to test hypotheses regarding differences in community structure between types of habitat (upper midlittoral, lower midlittoral and sublittoral) and locality (Charrana, Zona Oeste, Cala Faro, Farallones). Multivariate MDS (non-metric multidimensional scaling) statistics were also used based on the UPGMA method (Unweighted Pair-Group Method using arithmetic averages), along with the Bray–Curtis similarity index. MDS was used to test differences in community structures among habitats and localities. Clusters of sites identified as statistically significant using the profile test SIMPROF ($p<0.05$) were considered to have a similar community structure. Kruskal's stress coefficient was used to test the ordination (Kruskal & Wish, 1978). Data were square root transformed. The percentage similarity (SIMPER) procedure was then used to calculate the contribution of each species to the similarity between habitats and localities. Multivariate analyses were carried out using the PRIMER v.6+PERMANOVA package (Clarke, 1993).

Results

The total number of species (flora and fauna) detected during the present study (quantified by means of quadrats in addition to those recorded *in situ*) was 132. Neither epiphytic algae nor associated macrofauna were studied (Table 1). Seventeen of these species are listed as protected in the annexes of several International and European conventions (Table 1).

Qualitative description of assemblages highlighted that the rocky intertidal communities were dominated by the barnacle *Chthamalus* sp., molluscs belonging to the genus *Patella* and the calcareous algae *Lithophyllum byssoides* at the upper intertidal. On the other hand, the lower intertidal was dominated by seaweeds, such as *Cystoseira tamariscifolia*, *Hypnea musciformis* and *Corallina elongata*.

Subtidal rocky substrata were characterized by the presence of a facies dominated by the brown algae *Halopteris filiscina* and the sea urchin *Paracentrotus lividus*, with the non-native red algae *Asparagopsis taxiformis* being present in the Charrana area at depths between 0–10 m. A different facies was detected in the Zona Oeste area composed of the brown algae *Cystoseira mediterranea* and *H. filiscina* at similar depth ranges. Below 10 m depth, a soft bottom of fine-medium sand can be found on the west side of the study area (from Charrana to Cabo Viejo, beyond Zona Oeste). In the Cala Faro area, a facies of *H. filiscina*, the red algae *Peyssonnelia squamaria* and *A. taxiformis* were recorded. Finally, in the Farallones area, a facies of *H. filiscina* and *P. lividus* were observed from 0 to 5 m depth, whereas a different assemblage dominated by the orange coral *Astroides calycularis* and the white gorgonian *Eunicella singularis* were found from 5 to 15 m depth. At depths between 15 and 25 m, a typical coralligenous assemblage appeared, with the gold coral *Savalia savaglia*, the red gorgonian *Paramuricea clavata* and the bryozoans *Pentapora fascialis* and *Reteporella septentrionalis* being present. Many marine caves were also recorded (Table 2). Some of them were suitable as habitat for the Monk Seal (*Monachus monachus*), as they contained small pebbled beaches. Other caves showed highly structured assemblages dominated by sponges and cnidarians. A typical facies of these was composed of the orange coral *A. calycularis* and the sponges *Petrosia ficiformis* and *Phorbas tenacior*. Other species that can be found in the caves of Cap des Trois Fourches were the sponges *Clathrina clathrus*, *Chondrosia reniformis* and *Axinella damicornis*; the sea squirts *Polycitor adriaticum* and *Aplidium elegans*; the mollusc *Bertellina edwardsi* and the gorgonian *Leptogorgia lusitanica*. Statistics on descriptive parameters for the whole community associated with rocky shores are included in Table 3. For species richness, there were significant differences among habitats and localities, and a significant interaction can be found (HaxSi(Lo)). As a general pattern, the number of species was higher in the sublittoral, followed by the lower midlittoral and, finally, by the upper midlittoral (Fig. 2a). Nevertheless, this pattern is not consistent for all sites (see Charrana site 1; Fig. 3) and significant interaction HaxSi(Lo) can be recorded. Regarding localities, Charrana had a greater number of species (Fig. 2b). In terms of Shannon diversity, there were significant differences among habitats and sites, and significant interaction appeared (HaxSi(Lo)). For habitats, the pattern was similar to that found for species richness, although a sig-

Table 1. List of species found in Trois Fourches area (see Fig. 1).

FLORA	*Corallina elongata*	*Hemimycale columella*	***Annelida***	*Patella ferruginea* [1,2,4]	*Ciona* sp.	*Parablennius tentacularis*
Cyanophyceae	*Gelidium* sp.	*Ircinia* sp.	*Filograna implexa*	*Patella rustica*	*Clavelina nana*	*Phycis phycis*
Rivularia bullata	*Hypnea musciformis*	*Oscarella lobularis*	*Hermodice carunculata*	*Pinna rudis* [1,2]	*Didemnum* sp.	*Salpa salpa*
Chlorophyceae	*Jania rubens*	*Petrosia ficiformis*	*Protula* sp.	*Sepia officinalis*	*Halocynthia papillosa*	*Scorpaena* sp.
Bryopsis plumosa	*Laurencia obtusa*	*Phorbas tenacior*	***Echiura***	*Siphonaria pectinata*	*Phallusia mammilata*	*Serranus cabrilla*
Cladophora sp.	*Lithophyllum byssoides* [1,2]	*Sarcotragus* sp.	*Bonellia viridis*	*Stramonita haemastoma*	*Polycitor adriaticus*	*Serranus scriba*
Codium adhaerens	*Lithophyllum sp.*	***Cnidaria***	***Bryozoa***	***Arthropoda***	*Pseudodistoma crucigaster*	*Symphodus roissali*
Codium bursa	*Mesophyllum sp.*	*Actinia equina*	*Myriapora truncata*	*Balanus sp.*	***Elasmobranchii***	*Symphodus* sp.
Codium decorticatum	*Nemalion helminthoides*	*Aglaophenia* sp.	*Pentapora fascialis*	*Chthamalus* sp.	*Torpedo marmorata*	*Symphodus tinca*
Ulva rigida	*Peyssonnelia squamaria*	*Anemonia sulcata*	*Reteporella (=Sertella) septentrionalis*	*Pollicipes pollicipes*	***Actinopterygii***	*Thalassoma pavo*
Phaeophyceae	*Polysiphonia sp.*	*Astroides calycularis* [1,2,3]	***Mollusca***	*Scyllarus arctus* [5,6]	*Apogon imberbis*	*Thorogobius ephippiatus*
Cladostephus sp.	*Sphaeroccocus coronopifolius*	*Caryophyllia smithii*	*Bolma (=Astraea) rugosa*	***Echinodermata***	*Ariosoma balearicum*	*Trachinotus ovatus*
Colpomenia sinuosa	*Zonaria tournefortii*	*Cladocora caespitosa* [3]	*Bertellina edwardsi*	*Antedon mediterranea*	*Boops boops*	*Tripterygion* sp.
Cystoseira mediterranea [1,2]	***Magnoliophyta***	*Epizoanthus* sp.	*Chiton olivaceus*	*Arbacia lixula*	*Chromis chromis*	*Xyrichthys novacula*
Cystoseira tamariscifolia [2]	*Cymodocea nodosa* [1,2]	*Eunicella singularis*	*Cymbula nigra* [1,2]	*Astropecten aurantiacus*	*Coris julis*	
Dilophus spiralis	**FAUNA**	*Leptogorgia lusitanica*	*Dendropoma petraeum* [1,2]	*Holothuria forskali*	*Dactylopterus volitans*	
Dictyota dichotoma	***Porifera***	*Leptopsamnia pruvoti*	*Charonia lampas* [1,2]	*Marthasterias glacialis*	*Diplodus sargus*	
Halopteris filiscina	*Axinella damicornis*	*Paramuricea clavata*	*Lithophaga lithophaga* [1,2,3,4]	*Ophidiaster ophidianus* [1,2]	*Diplodus vulgaris*	
Padina pavonica	*Chondrosia reniformis*	*Pelagia noctiluca*	*Luria lurida* [1,2]	*Paracentrotus lividus* [6]	*Lepadogaster* sp.	
Rhodophyceae	*Clathrina clathrus*	*Savalia savaglia* [1,2]	*Mytilus galloprovincialis*	*Sphaerechinus granularis*	*Lithognathus mormyrus*	
Amphiroa rigida	*Crambe crambe*	***Platyhelminthes***	*Octopus vulgaris*	***Tunicata***	*Mullus surmuletus*	
Asparagopsis taxiformis	*Crella elegans*	*Prostheceraeus roseus*	*Osilinus turbinatus*	*Aplidium elegans*	*Muraena helena*	
Ceramium sp.	*Dysidea avara*		*Patella caerulea*	*Aplidium* sp.	*Oblada melanura*	

1: Annex I (flora) and II (fauna) Bern Treaty; 2: Annex II Barcelona Treaty; 3: Annex II CITES Treaty; 4: Annex V Directive 92/43; 5: Annex III Bern Convention; 6: Annex III Barcelona Treaty.

Table 2. List of marine caves surveyed in Trois Fourches area.

Nº cave	Coordinates	Habitat suitable for monk seal
1	38°25.955’ N / 02°59.641’ W	No
2	35°25.624’ N / 02°59.721’W	Yes
3	35°25.505’ N / 02°59.736’W	No
4	35°25.435’ N / 02°59.766’W	No

Table 3. Results of the three-factor ANOVA for species richness and Shannon-Wiener diversity. MS=mean square; P=level of significance; df=degrees of freedom.

		Species richness (S)			**Shannon diversity (H’)**		
Source of variation	df	MS	F	P	MS	F	P
Ha	2	48.3981	11.85	0.0007***	3.6548	21.62	0.0000***
Lo	3	10.1821	4.95	0.0313*	0.3734	2.62	0.1228
Si(Lo)	8	2.0556	1.32	0.2469	0.1425	2.33	0.0274*
HaxLo	6	10.0154	2.45	0.0710	0.3825	2.26	0.0899
HaxSi(Lo)	16	4.0833	2.63	0.0028**	0.1691	2.77	0.0017**
RESIDUAL	72	1.5556			0.0611		
TOTAL	107						
Cochran’s C-test		C=0.0774 NS			C=0.1506 NS		
Transformation		None			None		

NS: not significant; * *P<0.05*; ** *P<0.01*; *** *P<0.001*

nificant difference was detected between the upper and lower midlittoral (Fig. 2a). However, this pattern was not consistent for all sites (see Charrana site 1; Fig. 4). There were no differences in diversity between localities (Table 3; Fig. 2b).

The PERMANOVA showed significant differences in marine assemblages among habitats and localities (Table 4). The presence of an interaction (HaxLo) indicated that the differences were not consistent for all the habitats and localities. In fact, the two-dimensional MDS plot showed a segregation of sampling sites, mainly by habitat and, for the sublittoral, a spatial segregation by localities; however, some sites were closer to sites of a different habitat than to sites of the same habitat and/or locality (Fig. 5). SIMPER analysis showed a similarity of 11.44% between the sublittoral and lower midlittoral, 8.99% between the upper and lower midlittoral, and only 1.33% between the upper midlittoral and sublittoral. In this context, the species which most contributed to the similarity were *Chthamalus* sp. (51.49%) and *Patella caerulea* (10.39%) for the upper midlittoral, *Corallina elongata* (26.68%), *Cystoseira tamariscifolia* (20.82%) and *Jania rubens* (17.09%) for the lower midlittoral, and *Lithophyllum* sp. (19.06%), *Halopteris filiscina* (12.44%) and *Astroides calycularis* (11.95%) for the sublittoral. With regard to localities, Charrana and Farallones showed the highest similarity value in the marine communities (56.47%), whereas the lowest value was recorded between Zona Oeste and Cala Faro (40.97%). Surprisingly, the similarity in marine communities was not defined by proximity, indicating the absence of a spatial gradient.

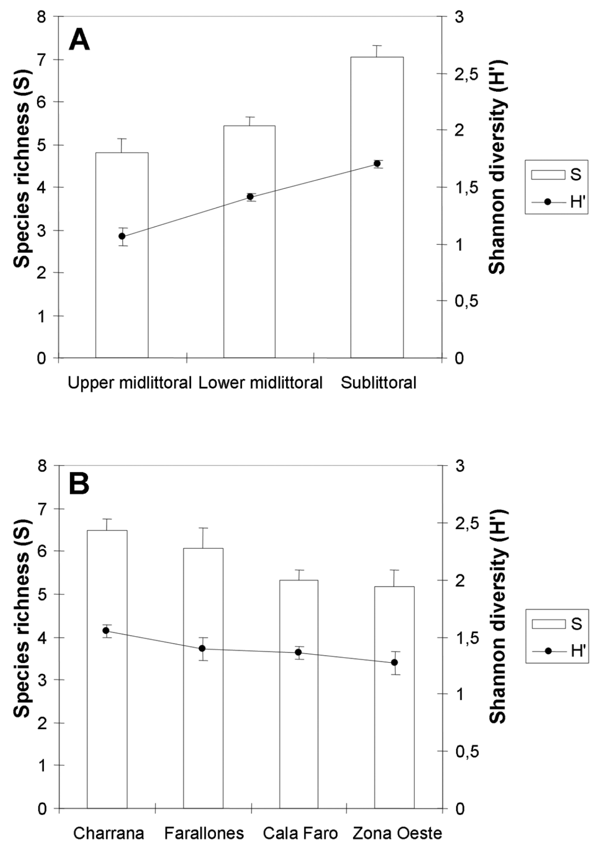

Fig. 2: Mean number of species (S) and Shannon diversity (H’) (±SD) for habitats (A) and localities (B). Species richness, SNK test for habitats: ** High=Low<Sublittoral; SNK test for localities: * Charrana=Farallones; Farallones=Cala Faro=Zona Oeste. Shannon diversity, SNK test for habitats: ** High<Low<Sublittoral; SNK test for localities: NS. * *P<0.05*, ** *P<0.01*; *NS: not significant*.

Table 4. Results of the multivariate permutational analysis (PERMANOVA) for marine communities. The matrix used is the same that for MDS analysis, SS = sum of squares; MS = mean square; P = level of significance; df = degrees of freedom.

Source	**df**	**SS**	**MS**	**Pseudo-F**	***P***
Habitat (Ha)	2	76178	38089	38.699	0.001**
Locality (Lo)	3	6844.8	2281.6	2.3181	0.001**
Ha x Lo	6	12115	2019.12	2.0515	0.001**
Residual	24	23622	984.25		
Total	20	1.18E5			

**p<0.01

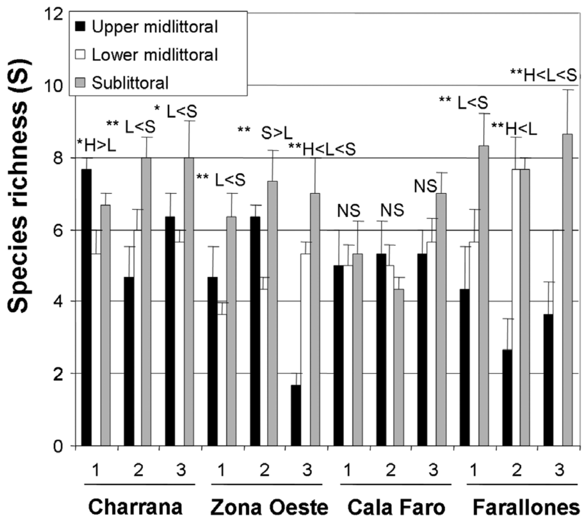

Fig. 3: Mean number of species per site (1, 2 and 3), habitat and locality. Codes above bars only indicate different habitats according to the SNK test, being similar those not showed. U: upper midlittoral; L: lower midlittoral; S: sublittoral. * *P<0.05*, ** *P<0.01*; *NS: not significant*.

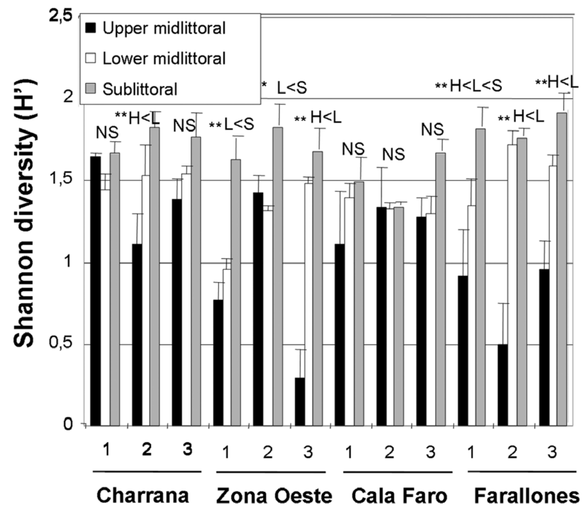

Fig. 4: Mean value of Shannon diversity per site (1, 2 and 3), habitat and locality. Codes above bars only indicate different habitats according to the SNK test, being similar those not showed. U: upper midlittoral; L: lower midlittoral; S: sublittoral. * *P<0.05*, ** *P<0.01*; *NS: not significant*.

The endangered species *Patella ferruginea* was distributed along the entire coastline of Cap des Trois Fourches. The populations were dominated by small-sized individuals and no specimens longer than 6 cm were found. Statistical differences were recorded for size among localities ($F_{4,83}$=10.58; *P<0.001*), with Farallones being the area with the highest mean size (Fig. 6). Densities ranged from 0.36 to 0.83 ind./m and no differences were detected among localities ($F_{4,10}$=0.473; *p= 0.755*) (Fig. 6).

Fish assemblages were mostly similar at each of the four localities studied. The species *Chromis chromis* and *Boops boops* dominated, although there were some differences in species composition. Furthermore, both species represented 92% of total species composition in Zona Oeste, whereas a third abundant species (*Parablennius tentacularis*) was reported in Charrana and Cala Faro. At Farallones, the dominant species accompanying *C. chromis* and *B. boops* were *Thalassoma pavo* and *Coris julis* (Table 5). The highest Shannon diversity value was recorded at Farallones (1.44), followed by Cala Faro (1.38), Charrana (1.27) and Zona Oeste (1.04). A multivariate analysis (MDS plot) showed great similarity between the fish assemblages of Cala Faro and Charrana, whereas Farallones had a different composition (Fig. 7). This dissimilarity, however, originated from differences in abundance rather than species composition.

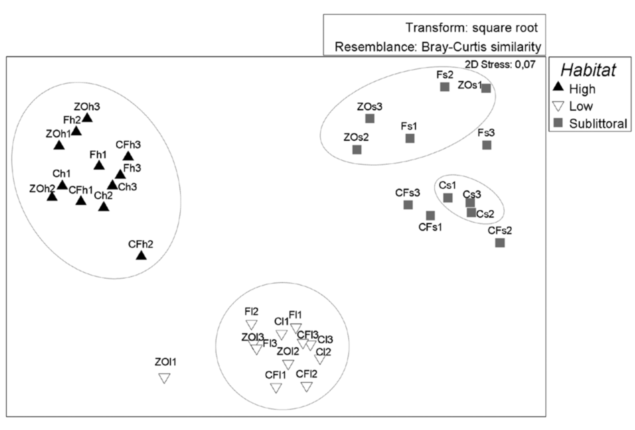

Fig. 5: Two-dimensional MDS plot for marine species coverage. Circles indicate homogenous groups according to the SIMPROF test (*P<0.05*). C: Charrana, ZO: Zona Oeste, CF: Cala Faro, F: Farallones, u: higher midlittoral, l: lower midlittoral, s: sublittoral.

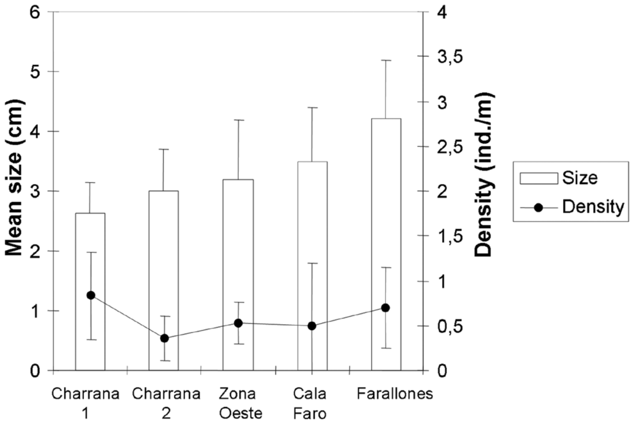

Fig. 6: Mean size (cm) and density (ind./m) of *Patella ferruginea* populations in the Trois Fourches area. An additional locality (Charrana 1: 35º23'21.86''N/3º00'34.47''W) was prospected for this species. Charrana 2 corresponds with the Charrana locality in Fig. 1. SNK test for size revealed three homogenous groups: 1) Charrana1=Charrana2=Zona Oeste; 2) Charrana2=Zona Oeste=Cala Faro; 3) Farallones.

Two meadows were detected and studied during the present study, close to the Charrana locality. Both were composed of the seagrass species *Cymodocea nodosa*. The first meadow (35º23.503N/3º00.751W, range 8.5–9.5 m in depth) was dense and continuous in extent, but limited in size (approx. 20x25 m). The second one (35º23.803N/3º00.627W, range 8.9–10.5 m in depth) was also dense and continuous and had a slightly greater size (approx. 25x35 m). Surrounding the meadows, small seagrass patches could be observed (1–2 m^2), distributed 20–40 m away from the nucleus of the meadow. The density in terms of number of shoots/m^2 and number of leaves/shoot was similar in comparison to other meadows studied in Andalusia, Northern Alboran Sea (Fig. 8).

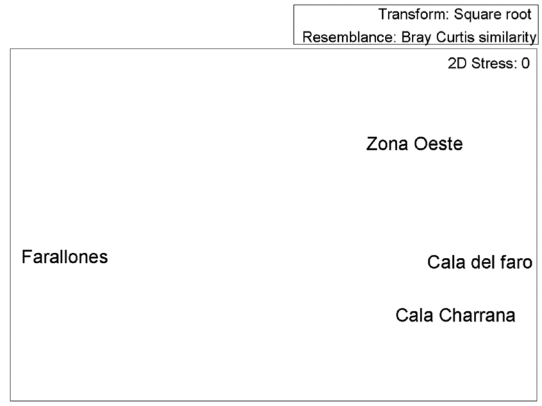

Fig. 7: Two-dimensional MDS plot for fish assemblages.

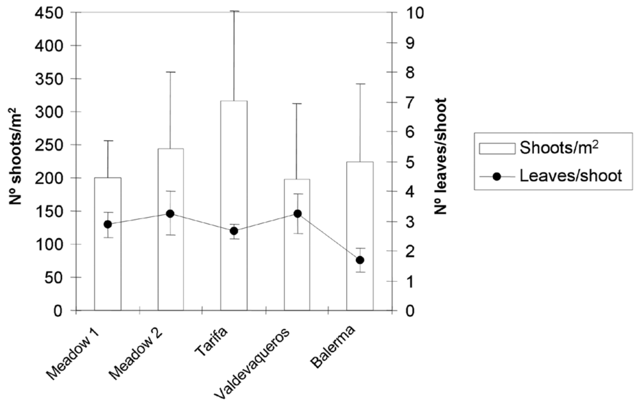

Fig. 8: Mean number of shoots/m^2 and mean number of leaves/shoot for the two studied meadows and the three patterns used for comparison (Tarifa as well-preserved and Valdevaqueros/Balerma as moderately-preserved meadows. See Laboratorio de Biología Marina, 2006). ANOVA test for shoots/m^2: $F_{4,95}$=3.71; *P<0.01*. SNK test (*P<0.05*): Meadow1=Meadow2=Valdevaqueros=Balerna<Tarifa. ANOVA test for leaves/tuft: $F_{4,95}$=30.31; *P<0.05*. SNK test (*P<0.05*): Meadow2=Valdevaqueros>Meadow1=Tarifa=Balerna.

Table 5. Abundance of fish species per transect.

	Charrana	Zona Oeste	Cala Faro	Farallones
Thalassoma pavo	7	32	32	***
Coris julis	73	40	24	***
Symphodus roissali	0	3	7	0
Symphodus tinca	0	8	1	6
Symphodus sp.	0	2	1	2
Diplodus vulgaris	40	30	132	18
Diplodus sargus	3	4	8	2
Serranus cabrilla	4	9	1	4
Serranus scriba	0	2	1	2
Boops boops	***	***	***	***
Chromis chromis	***	***	***	***
Lithognathus mormyrus	0	0	1	0
Mullus surmuletus	0	0	1	0
Sarpa salpa	0	0	20	0
Oblada melanura	0	20	3	0
Scorpaena sp.	1	0	0	0
Parablennius tentacularis	***	0	***	0
Apogon imberbis	0	2	0	1

*** Countless due to the high number of individuals. An arbitrary value of 1000 has been assigned for statistical analyses (see Material & Methods).

Discussion

The hard bottom marine communities of the Trois Fourches area showed an increasing gradient in terms of number of species and diversity from the upper midlittoral to sublittoral, which is in accordance with the expected pattern for rocky shores worldwide (Fa *et al*., 1997). The sublittoral was the most diverse habitat, with well settled orange coral populations, indicating the absence of sewage outfalls flowing beneath the surface. In fact, orange coral survival is affected by siltation (Ocaña *et al*., 2009) and is considered as a good indicator of well-oxygenated waters and an interesting bioindicator (García-Gómez, 2007; Casado-Amezúa, 2012). No clear pattern of spatial distribution was detected and the maximum values were recorded at opposite sides of the study area (Charrana and Farallones), a finding that supports the hypothesis of the absence of a diversity gradient in Trois Fourches. Nevertheless, the composition of the marine assemblages was not homogenous. In fact, the multivariate analysis revealed differences among locations, related to the expected 'patchiness' in marine communities (Raffaelli & Hawkins, 1996). This is an additional point of interest considering that community diversity is a criterion for MPA designation (Little and Kitching, 1996). Additionally, marine caves have aroused great interest over recent decades (Benedetti-Cecchi *et al*., 1996) and have been considered as singular and vulnerable habitats (Sará, 1976). In fact, they are included in European Directive 92/43 as marine habitats to be protected. In this sense, environmental conditions inside caves (low irradiance, oligotrophy and low hydrodynamism) allow the presence in shallow waters of species that are typical of deeper zones (Navarro-Barranco *et al*., 2012). Some endangered species included in several international conventions were observed in the marine caves of Trois Fourches, such as the slipper lobster *Scyllarus arctus* (listed as protected fauna by Annex III of Berna and Barcelona Treaties), the starfish *Ophidiaster ophidianus* and the orange coral *Astroides calycularis* (both listed as strictly protected fauna in Annex II of the Bern Convention and the Treaty of Barcelona). Finally, some of the surveyed caves were identified as suitable for the Monk Seal (*Monachus monachus*), a species at critical risk of extinction (IUCN ver. 3.1). In fact, the species was present in the area until recently (Mo *et al*., 2011).

A panoply of bioindicator species were well-developed at Cap des Trois Fourches, such as the seaweeds *Lithophyllum byssoides* and *Cystoseira mediterranea*, the anthozoans *Astroides calycularis*, *Actinia equina* and *Paramuricea clavata*, the sea squirts *Polycitor adriaticum* and *Halocynthia papillosa*, the fishes *Apogon imberbis, Coris julis* and *Thalassoma pavo*, and the seagrass *Cymodocea nodosa*. All of these are indicators of unpolluted waters without high levels of siltation (see Boudouresque *et al*., 2005; Ballesteros *et al*., 2007; García-Gómez, 2007, 2010; Grau *et al*., 2009). Furthermore, the coverage of Chlorophyta and Rhodophyta (≤25% and ≥45%, respectively) corresponded with a high quality environment for all the localities studied (see Wells *et al*., 2007).

Coralligenous assemblages are the second most important 'hot spot' of marine biodiversity in the Mediterranean after *Posidonia oceanica* meadows (Boudouresque, 2004). This habitat appears at different depths, depending on the geographical area in which it is located within the Mediterranean, but it can be found from 20 m depth in the western basin (Ballesteros, 2006). In this sense, coralligenous habitats can be reported in the Farallones but not on the west side of Trois Fourches, since in the latter there are no hard bottoms below 10 m depth. Another point of interest has been the presence of coralligenous species and/or coralligenous assemblages in shallow waters. The red gorgonian *Paramuricea* clavata is known to form marine forests from 25 m in depth (Oreja & López-González, 2008). However, the species was found from 18 m in depth. Conversely, the gold coral *Savalia savaglia* was found at 20 m depth, its bathymetrical localization being much deeper (Cerrano *et al*., 2010). This pattern was also found for other species such as *Dendrophyllia ramea* closer to the Al Hoceima National Park and Jebha, Morocco (Bazairi, unpub. data; Salvati *et al*., 2004; UNEP-UNEP-RAC/SPA, 2009). In this context, recreational diving and trawl fishing are major threats for these diverse habitats (Barea-Azcón *et al*., 2008; Terrón-Sigler *et al*., 2008) and, therefore, it seems that trawl fishing on Trois Fourches rocky bottoms is of low intensity. On the other hand, Cap de Trois Fourches is not intensively visited by diving centres, taking into account that there are no centres in this area and only a limited number are found in the city of Melilla, at a distance of 15 km.

The highly endangered species *Patella ferruginea* was distributed homogeneously through Cap des Trois Fourches with moderate density values, although González-García *et al*. (2006) indicated that *P. ferruginea* densities became progressively smaller from the east to the west side of Cap des Trois Fourches. It could be possible that the methodology used by these authors (sampling from boat) underestimated the real values in some areas. Furthermore, the mean density recorded for the Trois Fourches area was only exceeded by populations from Ceuta, Melilla and Chafarinas Islands (Spain), Habibas Islands (Algeria) and Zembra Island (Tunisia) (see Espinosa *et al*., 2014), being greater than those reported for the Al Hoceima National Park by Bazairi *et al*. (2004). Therefore, at Mediterranean scale, the populations of Trois Fourches represent an important stock, even though the populations are composed of small-sized individuals having an important influence on reproductive effort, considering that fecundity increases with size (Espinosa *et al*., 2006, 2009; Rivera-Ingraham *et al*., 2011).

Although fish communities are considered as good indicators of environmental conditions (Lloret & Rätz, 2000; Oliva-Paterna *et al*., 2003), only a few studies exploring this issue have been conducted in the Mediterranean (Benejam-

Vidal, 2008). The most abundant species are small-sized and have a low to medium fishing value. The shortage of large individuals in the area and the absence of species with a high fishing value, such as *Diplodus puntazzo*, *Epinephelus marginatus, Sciaena umbra, Dentex dentex* or *Seriola dumerili*, was remarkable. The abundance of these large predator species is a common trait in areas with a good conservation status (Claudet *et al*., 2006; Consoli *et al*., 2013) and their scarcity in Cap des Trois Fourches can be considered as an indicator of high fishing pressure. The differences in the conservation status in the region, established on the basis of information relating to fish and benthic assemblages, support the need to carry out a combined approach to assessing the biological quality of an area.

At local scale, meadows of *Cymodocea nodosa* found in Trois Fourches (Southern side of the Alboran Sea) showed similar density values (nº shoots/m^2 and nº leaves/shoots) to those reported for the north side of the Alboran Sea, which are considered as well-preserved meadows, and were greater than those found for moderately-preserved meadows (Laboratorio de Biología Marina, 2006). Moreover, the number of leaves per shoot would correspond to the mean number for well-preserved meadows (Terrados & Marbá, 2004). Nevertheless, the presence of small and sparse patches surrounding the meadows (area ratio 5:1, patches:meadow) indicated that conservation measures need to be taken in order to preserve these diverse ecosystems, such as controlling trawl fishing that is a major threat to these marine habitats (González-Correa *et al*., 2005). In fact, we have filmed while diving in the study area several brands possibly caused by trawling on sandy bottoms where the meadows were found.

Marine Protected Areas (MPAs) represent an efficient way of conserving marine fishing resources, as well as protecting ecosystems from human disturbances (García-Chartón *et al*., 2008) and future degradation (Halpern & Warner, 2003). An even larger community may benefit from the 'ecosystem services' provided by intact marine communities, such as wave buffering and biological filtering of contaminants, extending the benefits outside the MPA (Snelgrove, 1999). According to García-Chartón *et al*. (2008), the ecological goals and objectives of MPAs should be laid out clearly before an MPA is created, or even designed, as they form the basis for the design. In this context, Cap des Trois Fourches meets all these criteria for designation as an MPA, considering that the area displays high environmental quality, a variety of habitats (meadows, coralligenous assemblages, marine caves etc.) and hosts many endangered species and/or habitats used by endangered species for reproduction.

The economic benefits of MPAs are also an important consideration. The protection of the marine environment, together with regional integrated management of user conflicts, results in economic benefits, both for fishermen and the tourism industry. For example, it has been estimated that the tiny Port-Cros National Park in France (20 km^2) produces, directly and indirectly, a mean annual turnover of 300 M€ per year (IRAP, 1999). Taking into account the low level of economic activity in the Trois Fourches area (Khettabi, 2003), the local economy can be enhanced both for artisanal fishermen and local service agencies.

Conclusions

Taking into account the above-mentioned estimates, it is important to note that the south coast of the Mediterranean suffers from a shortage of MPAs in comparison with other Mediterranean areas. This compromises connectivity and endangers the sustainability of marine populations. For instance, in Mediterranean Morocco, the Al Hoceima National Park is the only MPA and is at a distance of more than 130 km from the next MPA eastward, while the mean distance between MPAs in the Mediterranean is 53 km (Portman *et al*., 2012). Therefore, the designation of an MPA in Cap des Trois Fourches (from the Farallones to Charrana areas) could improve this connectivity problem, filling an important gap in the Southern Mediterranean MPA network. In fact, a network of Mediterranean MPAs, if globally managed, could ensure the exchange of information between the different areas of the Mediterranean.

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References

AEFCS, 1996. *Projet d'étude et plan de gestion des aires protégées du Maroc.Plan Directeur des Aires Protégées du Maroc*. Administration des Eaux et Forêts et de la Conservation des Sols, Ministère de la l'Agriculture et de la Mise en valeur agricole, Technical report, No 9, 128 pp.

Allison, G.W., Lubchenco, J., Carr, M.H., 1998. Marine reserves are necessary but not sufficient for marine conservation. *Ecological Applications*, 8 Supplement, 79-92.

Amengual, J., Álvarez-Berastegui, D., Reñones, O., Coll, J., Marbà, N., 2008. *Evaluación rápida de zonas costeras como herramienta de planificación de Áreas Marinas Protegidas*. Organismo Autónomo Parques Nacionales, Ministerio de Medio Ambiente, Technical report, 78 pp.

Ballesteros, E., 2006. Mediterranean coralligenous assemblages: a synthesis of present knowledge. *Oceanography and Marine Biology: An Annual Review*, 44, 123-195.

Ballesteros, E., Torras, X., Pinedo, S., García, M., Magialajo, L. *et al*., 2007. A new methodology based on littoral community cartography dominated by macroalgae for the implementation of the European Water Framework Directive. *Marine Pollution Bulletin*, 55, 172-180.

Barea-Azcón, J.M., Ballesteros-Duperón, E., Moreno, D. (Eds.), 2008. *Libro Rojo de los Invertebrados de Andalucía*. Consejería de Medio Ambiente, Junta de Andalucía, Sevilla 1430 pp.

Bayed, A., Bazairi, H., Cebrain, D., 2005. The coastal habitat of the Mediterranean monk seal on the Mediterranean coast of Morocco. In: *Proceedings of the 19th Conference of the European Cetacean Society, La Rochelle, 2-7 April, 2005.*. European Cetacean Society

Bazairi, H., Dakki, M., Qninba, A., El Agbani, M.A., Benhoussa, A., 2011. Site Ramsar du Maroc: Cap des Trois Fourches. p. 57-64. In: *Zones humides du Maroc inscrites jusqu'en 2005 sur la Liste de la Convention de Ramsar*. Dakki, M., *et al*. (Eds). Institute des Sciences, Rabat.

Bazairi, H., Salvati, E., Benhissoune, S., Tunesi, L., Rais, C. *et al*., 2004. Considerations on a population of the endangered marine mollusc *Patella ferruginea* Gmelin, 1791 (Gastropoda, Patellidae) in the Cala Iris islet (National Park of Al Hoceima-Morocco, Alboran Sea). *Bolletino Malacologico*, 40, 95-100.

Benejam-Vidal, L., 2008. *Fish as ecological indicators in Mediterranean freshwaters ecosystems*. PhD Thesis, University of Girona, Spain, 136 pp.

Benedetti-Cechi, L., Airoldi, L., Abbiati, M., Cinelli, F., 1996. Exploring the causes of variation in assemblage of benthic invertebrates from a submarine cave with sulphur springs. *Journal of Experimental Marine Biology and Ecology*, 208, 153-168.

Bianchi, C.N., Morri, C., 2000. Marine biodiversity of the Mediterranean Sea: situation, problems and prospects for future research. *Marine Pollution Bulletin*, 40, 367-376.

Boström, C., Bonsdorff, E., 1997. Community structure and spatial variation of benthic invertebrates associated with *Zostera marina* (L.) beds in the northern Baltic Sea. *Journal of Sea Research*, 37, 153-166.

Boudouresque, C.F., 1996. *Impact de l'homme et conservation du milieu marin en Méditerranée*. GIS Posidonie publications, Marseille, 243 pp.

Boudouresque, C.F., 2004. Marine biodiversity in the Mediterranean: status of species, populations and communities. *Scientific Reports of Port-Cros National Park*, 20, 97-146.

Boudouresque, C.F., Cadiou, G., Le Diréac'h, L., 2005. Marine protected areas: a tool for coastal areas management. p. 29-52. In: *Strategic Management of Marine Ecosystems*. Levner, E. (Ed.). Springer, Netherlands.

Bueno del Campo, I., González-García, J.A., 1996. *Guía marina de la región de Melilla*. *Colección Ensayos Melillenses*. Fundación Municipal Sociocultural. Excmo. Ayuntamiento de Melilla, Melilla, 276 pp.

Casado-Amezúa, P., Goffredo, S., Templado, J., Machordom, A., 2012. Genetic assessment of population structure and connectivity in the threatened Mediterranean coral *Astroides calycularis* (Scleractinia, Dendrophylliidae) at different spatial scales. *Molecular Ecology*, 21, 3671–3685.

Cerrano, C., Danovaro, R., Gambi, C., Pusceddu, A., Riva, A. *et al*., 2010. Gold coral (*Savalia savaglia*) and gorgonian forests enhance benthic biodiversity and ecosystem functioning in the mesophotic zone. *Biodiversity and Conservation*, 19, 153-167.

Clarke, K.R., 1993. Non-parametric multivariate analyses of changes in community structure. *Australian Journal of Ecology*, 18, 117-143.

Claudet, J, Pelletier, D., Jouvenel, J.Y., Bachet, F., Galzin, R., 2006. Assessing the effects of marine protected area (MPA) on a reef fish assemblage in a northwestern Mediterranean marine reserve: Identifying community-based indicators. *Biological Conservation*, 130, 349-369.

Coll, M., Piroddi, C., Steenbeek, J., Kaschner, K., Ben Rais-Lasram, F. *et al*., 2010. The Biodiversity of the Mediterranean Sea: Estimates, Patterns, and Threats. *PLoS ONE*, 5(8), e11842. doi:10.1371/journal.pone.0011842.

Consoli, P., Sará, G., Mazza, G., Battaglia, P., Romeo, T. *et al*., 2013. The effects of protection measures on fish assemblage in the Plemmirio marine reserve (Central Mediterranean Sea, Italy): A first assessment 5 years after its establishment. *Journal of Sea Research*, 79, 20-26.

Dauvin, J.C., 1997. *Les biocénoses marines el litorales françaises des côtes Atlantique, Manche et Mer du Nord, synthesè, menaces et perspectives.* Muséum National d'Histoire Naturelle, Paris, 359 pp.

De Girolamo, M., Mazzoldi, G., 2001. The application of visual census on Mediterranean rocky habitats. *Marine Environmental Research*, 51, 1-16.

Den Hartog, C., 1970. *The seagrasses of the world*. Elsevier, Amsterdam, 275 pp.

Duarte, C.M., Sintes, T., Marbà, N., 2013. Assessing the CO_2 capture potential of seagrass restoration projects. *Journal of Applied Ecology*, 50, 1341-1349.

Espinosa, F., Guerra-García, J.M., Fa, D., García-Gómez, J.C., 2006. Aspects of reproduction and their implications for the conservation of the endangered limpet, *Patella ferruginea*. *Invertebrate, Reproduction and Development*, 49, 85-92.

Espinosa, F., Rivera-Ingraham, G.A., García-Gómez, J.C., 2009. Gonochorism or protandrous hermaphroditism? Evidence of sex change in the endangered limpet *Patella ferruginea*. *Marine Biodiversity Records*, 2, e153. doi:10.1017/S1755267209990790.

Espinosa, F., Rivera-Ingraham, G.A., Maestre, M., González, A., Bazairi, H. *et al*., 2014. Updated global distribution of the highly endangered marine limpet *Patella ferruginea*: an example of biodiversity loss in the Mediterranean. *Oryx*, 48, 266-275.

Fa, D., García-Gómez, J.C., García-Adiego, E., Sánchez-Moyano, E., Estacio-Gil, F., 1997. El litoral II: Zonas de Transición. p. 153-194. In: *Naturaleza de Andalucía. Tomo 2: El Mar*. Sosa, F.J. (Ed). Giralda, Sevilla.

Fonseca, M.S., Koehl, M.A.R., 2006. Flow in seagrass canopies: The influence of patch width. *Estuarine, Coastal and Shelf Science*, 67, 1-9.

Fraschetti, S., Terlizzi, A., Micheli, F., Benedetti-Cecchi, L., Boero, F., 2002. Marine protected areas in the Mediterranean Sea: objectives, effectiveness and monitoring. *P.S.Z.N. Marine Ecology*, 23, 190-200.

García-Charton, J.A., Pérez-Ruzafa, A., 1999. Ecological heterogeneity and the evaluation of the effects of marine reserves. *Fisheries Research*, 42, 1-20.

García-Charton, J.A., Pérez-Ruzafa, A., Marcos, C., Claudet, J., Badalamenti, F. *et al*., 2008. Effectiveness of European Atlanto-Mediterranean MPAs: Do they accomplish the expected effects on populations, communities and ecosystems? *Journal for Nature Conservation*, 16, 193-221.

García-Gómez, J.C., 2007. *Biota litoral y vigilancia ambiental en las Áreas Marinas Protegidas*. Consejería de Medio Ambiente, Junta de Andalucía, Sevilla, 193 pp.

García-Gómez, J.C., 2010. *Estudio de las comunidades intermareales y submareales de la isla de Tarifa, con inclusion de habitats protegidos (cuevas semisumergidas). Informe Final*. Autoridad Portuaria Bahía de Algeciras, Technical report, 201 pp.

González-Correa, J.M., Bayle, J.T., Sánchez-Lizaso, J.L., Valle, C., Sánchez-Jerez, P. *et al*., 2005. Recovery of deep *Posidonia oceanica* meadows degraded by trawling. *Journal of Experimental Marine Biology and Ecology*, 320, 65-76.

González-García, J.A., 1994. *La flora marina de Melilla. Colección Ensayos Melillenses*. Fundación Municipal Sociocultural. Excmo. Ayuntamiento de Melilla, Melilla, 212 pp.

González-García, J.A., Bueno del Campo, I., García-Piña, H., Bazairi, H., 2006. Apéndice II: Informe sobre *Patella ferruginea* en Melilla. In: *Inventario y seguimiento de Patella ferruginea en España, así como la elaboración de una propuesta de estrategia de conservación de la especie*. Ministerio de Medio Ambiente, Technical report, 199 pp.

González-García, J.A., García-Peña, H., Bueno del Campo, I., 2005. *Especies singulares y protegidas de la flora y fauna de Melilla y las Islas Chafarinas*. Fundación GASELEC, Melilla, 264 pp.

Grau, A., Blanco, A., Riera, F., 2009. The pearly razorfish (*Xyrichthys novacula*) in the marine protected area of Freus d'Eivissa i Formentera: the effect of the spatial protection. *Bolletí de la Societat d'Història Natural de les Balears*, 52, 193-201.

Guerra-García, J.M., Corzo, J., Espinosa, F., García-Gómez, J.C., 2004. Assessing habitat use of the endangered marine mollusc *Patella ferruginea* (Gastropoda, Patellidae) in northern Africa: preliminary results and implications for conservation. *Biological Conservation*, 116, 319-326.

Guidetti, P., 2000. Differences among fish assemblages associated with nearshore *Posidonia oceanica* seagrass beds, rocky-algal reefs and unvegetated sand habitats in the Adriatic Sea. *Estuarine, Coastal and Shelf Science*, 50, 515-529.

Halpern, B.S., Warner, R.R., 2003. Matching marine reserve design to reserve objectives. *Procceedings of the Royal Society of London B*, 270, 1871-1878.

Heck, K.L., 1981. Experiments on predator-prey interactions in vegetated aquatic habitats. *Journal of Experimental Marine Biology and Ecology*, 53, 125-134.

Heck, K.L., Able, K., Roman, C., Fahay, M., 1995. Composition, abundance, biomass and production of macrofauna in a New England estuary: comparison among eelgrass meadows and other nursery habitats. *Estuaries*, 18, 379-389.

IRAP. 1999. *Etude des retombées du Parc national sur l'activité économique et sur l'emploi*. Parc National de Port-Cros/IRAP Technical report, 76 pp.

Karamanlidis, A., Pires, R., Silva, N., Neves, H., 2002. The habitat of the endangered Mediterranean Monk seal (*Monachus monachus*) in the Archipelago of Madeira. *The Monachus Guardian*, 5 (2), 4.

Khettabi, A., 2003. *Diagnostic socioéconomique : Cap des Trois Fourches*. PNUE/Secretariat Etat Environment/Départ. Eaux & Forêts, Maroc, Technical report, 81 pp.

Krause-Jensen, D., Middelboe, A.L., Sand-Jensen, K., Christensen, P.B., 2000. Eelgrass, *Zostera marina*, growth along depth gradients: upper boundaries of the variation as a powerful predictive tool. *Oikos*, 91, 233-244.

Kruskal, J.B., Wish, M., 1978. *Multidimensional scaling*. Sage Publications, California, 11 pp.

Laboratorio de Biología Marina., 2006. *Empleo del sustrato rocoso en la vigilancia y control de la calidad ambiental de los fondos del litoral andaluz*. Consejería de Medio Ambiente, Junta de Andalucía, Technical report, 151 pp.

Lasiak, T., 1999. The putative impact of exploitation on rocky infratidal macrofaunal assemblage: a multiple-area comparison. *Journal of the Marine Biological Association of the United Kingdom*, 79, 23-34.

Lejeusne, C., Chevaldonné, P., Pergent-Martini, C., Boudouresque, C.F., Perez, T., 2010. Climate change effects on a miniature ocean: the highly diverse, highly impacted Mediterranean Sea. *Trends in Ecology & Evolution*, 25, 250-260.

Little, C., Kitching, J.A., 1996. *The Biology of Rocky Shores*. Oxford University Press, Oxford, 240 pp.

Lloret, J., Rätz, H.J., 2000. Condition of cod (*Gadus morhua*) of Greenland during 1982-1998. *Fisheries Research*, 48, 79-86.

Lotze, H.K., Lenihan, H.S., Bourque, B.J., Bradbury, R.H., Cooke, R.G. *et al*., 2006. Depletion, degradation, and recovery potential of estuaries and coastal seas. *Science*, 312, 1806-1809.

Middelboe, A.L., Sand-Jensen, K., Krause-Jensen, D., 2003. Spatial and interannual variations with depth in eelgrass populations. *Journal of Experimental Marine Biology and Ecology*, 291, 1-15.

MMAMRM, 2008. *Estrategia de conservación de la lapa ferrugínea (Patella ferruginea) en España*. Ministerio de Medio Ambiente, Medio Rural y Marino, Madrid, 49 pp.

Mo, G., Bazairi, H., Bayed, A., Agnesi, S., 2011. Survey on Mediterranean Monk Seal (*Monachus monachus*) sightings in Mediterranean Morocco. *Aquatic Mammals*, 37, 248-255.

Nakamura, Y., Sano, M., 2005. Comparison of invertebrate abundance in a seagrass bed and adjacent coral and sand areas at Amitori Bay, Iriomote Island, Japan. *Fisheries Science*, 71, 543-550.

National Research Council, 2001. *Report of the committee on the evaluation, design and monitoring of marine reserves and protected areas in the United States*. National Academy Press, Washington D.C., 71 pp.

Navarro-Barranco, C., Guerra-García, J.M., Sánchez-Tocino, L., García-Gómez, J.C., 2012. Soft-bottom crustacean assemblages in Mediterranean marine caves: the cave of Cerro Gordo (Granada, Spain) as case study. *Helgoland Marine Research*, 66, 567-576.

Ocaña O., Templado A., Templado, J., 2009. *Los paisajes sumergidos de la región de Ceuta y su biodiversidad*. Fundación Museo del Mar de Ceuta, Ceuta, 254 pp.

Oliva-Paterna, F.J., Vila-Gispert, A., Torralba, M., 2003. Condition of *Barbas scalateri* from semi-arid aquatic systems: effects of habitat quality disturbances. *Journal of Fish Biology*, 47, 1720-1734.

Oreja, C., López-González, P.J., 2008. Sea fans and corals: architects of our oceans. p. 25-50. In: *The Seas of Spain*, Martínez, R., Cornejo, J.M., (Eds). Ministerio de Medio Ambiente, Medio Rural y Marino, Madrid,

Portman, M., Nathan, D., Levin, N., 2012. From the Levant to Gibraltar: A Regional Perspective for Marine Conservation in the Mediterranean Sea. *AMBIO*: doi: 10.1007/s13280-012-0298-x.

Raffaelli, D., Hawkins, S., 1996. *Intertidal Ecology*. Chapman & Hall, London, 356 pp.

Ramos, M.A., 1998. Implementing the Habitats Directive for mollusc species in Spain. *Journal of Conchology Special Publication*, 2, 125-132.

Rivera-Ingraham, G.A., Espinosa, F., García-Gómez, J.C., 2011. Environmentally mediated sex change in the endangered limpet *Patella ferruginea* (Gastropoda: Patellidae). *Journal of Molluscan Studies*, 77, 226-231.

Salvati, E., Tunesi, L., Molinari, A., 2004. Presence of the Scleractinian *Dendrophyllia ramea* in the shallow waters of Mediterranean Morocco (Al Hoceima, Alboran Sea). *Rapport Communication internationale Mer Méditerranéen*, 37, 547.

Sarà, M., 1976. Il popolamento delle grotte marine: interesse di una salvaguardia. *Pubblicazioni della stazione zoologica di Napoli*, 40, 50-505.

Shannon, C.E., Weaver, W., 1963. *The mathemathical theory of communication*. University of Illinois Press, Urbana, 125 pp.

Shanks, A.L., Grantham, B., Carr, M.H., 2003. Propagule dispersal distance and the size and spacing of marine reserves. *Ecological Applications*, 13, 159-169.

Snelgrove, P.V.R., 1999. Getting to the bottom of marine biodiversity: sedimentary habitats-ocean bottoms are the most widespread habitat on Earth and support high biodiversity and key ecosystem services. *Bioscience*, 49, 129-138.

Templado, J., 2004. Las Praderas de Fanerógamas Marinas. Introducción. p. 57-60. In: *Praderas y bosques marinos de Andalucía*. Luque, A.A., Templado, J. (Eds). Consejería de Medio Ambiente, Junta de Andalucía, Sevilla.

Templado, J., Calvo, M., Moreno, D., Flores, A., Conde, F. *et al*., 2006. *Flora y fauna de la reserva marina y reserva de pesca de la isla de Alborán*. Ministerio de Agricultura, Pesca y Alimentación, Madrid, 269 pp.

Terrados, J., Marbá, N., 2004. Las Praderas de Fanerógamas Marinas. Características morfológicas. p. 136-138. In: *Praderas y bosques marinos de Andalucía*. Luque, A.A., Templado, J. (Eds). Consejería de Medio Ambiente, Junta de Andalucía, Sevilla.

Terrón-Sigler, A., Peñalver, P., Espinosa, F., León-Muez, D., 2008. Ensayo experimental para el trasplante de colonias de coral naranja (*Astroides calycularis*, Pallas 1766); especie insignia del litoral sur de la Península Ibérica. *Chronica naturae*, 1, 35-45.

Underwood, A.J., Chapman, M.G., Richards, S.A., 2002. *GMAV-5 for Windows. An analysis of variance programme*. Centre for Research on Ecological Impacts of Coastal Cities. Marine Ecology Laboratories. University of Sydney, Australia.

UNEP-MAP RAC/SPA, 2009. *Diagnostic de la biodiversité marine du Rif central (Méditerranée, Maroc) et orientations de gestion*. Regional Activity Centre for Specially Protected Areas, Technical report, No 47, 48, 49, 100 pp.

UNEP-MAP RAC/SPA, 2010. *The Mediterranean Sea Biodiversity: state of the ecosystems, pressures, impacts and future priorities*. Regional Activity Centre for Specially Protected Areas, Technical report, 100 pp.

Wells, E., Wilkinson, M., Wood, P., Scanlan, C., 2007. The use of macroalgal species richness and composition on intertidal rocky seashores in the assessment of ecological quality under the European Water Framework Directive. *Marine Pollution Bulletin*, 55, 151-161.

Wilson, F.S., 1990. Temporal and spatial patterns of settlement: a field study of molluscs in Bogue Sound, North Carolina. *Journal of Experimental Marine Biology and Ecology*, 139, 201-220.