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Mediterranean Gate Sanctuary for the Protection of Cetaceans

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ABSTRACT

The Alboran Sea, located at the western Mediterranean Sea, hosts a diverse and ecologically important cetacean community, including endangered species. However, current marine protected areas (MPAs) in the region are limited in scope, and existing conservation strategies are insufficient to address the wide-ranging ecological needs of cetaceans. This study aims to synthesise existing national and international conservation initiatives in the Alboran Sea, develop a prioritization framework and propose a global protection framework for the basin. Our main results highlight that the Alboran Sea presents diverse protection figures including multiple sites of community importance (SCI) for the conservation of cetaceans, as well as it has been designated a cetacean critical habitat, and three different important marine mammal areas (IMMAs) have been identified. In addition, by using species distribution models and a prioritization approach, we identified key areas requiring enhanced protection for multiple cetacean species. The prioritization analysis considered various conservation scenarios, including minimising area costs and accounting for human threats such as fishing and pollution. Three critical areas emerged from our analysis, bridging existing SCIs. So, in this context, we propose the establishment of new protected areas in the northern site of the basin and advocate for a large-scale marine sanctuary—the Mediterranean Gate Sanctuary—due to the overlap of several national and international proposals for protection. A threat-based, species- and space-oriented conservation approach is recommended to effectively safeguard the region's biodiversity. By fostering stakeholder engagement and transnational collaboration, this sanctuary could address the ecological challenges cetaceans face and ensure sustainable marine management in the Alboran Sea.

1 | Introduction

Cetaceans, including whales and dolphins, are not only charismatic and popular species, but they are essential to ecosystem functioning (Bossart 2011; Giménez et al. 2022; Kiszka et al. 2022). They can play disproportionately large effects on the communities they inhabit, maintaining local biodiversity, shaping community structure and promoting health, which makes them highly ecologically important (Bowen 1997; Roman et al. 2014). Despite their importance in the ecosystem, cetaceans are facing numerous threats in the Anthropocene era such as pollution (Jepson et al. 2016), fishing (Marçalo

et al. 2015) or climate change (Simmonds and Elliott 2009). Recent calls for the establishment of marine protected areas (MPAs) for cetaceans have gained attention worldwide (Gormley et al. 2012; Hoyt 2012; Evans 2018). This area-based approach toward conservation has been proven efficient for balancing marine conservation and human activities at sea in general (Halpern and Warner 2002; Claudet et al. 2008) and with cetacean species in particular (Gormley et al. 2012). However, the designation of MPAs for cetaceans needs to be improved, including size and network considerations, to meet the often complex, wide-ranging needs of cetaceans (Hoyt 2018, 2012; di Sciara et al. 2016).

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Marine sanctuaries for the protection of cetaceans, as an area-based conservation approach, have been established in various parts of the world to conserve their habitats and populations, recognising the importance of these species in marine ecosystems. The aims of these sanctuaries are diverse but the main goal is to provide a safe space where species can feed, breed and move. One of the earliest examples is Ireland's Whale and Dolphin Sanctuary. It was established in 1991, where all Irish territorial waters were declared a sanctuary increasing awareness about marine mammal conservation (Rogan and Berrow 1995). Another prominent example is the Pelagos Sanctuary for Mediterranean Marine Mammals created in 2002 (di Notarbartolo Sciarra et al. 2008), in this case a transboundary sanctuary between Italy, France and Monaco. Besides national and regional sanctuaries, international efforts have also been made to protect cetaceans on a larger scale. The International Whaling Commission (IWC) has established International Cetacean Sanctuaries that cover entire basins such as the Southern Ocean Whale Sanctuary established in 1994 (Gerber et al. 2005; Zacharias et al. 2006).

The Alboran Sea hosts a great diversity and abundance of cetaceans, including the endangered subpopulation of Mediterranean common dolphins (*Delphinus delphis*) (Bearzi et al. 2003; Vella et al. 2021), as well as the regular presence of striped dolphins (*Stenella coeruleoalba*), bottlenose dolphins (*Tursiops truncatus*), Risso's dolphins (*Grampus griseus*), long-finned pilot whales (*Globicephala melas*), goose beaked whale (*Ziphius cavirostris*), fin whales (*Balaenoptera physalus*) and sperm whales (*Physeter macrocephalus*). Up to 13 cetacean species have been recorded stranded on the Alboran Sea coast so far (Rojo-Nieto et al. 2011; Masski & De Stéphanis, 2015). The basin highlights a key area for the goose beaked whales, where it can be found

with the highest densities of this species in the Mediterranean (0.0054 animals/km²) with 429 (334–557; 95% CI) individuals (Cañadas and Vázquez 2014), and for common dolphins where the last abundant population in the Mediterranean Sea can be found (Cañadas and Vázquez 2017; Vella et al. 2021). In addition, it has recently been described that harbour porpoises (*Phocoena phocoena*) are regularly present in the Northern Alboran Sea (Blakeman et al. 2025).

In this study, we aim (a) to synthesise the important areas highlighted by national and international bodies toward the conservation of species and habitats in general and for cetaceans in particular in the southwestern Mediterranean Sea, (b) to develop a prioritization approach as a step toward providing support for new MPAs for cetaceans and (c) to propose a global protection framework for cetaceans in the Alboran Sea. Previous prioritization analyses in this area have only focused on two cetacean species (common and bottlenose dolphins) and have only considered fishing as a potential threat (Giménez et al. 2021). Here, a cetacean community approach is undertaken to ensure the effective conservation of the most frequent cetacean species in the Alboran Sea.

2 | Materials and Methods

2.1 | Study Area

The Alboran Sea (southwestern Mediterranean Sea, Spain. Figure 1) stands out as a highly productive sub-basin when compared with the oligotrophic Mediterranean Sea due to the presence of several important oceanographic features (Font 1987; Rubín et al. 1992; Videau et al. 1994; Huertas

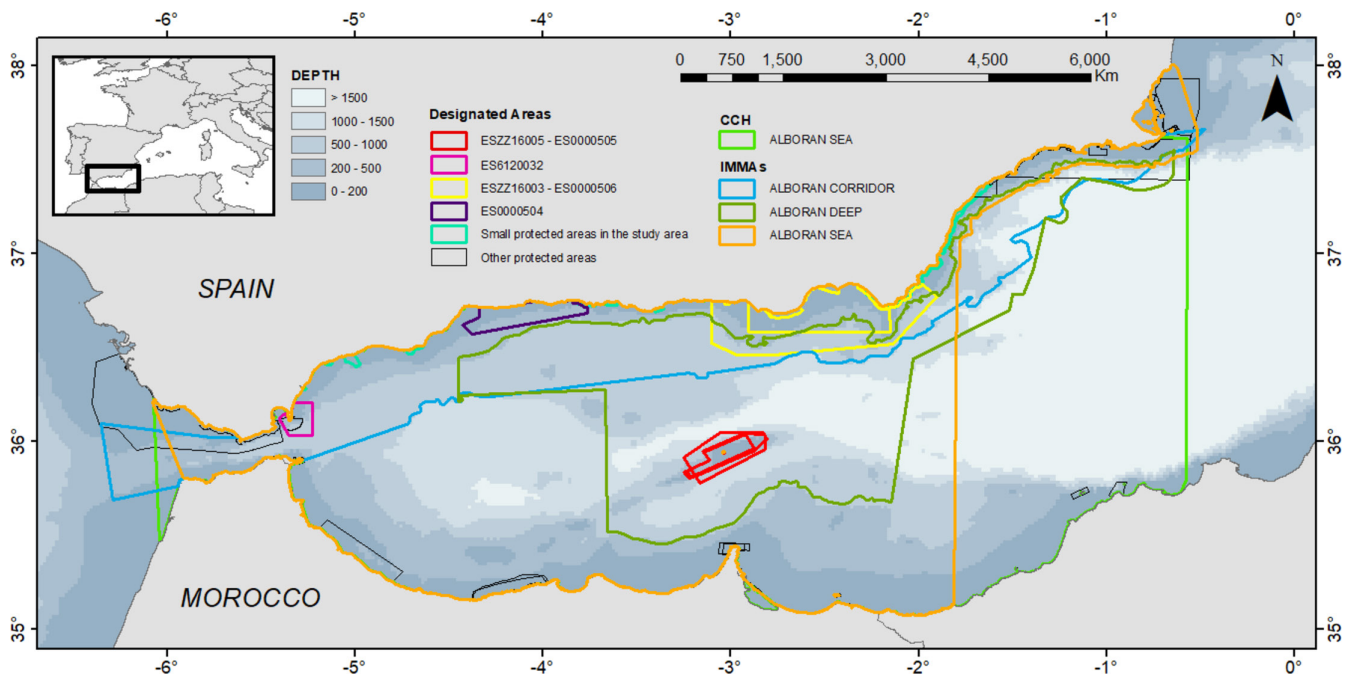


FIGURE 1 | Designated areas for protection in the Strait of Gibraltar, Alborán Sea and Gulf of Vera. Sites of Community Importance (SCIs) (Red: Espacio Marino Alborán SCI [ESZZ16005], Espacio Marino Isla de Alborán SPA [ES0000505], Pink: Estrecho Oriental SCI [ES6120032], Yellow: Sur de Almería—Seco de los Olivos SCI [ESZZ16003], Bahía de Almería SPA [ES0000506], Purple: Bahía de Málaga-Cerro Gordo SPA [ES0000504]), Important Marine Mammal Areas (IMMA) from <http://www.marinemammalhabitat.org/>, Cetacean Critical Habitats (CCH) from <https://accobams.org/> and other protected areas from the World Database on Protected Areas (WDPA) in <https://www.protectedplanet.net/are> also shown.

et al. 2012). It presents two anticyclonic eddies formed by the inflow of Atlantic waters at the surface, which induce intermittent upwelling and enhance marine productivity (Arin et al. 2002). The combination of these hydrodynamic processes and the intricate seafloor topography, characterised by steep escarpments, canyons and sea mountains, further contributes to the concentration of productivity (Rodríguez 1982; Rubín et al. 1992). Consequently, this area supports a rich biodiversity (Coll et al. 2010), particularly cetacean species (Cañadas 2006), see Figure 2.

2.2 | Conservation Areas for Species and Cetaceans in the Alboran Sea

Conservation areas declared in the Alboran Sea were searched in different national and international repositories. National designated areas were obtained from governmental repositories from the Spanish Ministry for the Ecological Transition and the Demographic Challenge (<https://www.miteco.gob.es/es/biodiversidad/temas/biodiversidad-marina/espacios-marinos-protectidos/areas-marinas-protectidas/areas-marin>

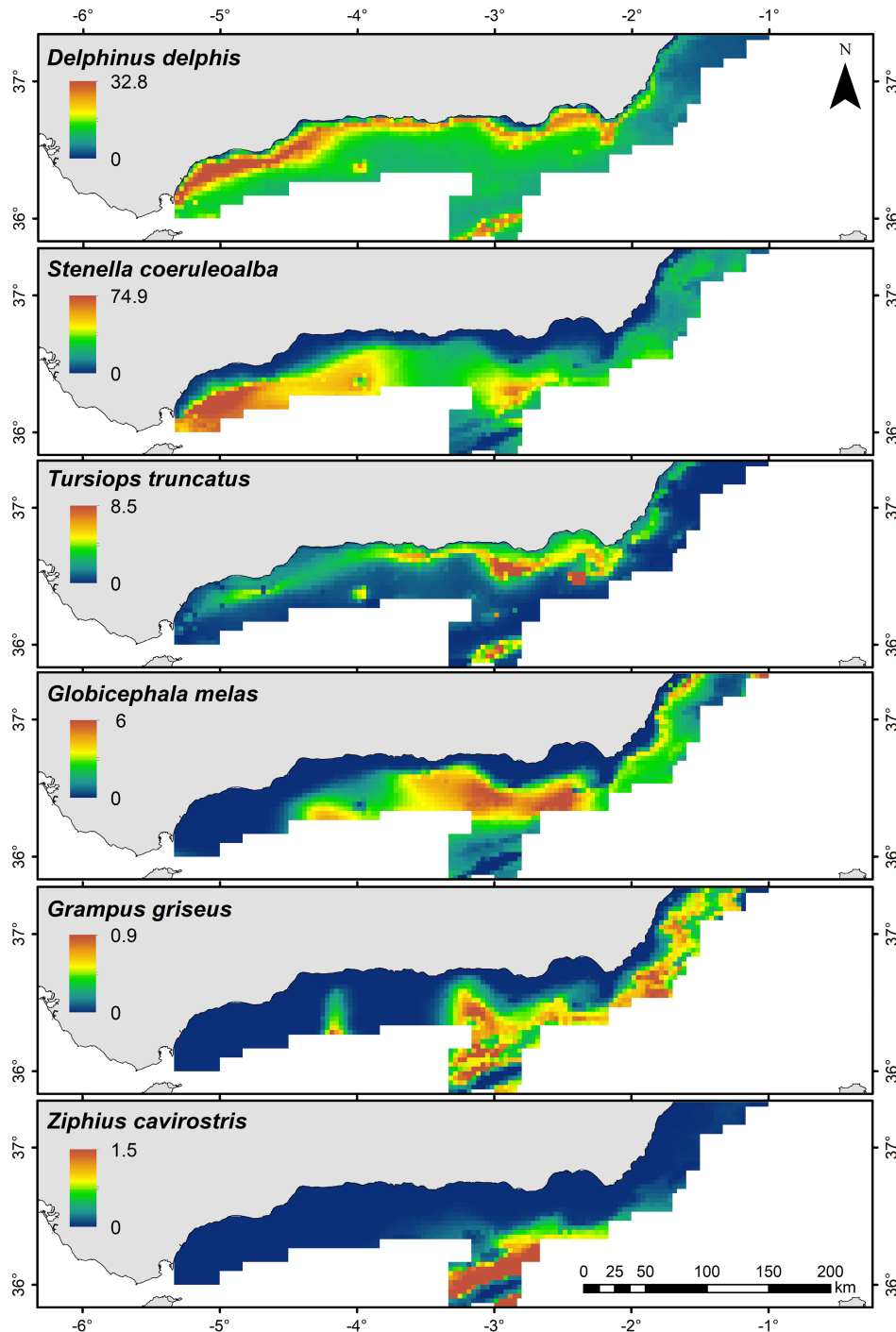


FIGURE 2 | Abundance (i.e., number of individuals) spatial distribution of common dolphins (*Delphinus delphis*), striped dolphins (*Stenella coeruleoalba*), bottlenose dolphins (*Tursiops truncatus*), long-finned pilot whale (*Globicephala melas*), Risso's dolphin (*Grampus griseus*) and goose-beaked whale (*Ziphius cavirostris*) (Giménez et al. 2018).

as-protégidas.html). International repositories included the Marine Mammal Protected Areas Task Force (<http://www.marinemammalhabitat.org/>) to include the Important Marine Mammal Areas (IMMAs), the Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and contiguous Atlantic Area database (ACCOBAMS; <https://accobams.org/>) on Cetacean Critical Habitats (CCH) and the World Database on Protected Areas (WDPA, <https://www.protectedplanet.net/>).

2.3 | Prioritization Analysis

2.3.1 | Cetacean Abundance Data

Spatially explicit abundance data for cetaceans were sourced from published studies (Figure 2, Giménez et al. 2018). The predicted cetacean abundance data (i.e., individuals) are structured into regular grid cells with a resolution of 2×2 min in latitude and longitude.

2.3.2 | Cost Data: Fishing Activity and Other Threats

Fishing effort in the study area (Figure S1) was extracted from the Global Fishing Watch dataset (<https://globalfishingwatch.org>). Daily information was summarised taking into account all fishing gears operating in the area. In addition, artisanal fishing effort (Figure S1) was extracted from Halpern et al. (2015). Marine traffic intensity (Figure S2) was extracted from Emodnet (<https://emodnet.ec.europa.eu/>). Other potential threats to cetaceans (inorganic pollution, ocean pollution, fertilisers, temperature anomalies and anthropization [i.e., population pressure]; Figure S3) were obtained from the global threat analysis of Halpern et al. (2015). Finally, plastic pollution was extracted from Liubartseva et al. (2018). All data were summarised for each planning unit (Figure 3). First, each threat was normalised to a scale ranging from 0 to 1. The normalised values were then summed, and the resulting scores were rescaled again to a range of 0 to 1. Planning unit resolution was designed to have the same resolution as cetacean abundance data (Figure 2) as recommended by Hermoso and Kennard (2012). The data were extracted and processed in R version 3.6.2.

3 | Prioritization Analysis

Spatial prioritization to define important areas for cetaceans was conducted using the *prioritizr* R package (Hanson et al. 2019). The package uses species distribution data to optimise priority areas based on conservation objectives, conditions and user-defined penalties. *Prioritizr* uses integer linear programming (ILP) techniques to provide a flexible interface for constructing and solving conservation planning problems. It supports a wide range of targets, constraints and penalties that can be used to tailor conservation planning problems to the specific needs of each study area. Unlike the algorithms conventionally used to solve conservation problems, the exact algorithms used here guarantee the search for optimal solutions (Hanson et al. 2019).

Four different scenarios (see Table 1) were considered varying the cost (using the area as a proxy for the cost of protection or using the sum of the identified threats to cetaceans in the Alboran Sea; Figure 3), and blocking or unblocking the already defined MPAs (Figure 1). In Scenarios B and D, the already designated areas (Figure 1) were blocked considering that these planning units are already protected, and only adding extra cells if needed to account for the protection targets. In all four scenarios, the boundary length modifier (BLM) was calibrated to create more compact areas by decreasing the outer perimeter. For each scenario, four different sub-scenarios were considered modifying the protection target (i.e., 10%, 20%, 30% or 40% of the abundance of each species within the study area). For each sub-scenario, a portfolio of 10 solutions was created (Figure 4) using the `add_gap_portfolio()` function with an optimality gap of 0.1 (i.e., returning solutions that are within 10% of an optimal solution) to give some flexibility when defining new areas. The Gurobi solver was used as an exact algorithm solver through the *prioritizr* R package (Hanson et al. 2019).

4 | Results

4.1 | Important Areas for Conservation Designated in Southwestern Mediterranean sea

Seventy-eight areas for conservation have been designated in the southwestern Mediterranean Sea (Strait of Gibraltar, Alboran Sea and Gulf of Vera). Sixty-three areas are in Spain, 11 are

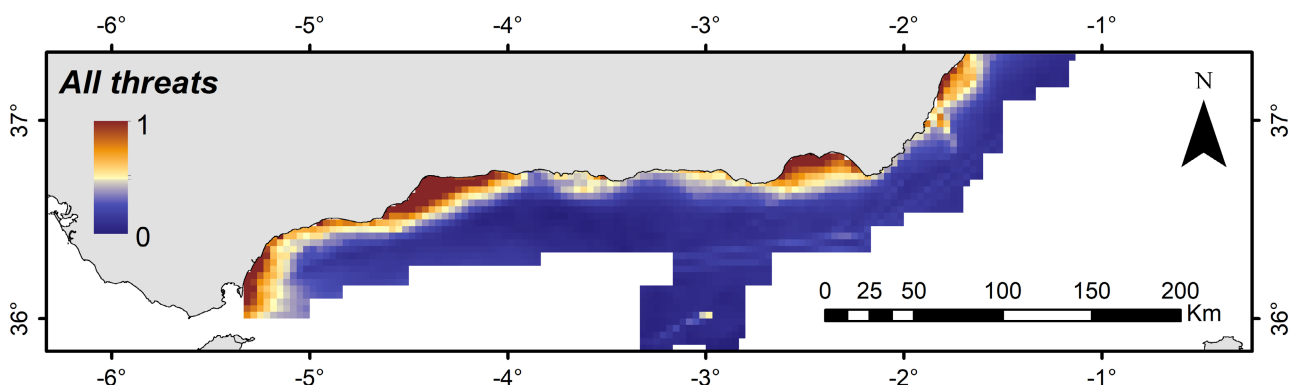


FIGURE 3 | All threats considered in the *prioritizr* analysis (Fishing activity (<https://globalfishingwatch.org>), Marine Traffic (<https://emodnet.ec.europa.eu/>) and other threats (inorganic pollution, ocean pollution, fertilizers, temperature anomalies, anthropization [Halpern et al. 2015], and plastic pollution [Liubartseva et al. 2018])). Values are scaled from 0 to 1.

TABLE 1 | Sixteen conservation scenarios varying the cost (area or all threats), blocking parameter (no blocked areas or the already protected areas) and the percentage of the abundance of each species to be protected.

	Scenario	Cost	Blocked areas	Abundance protected (%)	Figure
Scenario A	A1	Area	—	10	Figure 4A-1
	A2	Area	—	20	Figure 4A-2
	A3	Area	—	30	Figure 4A-3
	A4	Area	—	40	Figure 4A-4
Scenario B	B1	Area	Already protected areas	10	Figure 4B-1
	B2	Area	Already protected areas	20	Figure 4B-2
	B3	Area	Already protected areas	30	Figure 4B-3
	B4	Area	Already protected areas	40	Figure 4B-4
Scenario C	C1	All threats	—	10	Figure 4C-1
	C2	All threats	—	20	Figure 4C-2
	C3	All threats	—	30	Figure 4C-3
	C4	All threats	—	40	Figure 4C-4
Scenario D	D1	All threats	Already protected areas	10	Figure 4D-1
	D2	All threats	Already protected areas	20	Figure 4D-2
	D3	All threats	Already protected areas	30	Figure 4D-3
	D4	All threats	Already protected areas	40	Figure 4D-4

in Morocco, 2 are in Algeria and 2 are in the United Kingdom (Gibraltar). The type of designation is diverse, highlighting the designation of sites of community importance (SCI) under the Habitat Directive ($n=31$), special protection areas (SPA) under the Bird Directive ($n=19$) and specially protected areas of Mediterranean importance (SPAMI) under the Barcelona Convention ($n=7$). Other designations encompass nature reserves, natural parks, natural monuments and regional parks, among others (Table S1).

4.2 | Important Areas Designated for Cetaceans' Conservation in Southwestern Mediterranean sea

Important areas for cetaceans have been designated by national and international bodies in the southwestern Mediterranean Sea. The basin is considered a cetacean critical habitat (CCH) by ACCOBAMS constituting one of the most important areas in the Mediterranean Sea for the conservation of marine mammals (Micheli et al., 2013a). Recently, three different important marine mammal areas (IMMAs) have been identified through different workshops based on scientific evidence and expert opinion (IUCN-MMPATF, 2017a, 2017b, 2017c; IUCN-MMPATF 2017a). The primary goal of IMMAs is to highlight important areas for the survival of marine mammals, such as breeding and feeding areas, or migratory routes where marine mammals are particularly vulnerable (Tetley et al. 2022). Finally, three SCI within the Habitat Directive have been designated due to the presence of bottlenose dolphins as well as important marine habitats (i.e., 'Sur de Almería-Seco de los Olivos [ESZZ16003]', 'Espacio Marino de Alborán [ESZZ16005]' and 'Estrecho Oriental [ES6120032]'

SCI) (Figure 1). These areas are the smallest in size so they do not cover the entire range and movement of cetaceans in these waters, as they were not designated only for the cetacean presence.

5 | Prioritization Analysis

The four scenarios considered provide very similar results. The main difference lies in the fact that when designated areas for protection are blocked in, the portfolio of prioritization decreases in flexibility, so the new proposed areas are always selected in each realization within the portfolio (Figure 4).

Two to three important areas emerged from the analysis depending on the percentage of the abundance we decided to protect (Figure 4). One is situated between the 'Sur de Almería-Seco de los Olivos [ESZZ16003]' SCI and the 'Espacio Marino de Alborán [ESZZ16005]' SCI and a second area close to the 'Estrecho Oriental [ES6120032]' SCI. If the highest protection sub-scenario is considered (i.e., 40% of the abundance of each cetacean species), a third area emerges between the other two areas. Concretely, the third area is located in Avempace-Algarrobo Seamount from the Motril Marginal Plateau (also called Djibouti Plateau).

6 | Discussion

Traditionally, cetacean conservation in Europe has been mainly driven by species and space-based approaches under the Habitat Directive framework. Recently, a threat-based approach has

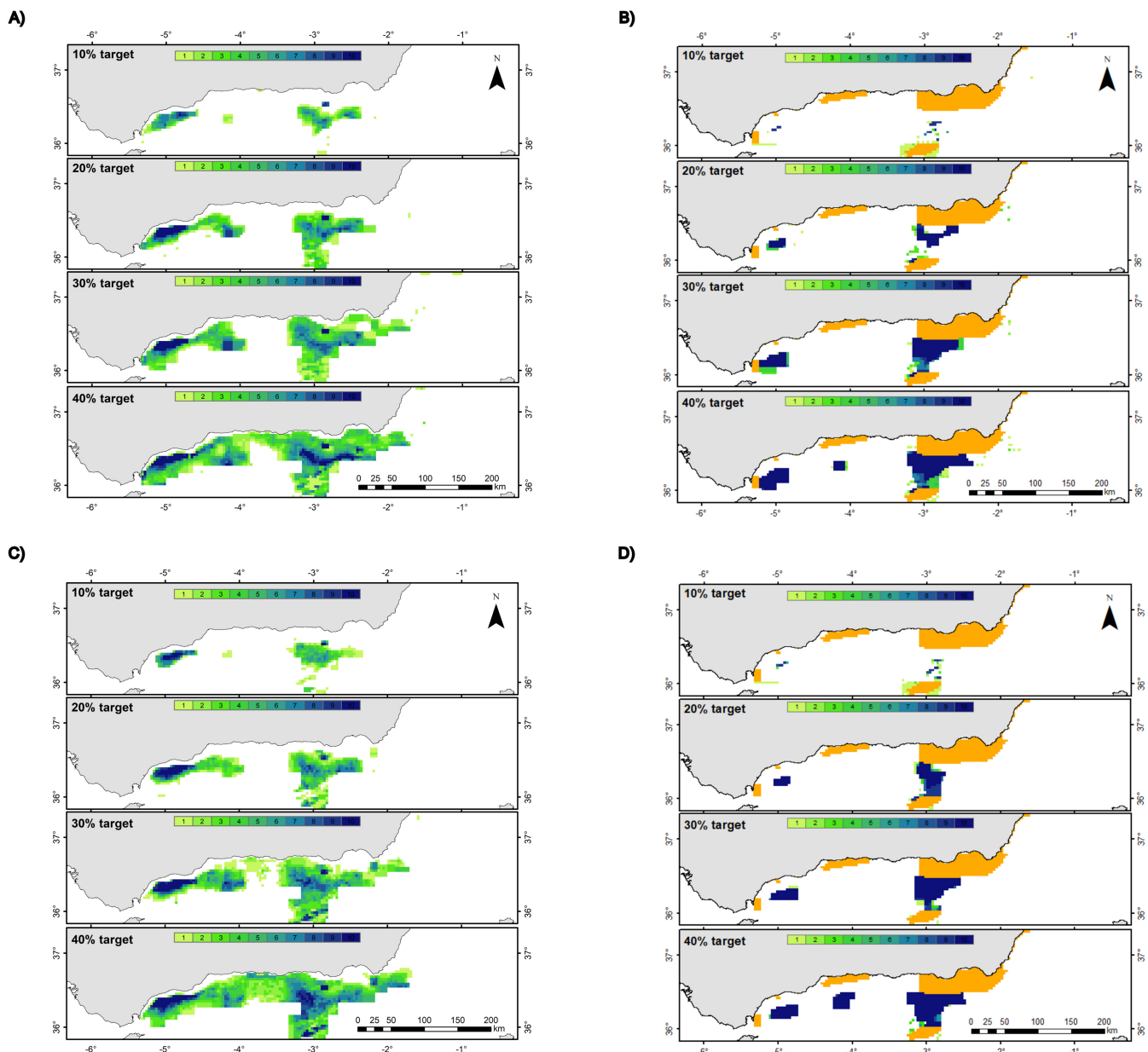


FIGURE 4 | Prioritizr results: (A) Area (km²) considered as a cost. (B) Area (km²) considered as a cost with SCI areas blocked. (C) All threats (Figure 3) considered as a cost. (D) All threats (Figure 3) considered as a cost with SCI areas blocked. Already designated SCI areas are depicted in orange. The colour scale represents how many times a cell has been selected.

been added to current directives through the Marine Strategy Framework Directive (MSFD). Hence, the combination of all approaches would overcome the critiques of only relying on MPAs for the protection of mobile megafauna (Wilson 2016).

Here, we propose the creation of the Mediterranean Gate Sanctuary (English)/Santuario Puerta del Mediterráneo (Spanish)/Sanctuaire Porte Méditerranée (French)/محمية باب البحر الأبيض المتوسط (Arabic). The extension of the sanctuary is proposed to be the same as the Alboran Sea CCH designated by ACCOBAMS (Figure 1) as all the other designated sites, such as IMMAs, fall inside the CCH limits. This sanctuary is not exclusively suggested by its importance for cetacean species but also because it is relevant for other biodiversity components (Coll et al. 2010). Some controversy may exist because the Alboran Sea was not considered an area of biodiversity concern

in terms of maximising the number of species per unit area (Coll et al. 2012), but some areas were identified as priority areas for the conservation of species at risk (PACS, Coll et al. (2015)). Different conservation agreements and basin-wide analyses highlight the area as important to conserve (Mouillot et al. 2011; Micheli et al. 2013; Portman et al. 2013). In addition, the Alboran Sea is considered a different Mediterranean subregion (di Notarbartolo Sciarra and Agardy 2010), so the preservation of this ecoregion would ensure a better representation of species as well as functional and genetic diversity in the Mediterranean basin (Giakoumi et al. 2013). This sanctuary can be framed inside the specially protected area of Mediterranean importance (SPAMI) network under the Barcelona Convention. This is an existing legal tool to create a network of MPAs beyond national jurisdiction. In this marine sanctuary, a threat-based approach should be implemented in conjunction with a comprehensive

MPA network combining space-, species- and basin-wide threat-based approaches to achieve a compromise between cetacean conservation and marine resource exploitation in the Alboran Sea. Marine no-take zones should be implemented as they are an effective tool for marine mammal conservation (Pauly et al. 2002), in areas highlighted in this study, together with complementary conservation measures.

Concretely, as a space-based conservation measure inside the sanctuary based on the results of the present paper, we propose the enlargement of the 'Estrecho Oriental SCI [ES6120032]' towards the east, as well as the connection between the 'Sur de Almería-Seco de los Olivos [ESZZ16003] SCI' and the 'Espacio Marino de Alborán [ESZZ16005] SCI' (see Figure 4). With this connection between the two already designated SCIs, we can create an area big enough to encompass the main distribution areas of the cetacean species in the northern part of the basin, giving connectivity to the already small designated SCI. Also, the protection of the Djibouti Plateau would benefit cetacean species at the highest protection targets, as well as other benthic and pelagic species that live in the area (Würtz and Rovere 2015). Further research is highly encouraged to detect new areas of high importance within the southern part of the sanctuary.

In the proposed marine sanctuary, an ecological-based management should be promoted avoiding politic-legal boundaries (Authier et al. 2017) because efficient conservation measures benefit from transboundary collaboration (Mazor et al. 2013; Kark et al. 2015). Collaboration between Spain, Morocco, Algeria and the United Kingdom (Gibraltar) is needed for a successful conservation approach. In the present 'combine to win' strategy, it is important to include all the sectors and stakeholders demanding marine space in the proposed sanctuary. For example, agreements with the International Maritime Organization (IMO) have been very successful for the conservation of cetaceans in southern Iberian waters where the Traffic Separation Scheme off Cabo de Gata was moved offshore for the protection of cetaceans (Tejedor 2008; Silber et al. 2012). Moreover, a nautical speed limit is recommended in the Strait of Gibraltar to avoid ship collisions with sperm whales in this crowded maritime corridor (Tejedor 2008), but its adherence is rare at the moment (Silber et al. 2012). This seasonal speed recommendation should be broadcast to mariners to achieve better fulfilment. Accordingly, agreements with the marine transport, fishing, oil and seismic sectors, among others, must also be established due to their putative fruitfulness in marine conservation.

These sanctuaries are normally seen as 'paper parks' with little to no political and economic enforcement (Abdulla et al. 2008; Spalding et al. 2008; Fenberg et al. 2012) or even without legal status (Rogan and Berrow 1995). To avoid the risk of becoming a 'paper park', a strong participative approach should be implemented to achieve a broad public acceptance (McCauley 2008) and ensure economic investment and political willingness (Rife et al. 2013). The charismatic nature of cetacean species can act as an umbrella for public engagement in the Sanctuary, gaining support, empowering its preservation and contributing to the conservation of this highly productive marine ecosystem.

Author Contributions

JG conceived the ideas and designed the methodology; AC collected the data; AC and JG analysed the data; JG led the writing of the manuscript with inputs from the rest of the authors. AC and RdS secured the funding. All authors contributed critically to the drafts and gave final approval for publication.

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Ethics Statement

The authors have nothing to report.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data used in this paper were previously published in other papers (i.e., cetacean spatial-explicit abundance data) or sourced from public repositories (e.g., Emodnet). Data can be requested from the original authors or downloaded from public repositories.

Permission to Reproduce Material From Other Sources

The authors have nothing to report.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Figure S1:** Commercial fishing activity from Global Fishing Watch data and artisanal fishing from Halpern et al. (2015). Values have been normalised to a scale ranging from 0 to 1. **Figure S2:** Marine traffic intensity (2017–2023) extracted from Emodnet (<https://emodnet.ec.europa.eu/>). Values have been normalised to a scale ranging from 0 to 1. **Figure S3:** Other threats (plastic pollution 2013–2017 [Liubartseva et al. 2018], inorganic pollution, ocean pollution, plumes of fertilisers, temperature anomalies and population pressure in 2013 [Halpern et al. 2015]). Values have been normalised to a scale ranging from 0 to 1. **Table S1:** Designated sites in the Strait of Gibraltar, Alboran Sea and Gulf of Vera. SCI, site of community importance; SPA, special protection area; SPAMI, specially protected areas of Mediterranean importance. ESP: Spain, MAR: Morocco, DZA: Algeria.