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Updating the Master Management Plan for El Cachucho MPA (Cantabrian Sea) using a spatial planning approach

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ABSTRACT

Located in the Cantabrian Sea (NE Atlantic), 30 nm off the Asturian coast, "El Cachucho" was the first off-shore Marine Protected Area (MPA) to be declared in Spain. The area includes Le Danois Bank and its intraslope basin. It joined the OSPAR Network of MPAs in 2009 and, thereafter, was included in the Natura 2000 Network in 2011. The main reason for its declaration as MPA was the presence of the 1170 Reefs habitat included in Annex I of the EU Habitats Directive. In 2018, the MPAs Master Management Plan was under revision and its design criteria were subjected to evaluation. We used Marxan decision support tool to evaluate the MPA's management design criteria. This tool selects the most important conservation features, while minimizing the socioeconomic cost. First, the 1170 Reefs habitat was defined as the main environmental value. Specifically, we took into account the six large sized target species that are more representative of this habitat in the area: the sponges *Asconema setubalense*, *Geodia* cf. *barretti* and *Phakellia robusta,* the anthipatarian *Leiopathes glaberrima,* and the gorgonians *Placogorgia sp.* and *Callogorgia verticillata.* A spatial distribution map was produced for each species using Generalized Additive Models (GAM). We also considered the presence of spawning stocks of fish species which are present in the area as an important conservation value. Their spatial distribution was modeled through Maxent software. Additionally, for the socioeconomic cost, fishing effort of the different fisheries operating in the area was estimated linking VMS/Logbook data before and after the MPA was declared. The first results obtained with the Marxan tool were presented in public consultation, in the context of the LIFE + INTEMARES Project, to help in decision making within the new Management Plan. Thus, to improve the management measures aimed at the conservation of the environmental values of the MPA, an enlargement of the protected area to the West was proposed, and a more reasonable use of the buffer area to fishermen than that defined in the former Management Plan was suggested. Involving all stakeholders in the development of the management plan for this MPA is a decisive step for the creation and consolidation of an important network of MPAs in Spain.

1. Introduction

Since *sustainable development* became a serious concern for the international community and was put on the agendas of national and local governments at Rio's Earth Summit (Declaration, R, 1992), many initiatives have been carried out by governments and individuals, organizations and institutions in response to the necessity of integrating environmental protection into development processes (Lafferty, 2004). Although ecosystem services valuation has been widely developed in terrestrial areas, similar studies in oceans and coastal areas have only increased recently, mainly to evaluate human impacts like energy production, fisheries, climate change, shipping and other stressors (MEA, 2005). Thus, Marine Spatial Planning (MSP) arose and developed from the need to embed human activities in ocean ecosystem management and protection (EC, 2005).

MSP is becoming an emerging marine management paradigm in many places around the globe. In Europe, Directive 2014/89/EU of the European Parliament and of the Council forces coastal Member States to develop maritime spatial plans by 31st March 2021 at the latest. This Directive was transposed to the Spanish legal system through Royal Decree 363/2017 and linked to Act 41/2010 for the protection of the marine environment. Active participation and engagement of stakeholders in the MSP process is fundamental to guarantee management plans that are coherent with the preservation of the marine environment and ensure a sustainable socio-economic growth (Guerry et al, 2012; Ehler and Douvere, 2009). To create an appropriate work forum, information exchange and collaboration among stakeholders is essential to develop guidelines and to support the implementation of national

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MSP.

MSP definitions point the same direction: is a public process (Ehler and Douvere, 2009) that requires the participation of stakeholders (Hemmati, 2012), and involves a decision-making approach (Coleman et al., 2011). Therefore, on one side, the involvement of all the actors in the establishment of the rules is mandatory since MSP seeks to achieve multiple objectives (socioeconomic, ecological, etc.) and must consider the expectations, opportunities or conflicts affecting or arising for the various actors and activities involved, which will make compliance easier. On the other side, MSP can't be understood without considering the Ecosystem-Based Management (EBM) approach, requiring a management strategy that takes into account entire systems, including humans and avoiding focusing on individual components of the ecosystem (Levin et al., 2009).

Implementation of MSP requires the establishment of MPAs (Marine Protected Areas) with clearly defined use zones (Ehler and Douvere, 2009). Some studies have evidenced that MPAs cause a general increase in species richness, abundance and biomass (Harmelin-Vivien et al., 2008), and that they are an effective management tool for artisanal fisheries (Goñi et al., 2008; Forcada et al., 2009). In this study, we focus on the first MPA declared in Spain, El Cachucho, which in December 2008, received preventive protection measures and was proposed to be a Site of Community Importance (SCI), mainly due to the presence of the 1170 Reefs habitat. In 2009 it was included in the OSPAR network of MPAs (Heredia et al., 2008), and was finally declared a SCI in January 2011, and MPA and Special Area of Conservation (SAC) in November 2011 (BOE, 2011).

Located in the Cantabrian Sea (NE Atlantic), “El Cachucho” fishing ground was studied by the ECOMARG project during the period 2003–2009, mainly focusing on the benthic-demersal ecosystem (https://www.ecomarg.com/index_en.html). The project provided important information on the morpho-sedimentary and bathymetric characteristics of the area (Van Rooij et al., 2010; Gómez-Ballesteros et al., 2015) as well as on the characterization and dynamics of the water masses (González-Pola et al., 2012). It also involved an integrated study of the main benthic compartments, including endobenthic, epibenthic, suprabenthic and demersal species (Kavanagh and Sorbe, 2006; Cartes et al., 2007a; Sánchez et al., 2008; Guerra-García et al., 2008; Cristobo et al., 2009; Frutos and Sorbe, 2010; Frutos et al., 2011; Rodríguez-Cabello et al., 2012; Altuna, 2013), and their habitat characterization (Sánchez et al., 2008, 2009, 2017; García-Alegre et al., 2014). The trophic ecology of the dominant species of fish and crustaceans was used to estimate the energy flows, the consumption and the niche overlap among high-level trophic groups (Cartes et al., 2007b; Preciado et al., 2009). This information, together with studies on the impact of fisheries operating in the area, was integrated in a trophodynamic mass-balance model to provide an efficient tool for the management of the MPA (Sánchez et al., 2010). Such a multi-methodological approach offered a holistic view of the ecosystem's variability, its communities and the distribution of fishing resources in the area, as well as a large amount of essential information to undertake the present study.

The current Management Plan for the “El Cachucho” MPA includes measures to prohibit the use of bottom-fishing gears (trawls, long-lines and gillnets) at Le Danois Bank (BOE, 2011). It authorizes fishing to a closed list of long-line vessels, but only in an area located away from the top of the bank, in the intraslope basin that acts as a buffer area (Fig. 1). A recent study on the spatial distribution of fishing effort from satellite tracking system, compared the main fishery activities on the area before and after the closure's enforcement (Punzón et al., 2016). Conversely, pelagic fisheries, such as anchovy, mackerel and tuna, have not been affected by the area's management plans. Previous studies of these fisheries in the MPA indicate that the mechanisms of production associated with the bank, as the presence of Taylor caps and high frequency internal wave dynamics (González-Pola et al., 2012), may enhance surface fisheries productivities, as in the case of tuna (Rodríguez-Cabello et al., 2009). In addition, other activities such as hydrocarbon and mineral exploration, military maneuvers and invasive scientific research are also prohibited.

Following its declaration as an MPA in 2011, a European legal requirement was enacted to update its Management Plan, not only to achieve a better conservation of its natural values, but also to face new challenges in the planning of the uses and activities that occur in the area. Consequently, the Directorate General for Sustainability of the Coast and the Sea of the Ministry of Agriculture and Fisheries, Food and Environment of Spain, began, in 2017, a participative process to update El Cachucho's management plan within the framework of the project LIFE INTEMARES IP, the largest marine conservation project in Europe (http://www.intemares.com/en). During this process, which included public participation events, members of the Local Government, fishery managers, fishermen associations, environmental NGOs, scientists, the tourism sector, etc. (altogether more than 40 people and 22 entities), were invited to participate in a workshop in March 2018 (INTEMARES, 2018). All the stakeholders had the possibility to speak, and a draft zoning plan using Marxan conservation planning software was discussed. This software aims at getting the minimum representation of the most important environmental values to be protected in the area (habitats or species), with the lowest economic cost (Ball et al., 2009) by selecting different Planning Units, the regular spatial cells in which the area is divided. The resolution of these Planning Units (PU) will be based on the data and the extent of the study area, and the cost represents a value, calculated with fishing effort in our case, that will have a PU (the higher the value, the less likely will be for the PU to be selected to become part of a specific scenario). This is a methodology that can play an important role in combining ecological data with the human activities that take place in specific areas, providing a variety of options that can be used as a mediation tool (Martín-García et al., 2015).

In this work we use Marxan decision support tool in a specific Management Plan process, including the design of new boundaries for the MPA and the validation and acceptance of decision-makers resolutions. The main objectives of this study are to:

- Identify the main environmental and socio-economic values of El Cachucho MPA and its area of influence, conducting a quantitative spatial representation.
- Guarantee the adequacy of the current Management Plan by ensuring the representativeness of the vulnerable habitats in the Natura 2000 context.
- Propose new management measures that promote the adequate protection of the environmental values with a minimum socio-economic impact on local communities.
- Highlight the relevance of an active involvement of stakeholders in the follow-up processes analyzing the effect of the implemented regulations in MPAs ecosystems.

2. Materials and methods

2.1. Study area

The El Cachucho MPA is located in the central Cantabrian Sea (44°03′N – 004°53′W), 30 nm off the Asturian coast. The protected area is divided into two well-defined regions, the Le Danois Bank (Le Danois, 1948), with a flat top at a depth of 425 m, and its intraslope basin (Van Rooij et al., 2010), a depression reaching depths of 800–1000 m, located between the bank and the Cantabrian Sea's continental shelf (Fig. 1). The bathymetric and high resolution seismic profile data and the oceanographic studies carried out during the ECOMARG and ESMAREC projects defined its morpho-sedimentary and hydrodynamic features (Van Rooij et al., 2010; González-Pola et al., 2012; Gómez-Ballesteros et al., 2015). The top part of Le Danois Bank is covered by a sparse, unconsolidated sediment layer with many rocky outcrops, while

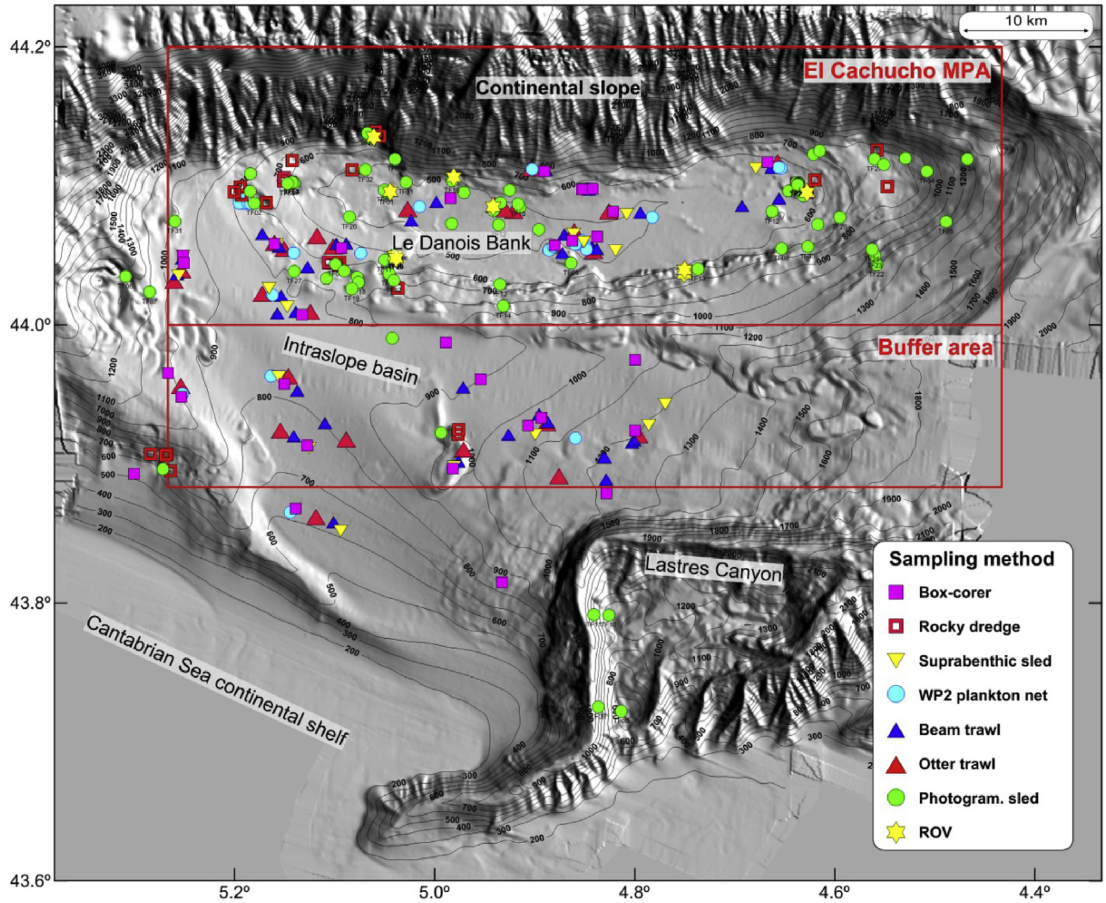

Fig. 1. Study area and samples carried out to characterize the habitats and species distribution from ECOMARG and ESMAREC surveys. (1.5-column fitting image).

the intraslope basin has a thicker sediment cover, including sedimentary drifts under current flows, suggesting different dynamics from those at the top of the bank (Van Rooij et al., 2010; González-Pola et al., 2012).

2.2. Environmental and biological data

Most of the biological information used in this study was obtained during six research surveys carried out within the ECOMARG project (https://www.ecomarg.com/index_en.html). An intensive sampling scheme with different methodological approaches was developed during the period 2003–2009, which was subsequently continued in 2014 and 2017 during studies monitoring the effects of the MPA declaration (ESMAREC project). The location of the different sampling systems, to obtain complete biological information, reflects the high spatial coverage and the research effort applied in the area (Fig. 1).

According to the Habitats Directive of the European Union (EC, 2013), the feature with the highest environmental conservation value of the area is the 1170 Reefs habitat. This habitat is represented in the area mainly by six large sized structuring benthic species: the sponges *Asconema setubalense*, *Geodia* cf. *barretti* and *Phakellia robusta,* the antipatarian *Leiopathes glaberrima,* and the gorgonians *Placogorgia* sp. and *Callogorgia verticillata* (Fig. 2).

A spatial distribution map was produced for each species using Generalized Additive Models (GAM), where the response variable was modeled as a function of the linear combination of smoothers that represent the effect of the independent variables (Hastie and Tibshirani, 1990). For each 1170 Reefs habitat structuring species, a univariate GAM model was conducted for each of the environmental variables considered (Table 1). Those environmental variables explaining a higher proportion of the variance were added one by one to each of the GAMs obtained in order to configure the multivariate model until the addition of more variables couldn't increase the overall variance (Brunel et al., 2018). All smooth terms p-values were significant ($p < 0.05$), or were rejected.

To ensure a precise geo-location of the biological samples, presence-absence data of the six species were used from images taken by the photogrammetric sled *Politolana* (Sánchez and Rodríguez, 2013) in three different surveys between the years 2014 and 2017. A total of 80 transects were obtained, 23 were studied using 4451 photographs, as detailed in Sánchez et al. (2017), from the ESMAREC 0514 survey. The rest were analyzed by real-time video during the ECOMARG 0717 and SponGES S0617 surveys (green circles on Fig. 1). This vehicle is equipped with an USBL (Ultra-Short Base Line) transponder which gives reliable values of the species' location (± 2 m resolution). As environmental variables, we used bathymetry derivatives (Bathymetric Position Index fine and broad, slope, roughness and depth), backscatter, morphology, and ground types from multibeam echo-sounder data (Fig. 3). Given that sampling was focused on hard bottom areas in order to obtain an idea of the distribution of the structuring species, we avoided categorical variables such as geomorphology or ground types when constructing the GAM, since on the one hand, presence-absence data did not have a uniform distribution for some categories, and on the other, we wanted to avoid dealing with factor variables when modeling the GAMs. All the explanatory variables were compared to the rest to avoid collinearity via Variance Inflation Factor (VIF), a redundancy test that indicates if the information that each variable provides is redundant with that given by the other variables (Nakazawa, 2014). Rugosity was discarded because it was considered redundant with slope. Thus, we obtained six different species distribution maps that we

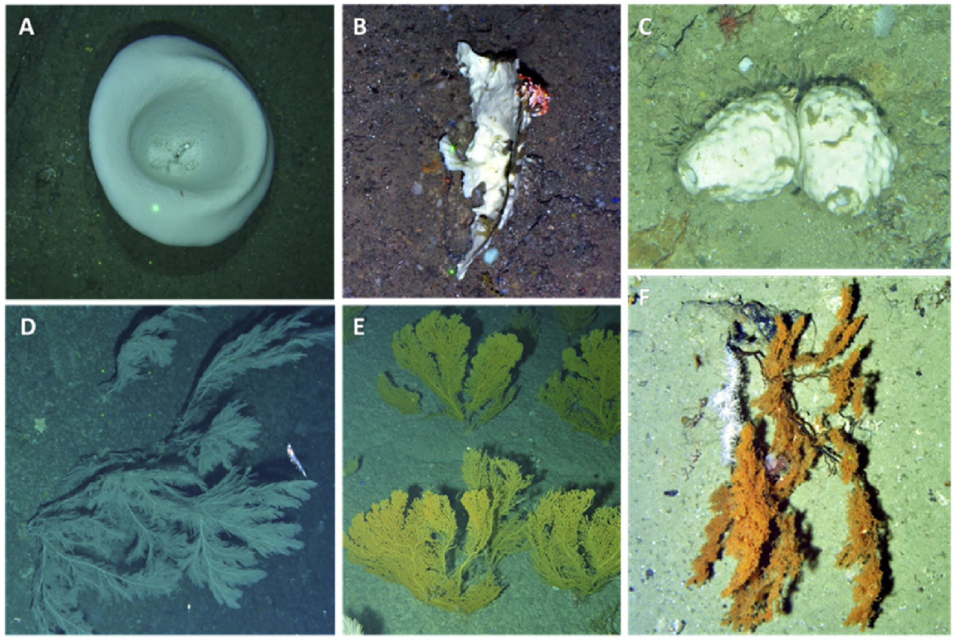

Fig. 2. Representative species of 1170-Reefs habitat in the study area: the sponges *Asconema setubalense* (A), *Phakellia robusta* (B) and *Geodia* cf. *barretti* (C); the gorgonians *Callogorgia verticillata* (D) and *Placogorgia* sp. (E); and the black coral *Leiopathes glaberrima* (F). (2-column fitting image).

Table 1
Variables used in GAM models to map the key species of the 1170 Reefs habitat. The deviance explained and the Un-Biased Risk Estimator (UBRE) score are also shown.

Species	Variables used in GAM	% Deviance explained	UBRE
Asconema setubalense	Depth + Backscatter + BPI broad	34.8	−0.88
Placogorgia sp.	BPI fine + Slope + Depth	70.7	−0.79
Callogorgia verticillata	Depth + BPI fine + BPI broad + Slope	55.5	−0.64
Geodia cf. *barretti*	Depth + Backscatter	38.2	−0.69
Phakellia robusta	Depth + BPI broad + Backscatter	34.9	−0.63
Leiopathes glaberrima	Depth + Backscetter	58.0	−0.83

converted into one, extracting the maximum cell value to obtain the habitat suitability map, the feature with the highest conservation value of the environmental layers used to run Marxan. In order to transform the final map into presence-absence data, values < 0.2 were converted to zero, and values ≥ 0.2 were converted to 1 according, on the one hand, to the backscatter (to ensure that areas with soft substrata where species characterizing 1170 Reefs habitat are absent were avoided), and on the other, to visual images (to prevent the inclusion of areas without 1170 Reefs coverage).

The main target species of the artisanal fleet that operated on the bank prior to the implementation of fishing regulations were monkfish (*Lophius piscatorius*), alfonsino (*Beryx decadactylus*), conger eel (*Conger conger*) and greather forkbeard (*Phycis blennoides*), all benthic/demersal species usually caught with gillnets and long-lines (Punzón et al., 2016). The MPAs declaration process of the Natura 2000 network is too often rejected by certain sectors who feel that socioeconomic aspects are not taken into account. It is thus necessary to emphasize that MPAs spatial planning criteria are not only focused on vulnerable habitats, but also those habitats that are essential for the development of the fisheries that operate outside the protected area. That is why we included, as an important environmental value, the Essential Fish Habitats (EFH) of those commercial species for which there is enough reliable information, such as blue whiting (*Micromesistius poutassou*), greather forkbeard, and spiny scorpionfish (*Trachyscorpia cristulata echinata*). Mature adults of these three species are very scarce in the continental shelf of the Cantabrian Sea (Sánchez et al., 2008). The distribution of EFHs was established taking into account the presence of spawners of the three species considered during sampling with otter-trawl and beam-trawl in the ECOMARG spring surveys. In addition, there are other vulnerable species which are not listed in Annex II of the Habitats Directive, such as some deep-sea sharks and the North Atlantic glass sponge *Pheronema carpenteri,* that are protected by the OSPAR Convention and IUCN (International Union for the Conservation of Nature) (Fig. 4). Since we do not have reliable absence data for these species and their position is not as accurate as that obtained with the photogrammetric sled, all maps were attained through the MAXENT predictive tool based on the species collected by trawling gears in 2003, 2004, 2008, and 2009. For the MAXENT process we also used the same explanatory environmental variables as for GAMs analysis, adding morphology and ground types. More details on the characteristics of these variables in the study area can be found in Sánchez et al., 2017). The deep-sea shark species considered were *Centrophorus squamosus*, *Centroscymnus coelolepis*, *Dalatias licha, Deania* sp., *Scymnodon ringens* and *Hexanchus griseus*. Information on their distribution was gathered during bottom-trawl surveys and long-line fishery vessels (Rodríguez-Cabello et al., 2012, 2014, 2016).

2.3. Socioeconomic data

Since there are no other socio-economic activities different from commercial fishing in the area, two parallel scenarios were developed having their boundary on the 23rd of December 2008, when the area was closed to fisheries (Punzón et al., 2016). Logbooks and VMS (Vessel Monitoring System) data from 2005 to 2014 were used as detailed in Abad et al. (2007), to define the different *mètiers* operating in the area using the Clustering Large Applications method (CLARA), a non-hierarchical cluster analysis adapted to large data sets (Kaufman and Rousseeuw, 2009). Linking VMS/Logbook data using vessel codes we obtained the spatial distribution of fisheries for each year. Thus, the average distribution of fishing effort by gear type was obtained for both periods, 2005–2008, and 2009–2014. Fisheries operating on the top of the bank were gillnets targeting Anglerfish (*Lophius* sp.), long-lines

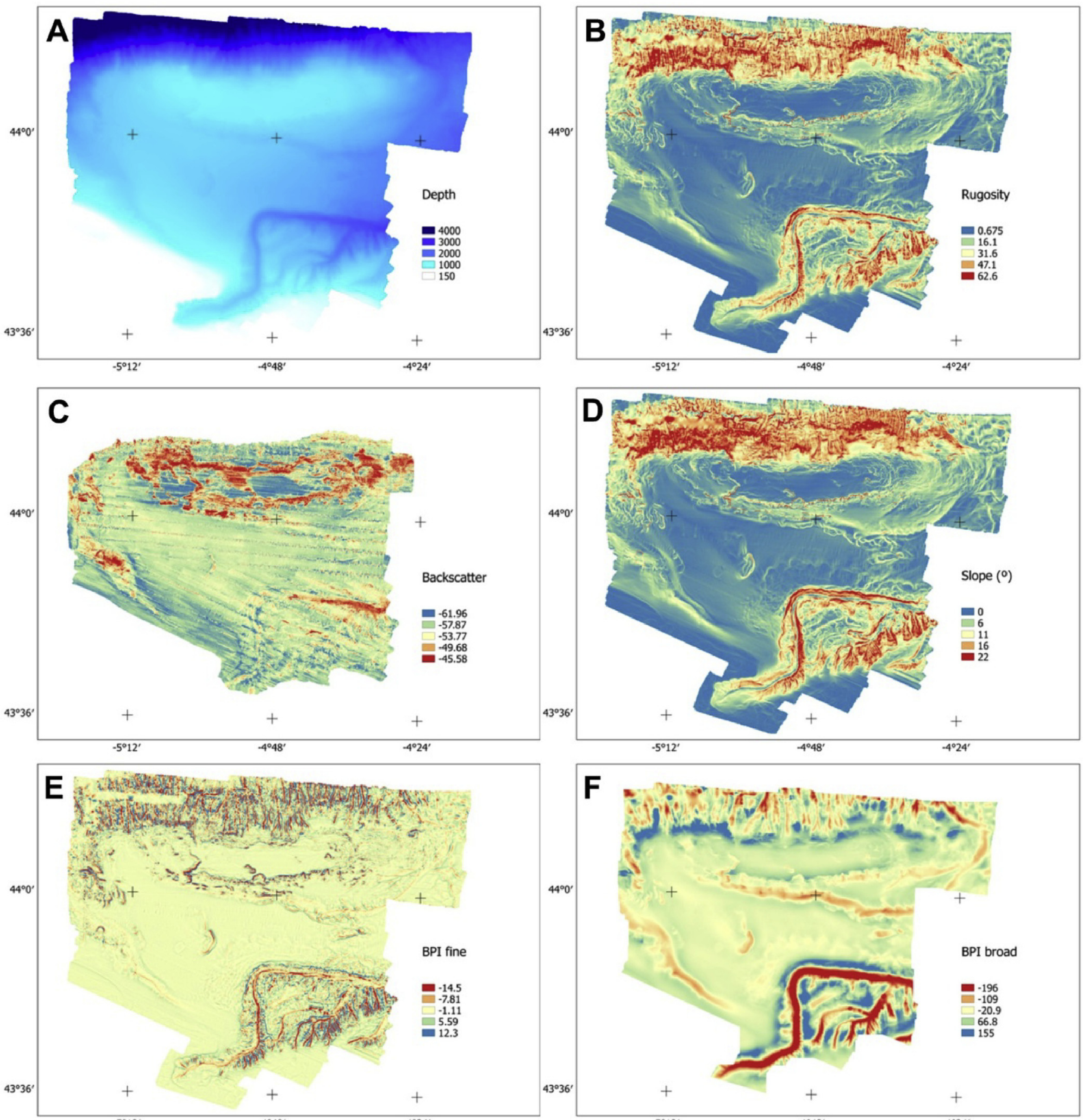

Fig. 3. Independent environmental variables used in GAM. Depth (m) (A) and backscatter (dB) (C) are the result of the multibeam echo-sounder. Rugosity (B), slope (°) (D) and fine (E) and broad BPI (F) have been selected as bathymetry derivatives. (2-column fitting image).

targeting greather forkbeard, conger eel and alfonsino, and long-lines targeting deep-sea sharks, or otter trawls and pair trawls targeting blue whiting, horse mackerel (*Trachurus* sp.), and Atlantic mackerel (*Scomber scombrus*) in the rest of the MPA and surrounding the bank (Abad et al., 2007; Punzón et al., 2016).

The number of fishing days was used as a measure of the fishing effort, to obtain the distribution of the fisheries during each period. In addition, since the price of fish is quite different among species, the mean market price for all species was calculated for each period to get a correction factor that was applied to effort depending on the target species. Thus, monkfish (*Lophius piscatorius*) had the maximum correction factor according to Asturias' fish market prices, while Atlantic mackerel had the lowest one. This value fluctuated between 0 and 1. Finally, to get the cost of both periods for each Planning Unit and taking into account that both periods have a different number of years, we calculated the average fishing days for the years included in each period, multiplied by the corresponding correction factor for each fishery. The sum of all fisheries results for each period gave the two layers showing the cost that each planning unit will have if it is selected to be part of the protected area (Fig. 5).

2.4. Analysis design

Since there is new information regarding inner and peripheral El

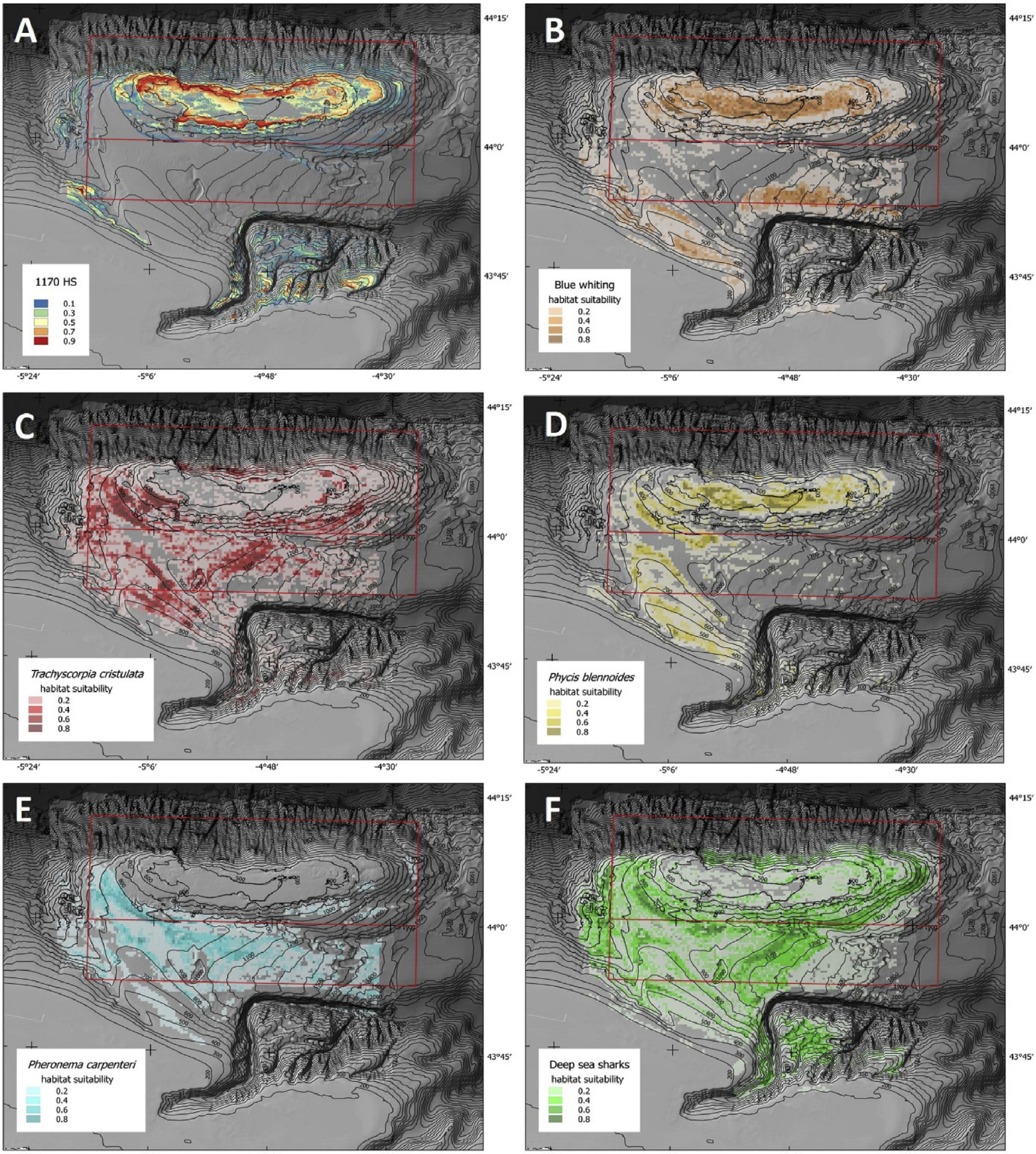

Fig. 4. Layers used for reserve design environmental criteria.: A) 1170 Reefs habitat; B), C) and D): essential habitats for blue whiting, spiny scorpionfish, and greather forkbeard respectively; E) North Atlantic glass sponge *P. carpenteri*; F) Deep sea sharks. (2-column fitting image). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Cachucho areas from recent surveys, which was lacking when the MPA was declared, the limits of the MPA needed reviewing, and participation of the various stakeholders in the Management Plan had to be reshaped. Thus, to check the adequacy of the actual limits of the El Cachucho MPA and in the context of the current Management Plan's revision, the Marxan decision support tool was employed. To begin with, our study area was divided into 19065 500 × 500 m planning units.

There are some important parameters that need to be set for running Marxan adequately. Regarding conservation values, the most important one is the *target* of each conservation feature. The *target* is the percentage that will be protected. Given that the 1170 Reefs habitat was the main reason for the area to be protected, we assigned a level of 80% of its total area in line with previous works, that establish high target

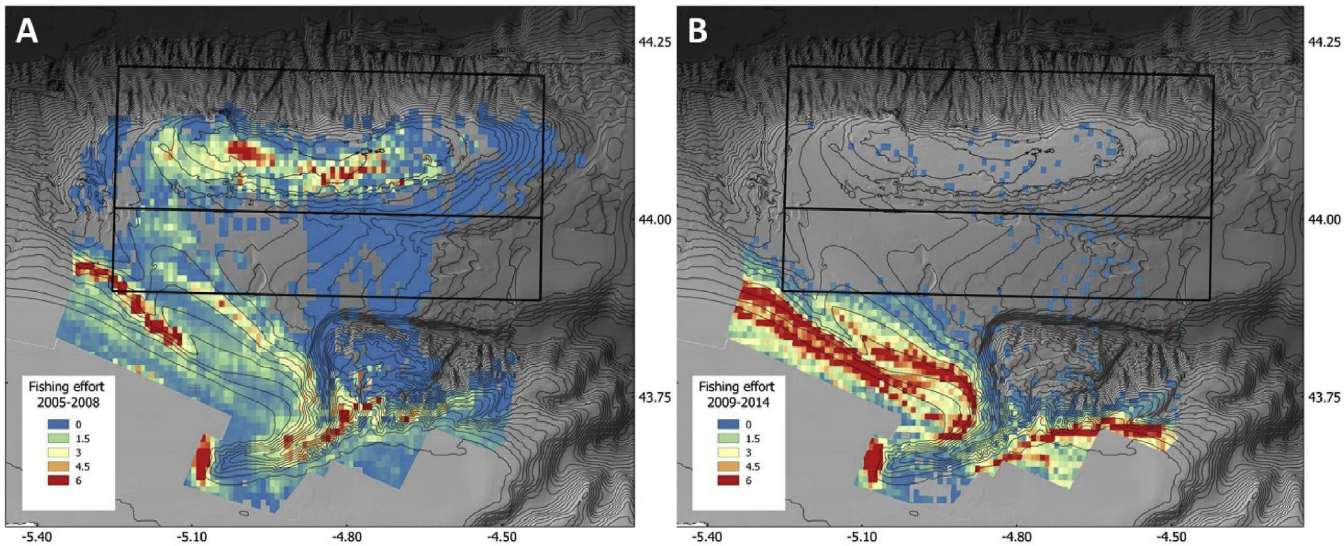

Fig. 5. Socioeconomic cost for running Marxan under two fishing scenarios: A) Before MPA declaration, years 2005–2008 and B) After MPA closure, years 2009–2014. The gradient starts from the areas with low concentration of fishing effort (blue), to the areas with high concentration of the effort (red). (2-column fitting image). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Table 2
Input values for Marxan. The different targets set for all the environmental values with respect to the total value, and the Species Penalty Factor (SPF) implemented for each of them.

Id	Name	Target	SPF	Total
1	*Trachyscorpia cristulata*	896.89	5	1494.81
2	*Micromesistius. poutassou*	572.99	5	954.98
3	*Phycis blennoides*	432.31	5	720.52
4	1170 Reefs habitat	13787.39	20	17234.24
5	*Pheronema carpenteri*	163.13	5	543.78
6	Deep sea sharks	720.51	5	2401.69

levels for vulnerable populations (Airamé et al., 2003; Stewart and Possingham, 2005; Malcolm et al., 2012; Martín-García et al., 2015). Additionally, 90% and 100% target levels were tested for the 1170 Reefs habitat, but the cost and the boundary length where noticeably higher and the final result was not very different. For the other layers we assigned 30% target levels, following general recommendations for habitats and species (Bohnsack et al., 2000; O'Leary et al., 2016; Jumin et al., 2018). Another important parameter based on conservation values is the penalty imposed for not achieving the target level, the SPF (*Species Penalty Factor*). The higher the value, the easier it will be to reach the conservation of the environmental value. The values reached for this factor are shown in Table 2, and were 20 for the 1170 Reefs habitat, and 5 for the rest of the species considered. Calibration was established according to the total cost. With these values we ensured that the species would reach the target levels, especially the 1170 Reefs habitat. This is what decision makers need to achieve, with a minimum total cost.

The third and probably the most determinant factor is the BLM (*Boundary Length Modifier*). BLM helps to shape the area considerably. The higher the value, the higher the aggregation in planning units, and it's easier the monitoring for environmental authorities. Besides, broadly speaking, the number of planning units selected will be higher as we increase BLM as will the surveillance and monitoring cost, which will enable showing some alternatives for the Management Plan review.

For the spatial zonation made using Marxan, the whole area was covered by 500 × 500 m polygons containing the conservation features and the socioeconomic cost that each cell would represent in case it was selected as belonging to the MPA. The model resulted in two different outputs: one is the best solution, and comprises a single flat polygon, and the other is the sum of solutions, showing a gradient which represents the number of times that a planning unit is selected from the number of repetitions that is chosen in the input values. In our case, the number of repetitions was 100, so the planning unit values went from 0 to 100. For our analysis, we considered the output consisting in the sum of solutions since it is a more flexible tool (Ardron et al., 2008), and more appropriate when an agreement between stakeholders is needed.

3. Results

3.1. Vulnerable habitat spatial distribution

Depth was the most important variable explaining species spatial distribution except for *Placogorgia* sp., which was mostly influenced by fine scale BPI (Table 2). Broad scale BPI and backscatter also contributed to a great extent to shape the distribution of the 1170 Reefs habitat. The highest deviance explained (> 70%) was for *Placogorgia* sp. multivariate model, though *L. glaberrima* and *C. verticillata* also reached values > 50%. The addition of more predictors to the formula did not improve explained deviance values nor reduced the UBRE (UnBiased Risk Estimator) score, penalizing the model by an increase in the degrees of freedom. The optimal number of variables for each species is shown in Table 2.

A distribution map was obtained for each sessile species. From these maps, we calculated the distribution of the 1170 Reefs habitat in our study area, as shown in Fig. 4A, obtaining a 32 × 32 m resolution map following the same methodology explained in Sánchez et al., 2017).

3.2. Modeling Essential Fish Habitats (EFHs)

For each of the essential habitats a spatial distribution was generated according to probability values (Phillips et al., 2006). Ten percent of the presence points were randomly used to validate the model. The AUC (Area Under the Curve) obtained was higher than 0.8 for all the models except for blue whiting, for which it was 0.75. AUC and variable contribution to the model are shown in Table 3, illustrating that the contribution of depth was almost 50% for blue whiting and deep sea sharks, and that slope was crucial for the greater forkbeard since its value was higher than 46%. As expected, the ground types layer had the lowest contribution values for mobile species, which were all near zero except in the case of the sessile sponge *P. carpenteri*, for which the value

Table 3
Samples used in the model, Area Under the Curve (AUC) value, and variable contribution for each species in Maxent modeling.

Species	Samples	AUC	Variable contribution						
			BPI_b	BPI_f	Ground types	Slope	Depth	Geomorphology	Backscatter
Deep Sea Sharks	1127	0.94	6.83	18.48	0.89	15.78	48.13		9.89
P. carpenteri	6171	0.81	14.27	7.65	12.12	25.26	10.45	30.24	
P. blennoides	344	0.98	12.53			46.90	23.58		16.99
M. poutassou	10829	0.75	4.61	3.98	0.01	38.02	47.95	4.60	0.83
T. cristulata	222	0.98	12.72	24.28	3.19	8.20	28.29	6.29	17.03

was 12.12%.

Finally, we obtained five 500 × 500 m distribution maps, which show that the spawning grounds of blue whiting (Fig. 4B) and greater forkbeard (Fig. 4D) are mainly concentrated at the top of the bank, while the spiny scorpionfish's essential habitat is mainly concentrated in the inner basin (Fig. 4C), the soft bottom area. As for deep sea sharks, their distribution is mostly located in the flanks and the south slope of the bank (Fig. 4F). Finally, the sponge *P. carpenteri* is mainly found at the bank's southwest (Fig. 4E), where muddy substrata predominate and which also constitutes the EFH of spiny scorpionfish.

3.3. Shaping fishing effort

The maps of the fishing scenarios corresponding to the two periods show a completely different situation. On the one hand, the fishing effort during years 2004–2008 (Fig. 5A), when the rocky bottoms at the top of the bank were occupied by gillnets and long-lines, the most affected fisheries by the MPA's closure enact. Otter trawl and pair trawl mainly operated in the southern part of the study area, along the sedimentary grounds of the Cantabrian Sea's continental shelf, following the 800 m isobath and around the 400–600 m depth, respectively.

The second scenario is shown in Fig. 5B, no fisheries entering the bank or the buffer area. During this period, trawling fisheries also stopped to operate in the limits of the southern buffer area (Punzón et al., 2016), although they were not as affected as the ones that operated in the top of the bank.

A clear effect of the bottom fisheries closure implemented by the plan's management measures was the increase in fishing effort in the areas of the continental shelf near the MPA's boundaries (Fig. 5).

3.4. Spatial conservation priorities

The Marxan tool was run under both scenarios with different BLM values (Fig. 6), 0.001, 0.01 and 0.1. The column on the left shows the scenarios taking into account the fishing effort before the closure, and the column on the right the scenarios after the closure. In general, as shown in Table 4, with higher BLM values, best solution cost increase while the boundary length decreases in the case of the maps representing planning units before the closure. As for years after the closure, the cost was very low for a BLM of 0.001, increasing with higher BLM values. However, the boundary length remained basically the same.

We assume that the map that best reflects the complex reality of the area is the one that is shown in Fig. 6C, which was chosen to present the draft zoning plan to the different stakeholders and decision makers during the meeting. The results of this approach show more planning units with a high environmental value at the top of the bank and within the boundaries of the zone of maximum protection. However, there are also some relevant environmental values outside the MPA that should be considered when revising the management plan. Some of them were located in the western area of the MPA and others in the deeper southern area of the Lastres canyon. In both areas, socioeconomic values associated to fisheries were irrelevant since they have deep bottoms (Fig. 5).

3.5. Stakeholder participatory process

During the diagnosis workshop, the new topics proposed by stakeholders were added to the government's managing proposal (INTEMARES, 2018). After an in-depth analysis of the issues raised, the identified priorities were discussed and analyzed in more depth at the meetings, were proposals for improvement regarding the most relevant aspects were debated. The main topics of discussion in the participatory process agreed with the improvement of the closed area's borders and with the identification of potential areas to be used in the scientific monitoring with the collaboration of local fishermen. With regards to the current management plan the main proposals to be discussed were the following:

- To study the improvement in fisheries yields close to the MPA and identify areas of interest for artisanal selective gear fishing.
- To establish collaborations between the scientific and fisheries sectors and NGOs to monitor the management measures adopted.
- Come back to the fisheries sector with monitoring results and assign budgets to the management plan.
- Define a monitoring participatory commission and assess the possibility of creating a joint management body in the area.

Finally, the main conclusions of the workshop with stakeholders, relative to the new management plan were:

- An open list of boats was already allowed to fish in the buffer zone using longline. Nevertheless, according to the results achieved, an agreement to estimate the maximum number of boats that can fish at the same time in the buffer area will be necessary.
- It would be good to enlarge the protected area towards the West in very deep waters as this would not affect fisheries. This extension would not impede bottom longliners' fishing in the area, while possible mitigating measures to reduce their impact on these habitats should be studied.
- The small sedimentary area of the top of the bank (blue units in Fig. 6C) will only be used for the monitoring studies with the gillnet fisheries.

Fig. 7 summarizes the main areas subject to discussion during the workshop while drafting the new management plan of the MPA. Subsequently, and based on the agreements reached during this workshop, a new version of the MPA management plan was put to public consultation before being approved by the Council of Ministers.

4. Discussion

Achieving environmental objectives when defining a MPA, depends on the definition of its environmental values and, fundamentally, on stakeholders' direct participation in the process (Charles and Wilson, 2008; Hemmati, 2012; Olsen et al., 2014; Jumin et al., 2018). This necessitates that the various sectors involved are acquainted with the scientific arguments that support the creation of these protected zones, many of them aimed at the sustainable development of the economic

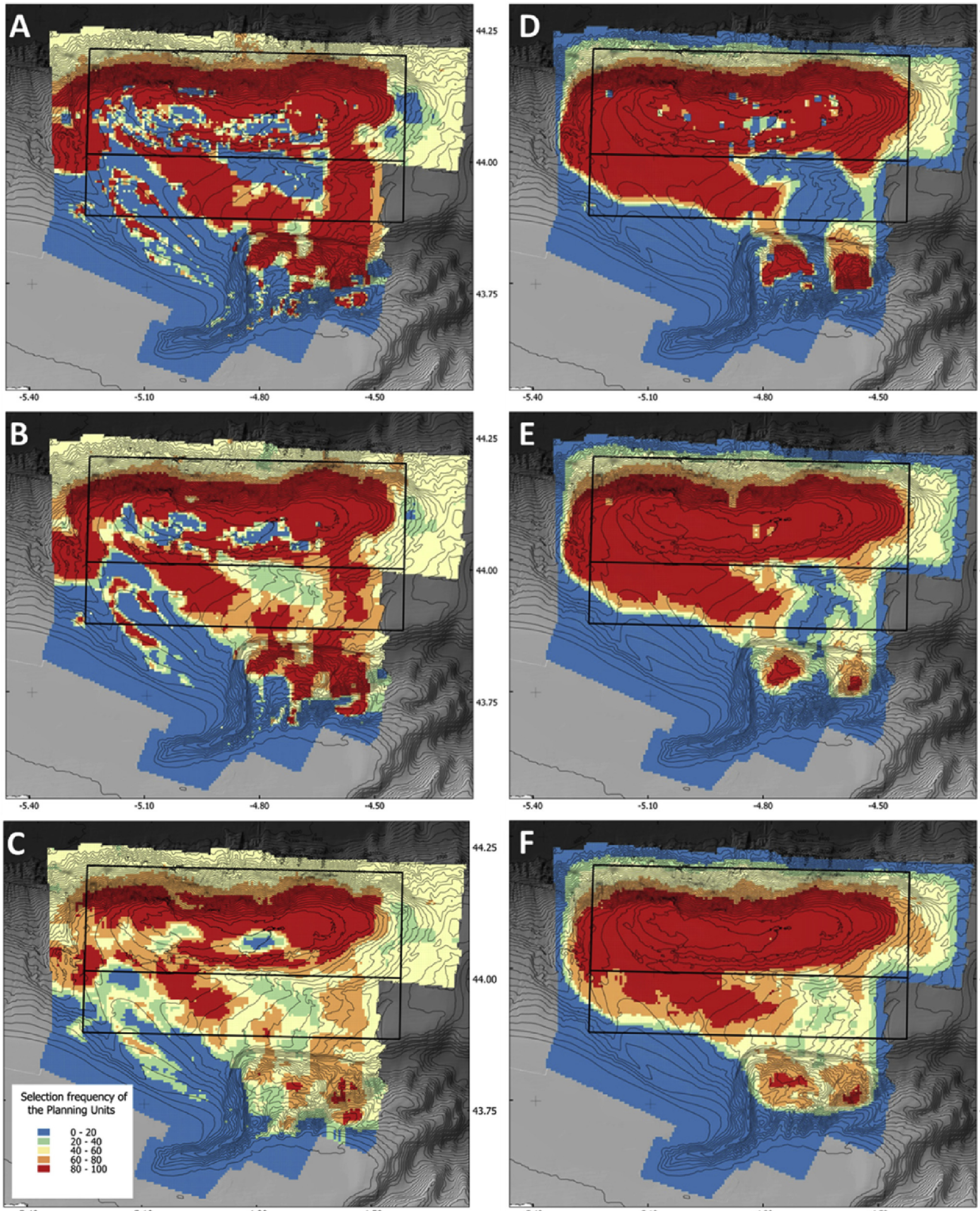

Fig. 6. Marxan outputs as selection frequency of planning units. The first column, A), B) and C), shows the results of Marxan before the area was closed to the fisheries with BLM values of 0.001, 0.01 and 0.1 respectively. The column on the right, maps D), E) and F), the results of Marxan after the closure with BLM values of 0.001, 0.01 and 0.1. (2-column fitting image).

Table 4
Boundary Length Modifier (BLM), cost of the best solution, number of Planification Units (PUs), and boundary length for each of the different scenarios shown in Fig. 6.

	Map	BLM	Cost	PUs	Boundary Length
Before	A	0.001	8612	9885	1433500
	B	0.01	9042	10000	879000
	C	0.1	12964	9996	652000
After	D	0.001	50.1	7850	423000
	E	0.01	86.8	8926	443000
	F	0.1	194.7	9977	442000

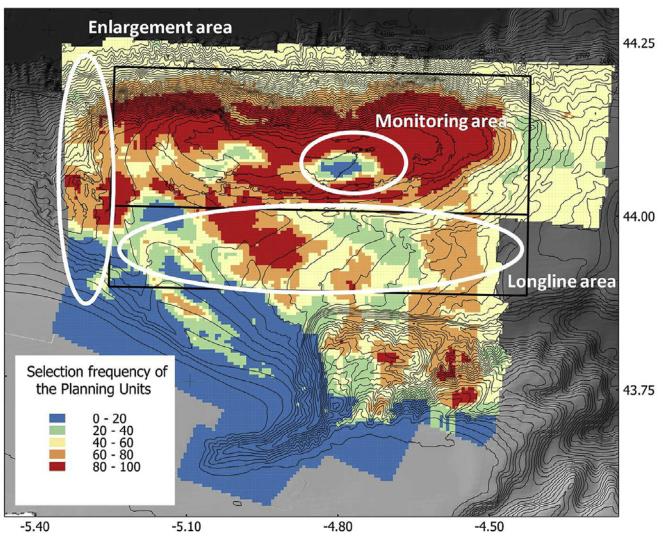

Fig. 7. Tasks to be discussed in the workshop. Highlighted in white are shown some of the areas proposed to be reviewed during the Management Plan revision process. (1.5-column fitting image).

activities (like fishing) that have as main beneficiary the governance of the MPA. In our case, including fishing activities and essential habitats of the main commercial species when designing the proposal, allowed us to suggest an integrative solution where the protection of vulnerable habitats was maximized, together with different options for a sustainable exploitation inside MPA, so it was possible to convey the notion that the environmental values of the MPA benefit the development of economic activities inside and outside the MPA.

4.1. Environmental and socio-economic values

Among the different scenarios shown in Fig. 6, the ones with lower BLM values were difficult to accept by representatives of fishermen and the authorities due to the excessive boundary length and the difficulties that its irregular shape would cause in the monitoring and management of the MPA. As for scenarios with a higher BLM, the map in Fig. 6F has been shaped with the lines drawn by the authorities in the MPA's declaration, which weren't considered fair for the different fisheries involved, so there was only one scenario available to serve all the actors' interests. Therefore, the scenario presented in Fig. 6C, where all the targets were met, was selected for the INTEMARES workshop assessment to give an image of fisheries before the closure and to restore stakeholders' confidence. The deepest zone of the Lastres canyon (southern area outside the MPA's borders, Fig. 7) was not taken into account for conservation purposes because there weren't enough samples evidencing the presence of the 1170 Reefs habitat (Fig. 1) and to avoid disaggregation of MPA limits. Since the MPA's designation, fishery regulations have imposed certain prohibitions, such as the ban to fish beyond 600 m for gillnets (EC, 2016), or to fish deep-sea sharks (EC, 2017). When the MPA was shaped for the first time, there already was a deep knowledge of the area occupied by large sized structuring species at the top of the bank, so it was decided to be the maximum protection area for being the most represented by the management habitat. Thus, following results of the modeling approach and the confirmation of the existence of 1170 Reefs habitat by *ground-truthing* (Fig. 1) to the west of the maximum protection area, an enlargement of 4.3 nm to the West was recommended to managers (Fig. 7). Furthermore, since the main affected fisheries were longlines and gillnets, and in order to incorporate stakeholder participation in the monitoring assessments, a sedimentary ground area located inside the maximum protection area but without the presence of vulnerable large benthic species was proposed. At this location, gillnets targeting monkfish will be allow, although only with observers on board, to study whether protected areas benefits fisheries development or not (Fig. 7). In this context and within the future monitoring plan of the MPA it is designed to make tagging experiences of monkfish with electronic tags to estimate its role as essential fish habitat (spawning area). Long-line fishing in the buffer area could also be allowed at the south of parallel 44°N. This has been a continuous claim of fishermen, particularly those who were not incorporated in the closed list of vessels included in the previous Management Plan.

4.2. Relevance of stakeholders in the implemented regulations

The involvement and participation of stakeholders from the early stages of the MSP planning process is essential to guarantee a successful management plan. Public entities with jurisdiction in the licensing and inspection of activities and uses of marine space or coastal zones, and representative organizations from relevant sectors (especially fisheries) in the area, must be taken into account for an active participation process. All uses and pressures must be analyzed in order to consider all the activities that might represent a risk for marine conservation.

Due to the fact that stakeholder participation was not a priority in the implementation of the conservation measures at the beginning of the MPA process, a workshop offering a clear commitment where the opinions of the different actors involved in the process would be listened to and taken into account in the Management Plan's revision was necessary. Therefore, the present study tried to get both fisheries management and conservation studies together, by evaluating the importance that essential habitats of commercial species have for fisheries sustainability (Harmelin-Vivien et al., 2008). Indeed, an essential aspect to be assumed by stakeholders and decision-makers alike is that MPA designation must be considered a continuous process, where monitoring can sometimes modify the zonation of the area.

During the workshop, it was proposed that a summary and analysis of stakeholder perceptions about the needs and opportunities for a sustainable marine spatial plan for El Cachucho should be conducted. In this sense, the development of a proposal for shared management regarding governance, monitoring and measures for marine protection should be the final goal. In our study, scientific data for an environmental characterization of the area integrated with fishing socio-economic data made it possible to generate predictive models of the presence of the 1170 Reefs habitat without forgetting the existence of human pressures. The final produced maps, gathering all the information available on the area, were used as useful tools to achieve an active participation of stakeholders and facilitate decision making by planners. The main reason of the implemented regulations was to consider a complete unit for the El Cachucho MPA compliant with the dynamic processes for an ecosystem-based approach sustainable with the fishing activities developed in the area.

There are several evidences that point to the fact that the success of conservation assessments relies more on understanding and reflecting the social condition of a specific planning region than on the algorithm used in the decision-making process (Smith et al., 2008; Delavenne et al., 2011). Thus, if a big sampling effort on the managed habitat is necessary to fulfill international conservation commitments, no less effort should be placed in giving fishermen both the maps showing essential habitats for commercial species, and a monitoring plan involving the sector.

4.3. Implications of the new proposed management plan

We can be tempted to trace lines and shape areas that outline vulnerable habitats in order to protect them, but the Convention on Biological Diversity aims to turn 10% of marine habitats into protected areas by 2020 (Convention on Biological Diversity, 2004) and this process will be difficult to accomplish if those sectors which are directly concerned in the establishment of these areas are ignored. Currently, some areas are starting the delimitation process and it would benefit the authorities involved to have guidelines on how to include stakeholders during the first phases of the process. The decision support software Marxan provides decision makers with a tool that gives them different options to keep a fluent communication with stakeholders with a result that can be understood by every actor. MSP is often considered a pragmatic approach to implement an ecosystem-based management in order to manage marine space in a sustainable way (Olsen et al., 2014). Also, MSP is a dynamic process, where ecosystems cannot be planned but the activities and uses carried out within them can. Therefore, the process varies in space and time (Ban and Klein, 2009) and this force to review management plans, especially in MPAs, to verify the efficiency of measures adopted in the respective management plans. Monitoring of these areas, in addition to stakeholder engagement, is fundamental for the revision of these plans. In this sense, the new proposed plan for El Cachucho, obtained after six years of MPA monitoring, including the fishermen collaboration, is an improvement of the management measures aimed at a more effective protection of the environmental values of this deep ecosystem while facilitating a more reasonable use of the buffer zone by the fisheries sector.

Decision-support tools can help to resolve conflicts between sectors, between decision-makers and a specific stakeholder sector or within a sector only if decision-makers are able to involve stakeholders in the process of MPA establishment and in monitoring activities. Fishermen have witnessed the huge sampling effort that has been conducted at El Cachucho during the different projects for years, but they will perceive the MPA as a closed fishing ground unless they participate in monitoring (by being allowed to fish with observers on board) or they are convinced that preserving essential habitats is crucial for the development of the fisheries that operate outside the MPA.

The great effort made during the ECOMARG and INTEMARES project to involve the socio-economic sectors and users of the sea in the management of Natura (2000) is a decisive step for the creation and consolidation of an important network of MPAs in Spain. The development of MSP processes represents an innovative practice at the national and international level, constituting a challenge both for public action and for private initiatives that try to integrate all public and private actors involved in marine conservation proactively.

Despite the difficulties in making the ecosystem approach operational in the marine environment (Douvere, 2008), mainly due to the comparable lack of information regarding ocean dynamics, monitoring and management plans of MPAs must move in the same direction as in terrestrial systems: they represent important opportunities to move towards a deeper knowledge of these marine ecosystems, integrating human activities and even using them to get closer to making the ecosystem approach a reality.

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