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Conservation Attitudes and Perceived Biodiversity Among Divers on the Spanish Mediterranean Coast: Insights from Local Ecological Knowledge

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Abstract: The Mediterranean Sea, a global biodiversity hotspot, faces significant threats that compromise its ecological health. While Marine Protected Areas (MPAs) play a crucial role in biodiversity conservation, their effectiveness is debated, and empirical data on their impact remain limited. This study evaluates the utility of Local Ecological Knowledge (LEK) from divers along the Spanish Mediterranean coast to assess perceived abundance of sentinel species in both MPAs and non-protected areas, in relation to empirical data, alongside divers' attitudes toward ocean threats and conservation strategies. Divers perceived higher abundance and subjective health indicators of key species, such as *Posidonia oceanica*, octocorals, and top predators within MPAs, which aligns with empirical evidence supporting MPA effectiveness in conserving biodiversity and mitigating human disturbances. Notably, divers showed knowledge gaps, particularly underestimating climate change impacts while overemphasizing pollution threats. Diver education emerged as a critical factor in shaping conservation attitudes, with higher education levels correlating with increased environmental awareness and stronger support for conservation measures. This study underscores the potential of leveraging LEK in marine conservation strategies while acknowledging limitations related to self-reported data and regional specificity, advocating for expanded geographic scope and integration with empirical data in future research.

Keywords: citizen science; Mediterranean Sea; marine biodiversity monitoring; marine protected areas; recreational diving surveys; conservation attitudes; environmental stewardship; education

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1. Introduction

The Mediterranean Sea is a major global biodiversity hotspot, home to approximately 17,000 marine species, with around 20% being endemic to the region. Among these are numerous species of conservation concern and unique endangered habitats, such as *Posidonia oceanica* meadows, which play a crucial role in maintaining local ecological processes and supporting endemism [1]. However, it is also highly threatened [2–4]. Major pressures include habitat degradation, overexploitation, overfishing, pollution, climate change, eutrophication, and biological invasions [4]. These pressures have escalated over recent decades and are expected to intensify in the future [5,6]. These impacts are distributed unevenly across the Mediterranean, with the coastal areas and continental shelves, particularly in the Western Mediterranean, being the most affected by both anthropogenic and natural pressures [1,4].

Marine Protected Areas (MPAs) have become a vital tool for conservation strategies, contributing to increased species richness, abundance, and biomass, reducing habitat degradation, and maintaining ecosystem functioning and resilience [7–9]. In the Mediterranean Sea, more than 1200 MPAs have been established, covering 8.33% of its surface area. However, these zones suffer from inconsistent and inadequate ecological representation [10]. Particularly concerning is the fact that no-take zones, which prohibit all extractive activities, account for less than 0.05% of the sea's total area. This issue is more pronounced in the Southern Mediterranean, where only 0.59% of the region is protected, primarily due to a lack of comprehensive scientific data. This situation underscores the need for a more connected network of MPAs to achieve more balanced and effective ecological coverage [11,12].

Recently, Local Ecological Knowledge (LEK), a form of citizen science, has emerged as a cost-effective strategy to address data gaps in marine science, offering valuable insights into local ecosystems and species behaviors that traditional scientific research may overlook [13–15]. LEK is defined as the collective understanding of the environment developed by a specific community over time, shaped by cultural transmission and sustained interactions with their natural surroundings [16]. This knowledge, which is derived from the long-term experiences of community members such as fishers, provides crucial information on environmental conditions and biodiversity trends [17–19]. When integrated with scientific data, LEK offers a cost-effective method to bridge data deficiencies, particularly in regions with limited resources [18].

There is a growing body of literature highlighting the increasing use of LEK approaches within the diving community, recognizing the significant potential and opportunity they present for marine conservation. Engaging divers in monitoring efforts not only allows for the collection of valuable ecological data over extensive spatial and temporal scales but also fosters a deeper sense of stewardship among stakeholders. Recent studies have demonstrated the effectiveness of these approaches in monitoring climate-related responses in Mediterranean Marine Protected Areas [20] and exploring opportunities to enhance MPA effectiveness through deeper habitats, such as the mesophotic zone [21]. These examples underscore the promising applications of LEK for expanding our understanding and management of marine ecosystems. Additionally, the Western and Southern Mediterranean regions are of special interest due to their relatively low data availability, highlighting the need for more comprehensive studies in these areas [18,19].

The aim of this study is to explore the utility of LEK provided by recreational and professional divers along the Spanish Mediterranean coast in assessing the perceived abundance of several sentinel species in both MPAs and non-protected areas. This research compares these subjective, semi-quantitative perceptions with empirical data from field studies, examines divers' attitudes toward ocean threats, and considers their implications for conservation and educational initiatives, to assess the potential benefits of integrating LEK into marine conservation strategies in this specific geographic region.

2. Materials and Methods

2.1. Study Area

The study area for this research encompasses the coastal waters of the Spanish Mediterranean. Characterized by a narrow continental shelf, with depths of 50 m occurring roughly three nautical miles from the shore, the Spanish Mediterranean coast extends over 1700 km and represents the westernmost region of the Mediterranean Sea. This area is bordered by the Gulf of Lions to the north, the coast of Morocco to the south, and the Sardinian coast and Tyrrhenian Sea to the east (Figure 1). Designated MPAs at date of data collection were included (Figure 2) and, among them, Cabo de Palos—Islas Hormigas, Illes Medes, Cabo de Gata—Níjar, Islas Columbretes, Cap de Creus, and Freus d'Eivissa i Formentera have known no-take zones established to protect vital marine habitats and biodiversity.

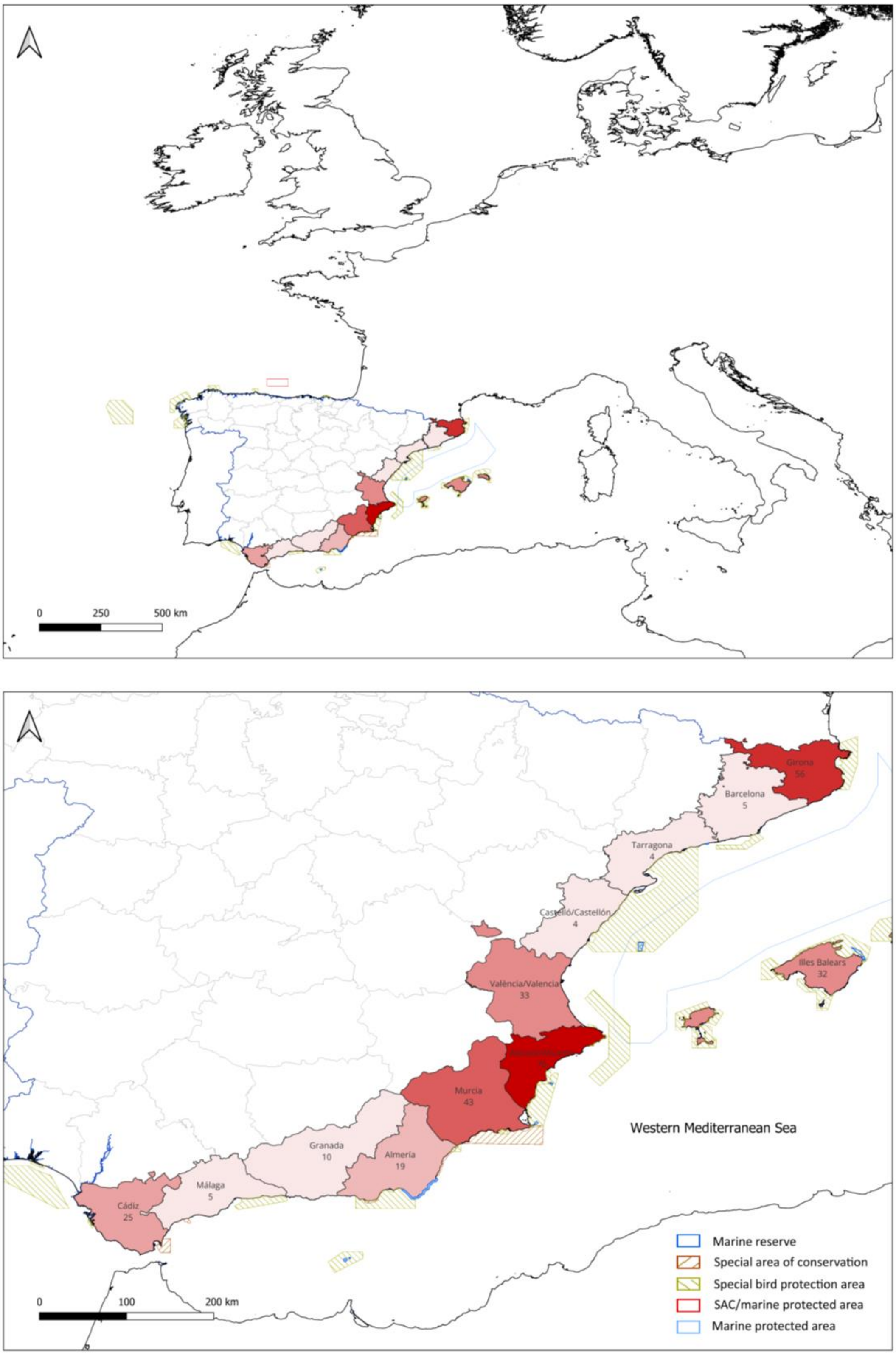

Figure 1. Frequency map representing the number of participants usually diving in each of the Spanish Mediterranean provinces and the current Marine Protected Area Network of Spain. SAC, special area of conservation.

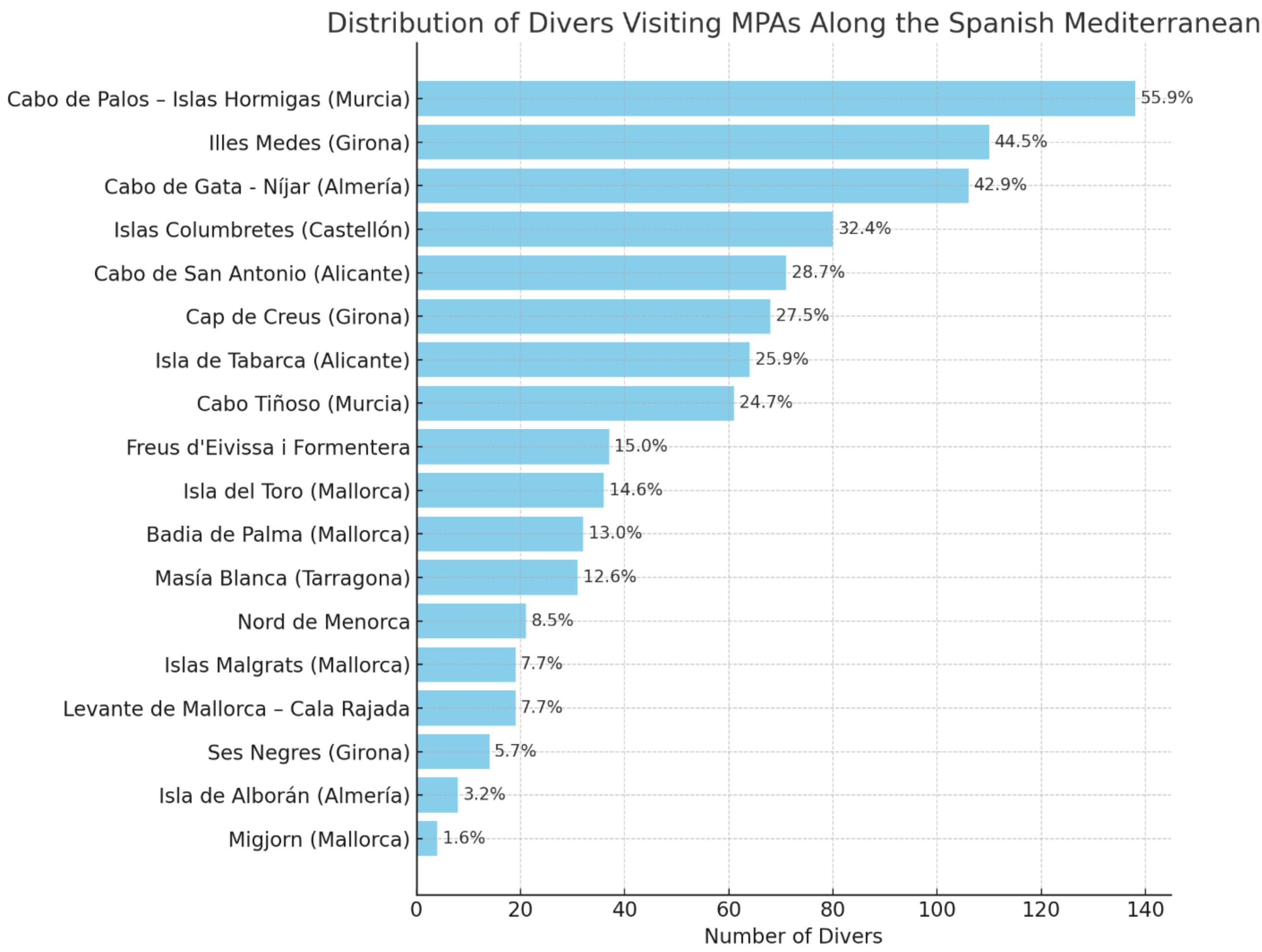

Figure 2. Number and frequency of participants that have dived in the different MPAs of the Spanish Mediterranean coast. Note: The province is shown in brackets only when it is not included in the official name of the MPA.

2.2. Survey

From March to June 2020, a structured online survey was administered to divers along the Spanish Mediterranean coast to gather their perceptions on biodiversity in non-protected areas and MPAs, as well as their views on the status and threats facing the marine ecosystem. Divers were recruited through dive centers, associations, and clubs that have been operating in the region for at least 5 years. Both local divers and divers from other regions of Spain who frequently visit the Mediterranean were eligible to participate. Additionally, it was promoted through organizational websites, social media channels, and key user magazines. The survey responses were collected anonymously and in full compliance with the General Data Protection Regulation (EU) 2016/679 of the European Parliament and Council, as well as the Spanish Organic Law on Data Protection 3/2018. Prior to deploying the questionnaire, several infographics were created, and dive center managers were directly engaged to explain the study's objectives and encourage participation.

The questionnaire took approximately 15 min to complete and was divided into different sections: demographics, public perceptions on perceived species abundance in MPAs and non-protected areas, individual opinions on the subjective status of the Mediterranean, and threats to marine ecosystems and personal implication in conservation or educational strategies.

Before responding to questions regarding the presence of various taxa, participants were first asked to identify MPA and non-protected marine sites in their region that they had visited in the past 36 months, ensuring that their responses were based on their experiences from that time frame. To minimize subjectivity in the assessment of species abundance ("occasional", "abundant", or "very abundant"), participants then underwent a training session using representative photographs and species identification cards specific to the taxa evaluated in the questionnaire. Furthermore, where appropriate, to accurately assess the "health" of key species of seagrasses and octocorals, infographics were provided illustrating both healthy and unhealthy specimens. Criteria such as the presence of lesions, discoloration, abnormal growths, or signs of disease were outlined as indicators of an unhealthy specimen. To further ensure accuracy, participants were tested on their ability to correctly identify species from a series of photographs, and only those achieving an identification accuracy rate of over 80% were allowed to proceed with the questionnaire.

The survey sections focused on the perceived presence of sentinel species included questions about the abundance and status of seagrasses, octocorals, invasive algae, herbivorous species, and non-herbivorous species, as well as observations related to marine litter and pollution. While perceived abundances were measured using Likert scales, other descriptive variables were not rated in this way. Instead, participants were asked to identify the most frequently observed patterns among the parameters analyzed. To facilitate accurate species identification and reduce potential biases, representative photographs and species identification cards were embedded within the survey. Due to common misidentification among many respondents, the species *Siganus luridus* and *Siganus rivulatus* were excluded from the analysis. A five-point Likert scale was employed to capture respondents' semi-quantitative perceptions of species abundance distribution, as well as their views on the overall subjective health of the Mediterranean, threats to marine biodiversity, and conservation strategies. The assessment of the Mediterranean's health was intentionally designed as a social perception question, aimed at understanding the community's general sentiment rather than providing an objective or scientific evaluation. No specific criteria were given, allowing participants to base their responses on their personal experiences and observations. Additionally, the survey included a mix of closed questions (yes/no/maybe) and open-ended questions to gather comprehensive insights from the participants.

Participants were encouraged to contact via phone or email to ask for any possible clarification or provide additional information such as photographic or video data, and direct contact between the subjects and the research team was facilitated. The survey questions are detailed in Supplementary File (S1).

2.3. Statistical Analysis

The results of the public survey were compiled in a database. The statistical analyses were conducted with R statistical software version 4.4.1 (R Development Core Team, 2017, Vienna, Austria). Maps were created with QGIS version 3.34.12. Descriptive analyses were performed in order to summarize the demographics of the subjects. In this regard, and as represented in Table 1, quantitative data were expressed as mean and standard deviation (SD), whilst qualitative data were summarized as counts (n) and frequencies. T-tests or ANOVA tests were used when appropriate to compare the mean age of the participants depending on several grouping factors such as education, diving certification, and factorized number of dives. Normality was confirmed with quantile–quantile plots and the Kolmogorov–Smirnov test. A two-tailed *p*-value below 0.05 was considered statistically significant.

Table 1. Summary of demographic data of the recreational divers participating in the study. Mean (SD)—*n* (%) refers to the data presented for quantitative and qualitative variables, respectively. *t*-tests or ANOVA were used to compare participants' mean age based on education, diving certification, and number of dives, which appear as subsections in the age category.

Variable		Mean (SD)—*n* (%)	*p*-Value
Age		41.71 (11.25)	
	MPA		*t*-test $p < 0.0001$
	Yes	43.51 (10.68)	
	No	34.42(10.65)	
	Studies		ANOVA $p < 0.05$
	Primary Education	54.33 (2.31)	
	General Certificate of Secondary education (GCSE)	42.08 (11.76)	
	General Certificate of Education (GCE) or Vocational Education and Training (VET)	43.43 (10.11)	
	Certificate of Higher Education (HNC) or University Degree	40.08 (11.76)	
	Master's Degree (MSc)	40.21 (10.46)	
	Doctorate (PhD)	44.35 (12.61)	
	Diver certification		ANOVA $p < 0.0001$
	Open Water Diver	34.33 (11.78)	
	Advanced Open Water Diver	40.53 (11.81)	
	Rescue Diver	42.07 (10.24)	
	Divemaster	43.76 (9.46)	
	Assistant Instructor	43.29 (12.63)	
	Instructor	44.92 (10.24)	
	Number of dives		ANOVA $p < 0.0001$
	Less or equal to 10	28.71 (7.35)	
	11–25	29.90 (11.40)	
	26–50	35.68 (11.48)	
	51–100	37.73 (9.91)	
	101–200	42.68 (8.77)	
	More than 200	45.81 (9.69)	
Years of experience		13.51 (10.37)	
Diving certification			
Open Water Diver		48 (15.53)	
Advanced Open Water Diver		75 (24.27)	
Rescue Diver		40 (12.94)	
Divemaster		50 (16.18)	
Assistant Instructor		8 (2.59)	

Table 1. *Cont.*

Variable	Mean (SD)—*n* (%)	*p*-Value
Instructor	88 (28.480)	
Studies		
Primary Education	4 (1.46)	
General Certificate of Secondary education (GCSE)	12 (3.90)	
General Certificate of Education (GCE) or Vocational Education and Training (VET)	94 (30.52)	
Certificate of Higher Education (HNC) or University Degree	122 (39.61)	
Master's Degree (MSc)	59 (19.16)	
Doctorate (PhD)	17 (5.52)	
Number of dives		
Less or equal to 10	19 (6.96)	
11–25	21 (6.77)	
26–50	22 (7.10)	
51–100	34 (10.97)	
101–200	38 (12.26)	
More than 200	176 (56.77)	

On the one hand, for evaluating the perceived abundance of different taxa, ordered logistic regression was used to analyze Likert scale items as dependent variables, as it is well suited for ordinal response variables and has been shown to be effective for experiments with Likert item data, even with paired or repeated observations, as in our case. The odds ratio (OR) and 95% confidence interval (95% CI) for those observations rated as "common" or "very common" in both groups (MPAs and non-protected areas) were calculated for comparison. Bar plots were developed with the *likert* R package [22] for Likert data graphic representation.

Additionally, linear mixed-effects models were applied to assess the influence of MPA status and diving experience on perceived species abundance using ordinal data using the *lme4* package in R. Various models were explored to address potential biases and to ensure no collinearity. Fixed effects included MPA status and dive frequency (categorized into five levels), while random effects were incorporated for province and individual diver ID to account for geographical and individual variability due to repeated observations.

The model was fitted using Restricted Maximum Likelihood (REML). Model fit was evaluated based on the fixed-effect estimates, standard errors, and variance components of the random effects. Initially, educational level was included as a random effect, but it was removed due to near-zero variance, indicating that it did not significantly contribute to the model. Age was also considered a fixed effect, but it was excluded to focus on MPA status and number of dives as the primary predictors, and due to its lack of significant impact on the response variable. The final models included MPA status and number of dives as fixed effects, while ID and province (despite not being strongly associated) were retained as random effects to account for individual and geographical variability.

On the other hand, several qualitative perceptions regarding the global characteristics and disturbances of each analyzed taxon were considered (see File S1). Participants were asked to identify the most frequently observed patterns for the analyzed parameters (e.g., overall health status, major disturbances, among others), rather than rating each category using Likert scales. The Chi-square test or Fisher's exact test, depending on data characteristics, was used to compare the frequency of participants' responses across the different variables within the entire cohort.

3. Results

3.1. Demographics

A total of 384 divers were eligible to participate in the study, of whom 310 (80.73%) successfully qualified and completed the survey in its entirety. The regions most frequently dived by these respondents are depicted in Figure 1, while Figure 2 provides a breakdown of the number of participants who have visited dive sites in MPAs along the Spanish Mediterranean coast. All participants who dived in MPAs had also dived in non-protected areas. However, 62 divers had only dived in non-protected areas. The mean age of the participants was 41.71 years (SD = 11.25), with significant variations observed according to educational level, diver certification, and prior diving experience, quantified by the approximate total number of dives. Interestingly, divers with only a primary education were significantly older than those with higher educational attainment (ANOVA $p < 0.05$). Moreover, a positive correlation was found between the mean age and both the level of diver certification and the number of previous dives. Younger divers were notably less likely to have visited MPAs.

Nearly 60% of the participants had completed more than 200 dives, and the vast majority held at least an advanced diving certification. Furthermore, nearly 40% of the participants had undergone professional diving training, and over 60% had attained at least a university degree or a Certificate of Higher Education. Additional details on the participants' characteristics are provided in Table 1.

3.2. Divers' Perceptions on Species Abundance in MPAs and Non-Protected Areas

Divers were asked to provide semi-quantitative ratings of species abundance using a five-point Likert scale, based on their experiences in both MPA and non-protected areas. The analysis included the most representative seagrasses, octocorals, invasive algae, herbivorous species, and non-herbivorous species. Additionally, these reports were statistically compared between both areas.

3.2.1. Seagrasses

This study focused on two species: *Posidonia oceanica* and *Cymodocea nodosa*. Divers provided structured semi-quantitative and qualitative data on the relative abundance, distribution, health status, and impacts (both natural and anthropogenic) in MPAs compared to non-protected areas.

Posidonia oceanica was perceived as "common" or "very common" in 76% of observations within MPAs, compared to 45% in non-protected areas (Figure 3). According to the ordinal logistic regression model, the odds of *P. oceanica* being rated as "common" or "very common" were 3.78 times higher in MPAs than in non-protected areas (95% CI: 2.71–5.30). Additionally, a linear mixed-effects model was applied to assess the influence of MPA status and diving frequency on *P. oceanica* abundance. The model included MPA and dives as fixed effects, while province and diver ID were treated as random effects. The results showed a significant positive effect of MPA presence (estimate = 0.91, $p < 0.001$), supporting that higher perceived abundances of *P. oceanica* were associated with MPAs. The variance attributed to province (0.14) and individual ID (0.30) indicated low variability across these levels. No significant effect was observed for dive frequency categories, suggesting that diver experience, as categorized, did not significantly influence perceptions of *P. oceanica* abundance. Moreover, its distribution significantly differed between the two types of areas (Fisher's exact test, $p < 0.001$). In non-protected areas, *P. oceanica* meadows were predominantly located on sandy seabeds (61.5%), whereas in MPAs, a more heterogeneous distribution was observed: 48.5% on sandy seabeds, 4.5% on rocky seabeds, and 47% on mixed seabeds.

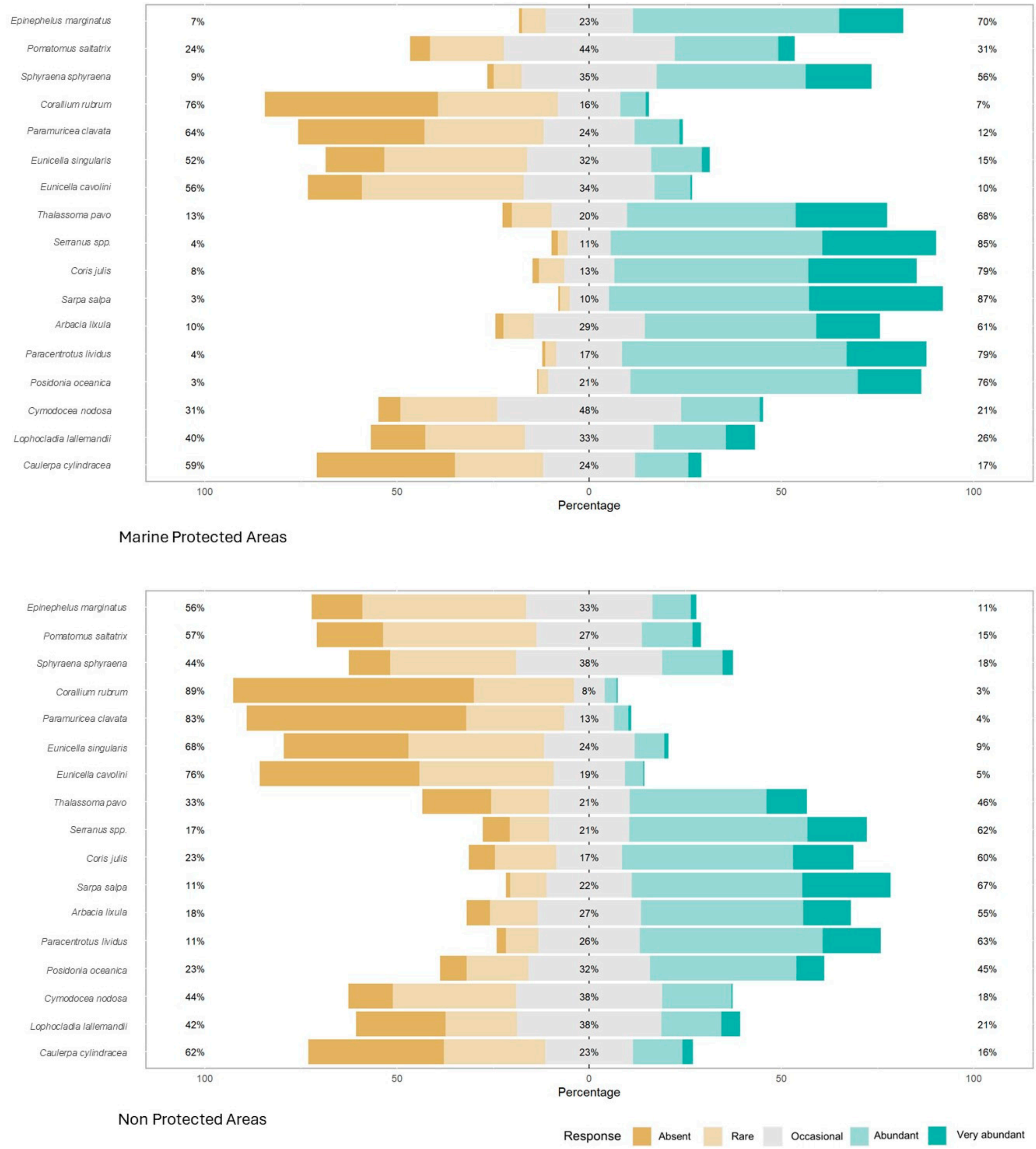

Figure 3. Perceived abundance of representative species in Marine Protected Areas (MPAs) and non-protected areas along the Spanish Mediterranean coast. The frequencies are displayed as a sum of "Absent" and "Rare" responses on the left side and "Abundant" and "Very Abundant" responses on the right side for each species, highlighting the perceived differences in species presence between the two types of areas.

Characteristics of the meadows were also recorded. The proportion of *P. oceanica* meadows reduced to isolated tufts was significantly higher in non-protected areas compared to MPAs (61.6% vs. 44.7%, Chi-square test, $p = 0.0001$). Additionally, 74.5% of respondents reported subjectively healthy meadows in MPAs, in contrast to 62.5% in non-protected areas (Chi-square test, $p = 0.0036$). However, in both environments, over 70% of divers observed direct human contact with the seabed, touching, or standing on the seabed, as well as dragging or displacing marine organisms or structures. Anthropogenic impacts were reported significantly more frequently in non-protected areas, whereas environmental alterations, such as water turbidity and algae coverage, were observed slightly more often in MPAs (Chi-square test, $p = 0.012$). A summary of the various impacts on seagrasses is provided in Table 2.

Table 2. Impacts and health status of two species of seagrasses in MPAs and non-protected areas. Data are presented as absolute numbers, with frequencies shown in brackets.

	Abundant dead zones	Direct human disturbances (anchoring, propeller, trawling. . .)	Litter and human waste	Algae coverage	Water turbidity	No identifiable disturbances
Posidonia oceanica						
MPAs	17 (7)	69 (28.3)	81 (33.2)	16 (6.6)	17 (7)	44 (18)
Non-protected areas	33 (11.7)	93 (32.9)	103 (36.4)	14 (4.9)	16 (5.7)	24 (8.5)
Cymodocea nodosa						
MPAs	25 (12)	44 (21.1)	60 (28.7)	13 (6.2)	8 (3.8)	59 (28.2)
Non-protected areas	38 (15.1)	63 (25.1)	93 (37.1)	6 (2.4)	16 (6.4)	35 (13.9)

Cymodocea nodosa was reported as "common" or "very common" by 21% of divers in MPAs and 18% in non-protected areas (Figure 3). The odds of *C. nodosa* being perceived as "common" or "very common" were 1.57 times higher in MPAs than in non-protected areas (95% CI: 1.14–2.16). A linear mixed-effects model confirmed a modest but significant effect of MPAs on the perceived abundance of *C. nodosa* (estimate = 0.23, $p < 0.001$). Random effects for province and diver ID showed minimal variability. Among dive frequency categories, only the group of 11 to 25 dives showed a slight but significant increase in perceived abundance (estimate = 0.44, $p < 0.05$). Other dive categories did not have a significant impact. No significant differences were observed in the perceived distribution of the meadows or in direct diver contact. The meadows, mainly consisting of isolated tufts, were predominantly located on sandy seabeds. Nevertheless, 77% of the *C. nodosa* populations were reported as healthy in MPAs, compared to 62.6% in non-protected areas (Chi-square test, $p = 0.001$). The reported impacts were nearly identical to those observed for *P. oceanica* (Chi-square test, $p = 0.0008$). Further details can be found in Table 2.

3.2.2. Octocorals

The analysis focused on four octocoral species (*Eunicella singularis*, *Eunicella cavolini*, *Paramuricea clavate*, and *Corallium rubrum*), examining their abundance, distribution, and health status. Subjective abundance data are illustrated in Figure 3.

Eunicella singularis was reported as "common" or "very common" in 15% of observations within MPAs, compared to 9% in non-protected areas. Ordinal regression analysis indicated that the likelihood of *E. singularis* being reported as abundant in MPAs was 2.12 times higher than in non-protected areas (95% CI: 1.54–2.91). The linear mixed-effects model further supported the influence of MPA status, with a significant positive effect (estimate = 0.28, $p < 0.001$). The random effects for province and diver ID accounted for minimal variability, indicating consistent patterns across locations and individual divers. Among dive frequency categories, the lowest dive group ($\leq$10 dives) showed a significant negative effect (estimate = -0.67, $p < 0.01$), while other dive levels did not show significant effects. The distribution of *E. singularis* did not differ significantly between MPAs and non-protected areas (Chi-square test, $p = 0.09$); it was primarily found on rocky bottoms (approximately 65%), with smaller proportions on vertical walls (about 20%) and reef-like formations (around 15%). Healthy specimens were observed more frequently in MPAs than in non-protected areas (Chi-square test, $p = 0.03$).

For *E. cavolini*, 10% of observations in MPAs and 5% in non-protected areas described the species as "common" or "very common." The odds of observing *E. cavolini* as abundant were 3.10 times higher in MPAs compared to non-protected areas (95% CI: 2.23–4.33). The linear mixed-effects model confirmed the significant positive effect of MPA status on *E. cavolini* abundance (estimate = 0.43, $p < 0.001$). The random effects for province and individual ID accounted for some variability, but the influence was modest. Among the dive frequency categories, the 26–50 dive (estimate = -0.38, $p < 0.05$) and 51–100 dive (estimate = -0.34, $p < 0.05$) groups showed significant negative effects, suggesting that divers in these categories reported a lower perceived abundance of *E. cavolini* compared to others. Its distribution pattern was similar to that of *E. singularis*, with healthy specimens reported in 77.6% of observations in MPAs, significantly higher than the 61.7% reported in non-protected areas (Chi-square test, $p = 0.0016$).

Paramuricea clavata was described as "common" or "very common" in 12% of records from MPAs, compared to 4% from non-protected areas. According to the ordinal logistic regression model, the odds of *P. clavata* being rated as common or very common were 2.73 times higher in MPAs than in non-protected areas (95% CI: 1.96–3.82). The linear mixed-effects model supported the significant positive impact of MPA status on *P. clavata* abundance (estimate = 0.37, $p < 0.001$). The variance attributed to individual ID and province was also modest. The influence of dive frequency categories was not statistically significant for any level. It was primarily distributed on rocky substrates (50%), with additional occurrences on vertical walls (35%) and reef-like formations (15%). While the distribution did not differ significantly between MPAs and non-protected areas, specimens in MPAs were perceived to be healthier (81%) than those in non-protected areas (65.9%) (Chi-square test, $p = 0.004$).

Corallium rubrum was reported as "abundant" or "very abundant" in 7% of observations within MPAs, compared to 3% in non-protected areas. The ordinal regression indicated that the odds of *C. rubrum* being perceived as abundant were 2.12 times higher in MPAs than in non-protected areas (95% CI: 1.49–3.01). The linear mixed-effects model confirmed the significant positive association of MPA status with *C. rubrum* abundance (estimate = 0.27, $p < 0.001$). The variance attributed to individual ID and province was modest, and dive experience did not significantly influence its perceived abundance. In MPAs, *C. rubrum* was most commonly observed on rocky bottoms (63.6%), followed by vertical walls (25%) and reef-like formations (11.4%). In non-protected areas, the species was distributed on rocky bottoms (48.2%), vertical walls (31.6%), and reef-like formations (20.2%). These differences in distribution were statistically significant (Chi-square test, $p = 0.039$). No significant differences were found in the perceived health status of *C. rubrum* between the two area types.

3.2.3. Invasive Algae

This study examined two invasive algae taxa: *Caulerpa* spp. and *Lophocladia lallemandii*. No significant differences were found in the perceived abundance or distribution of these species between MPAs and non-protected areas. The linear mixed-effects models for both *Caulerpa cylindracea* and *Lophocladia lallemandii* revealed no significant association between MPA status and the perceived abundance of these invasive species (*C. cylindracea* estimate = −0.048, p = 0.425; *L. lallemandii* estimate = 0.055, p = 0.447). This suggests that protection status did not substantially influence the presence of these species. However, both models highlighted a significant association with dive experience. Divers with over 200 logged dives reported significantly higher occurrences for both *C. cylindracea* (estimate = 0.56, $p < 0.01$) and *L. lallemandii* (estimate = 0.625, $p < 0.01$), indicating that more experienced divers are more adept at detecting these species. The random effects analysis for both models showed variability among individual divers and provinces, but the contribution of these effects was minimal overall. *Caulerpa* spp. was predominantly observed on rocky seabeds, accounting for approximately 55% of responses. In contrast, *L. lallemandii* was primarily reported within seagrass meadows, followed by occurrences on rocky substrates, over octocoral or algal assemblages, and, to a lesser extent, on sandy seabeds (about 19%). Additional details on their distribution are provided in Table 3.

Table 3. Distribution of invasive macroalgae species in MPAs and non-protected areas. Data are presented as absolute numbers, with frequencies shown in brackets.

	Sandy seabed	Rocky seabed	In relation with *Posidonia* or *Cymodocea*	In relation with corals and gorgonians
Caulerpa cylindracea				
MPAs	16 (11.9)	72 (53.7)	15 (11.2)	31 (23.1)
Non-protected areas	26 (16.4)	95 (59.7)	19 (11.9)	19 (11.9)
Lophocladia lallemandii				
MPAs	35 (19.7)	29 (16.3)	73 (40)	41 (23)
Non-protected areas	31 (15.9)	46 (23.6)	78 (41)	40 (20.5)

3.2.4. Herbivorous Fish and Sea Urchins

This study also focused on several representative species from different taxa, particularly the herbivorous fish *Sarpa salpa* and two sea urchin species, *Paracentrotus lividus* and *Arbacia lixula*. *S. salpa*, known for being highly recognizable and the most frequently encountered herbivorous fish, was analyzed based on perceived abundance. The presence of *P. lividus* and *A. lixula* was also assessed. *S. salpa* was globally the most commonly reported species both in MPAs and non-protected areas, as seen in Figure 3. It was perceived as common or very common in 87% of the observations in MPAs, compared to 67% in non-protected areas. The odds of abundant reports in MPAs were 2.32 (1.67–3.22) times higher than in non-protected areas.

Perceived abundance data on species of sea urchins are represented in Figure 3. *P. lividus* and *A. lixula* were the second and fifth most reported species in non-protected areas, and the third and eighth in MPAs, respectively.

The linear mixed-effects models for these species demonstrated a consistent pattern where MPA status was significantly associated with their perceived abundance. For *A. lixula*, MPA presence was linked to a higher perceived abundance (estimate = 0.242, $p < 0.01$). Similarly, *P. lividus* and *S. salpa* also showed significant associations with MPA status, with estimates of 0.437 ($p < 0.001$) and 0.619 ($p < 0.001$), respectively, indicating that these species are more commonly reported in MPAs compared to non-protected areas.

In terms of dive experience, no significant effects were consistently observed across the species, except for a marginal increase in perceived abundance for *P. lividus* in the 11–25 dive range (estimate = 0.787, p = 0.06). Variability among individual divers and provinces was observed but remained relatively minimal across all models, indicating that while there is some geographical and individual diver effect, the MPA status remains a robust predictor of perceived abundance for these species.

3.2.5. Non-Herbivore Species

Subjective and semi-quantitative species abundance perceptions on some top predators and other coastal non-exclusively herbivore species were assessed.

- Dusky grouper (*Epinephelus marginatus*)

The perceived abundance of the dusky grouper was also evaluated. It was reported as "abundant" or "very abundant" by 70% of respondents within MPAs, compared to only 11% in non-protected areas (Figure 3). The odds of *E. marginatus* being perceived as abundant were 17.68 times higher in MPAs than in non-protected areas (95% CI: 11.92–26.65).

- Mediterranean barracuda (*Sphyraena sphyraena*)

The Mediterranean barracuda was perceived as "common" or "very common" in 56% of observations within MPAs, compared to 18% in non-protected areas (Figure 3). According to the ordinal logistic regression model, the odds of barracuda being reported as common or very common were 6.40 times higher in MPAs than in non-protected areas (95% CI: 4.53–9.11).

- Bluefish (*Pomatomus saltatrix*)

The bluefish was described as common or very common in 31% of the observations in MPAs, versus 15% in non-protected areas (Figure 3), and the abundance OR in MPAs compared to non-protected areas was 3.41 (2.45–4.77).

- Ornate wrasse (*Thalassoma pavo*)

Abundant or very abundant reports on the ornate wrasse were noted by 68% of the respondents in MPAs versus 46% in non-protected areas (Figure 3). The odds of being abundant or very abundant in MPAs were 2.78 (2.03–3.84) times that of non-protected areas.

- Combers (*Serranus* spp).

Comber species *S. scriba* and *S. cabrilla* were also studied. Combers were perceived as common or very common in 85% and 62% of the observations in MPAs and non-protected areas, respectively (Figure 3). The perceived abundance OR in the ordinal regression analysis was 2.87 (2.05–4.04).

- Mediterranean rainbow wrasse (*Coris julis*)

The Mediterranean rainbow wrasse was reported as abundant or very abundant in 79% and 60% of the responses in MPAs and non-protected areas, respectively (Figure 3). The perceived abundance OR in the ordinal regression analysis was 2.40 (1.73–3.33).

The linear mixed-effects models for these non-herbivorous species demonstrated that the perceived abundance of all these species was higher in MPAs. For *E. marginatus* (estimate = 1.29, $p < 0.001$), *S. sphyraena* (estimate = 0.92, $p < 0.001$), and *P. saltatrix* (estimate = 0.55, $p < 0.001$), the MPA status was associated with higher reported abundances. Similarly, *T. pavo* (estimate = 0.64, $p < 0.001$), *Serranus* spp. (estimate = 0.59, $p < 0.001$), and *C. julis* (estimate = 0.52, $p < 0.001$) also showed significant positive associations with MPAs

Dive experience did not show consistent significant effects across the models, except for *C. julis*, where divers with over 200 logged dives reported significantly higher abundances (estimate = 1.13, $p < 0.001$). Variability among individual divers and provinces was present, with the individual diver effect being more pronounced, indicating that personal experience and location influenced perceived species abundances to some extent. However, MPA status remained, again, the strongest predictor of abundance for these species.

3.3. Attitudes Toward Conservation and Perceptions on Health Status and Threats of the Mediterranean

Survey participants were asked whether they believed that Mediterranean biodiversity is threatened by human activities. Overall, more than 84% of divers agreed, with 65.8% expressing total agreement (Figure 4). When responses were analyzed based on the participants' education level using ordinal logistic regression, significant differences emerged. Divers with only a primary education were 90.3% less likely to agree that Mediterranean biodiversity is threatened by human activities compared to those with higher educational levels (OR: 0.097; 95% CI: 0.017–0.50). No significant differences were observed concerning the divers' certification level or the number of dives completed.

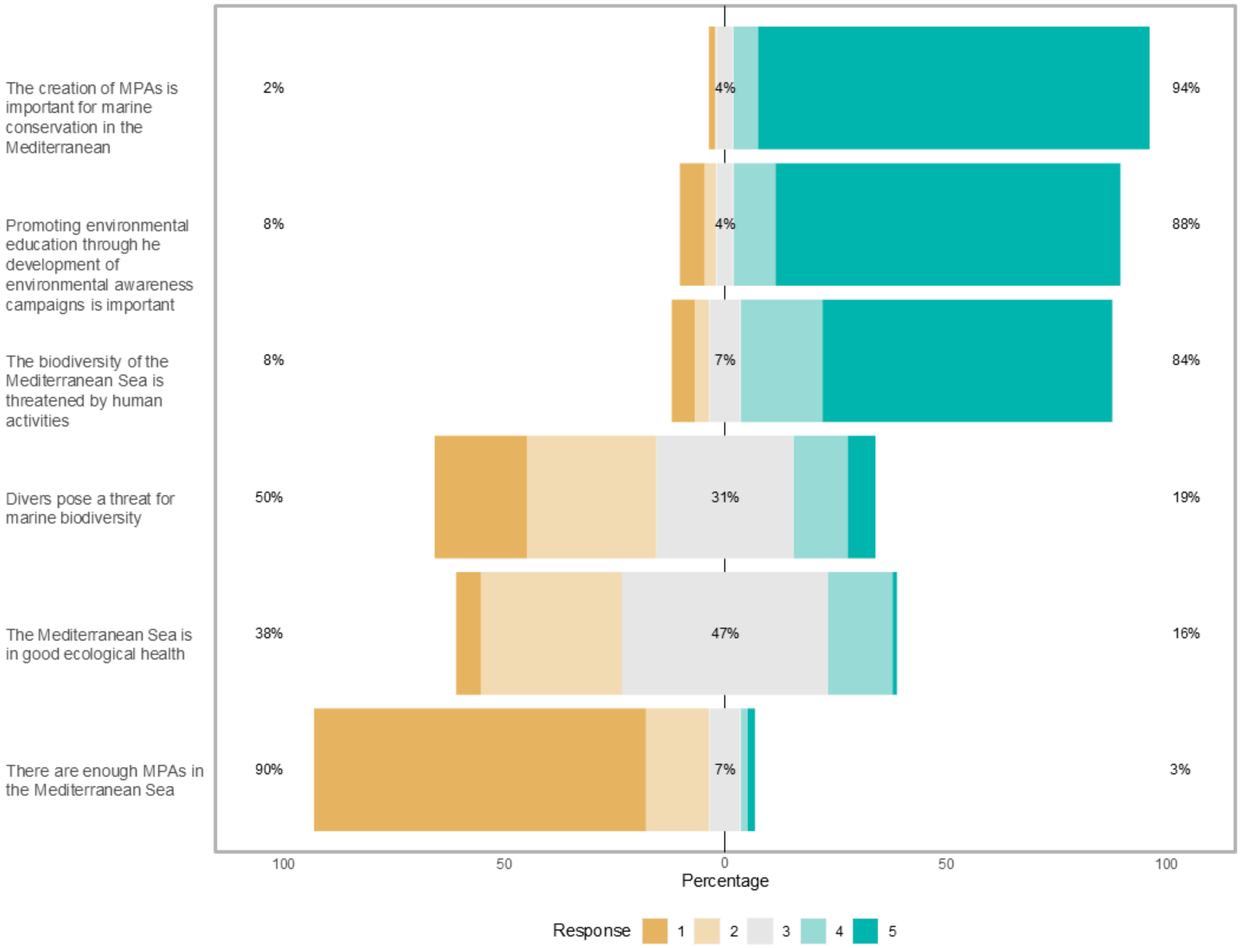

Figure 4. Divers' opinions on the ecological health of the Mediterranean Sea, the impact of MPAs, and the importance of educational campaigns for marine biodiversity conservation. Responses are rated on a 5-point scale, where 1 indicates "Strongly Disagree" and 5 indicates "Strongly Agree". Percentages represent the distribution of responses: levels 1–2 are shown on the left, level 3 in the center, and levels 4–5 on the right.

Participants were also asked whether they considered divers to be a threat to the ecosystem. Only 19% viewed themselves as a threat, while 31.05% neither agreed nor disagreed (Figure 4). Among those with primary education as their highest level of education, the likelihood of agreeing that divers pose a threat was 92.1% lower than among participants with higher educational levels (OR: 0.079; 95% CI: 0.004–0.586). No significant differences were found in responses based on dive experience or certification level.

Divers were additionally prompted to subjectively assess the health status of the Western Mediterranean Sea using a scale from 1 to 5, where 1 represented "totally sick" and 5 indicated "totally healthy". Over 37.5% of respondents perceived the Mediterranean Sea as being in some state of poor health, while 46.73% rated it as neither sick nor healthy (Figure 4). Among participants with secondary education, the odds of rating the health status as 4 or 5 were 3.76 times higher compared to divers with other educational levels (95% CI: 1.20–11.89). No significant differences were noted for other educational levels.

When asked about the primary threats to the Mediterranean Sea, 41.83% of respondents identified pollution as the main threat, followed by 37.58% who cited overfishing and overexploitation. Habitat degradation was mentioned by 12.09% of participants, while 7.19% identified climate change, and 1.31% pointed to invasive species as the major threat.

Additionally, perceptions regarding the necessity and significance of MPAs were evaluated. Nearly 89% of divers considered the creation of MPAs to be very important (Figure 4), with no significant differences observed based on certification level, educational background, or diving experience. When asked about the sufficiency of MPAs in the Spanish Mediterranean, 89.57% of participants felt that there were far fewer MPAs than needed. Divers with fewer than 10 dives were more likely to believe that the current number of MPAs was sufficient or even excessive (OR: 3.96; 95% CI: 1.16–14.19).

Finally, divers' views on the importance of educational initiatives to promote sustainable diving practices and enhance marine conservation were assessed. Over 88% of respondents agreed that educational programs could support conservation efforts and foster sustainable diving practices, as well as greater respect for the marine ecosystem. No significant differences were found in these perceptions based on certification level, education, or diving experience.

4. Discussion

This study explores the integration of divers' LEK along the Spanish Mediterranean coast in assessing the perceived abundance of several sentinel species in both MPAs and non-protected areas with scientific assessments. It also highlights the influence of general education in shaping divers' perceptions of marine conservation, demonstrating their awareness of threats to Mediterranean biodiversity and their support for protected areas. Additionally, it identifies knowledge gaps, particularly concerning the impacts of climate change, which could be addressed through targeted educational initiatives to strengthen conservation strategies.

Citizen science and LEK programs have increasingly proven effective for collecting ecological data and involving stakeholders in conservation activities. Initiatives like REEF.org [23] or the Surfrider Foundation [24], among others, highlight how these efforts can yield valuable information on marine ecosystems while also promoting environmental responsibility among divers, surfers, and coastal communities. Building on these examples, our study demonstrates the potential of using divers as a key stakeholder group for marine biodiversity monitoring along the Spanish Mediterranean coast.

Firstly, our findings indicate that divers perceive *P. oceanica* meadows as more abundant and healthier within MPAs compared to non-protected areas, as shown by the mixed-effects model, which confirmed a statistically significant association between MPA status and perceived abundance. This perception is consistent across different provinces, suggesting the effectiveness of MPAs in maintaining healthier seagrass habitats. These perceptions align with empirical studies that have identified MPAs as effective in protecting seagrass meadows from both natural and anthropogenic stressors [25,26]. Previous long-term monitoring programs have consistently used *P. oceanica* as a biomarker for assessing the ecological status of the Mediterranean, revealing similar trends in meadow regression due to human disturbances [27,28]. Furthermore, our study observed that *P. oceanica* meadows in MPAs are perceived to experience less anthropogenic pressure, such as pollution and mechanical damage, than those in non-protected areas, echoing findings from empirical studies that show lower human-induced disturbances within well-managed MPAs [29,30].

Similarly, the perceived higher abundance of octocoral species (*E. singularis*, *E. cavolini*, *P. clavate*, and *C. rubrum*) within MPAs aligns with empirical evidence supporting the effectiveness of MPAs in conserving slow-growing, structurally complex species [31,32]. These keystone species of Mediterranean coralligenous assemblages are highly vulnerable to overfishing, habitat destruction, and climate change [33–36]. Diver observations of healthier populations in MPAs suggest that these areas can enhance resilience and recovery [37]. However, their effectiveness is often limited by the small extent of strictly protected zones and the allowance of artisanal fishing and recreational diving within many of them. These ongoing activities continue to pose significant challenges to the full protection of these critical habitats [38,39]. Additionally, divers may not fully recognize the impact of their presence on benthic diversity, despite evidence of disturbances associated with diving activities, as reported in this study.

For invasive macroalgae, the models revealed no significant difference in perceived abundance between MPAs and non-protected areas, though dive experience was a significant factor, with experienced divers reporting these species more frequently. This suggests that while MPAs may not entirely prevent the spread of these invasive species, diver experience plays a crucial role in their detection. This discrepancy may indicate that while MPAs provide some level of protection, they are not immune to the spread of invasive species, a finding that is in line with empirical studies suggesting that invasive macroalgae can thrive across various substrates and conditions, even within protected areas [40–42]. The observed adaptability and plasticity of *C. cylindracea* and *L. lallemandii*, particularly their association with *Posidonia* and *Cymodocea* meadows, suggests that MPAs might provide a complex habitat structure that inadvertently facilitates the proliferation of certain invasive species. However, it is also important to recognize that diverse and abundant ecosystems generally contribute to greater resilience against such invasions, as they provide stability and buffer ecosystems from extensive impacts [43].

Furthermore, these findings identified significant differences in the perceived abundance of both herbivorous and non-herbivorous species between MPAs and non-protected areas. The mixed-effects models highlighted that large predators, such as the dusky grouper (*E. marginatus*), Mediterranean barracuda (*Sphyraena sphyraena*), and bluefish (*Pomatomus saltatrix*), were significantly perceived as more abundant in MPAs, highlighting the positive effect of these protected areas on apex predators and higher trophic levels [44,45]. This increase aligns with meta-analyses and large-scale surveys showing higher biomass and density of predatory fish in MPAs compared to fished areas [46,47]. For example, in the large region-wide survey carried out by Guidetti and colleagues (2014), high trophic levels showed higher density and biomass in MPAs when compared with fishing areas and, as in our case, *E. marginatus* determined the response to protection at the Medes Islands, Portofino, Tavolara, and Formentera [44]. This trend reflects the effectiveness of MPAs in reducing fishing pressure and aiding the recovery of overfished species. In contrast, herbivores such as *S. salpa* and sea urchin species, though more abundant in MPAs, showed smaller differences in perceived abundance compared to non-protected areas, suggesting a more complex interplay between protection, species behavior, commercial interest in EU markets, and ecological roles that may vary with local conditions and enforcement levels within MPAs.

This work provides valuable insights into divers' attitudes toward marine conservation and their perceptions of the health and threats facing the Mediterranean Sea. The findings indicate that divers are generally aware of the significant threats to marine biodiversity, with over 84% agreeing that human activities pose a major risk, aligning with scientific evidence on issues such as habitat loss, overfishing, and pollution [4]. However, divers tend to underestimate the impact of climate change while overestimating the effects of pollution, highlighting an improvable knowledge gap. This discrepancy highlights the need for targeted educational initiatives to enhance awareness of the multifaceted nature of environmental threats, particularly the long-term effects of climate change on marine ecosystems.

In this study, education emerged as a key factor influencing divers' perceptions, with those having higher education levels more likely to recognize threats and support conservation measures. This aligns with previous research showing that education enhances environmental awareness and concern [48,49]. Nearly 89% of divers supported the creation of more MPAs, reflecting widespread recognition of their benefits for marine biodiversity, consistent with studies demonstrating their effectiveness in increasing species richness and resilience [7,44]. Despite this awareness, only a small percentage of divers viewed themselves as a threat to marine ecosystems, suggesting a need for increased education on sustainable diving practices. Additionally, many divers perceived the Mediterranean Sea as neither fully healthy nor entirely degraded, which contrasts with scientific assessments indicating significant degradation in non-protected areas. The clear association between education and conservation concern suggests that educational programs could play a key role in fostering greater environmental stewardship among divers, particularly those with lower levels of formal education. Enhancing understanding of these issues through better communication of scientific data could help align divers' perceptions with conservation realities.

However, several important limitations must be acknowledged. Firstly, although this is a pilot study with around 400 divers, I acknowledge the limitations posed by this sample size, particularly regarding the generalizability of the findings to a broader population. Future studies should aim for larger sample sizes to improve statistical power and ensure more robust conclusions. Moreover, the data were based on self-reported perceptions, which may introduce biases related to individual knowledge, memory bias, experience, and subjective interpretation. Despite efforts to standardize responses through a first aptitude test, training and visual aids, the misidentification of species remains a source of error. Indeed, some species were not finally included in the data collection and the analysis due to more than 20% misidentification risk. Additionally, the study's reliance on an online survey may have limited participation to those with access to digital platforms. The regional focus on the Spanish Mediterranean coast also restricts the generalizability of the findings to other parts of the Mediterranean, which may have different ecological and socio-economic contexts. In this regard, the information is also limited to specific dive sites with specific features used by divers as well as heterogeneous coverage of the geography, with a more important burden of results for larger number of observations due to popularity or population. One limitation of this study is the assumption of habitat homogeneity across MPAs and non-protected areas. Given the large scale and number of sites surveyed with a general exploratory approach, homogeneous distributions of habitats such as seagrass meadows, rocky bottoms, and reef-like formations had to be statistically assumed. While many MPAs do contain these habitats, this generalization may overlook site-specific differences. Future studies should incorporate detailed habitat mapping to better account for this variability and improve accuracy, for example in assessing octocoral abundance. Moreover, while LEK could offer valuable insights, it is inherently less precise than systematic scientific data. Future studies should aim to integrate LEK with empirical scientific data more robustly and consider expanding the geographical scope and participant diversity to enhance the comprehensiveness and applicability of the findings.

Given the positive response from participants and the generally high levels of experience and engagement observed, there is an opportunity to implement an ongoing survey program. The demographic profile of our participants, many of whom have been diving for over a decade, suggests that they have long-term exposure to ecological changes in the region. By inviting divers to complete questionnaires on an annual or biannual basis, we could expand our analysis to include temporal comparisons, offering a more comprehensive understanding of changes in species abundance and habitat health over time. In this regard, the recent increasing frequency and intensity of marine heatwaves (MHWs) and mass mortality events (MMEs) in the Mediterranean [3] and even in the last 4 years since the data collection, underline the urgency of such ongoing monitoring. These events have affected thousands of kilometers of coastline and multiple marine habitats, posing significant threats to ecosystem health and functioning. By engaging experienced divers in a long-term survey program, we could track these impacts more precisely and assess whether perceptions align with observed ecological changes. This would also allow us to identify any shifts in species abundance or habitat conditions, contributing critical data that align with empirical observations of climate change impacts in the Mediterranean.

5. Conclusions

Overall, this study highlights the critical role of divers as stakeholders in marine conservation. Their support for MPAs and educational initiatives presents an opportunity for conservation managers to engage divers in more active stewardship roles. Addressing the gaps in understanding regarding the full spectrum of threats and the potential impacts of recreational activities is essential for aligning divers' perceptions with scientific knowledge and enhancing the effectiveness of conservation strategies in the Mediterranean.

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