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Contribution of Marine Protected Areas (MPAs) towards ecosystem services and fisheries: An experts' perspective from Mediterranean MPAs

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ABSTRACT

The Ecosystem Service framework is essential for understanding the role of Marine Protected Areas (MPAs) in delivering conservation benefits and societal goods such as fisheries. A perception analysis was conducted to capture the views of 33 experts on MPA-associated ecosystem services. Moreover, using *The MPA Guide*, we applied a scenario-based approach to assess the potential impact of different degrees of protection (i.e., fully, highly, lightly, and minimally protected levels) on fisheries-related ecosystem services. An expert-based evaluation explored the influence of these protection levels on fisheries-related ecosystem services across two prospective timeframes, set at 3- and 7-years post-implementation. Findings indicate a broad consensus on the perceived importance of cultural services attributed to MPAs. Provisioning MPA-associated ecosystem services are moderate, and their relevance varies by experiential and disciplinary backgrounds of experts. Fully and highly protected levels were perceived as the most effective in enhancing fisheries-related ecosystem services, particularly through increased fish abundance, individual size, and biomass. While provisioning fisheries-related ecosystem services were clearly perceived as increasing over time, especially under higher protection levels, the trends for regulation/maintenance and cultural fisheries-related ecosystem services were more subtle. This study highlights the need for adaptive protection strategies that account for temporal scales, reinforcing the role of long-term monitoring frameworks that capture both socioeconomic and social-ecological outcomes. Moreover, by introducing a qualitative cost-effective expert judgment, this methodology can be implemented in data-poor contexts such as the Mediterranean region. The findings provide valuable insights for policymakers and MPA planners striving to implement the EU 2030 Biodiversity Strategy in the Mediterranean Sea in terms of design, zoning, and governance of strictly protected MPAs that are both ecologically effective and socially acceptable.

1. Introduction

In 2021, 37.7 % of global fish stocks were classified as overfished (FAO, 2024), highlighting a critical challenge in fisheries management. This overexploitation disrupts both ecological ecosystem services and the economic benefits they sustain, undermining the socioeconomic gains that fisheries provide (Costello and Scott Baker, 2011; Lauck et al., 2020; McCauley et al., 2015). To avert negative effects on ecosystem services, changes in fisheries management practices and policies are needed (Frid et al., 2023; Caldwell et al., 2024; Costello, 2024). In light of this, Marine Protected Areas (MPAs) have been widely used as tools for sustainable utilization of marine resources through fisheries management (Edgar et al., 2014; García-Charton et al., 2008; Green et al., 2014; Krueck et al., 2017; Lynham and Villaseñor-Derbez, 2024).

MPAs are globally defined by the International Union for Conservation of Nature (IUCN) as, "*A clearly defined geographical space, recognized, dedicated, and managed through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values*" (Dudley, 2008). However, the protection levels within MPAs vary widely, from areas of partial protection to areas of full

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protection (Giakoumi et al., 2017; Horta e Costa et al., 2016). Fully protected marine areas often provide significant conservation benefits (Grorud-Colvert et al., 2021), which in turn support key socioeconomic benefits, such as fisheries (Driedger et al., 2023; Kerwath et al., 2013; Russ and Alcala, 2011; Sala and Giakoumi, 2018). In contrast, the effectiveness of partially protected marine areas in delivering similar benefits remains a topic of debate (Halpern et al., 2009; Lester and Halpern, 2008; Pascoe et al., 2025; Phillips et al., 2025; Sciberras et al., 2015).

Insufficient protection of marine biodiversity and critical habitats continues to undermine ecosystems' ability to sustain essential services and the livelihoods of fisheries-dependent communities (Costanza et al., 1997; Costello, 2024). This underscores the intrinsic link between societal benefits derived from ecosystem services and the ecological functions underpinning them (Turnbull et al., 2021). In 2010, the Convention on Biological Diversity (CBD) adopted Aichi Target 11, aiming to protect 10 % of the world's oceans by 2020. However, this goal was not achieved. In response, the Kunming-Montreal Global Biodiversity Framework (KM-GBF), adopted in 2021, set a more ambitious target: protecting 30 % of the world's oceans by 2030 (Target 3) (CBD, 2022).

At a continental level, the European Union (EU) and its Member States have aligned their conservation efforts with the KM-GBF. The EU Biodiversity Strategy (BDS) for 2030 commits to protecting 30 % of EU marine areas, including 10 % designated as strictly protected marine areas (EC, 2020). According to the definition of the EU BDS 2030, "*the strict protection does not necessarily mean the area is not accessible to humans, but leaves natural processes essentially undisturbed to respect the areas' ecological requirements*". While these targets encompass the entire EU, their implementation requires region-specific strategies tailored to the ecological, social, and economic contexts of biogeographical regions, sea basins, and localized areas (EC, 2020). The Mediterranean basin, recognized as a biodiversity hotspot (Myers et al., 2000), exemplifies this complexity. Despite its ecological significance and the intense human activity it supports, only 0.04 % of the Mediterranean Sea's surface area was under strict protection by 2020 (MedPAN and UNEP/MAP-SPA/RAC, 2023).

In the Mediterranean Sea, while the fisheries-related ecosystem services provided by fully protected marine areas, such as increased fish abundance, diversity, and biomass (Bayle-Sempere et al., 2024; Goñi et al., 2010; Lester et al., 2009), are well-documented, the capacity of partially protected marine areas to deliver comparable outcomes remains uncertain (Di Franco et al., 2009; Giakoumi et al., 2017; Guidetti et al., 2014; Zupan et al., 2018a). Moreover, conflicts over establishing fully protected marine areas are common, particularly among fishers who view such measures as threats to their livelihoods due to restricted access to fishing grounds (Boubekri and Djebar, 2016; Di Lorenzo et al., 2016). These tensions highlight the need for a more nuanced approach to marine conservation that accounts for diverse stakeholder perspectives (Cánovas-Molina and García-Frapolli, 2020). The ecosystem service concept, which links ecological functions to tangible socioeconomic benefits, provides a valuable framework for addressing these challenges. By demonstrating how MPAs contribute to local fisheries and other societal benefits, the ecosystem service concept has the potential to align conservation goals with the interests of fishing communities. Achieving this alignment requires collaboration among stakeholders such as fishers, scientists, MPA managers, and policymakers, and the adoption of diverse methods, including expert judgment, to effectively communicate the value of ecosystem services in enhancing human well-being and supporting sustainable fisheries management (Culhane et al., 2020).

A qualitative MPA assessment framework (i.e., *The MPA Guide*) was recently published and categorized MPAs by stage of establishment and level of protection (Grorud-Colvert et al., 2021). Use of this *MPA Guide* by experts can improve effective design, implementation, assessment, and tracking of existing and future MPAs to achieve conservation goals by using scientifically grounded practices (Grorud-Colvert et al., 2021). To date, a regional understanding is still lacking regarding expert perceptions of the ecosystem services provided by MPAs and their expected contribution to local fisheries, particularly across different protection levels.

Accordingly, this study examines how varying protection levels influence the provision of various ecosystem services in Mediterranean MPAs. While the analysis is primarily exploratory, it is guided by the general hypothesis that higher protection levels are perceived to enhance ecosystem service provision, particularly those related to fisheries. The study further aims to identify potential differences in expert perceptions across short- and medium-term timeframes, providing a preliminary basis for future hypothesis-driven analyses. Specifically, based on expert-derived scores, we: (1) quantify the perceived extent to which MPAs can deliver key individual ecosystem services, and assess how these perceptions vary both among services and across the three main ecosystem service categories (i.e., provisioning, regulation/maintenance, and cultural); (2) examine the factors influencing experts' assessments of the relevance of each ecosystem service to MPAs; and (3) assess how different protection levels (i.e., full, high, light, and minimal) are perceived to support fisheries-related ecosystem services over two post-implementation timeframes (after 3 and after 7 years of the implementation of the specific protection level). By synthesizing expert-based assessments within a scenario framework, this study provides a qualitative perspective that complements existing quantitative approaches. It contributes to bridging the gap between scientific knowledge and policy implementation, particularly in data-poor contexts, by informing the optimization of MPA design and adaptive fisheries management in the Mediterranean Sea.

2. Material and methods

2.1. Study area

This research was conducted in the framework of the Horizon Europe project "EFFECTIVE" (Enhancing social well-being and economic prosperity by reinforcing the EFFECTIVEness of protection and restoration management in Mediterranean MPAs; https://effective-euproject.eu/). EFFECTIVE's work is focused on four pilot sites (Fig. 1). Although the perception analysis results are discussed in the context of four selected MPAs (Fig. 1), the expert perception evaluation was conducted with experts from across the Mediterranean basin.

In the Medes Islands MPA, the economic relevance of fisheries is significantly lower than that of non-extractive activities such as scuba diving (Merino et al., 2009). According to the bioeconomic model developed by Merino et al. (2009), scuba diving generated 43 % of the MPA's revenue, while fisheries contributed only 6 %. Notably, the no-take zone (NTZ) in this MPA accounts for only 9 % of its total area (Martín et al., 2012) and corresponds to a highly protected level according to *The MPA Guide*, while the remaining 91 % are lightly protected (Table 1).

In the Delta del Ebro MPA, human activity, particularly rice farming, has significantly altered the deltaic environment (Ibáñez and Prat, 2003; Peris et al., 2022). Over half of the area is occupied by rice fields, which benefit from the various ecosystem services provided by surrounding wetlands, lagoons, and coastal ecosystems (Matamoros et al., 2020). However, this activity, together with other intensive human activities (e.g., aquaculture, fishing, tourism, etc.), has led to environmental degradation, contributing to the decline of critical habitats such as *Cymodocea nodosa* seagrass beds, which support endangered Mediterranean species like the fan mussel, *Pinna nobilis* (UNEP/MAP-SPA/RAC, 2018). Overall, this MPA is classified as minimally protected under *The MPA Guide* framework (Table 1).

The Tavolara-Punta Coda Cavallo MPA encompasses zones of differing protection levels (Di Franco et al., 2009). Approximately 3.5 % of its area is fully protected, while the remaining 96.5 % are highly protected according to *The MPA Guide*. It contains ecologically valuable

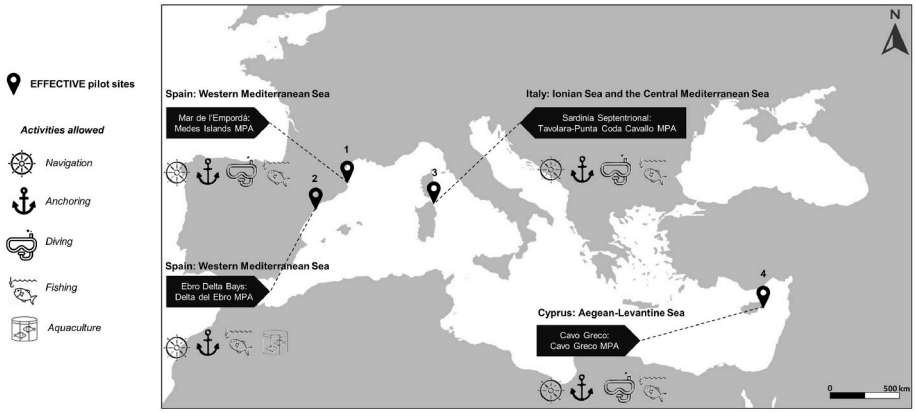

Fig. 1. Location of the four pilot sites within the EFFECTIVE project.

Table 1
List of the four MPA case studies. MAPAMED ID is the identification number for the MPA in the Mediterranean database of Marine Protected Areas (2019 edition, version 2. © 2022 by SPA/RAC and MedPAN. Licensed under CC BY-NC-SA 4.0.), and EEZ stands for Exclusive Economic Zone. MSFD: Marine Strategy Framework Directive, N/A: Not Assigned. Data sources: J.W. Day et al. (2019), Di Franco et al. (2009), Martín et al. (2012), and Moutopoulos et al. (2021).

Name	MAPAMED ID	EU MSFD region	EEZ	Integral reserve (%)	Established date	Level of protection[a]
Medes Islands MPA	1106	Western Mediterranean Sea	Spain	~9 % No-take area for fishing only	2001	~9 % highly protected ~91 % lightly protected
Delta del Ebro MPA	1541	Western Mediterranean Sea	Spain	N/A	1992	Minimally protected
Tavolara-Punta Coda Cavallo MPA	905	Ionian Sea and the Central Mediterranean Sea	Italy	~3.5 % No-take area	1997	~3.5 % fully protected ~96.5 % highly protected
Cavo Greco MPA	1518	Aegean-Levantine Sea	Cyprus	~21 % No-take area	2018	~21 % fully protected ~79 % lightly protected

[a] This was determined based on the maximum allowable impact of seven human activities commonly occurring within MPAs or specific MPA zones (see Grorud-Colvert et al., 2021 for details on how to determine the level of protection using *The MPA Guide* framework).

habitats such as coralligenous reefs and *Posidonia oceanica* meadows, contributing to making this MPA of high conservation value (Canessa et al., 2021). At a regional scale (e.g., Mediterranean Sea), expanding the fully protected coverage of high-quality habitats like these could help meet the 10 % strict protection target within the broader 30x30 conservation goal, while generating productive marine ecosystem services in a resilient and well-connected Mediterranean MPA network (Abdulla et al., 2009; MedPAN and UNEP/MAP-SPA/RAC, 2023).

Finally, the Cavo Greco MPA was established in 2018 as a multiple-use MPA designed to meet diverse objectives including biodiversity conservation and fisheries management (Moutopoulos et al., 2021). According to Table 1, Cavo Greco comprises a fully protected no-take zone (21 % of the area) while the remaining 79 % are classified as lightly protected under *The MPA Guide* framework.

2.2. Selection of ecosystem services

For the selection of ecosystem services, we used the Common International Classification of Ecosystem Services (CICES V5.2, Haines-Young, 2023) as a basis. CICES represents the most common reference framework, particularly in a European context, for the classification of ecosystem services (EC, 2011; La Notte et al., 2017). In this study, we utilized two CICES classification levels to organize and classify ecosystem services delivered by MPAs. At the broadest level, "Section", ecosystem services are grouped into three categories: Provisioning, Regulation/Maintenance, and Cultural. These were further refined at the more granular "Class" level, where we harmonized ecosystem service classes to account for site-specific ecological and socioeconomic contexts, and selected the final set of ecosystem services accordingly.

Even if CICES was first developed for terrestrial environments, it has recently been adapted for the marine environment. Based on the work of Culhane et al. (2019), a set of 48 classes of ecosystem services were considered as relevant to the marine environment and referenced to CICES (Fig. 2). We thus screened through all the 48 classes to identify, *a priori*, those likely associated with MPAs, following the "Cascade" model (De Groot et al., 2010; Haines-Young and Potschin, 2010). Thus, a clear difference was established between the ecosystem services generated by ecosystem functions, which in turn are underpinned by biophysical structures and processes, and the benefits, economic or non-economic, material or non-material, that humans can obtain from the use of a good or service (De Groot et al., 2010). Accordingly, we first excluded 8 classes that, although directly linked to benefits arising in marine and coastal areas, represent final benefits rather than ecosystem services *per se*. Next, we screened the 40 remaining classes of ecosystem services and identified 28 relevant ones, 11 for provisioning, 11 for regulation and maintenance, and 6 for cultural services, based on their association with MPAs. These classes were then harmonized to derive a set of MPA-associated ecosystem services (Supplementary Material; Table S1). Similarly, we identified among the 28 MPA-associated ecosystem services those that could potentially, even indirectly, relate to fisheries. This second screening resulted in a final selection of 15 fisheries-related ecosystem services (Table 2).

2.3. Questionnaire design and assessment approach

To address the aims of this study, we prepared an online questionnaire (Supplementary Material; Questionnaire) that was distributed to Mediterranean marine conservation experts including scientists, MPA

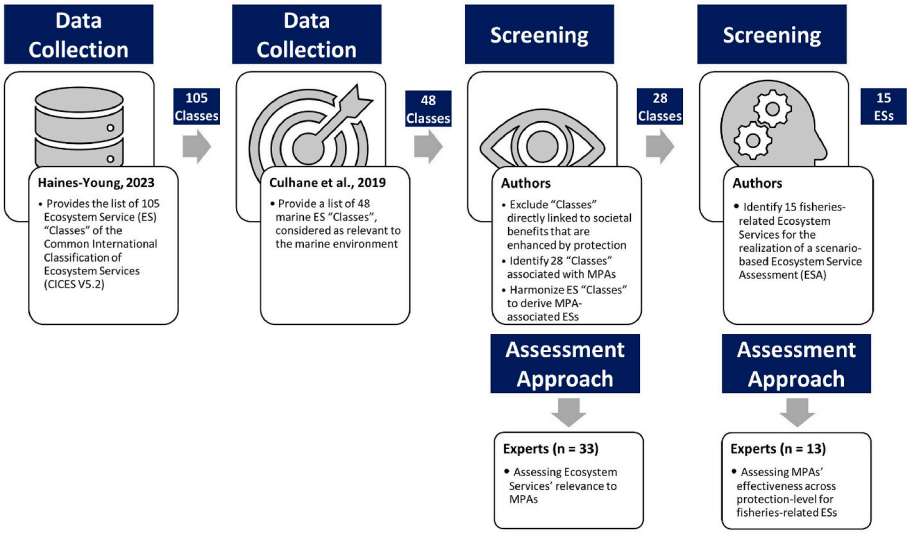

Fig. 2. Overview of the methodology for identifying Ecosystem Services (ESs) associated with MPAs and fisheries.

managers, policymakers, civil society representatives, and other groups in the whole Mediterranean region via personal contacts, EFFECTIVE project's consortium, snowball effects on social media, as well as through newsletters of the Mediterranean network of MPA managers (MedPAN), the MPA Help Community, and the IUCN-Med.

The questionnaire was administered online via *SoSci Survey platform* in the spring of 2025 and remained open for three months. To facilitate participation across different Mediterranean subregions, it was made available in five languages: Arabic, English, French, Italian, and Spanish. Respondents were provided with detailed information about the study and the classification methodology of the four levels of protection in *The MPA Guide* framework at the outset, and informed consent was obtained. Participation was voluntary, with assurances of confidentiality and compliance with the EU General Data Protection Regulation (GDPR; Regulation (EU) 2016/679). Full details of the consent procedure and data protection statement were provided on the first page of the questionnaire (see Supplementary Material; Questionnaire).

The questionnaire comprised three main sections. First, it collected basic socio-demographic information about the experts (Section 1). Second, it assessed experts' perceptions of the relevance of the 28 ecosystem services (Table S1) to MPAs (Section 2). Third, it examined perceived potential impacts of different protection level scenarios on fisheries-related ecosystem services (Table 2) (Section 3).

The questionnaire employed structured Likert-type questions. A 5-point Likert scale (ranging from "none" to "very high") was used to assess the relevance of each ecosystem services in Table S1 to MPAs. A 9-point Likert scale (from "very high decrease" to "very high increase") was used to evaluate the expected change in fisheries-related ecosystem services (Table 2) under four protection level scenarios, across two prospective timeframes (+3 and + 7 years).

2.3.1. The protection level scenarios

Four hypothetical scenarios were considered to assess the potential impact of protection levels on fisheries-related ecosystem services. The scenario-based Ecosystem Service Assessment (ESA) method was developed following *The MPA Guide* framework (Grorud-Colvert et al., 2021), which distinguishes four levels of protection based on the extent of extractive or destructive activities allowed within MPAs. Specifically, MPAs were categorized as:

(i) Fully protected, where no extractive or destructive activities (e.g., fishing, mining) are allowed, and all abatable impacts are minimized;
(ii) Highly protected, where only low-impact extractive activities may occur (e.g., small-scale, selective, or low-intensity fishing), while other impacts are minimized;
(iii) Lightly protected, where moderate-impact extractive or destructive activities are allowed, offering partial biodiversity protection; and
(iv) Minimally protected, where extensive extraction or other high-impact activities are permitted, though the site still provides limited conservation benefits under IUCN criteria.

These categories were used to simulate contrasting management scenarios and evaluate how different protection levels could influence the delivery of fisheries-related ecosystem services under optimal management conditions (see Fig. 1 in *The MPA Guide* for further methodological details).

Given evidence suggesting that the effects of MPAs on local fisheries are also influenced by the duration of protection (Claudet et al., 2008; Russ et al., 2004; Vandeperre et al., 2011), each scenario evaluated two post-implementation timeframes: three and seven years after the implementation of the designated protection level.

Finally, and although a spatially explicit approach with zoning and variable protection levels within a single MPA would offer a more refined ESA, this was beyond the study's scope. To ensure consistency in expert assessments, MPAs were treated as homogeneous zones, assuming uniform application of the assigned protection level.

2.4. Data analysis

All data analyses were conducted using R version 4.5.0 (R Core Team, 2025). R packages used included *FSA* (for Dunn's post-hoc tests), *dplyr* and *tidyr* (for data manipulation), *likert* (for analysis of Likert-scale responses), and *ggplot2* (for visualization). Base R functions from the *stats* package were also used (e.g., kruskal.test(), friedman.test(), wilcox.test()).

Non-parametric tests were applied because the data did not meet the assumptions required for parametric statistics. To assess variation in expert perceptions of MPA-associated ecosystem services, we used a Kruskal–Wallis H test. To further examine pairwise differences between MPA-associated ecosystem services, we conducted post-hoc comparisons using Dunn's test with Bonferroni correction.

To assess differences in expert-assigned scores among the three-ecosystem service categories, we performed a Friedman test. When significant differences were found, pairwise post-hoc Wilcoxon signed-

Table 2
List of the selected 15 Ecosystem Services (ESs) with relevance to fisheries and MPAs and selected *a priori* from the list of classes associated with MPAs (see Table S1). References for each ES are not exhaustive but are representative of this evidence. Adapted from Grorud-Colvert et al. (2021) and Marcos et al. (2021).

No.	Section	Fisheries-related Ecosystem Service	Description	Class – associated with MPAs	CICES code	References
1	Provisioning	Increase fish abundance	In general, protection results in increases in abundance of organisms within the MPA and in fishing grounds around the MPA	MPAs used for nutritional purposes	1.1.6.1	Nowakowski et al. (2023); Goñi et al. (2008), 2011; Claudet et al. (2008); Giakoumi et al. (2017); Zupan et al. (2018b)
2	Provisioning	Increase individual size	The protection increases individual size and shifts the population structure towards bigger fish			Pérez-Ruzafa et al. (2018); Sala and Giakoumi (2018); Claudet et al. (2006); Ruttenberg et al. (2011); García-Rubies et al. (2013); Abesamis et al. (2014); Malcolm et al. (2015); Harasti et al. (2018)
3	Provisioning	Increase fish biomass	Protection generally results in increases in abundance and larger average body sizes, leading to an increase in fish biomass			Frid et al. (2023); Kaplan et al. (2019); Lester et al. (2009); Sala et al. (2012); Guidetti et al. (2014); Agnetta et al. (2019)
4	Provisioning	Enhance genetic diversity	MPAs promote genetic diversity and protect gene pools	MPAs used to extract genetic material from individual (plants, seaweed, and animals)	1.2.1.3 1.2.2.3	Pérez-Ruzafa et al. (2006); Miethe et al. (2010); Fidler et al. (2018); Jones et al. (2018); Sørdalen et al. (2018)
5	Regulation & Maintenance	Enhance the production of eggs and larvae	Bigger animals generally have a higher reproductive capacity and efficiency	MPAs aid in eggs and larvae dispersal	2.3.2.1	Planes et al. (2009); Christie et al. (2010); Goñi et al. (2010); Harrison et al. (2012); Di Franco et al. (2015)
6	Regulation & Maintenance	Connectivity of populations	In MPAs, the dispersal of eggs over long distances leads to better connectivity among distant areas and populations			Smith and Metaxas (2018); Pelc et al. (2010); Di Franco et al. (2012); Andrello et al. (2017); Roberts et al. (2017); Manel et al. (2019); Assis et al. (2021)
7	Regulation & Maintenance	Provide a nursery for fish and invertebrates	MPAs protect refuge areas (e.g., nursery grounds), essential for vulnerable life stages of species	MPAs aid in maintaining nursery populations and habitats	2.3.2.3 2.3.2.4 2.3.2.5	Liquete et al. (2016); Kersting and García-March 2017; Hinz et al. (2019); Félix-Hackradt et al., 2013, 2014; Del-Pilar-Ruso and Bayle-Sempere (2006); Colloca et al. (2015)
8	Regulation & Maintenance	Improve spawning habitats	MPAs maintain and recover key functioning habitats over different timescales (i.e., years to decades)			Bode et al. (2025); Williamson et al. (2014)
9	Regulation & Maintenance	Protect spawners	MPAs enhance the protection of spawning aggregations, including for highly migratory species			Nemeth (2005); Grüss et al. (2014); Erisman et al. (2017); Farmer et al. (2017); Sadovy de Mitcheson et al. (2020)
10	Regulation & Maintenance	Promote fish stocks recovery	MPAs protect a proportion of the population from exploitation			Lauck et al. (2020); Roberts et al. (2005); Krueck et al. (2017)
11	Regulation & Maintenance	Allow for the spillover of adults and juveniles	MPAs allow a net movement of targeted fish species to adjacent fishing grounds			Bayle-Sempere et al. (2024); Abesamis and Russ (2005); Halpern et al. (2009); Di Lorenzo et al. (2016), 2020
12	Cultural	Scientific knowledge/ research, monitoring, education and training	MPAs as an open-air laboratory for scientific research, monitoring, education, and training in the field of fisheries science	MPAs enable the advance of research, education, and knowledge on the natural world	3.2.1.1 3.2.1.2	Galzin et al. (2004)
13	Cultural	Maintain diversity of fish species	Protection results in an increase in biodiversity as populations recover and vulnerable, previously absent, species recolonize	MPAs have an existence value, we think they should be created to conserve the integrity of habitats and species	3.4.2.1	Mello et al. (2020); Lester and Halpern (2008); Russ and Alcala (2011); Nash and Graham (2016)
14	Cultural	Maintenance of traditional fishing techniques, fishing gears, and emblematic species and habitats	MPAs should exist for future generations	MPAs should exist for future generations to enjoy or use	3.4.2.2	González-Correa et al. (2007), 2015; Gómez et al. (2006); Forcada et al. (2010); Ban and Frid (2018); Mouillot et al. (2008); Pichegru et al. (2010); Gormley et al. (2012); Goetze et al. (2015); McLaren et al. (2015); Dwyer et al. (2020)
15	Cultural	Facilitate fishers' involvement	MPAs provide a foundation to increase fishers' awareness and compliance			Mascia et al. (2010); Arias et al. (2015); Rice et al. (2012); Weigel et al. (2014); Di Franco et al. (2016)

rank tests with Bonferroni correction were conducted to compare categories. Perceived relevance was measured using a 5-point Likert scale (none, low, moderate, high, and very high), which we recoded into numerical ranks (1, 2, 3, 4, and 5, respectively). Responses marked as "I don't know" and experts with missing responses were excluded from the Friedman test to ensure balanced repeated-measures data.

Moreover, we used a Mann-Whitney *U* test for post-hoc tests to assess whether there were significant differences in Likert scores as a function of different socio-demographic attributes of the experts, such as expert's experience ($\leq$5 vs. >5 years), region of work (EU vs. non-EU countries), and primary field of expertise (natural sciences vs. social sciences). This approach follows previous studies using fishers' local knowledge (e.g.,

Gianelli et al., 2021; Boubekri et al., 2022, 2023), demonstrating its suitability to analyze variation across groups.

For the fisheries-related ecosystem services perceived changes, we used a Kruskal-Wallis H test to test for main effects between the four scenarios in terms of increase and/or decrease in an ecosystem service, and a Mann-Whitney *U* test for post-hoc tests for differences between the two prospective timeframes. These tests helped us to identify the scenario of high increase and/or decrease per ecosystem service for each timeframe.

As the evaluation of expected changes in fisheries-related ecosystem services was based on a 9-point Likert scale (very high decrease, high decrease, moderate decrease, slight decrease, no change, slight increase, moderate increase, high increase, and very high increase), we recoded these ordinal responses into numerical ranks (1, 2, 3, 4, 5, 6, 7, 8, and 9, respectively). For all statistical analyses, the level of significance was $\alpha = 0.05$.

Given the exploratory nature of this study and the limited sample size, these non-parametric tests were primarily intended to identify general patterns and tendencies rather than to establish causal relationships. We acknowledge that conducting multiple pairwise comparisons may increase the likelihood of Type I errors (false positives); however, our use of Bonferroni correction and our interpretation of the results as indicative rather than confirmatory mitigate this concern. Accordingly, the statistical outcomes are discussed as complementary evidence supporting broader perceptual trends rather than as formal hypothesis tests.

Finally, before administering the questionnaire to potential respondents, the latter was pre-tested with a sample of five colleagues, and modifications were made based on their feedback to enhance clarity and relevance of the questions.

3. Results

3.1. Dataset summary

Response rates varied across the three sections of the questionnaire, which addressed, respectively: (1) experts' socio-demographic information, (2) relevance of MPA-associated ecosystem services, and (3) perceived potential changes in fisheries-related ecosystem services under alternative protection-level scenarios. A total of 33 experts completed sections 1 and 2, while only 13 of them completed all three sections (Supplementary Material; Table S2 and Questionnaire). The limited engagement in section 3 (i.e., scenario-based assessment) may reflect insufficient contextual understanding required to meaningfully assess the impacts of hypothetical protection level scenarios. Notably, among the 33 respondents, 42 % self-reported limited or no knowledge of fisheries management (Table S2). Importantly, the same subsample of 13 experts evaluated both the "3-year" and "7-year" scenarios within section 3. The three questionnaire sections are thematic and do not correspond to separate groups of respondents or time points, which ensures that the temporal comparisons are based on consistent expert input.

The sample comprised 33 respondents, with ages ranging from 20–29 years–50 years or older, with almost half (45 %) aged 30–39 (see Table S2). The sample was evenly balanced by sex, with 48 % female and 52 % male respondents. Respondents' experience in working on MPAs was mostly between 2 and 20 years (i.e., 72 %), with an estimated mean of approximately 8 years based on the reported intervals (see Table S2). With regards of the primary field of expertise, 52 % of respondents associated it to marine conservation, 33 % to marine ecology, 27 % to marine biology, 6 % to social sciences, 15 % to geography, 18 % to economics, and 33 % to interdisciplinary sciences (these fields are not mutually exclusive, e.g., one respondent could list one or multiple fields of expertise). Out of all survey participants, 33 % have their work primarily based in EU member countries while, 67 % in non-EU countries (Table S2).

3.2. Expert perceptions of MPAs' contribution to ecosystem services

The expert-assessed relevance of ecosystem services to MPAs varied considerably across the three main ecosystem service categories, revealing distinct patterns of perceived importance. These differences are illustrated in Fig. 3, which shows the proportion of respondents assigning each level of relevance (i.e., from none to very high) to individual ecosystem services within each service category. Fig. 3a shows that among provisioning services, only one (i.e., MPAs used for nutritional purposes) was considered of high or very high relevance by over 50 % of respondents. Fig. 3b highlights a large variation in expert-assessed relevance among regulation and maintenance ecosystem services. Several ecosystem services of this category, including *controlling or preventing soil loss*, *protecting against flood*, *protecting coastal cliffs*, *eggs and larvae dispersal*, were rated high or very high by more than 60 % of respondents. Fig. 3c indicates that all six cultural ecosystem services were perceived as highly or very highly relevant by over 60 % of respondents.

3.3. Variation in expert perceptions of MPA-associated ecosystem services

A Kruskal–Wallis test revealed a statistically significant difference in expert scores across the 28 MPA-associated ecosystem services ($H = 190$, $df = 27$, $p < 0.0001$). Post-hoc pairwise comparisons using Dunn's test with Bonferroni correction identified the specific differences between services. Table S3 presents the top 10 most significant post-hoc pairwise comparisons based on the smallest adjusted p-values.

The Friedman test revealed a statistically significant difference in expert scores across the three-ecosystem service categories (Friedman chi-squared = 16.286, $df = 2$, $p = 0.00029$), indicating that at least one category was rated differently by experts.

The results of the Wilcoxon signed-rank post-hoc tests reveal statistically significant differences in expert scores between certain pairs of ecosystem service categories (Table S4). Specifically, expert scores for provisioning services were significantly different from those for regulation/maintenance and cultural services ($p < 0.01$). However, the comparison between the regulation/maintenance category and the cultural one was not statistically significant ($p = 0.0862$).

Comparisons of expert-assessed relevance of MPA-associated ecosystem services revealed several differences linked to socio-demographic characteristics. Specifically, both years of experience and primary field of expertise significantly influenced the relevance scores assigned to certain ecosystem services (Table S5). In contrast, the region of work had no significant effect on expert assessments.

3.4. Contribution of protection levels to fisheries-related ecosystem services

Statistically significant differences in perceived changes across the protection level scenarios were observed for 14 out of 15 fisheries-related ecosystem services in the short-term, and for all ecosystem services in the medium-term (Table 3). It should be noted that these results are based on a relatively small subsample of 13 experts who completed the scenario-based assessment, which may limit the representativeness of the findings. The Mann-Whitney *U* test also showed significant differences between the two prospective timeframes for three provisioning fisheries-related ecosystem services, whereas the perceived changes were not statistically significant for all cultural fishery-related ecosystem services (Table 3). Regulation and maintenance fisheries-related ecosystem services showed statistically significant differences between the two prospective timeframes for only three services out of seven.

3.4.1. Short-term variations in perceived changes in fisheries-related ecosystem services

Fig. 4 shows that expert-assessed relevance of each fisheries-related ecosystem service varied substantially across the four protection level

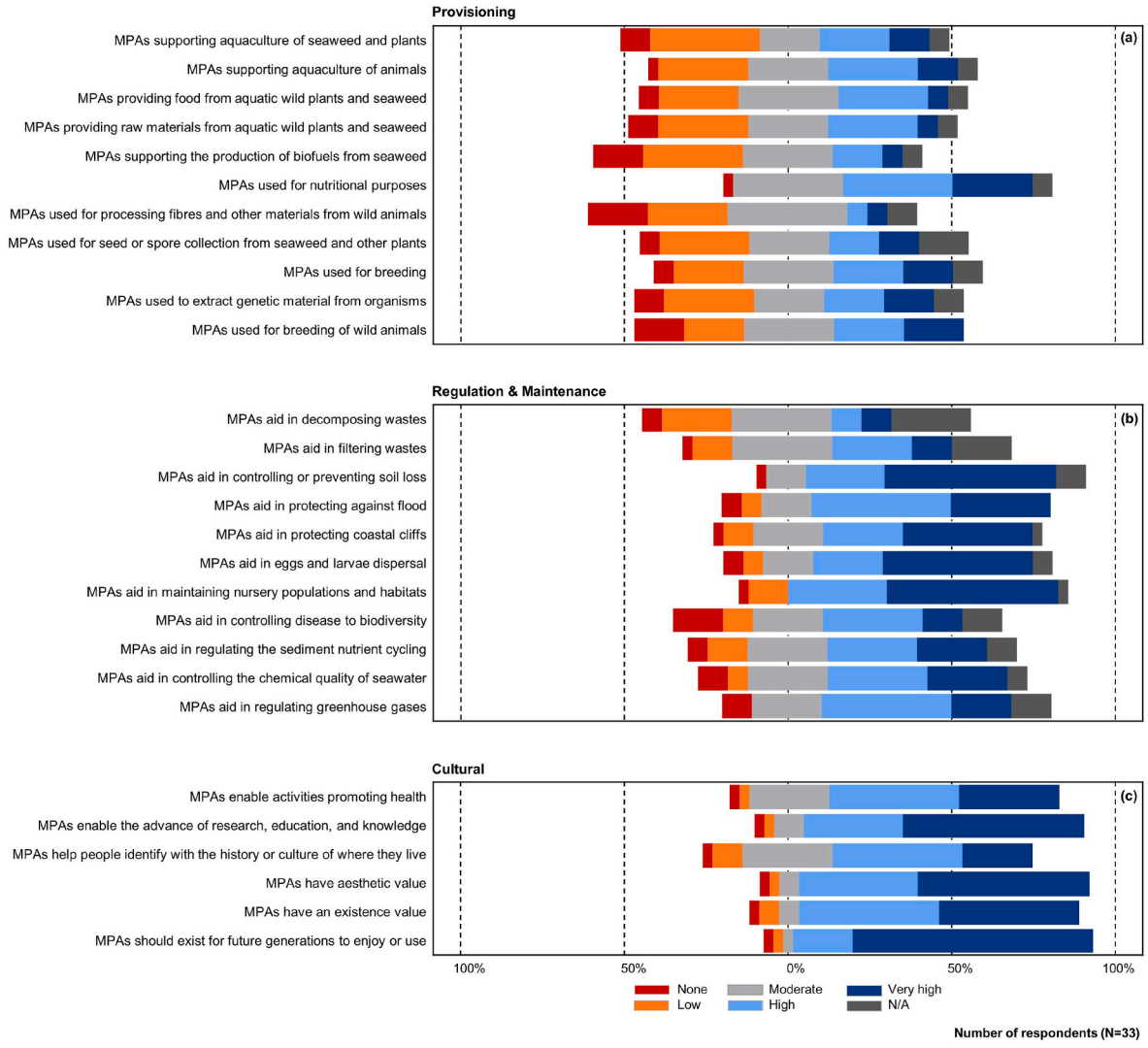

Fig. 3. The perceived relative importance of Ecosystem Services (ESs) to MPAs. N/A: Not Answered. (N = 33).

Table 3
Kruskal-Wallis H analysis of variance and post hoc Mann-Whitney U comparisons for fisheries-related ecosystem services perceived changes between the two prospective timeframes. +3: after 3 years of implementation; +7: after 7 years of implementation; ns: non-significant. (N = 13).

	Fisheries-related ecosystem services	Kruskal-Wallis for +3		Kruskal-Wallis for +7		Mann-Whitney for +3 vs. +7	
		H	*P*	H	*P*	U	*P*
Provisioning	Increase fish abundance	16.07	0.0011***	29.13	<0.0001***	914.0	0.0056**
	Increase individual size	20.12	0.0002***	28.64	<0.0001***	910.5	0.0081**
	Increase fish biomass	14.64	0.0022**	28.78	<0.0001***	910.0	0.0258*
	Enhance genetic diversity	9.299	0.0256*	21.15	<0.0001***	971.5	0.3053 (ns)
Regulation & Maintenance	Enhance the production of eggs and larvae	20.08	0.0002***	28.09	<0.0001***	1028	0.1197 (ns)
	Connectivity of populations	15.19	0.0017**	19.10	0.0003***	865.5	0.0926 (ns)
	Provide a nursery for fish and invertebrates	20.12	0.0002***	20.39	0.0001***	1042	0.1437 (ns)
	Improve spawning habitats	24.04	<0.0001***	29.78	<0.0001***	1001	0.0280*
	Protect spawners	18.95	0.0003***	23.54	<0.0001***	934.0	0.0760 (ns)
	Promote fish stocks recovery	15.74	0.0013**	27.06	<0.0001***	899.5	0.0096**
	Allow for the spillover of adults and juveniles	18.27	0.0004***	23.45	<0.0001***	861.0	0.0301*
Cultural	Scientific knowledge/research, monitoring, etc.	14.39	0.0024**	11.84	0.0080**	1160	0.1992 (ns)
	Maintain diversity of fish species	18.49	0.0003***	22.31	<0.0001***	1061	0.1849 (ns)
	Maintenance of traditional fishing techniques	8.140	0.0432*	17.08	0.0007***	1091	0.1549 (ns)
	Facilitate fishers' involvement	6.152	0.1044 (ns)	15.28	0.0016**	1092	0.2661 (ns)

scenarios after three years of implementation. The perceived potential contribution of protection level to fisheries-related ecosystem services was highest under the fully protected level scenario. More than 50 % of respondents reported a high to very high increase for one provisioning fisheries-related ecosystem service (i.e., increase fish abundance), for all regulation and maintenance fisheries-related ecosystem services except for *promoting fish stocks recovery*, and for all four cultural fisheries-related ecosystem services. Under the highly protected level scenario,

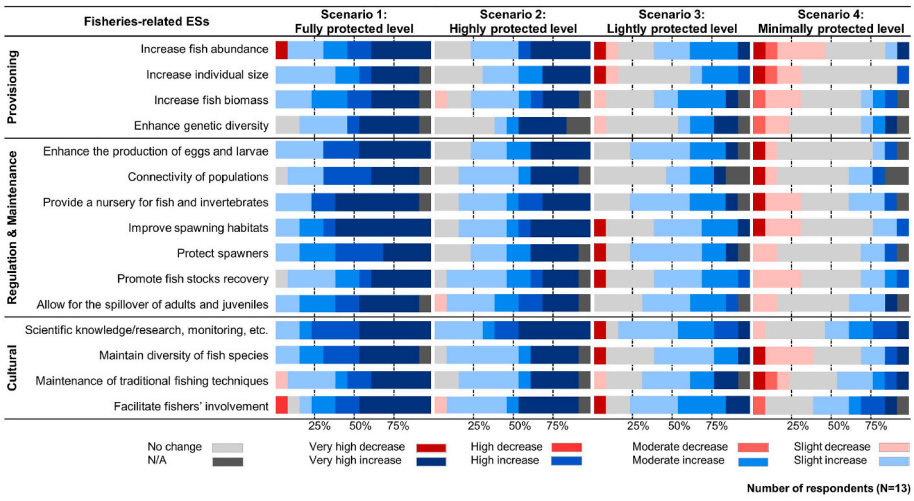

Fig. 4. Comparative fisheries-related ecosystem service assessment of four hypothetical protection level scenarios (cf. Grorud-Colvert et al., 2021) in the short-term (i.e., after 3 years of the implementation of the specific protection level). Red colour: decrease, grey colour: no change, and blue colour: increase in ecosystem services. N/A: Not Answered. (N = 13). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

only one cultural fisheries-related ecosystem service (i.e., scientific knowledge/research, monitoring, education, and training) was perceived by at least 50 % of respondents as having increased highly or very highly (Fig. 4). These results should, however, be interpreted with caution, as they are based on a small subsample of 13 experts who completed the fisheries-related scenarios.

In the lightly protected level scenario, at least 50 % of respondents reported an increasing trend (from slight to very high) for two provisioning fisheries-related ecosystem services (i.e., increase fish abundance and biomass), while the remaining two others were perceived as having either decreased or remained unchanged by more than 50 % of respondents (Fig. 4). For regulation and maintenance fisheries-related ecosystem services, while 46 % of respondents reported no change for population connectivity, more than 60 % indicated some level of increase (from slight to very high) for the other six services. All cultural fisheries-related ecosystem services were reported by at least 60 % of respondents as showing an increasing trend. In the minimally protected level scenario, at least 69 % of respondents reported either no change or a decrease across all provisioning fisheries-related ecosystem services. A similar pattern was observed for regulation and maintenance fisheries-related ecosystem services, with at least 61 % of respondents perceiving no improvement (Fig. 4). Only two cultural fisheries-related ecosystem services (i.e., 'scientific knowledge/research, monitoring, education, and training' and 'facilitating fishers' involvement') were perceived by at least 50 % of respondents as having increased, whereas the other two were reported by more than 50 % of respondents as having either decreased or not changed (Fig. 4).

3.4.2. Medium-term variations in perceived changes in fisheries-related ecosystem services

The medium-term perspective (after seven years of protection) revealed evolving patterns across the four protection level scenarios, with some reinforcing and others diverging from the short-term trends observed in Fig. 4.

Overall, the fully protected level scenario was perceived as having the greatest potential to support all 15 fisheries-related ecosystem services. More than 69 % of respondents indicated a high to very high increase in all services, with cultural fisheries-related ecosystem services topping 84 %, and over 75 % for those related to regulation and maintenance (Fig. 5).

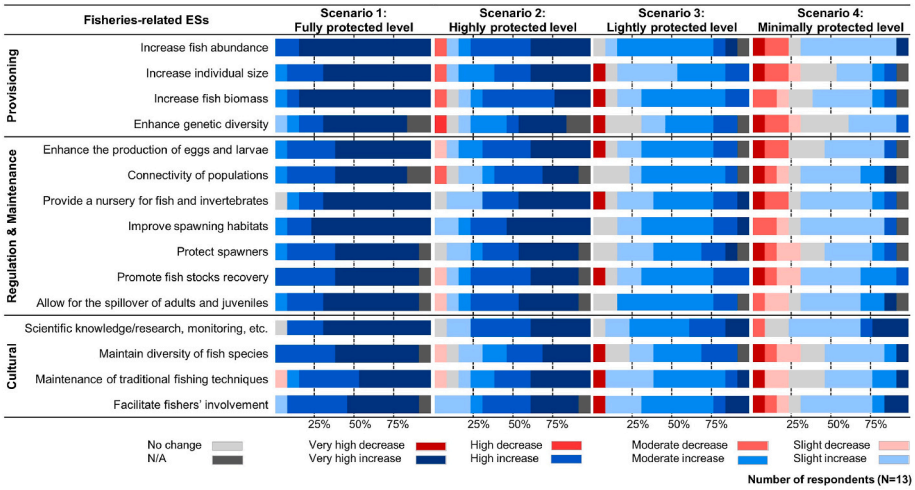

Fig. 5. Comparative fisheries-related ecosystem service assessment of four hypothetical protection level scenarios (cf. Grorud-Colvert et al., 2021) in the medium-term (i.e., after 7 years of the implementation of the specific protection level). Red colour: decrease, grey colour: no change, and blue colour: increase in ecosystem services. N/A: Not Answered. (N = 13). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Under the highly protected level scenario, at least 61 % of respondents reported a high to very high increase for three provisioning fisheries-related ecosystem services (i.e., increase fish abundance, individual size, and biomass). All regulation and maintenance, as well as cultural fisheries-related ecosystem services, were perceived as having increased to a high or very high extent by at least 50 % of respondents (Fig. 5). This marks a broader and more favorable perception than in the short-term, when only one cultural fisheries-related ecosystem service had surpassed the 50 % threshold (see Fig. 4).

In the lightly protected level scenario, responses showed a notable improvement over time, with at least 61 % of respondents reporting slight to high increases across all fisheries-related ecosystem services (Fig. 5). This contrasts with the short-term perspective, where the same scenario was associated with mixed or predominantly neutral perceptions.

Finally, the minimally protected level scenario also showed perceptual gains in the medium term. At least 50 % of respondents reported increases for two provisioning fisheries-related ecosystem services (i.e., increase fish abundance and biomass) (Fig. 5), in contrast with the short-term perceptions, where at least 69 % had reported no change or decreases for all provisioning fisheries-related ecosystem services. A similar shift was noted for regulation and maintenance fisheries-related ecosystem services, where at least 61 % of experts perceived increases in five out of seven services (Fig. 5). In the short term, all fisheries-related ecosystem services in this category had been viewed by at least 61 % of respondents as unchanged or declining. Although the overall performance of the minimally protected level scenario remains the weakest in the medium-term, it now compares more favorably with the lightly protected level scenario than it did in the short-term; suggesting a modest upward trend in perceived benefits over time. Regarding cultural fisheries-related ecosystem services, at least 50 % of experts reported increases for all services in this category (Fig. 5). As for the short-term analysis, these medium-term findings should be interpreted with caution, as they are derived from a small subsample of 13 experts who completed the fisheries-related scenario assessment.

4. Discussion

Combining expert knowledge with data-intensive assessment tools offers a valuable and pragmatic starting point for designing MPAs and developing fisheries management strategies that align expectations with realistic conservation outcomes (Schernewski et al., 2022; Sullivan-Stack et al., 2024). By using *The MPA Guide* framework, we conducted a consistent, expectation-based analysis of potential conservation outcomes, providing an evidence-informed foundation for optimizing MPA design and enhancing fisheries management, without requiring extensive resources or time (Grorud-Colvert et al., 2021). This approach is particularly well-suited to the Mediterranean region, where complex Social-Ecological Systems (SESs) often challenge the applicability of standardized ESA methodologies. Importantly, our study adds value beyond illustrating expected perceptual patterns, by integrating expert judgment across multiple protection levels, and timeframes. This integration provides a nuanced understanding of how ecosystem service provision may vary under different management scenarios, offering a preliminary yet informative basis for adaptive MPA planning. Finally, this study explored key drivers that could inform future MPA design and management, discussing their implications within the SES context of the four MPAs selected for the EFFECTIVE project. This evidence-informed, scenario-based approach offers managers preliminary insights into how protection intensity and duration may shape both ecological and socioeconomic outcomes, thereby supporting adaptive management and policy decisions.

Nevertheless, given the exploratory nature of this expert-based analysis and the limited sample size, the statistical comparisons presented should be interpreted as indicative rather than confirmatory. The use of non-parametric tests aimed to identify broad perceptual patterns rather than formally test hypotheses. Although this approach cannot eliminate the risk of Type I errors associated with multiple pairwise comparisons, an emphasis on qualitative trends helps mitigate this limitation. Accordingly, the findings are discussed as emerging tendencies that can guide future, hypothesis-driven research based on larger samples and more complex statistical models.

4.1. MPAs' ecosystem service contribution

The consensus among experts on the high contribution of MPAs to cultural ecosystem services may be explained by the greater frequency of cultural MPA-associated ecosystem services in the Mediterranean, as reported in scientific literature, compared to provisioning or regulation/maintenance services (Fig. 3). For instance, Pita et al. (2024) found that cultural services accounted for 56 % of publications (scientific and grey literature) related to the Cabo de Gata-Níjar MPA (Andalucía, Spain), based on a comprehensive review of studies between 1943 and 2019. These were followed by regulation and maintenance services (33 %), and provisioning services (10 %). Within the cultural ecosystem service category, knowledge systems were the most frequently cited (39 %). This is in line with the present study's findings, in which up to 85 % of respondents attributed high relevance to the cultural service *MPAs enable the advance of research, education, and knowledge* (Fig. 3c). Other cultural ecosystem services, such as the value of MPAs for future generations and their aesthetic contribution, were also rated highly by 91 % and 88 % of experts, respectively. These results highlight both the intrinsic non-material value of MPAs and their potential economic benefits, particularly through marine and coastal tourism. MPAs often attract divers, snorkelers, and other recreational users who seek rich marine life and scenic beauty not typically found in unprotected areas (Williams and Polunin, 2000).

In contrast, ten out of eleven provisioning MPA-associated ecosystem services were assigned moderate to low relevance by more than half of the experts (Fig. 3a). However, this general pattern varied for four specific services, depending on the experts' experience and disciplinary background (Table S5). For example, experts with $\leq$5 years of experience more frequently attributed higher relevance to services such as seaweed-based aquaculture, biofuels production, and genetic material extraction (Table S5). This may reflect a knowledge gap or limited exposure to relevant literature among less experienced experts. From a disciplinary perspective, experts with a natural sciences background tended to assign higher relevance to MPAs as areas for wild animal breeding than those with a social sciences background (Table S5). This discrepancy likely reflects the disciplinary orientation of ecological and biological training, where such topics are more commonly addressed. Interestingly, the only provisioning MPA-associated ecosystem service rated as highly relevant by over half (i.e., 57 %) of respondents was the use of MPAs for nutritional purposes (e.g., fisheries). This highlights the perceived link between MPAs and fisheries benefits, underscoring their role in supporting fisheries management objectives (Edgar et al., 2014; García-Charton et al., 2008; Lynham and Villaseñor-Derbez, 2024).

The high perceived relevance of MPAs for regulation and maintenance services observed in this study is consistent with the scientific literature. A recent review confirms strong empirical support for these contributions (Marcos et al., 2021). The most prominent among these is the role of MPAs in maintaining nursery populations and habitats, a service rated highly by over 82 % of experts (Fig. 3b). This likely reflects robust evidence showing that MPAs promote survival and recovery of organisms in vulnerable early life stages (Curnick et al., 2020). Another regulation MPA-associated ecosystem service frequently rated (i.e., 76 % of high or very high relevance scores) concerns soil loss prevention through sediment stabilization, mainly by seagrass meadows (*Posidonia oceanica*), macroalgae, microphytobenthos, macrophytes, and biogenic reef structures (epifauna and infauna) (Fig. 3b). This finding is also corroborated by the literature review conducted by Marcos et al. (2021), which highlighted the link between habitat heterogeneity loss and

decreased ecosystem service provision (Stephenson et al., 2019), and emphasized the importance of protecting biogenic habitats in the Mediterranean Sea (D'Onghia et al., 2010; Costanzo et al., 2021). In addition, two-thirds of experts attributed high evidence strength to the role of MPAs in dispersal of eggs and larvae (Fig. 3b). This perception is likely explained by a well-established body of research in the Mediterranean, where numerous studies report a net export of biomass to adjacent fishing grounds via the spillover effect (e.g., Bayle-Sempere et al., 2024; Claudet et al., 2008; Di Franco et al., 2015; Di Lorenzo et al., 2016, 2020; Frid et al., 2023; Goñi et al., 2008, 2010). By comparing expert perceptions with published empirical evidence, this study identifies areas where expert knowledge appears to converge with, or provide complementary perspectives to, existing findings. This comparison illustrates how expert-based ESA can serve as a useful interpretative and integrative tool, helping to contextualize current scientific evidence and support adaptive management strategies, particularly in data-limited contexts. Overall, the alignment between expert assessments and the scientific evidence base reinforces the value of incorporating expert knowledge into marine conservation science as a complement to empirical assessments (Giakoumi et al., 2024).

4.2. Influence of duration and protection level on fisheries-related ecosystem services

Expert perceptions regarding provisioning fisheries-related ecosystem services, such as increases in fish abundance, individual size, and biomass, exhibited critical temporal dynamics. In the short-term assessment (Fig. 4), these ecosystem services were perceived to increase notably under fully and highly protected level scenarios. Given that fishing pressure is typically highest on larger individuals, the observed increase in fish size is among the most frequently documented effects of MPAs (Claudet et al., 2008; Pérez-Ruzafa et al., 2018). In the medium term however, experts reported strong perceptions of provisioning fisheries-related ecosystem services not only under fully and highly protected level scenarios but also under the lightly protected level one (Fig. 5). This shift may reflect the progression of biological recovery processes, time-lagged stock responses, and a reassessment of the contributions of partial protection to fisheries outcomes (Zupan et al., 2018a).

Regarding regulation and maintenance fisheries-related ecosystem services, such as *improving spawning habitat*, *promoting fish stocks recovery*, and *allowing for the spillover of adults and juveniles*, experts perceived these as increasingly relevant under the fully protected level scenario, with stronger support emerging in the medium-term (Fig. 5). These services tend to be less visible in the short term; however, their provision depends critically on the mitigation of external limiting factors (Magris et al., 2018). Habitat extent and quality, for instance, strongly influence the carrying capacity of adult populations responsible for larval production (Cabral et al., 2016). These results show the sensitivity of ecological functional processes to both the level and duration of protection, which are essential for sustaining fisheries.

In contrast to provisioning and regulation/maintenance fisheries-related ecosystem services, no statistically significant differences were observed for cultural services between the two timeframes, despite a slight increase in their perceived relevance in the medium-term (Table 3, Figs. 4 and 5). This suggests that expert perceptions of fisheries-related cultural services, such as *facilitating fishers' involvement*, are less temporally dynamic. Their relative stability may stem from the fact that cultural services are socially constructed and mediated through community values and stakeholder lifestyles, rather than directly through ecological change (Silva and Lopes, 2015). Thus, the perceived enhancement of these ecosystem services may require more than ecological recovery alone; it may call for a holistic conservation approach that values local knowledge systems, cultural traditions, aesthetic appreciation, and emotional connections to marine environments (Ledoux and Turner, 2002). Our approach helps to explore potential temporal dynamics and trade-offs in ecosystem service provision across different protection scenarios, offering a practical framework for managers to anticipate possible short- and medium-term outcomes and to prioritize interventions accordingly. For example, our results indicate that provisioning fisheries-related ecosystem services, such as *increasing fish abundance, individual size,* and *biomass*, are perceived as increasing over time, particularly under higher protection levels (i.e., fully and highly protected levels). In contrast, regulation and maintenance fisheries-related ecosystem services, such as *providing a nursery for fish and invertebrates*, show more subtle changes, and cultural fisheries-related ecosystem services, including *facilitating fishers' involvement* and *promoting scientific knowledge*, appear largely unaffected. This demonstrates how our approach can identify which ecosystem services are most responsive to varying protection levels and temporal horizons, guiding managers in prioritizing interventions that maximise both ecological and socioeconomic outcomes.

4.3. Implications for optimizing MPA design, management, and fisheries sustainability

The perceived contribution of MPAs towards cultural ecosystem services was the strongest among the three-ecosystem service categories. For instance, the aesthetic value of MPAs was scored as highly relevant by 88 % of respondents. Nevertheless, in the event that studies indicate that an MPA may attract recreational users, it is generally understood that these users are seeking mainly rich marine life and pristine landscapes (Williams and Polunin, 2000). Consequently, a higher protection level should be implemented for each MPA that intends to benefit from the provision of such ecosystem services. For example, in the Medes Islands MPA, the extension of the strict protection has the potential to enhance both fish biomass and biodiversity, thereby generating additional direct and indirect tourism revenues (Cabral et al., 2025). Nevertheless, any decision to modify the protection level of this MPA should be made following extensive consultation with all local stakeholders, particularly those whose livelihoods are adversely affected in the short term (e.g., fishers). The long-term success of this MPA is contingent not only on the achievement of measurable socioeconomic benefits, such as tourism revenues, but also on how those benefits, and the processes used to attain them, are perceived by local stakeholders (Enthoven, 2025). Furthermore, the issue of tourist overcrowding must be given due consideration, as it has the potential to diminish the site's ecological integrity and overall appeal (Alban and Boncoeur, 2006).

A considerable number of regulation and maintenance MPA-associated ecosystem services were identified by experts as being of very high relevance, including the maintenance of nursery populations and habitats (Fig. 3b). In the case of the Delta del Ebro MPA, its minimal protection level has led to the degradation of the key habitat of *Cymodocea nodosa* seagrass beds. While fully protected MPAs could help protect such key habitats, which are required for vulnerable and endangered species (i.e., *Pinna nobilis*) (Roberts and Hawkins, 2000), the increase of the protection level alone may not be sufficient. Restoration measures are required prior to the protection ones. Thus, it is noteworthy that a considerable proportion of the expected ecosystem services from this region are contingent on the presence of habitats that meet fundamental ecological thresholds. Nevertheless, effective restoration necessitates the regulation of ongoing human activities, such as the prohibition of those activities that increase water turbidity. Consequently, while augmenting the protection level of this MPA is imperative, it is inadequate to mitigate anthropogenic impacts in the absence of comprehensive SES-based management.

With respect to fisheries-related ecosystem services, the majority of experts indicated that *allowing for the spillover of adults and juveniles* and *connectivity of populations* are increasingly relevant under full protection, with stronger support emerging in the medium-term (Figs. 4 and 5). However, even if ensuring a high protection level is essential for enhancing the delivery of these ecosystem services, the success of

processes leading to well-connected populations relies not only on the protection status within a given MPA but, more importantly, on the availability of other strictly protected areas acting as safe havens (Andrello et al., 2013). Such areas must be situated at ecologically significant distances to function as stepping stones, thereby facilitating population connectivity (Andrello et al., 2017). Consequently, the incorporation of stricter protection measures and the establishment of ecological connectivity must be considered jointly during the design of MPA networks. This assertion holds particular pertinence in the context of the Tavolara-Punta Coda Cavallo MPA, which is situated in proximity to the Pelagos Sanctuary for marine mammals, the Mediterranean's largest MPA and the first transboundary MPA established in open waters (MedPAN and UNEP/MAP-SPA/RAC, 2023).

Facilitating fishers' involvement was the only fisheries-related ecosystem service where expert perceptions didn't change across the different protection levels in the short-term (Table 3). In the Cavo Greco MPA, a relatively new established MPA, support for fisheries regulation enforcement may depend on how spatial restrictions are perceived by fishers (Thomassin et al., 2010). Globally, the zoning of this MPA aims to achieve sustainable use consistent with conservation (Douvere, 2008). In this context, expert-based ESA offers a cost-effective, practical tool for guiding zoning and fisheries management, particularly in data-poor regions with limited MPA coverage such as the Aegean-Levantine Sea (MedPAN and UNEP/MAP-SPA/RAC, 2023). By explicitly capturing expert expectations across multiple protection levels and timeframes, this approach offers indicative insights that can enhance scientific understanding and inform management practice, supporting adaptive decision-making and highlighting potential trade-offs.

Overall, our findings offer indicative insights that can support the operationalization of the EU Biodiversity Strategy for 2030 and the design of effective MPA networks. By highlighting which ecosystem services are perceived to respond most positively to higher protection levels and longer durations, the results may help identify where stricter measures could potentially yield greater ecological and socioeconomic benefits. Importantly, integrating expert-based ESA within MPA planning can serve as a complementary tool to guide adaptive zoning and the progressive upgrading of protection levels, especially in data-limited contexts. Moreover, the study emphasizes the importance of involving local stakeholders early in the decision-making process to enhance legitimacy and compliance with protection measures. In this regard, expert elicitation can act as a dialogue-support mechanism to better align scientific evidence with stakeholder perceptions. Finally, by illustrating possible links between ecosystem service provision, stakeholder acceptance, and policy objectives, this exploratory approach can inform broader EU-level initiatives such as the Marine Strategy Framework Directive (MSFD), the Common Fisheries Policy (CFP), and efforts toward a coherent, transboundary network of marine strictly protected areas across the Mediterranean. Specifically, our approach can help policymakers identify which ecosystem services, such as the *improving spawning habitats*, require targeted actions to meet MSFD Good Environmental Status objectives. For the CFP, insights into how protection levels influence *fish stock recovery* and *individual size* distributions can inform decisions on spatial restrictions, sustainable quotas, and the timing of seasonal closures.

4.4. Study limitations

While this study provides valuable insights into expert-based scenario assessments within ESA frameworks, several limitations must be acknowledged.

Such assessments are inherently shaped by subjectivity and variability arising from differences in individual knowledge, disciplinary background, and potential cognitive biases (Schernewski et al., 2022). Additionally, as with any online survey-based methodology, the data collected have some limitations, as they may be affected by respondents' willingness to participate and by their full understanding of the questionnaire content (Bell et al., 2022). Consequently, the relatively small number of experts participating in our study is likely to limit the representativeness of the findings. Although 33 experts were initially involved, only 13 of them completed the scenario-based assessment section (i.e., section 3). This partial response may reflect respondent fatigue due to the length and cognitive complexity of this section (Giakoumi et al., 2024). It should be noted that some analyses, particularly those concerning the scenario-based assessment of fisheries-related ecosystem services, were based on this smaller subsample of 13 respondents, which is likely to limit the representativeness of the findings. Nevertheless, low participation levels have been reported in other expert-based studies; for instance, Karstens et al. (2019) engaged 18 experts, while Schernewski et al. (2022) relied on input from 27 participants. Still, a larger and more geographically diverse expert panel would enhance the robustness and generalizability of the findings.

Furthermore, relying solely on expert respondents may introduce bias, as Raabe et al. (2024) suggest that focusing mainly on direct user groups (e.g., fishers) can overlook broader societal perspectives and intrinsic values attached to marine life. In addition, the recruitment strategy used (i.e., based on professional networks and project-related contacts) may have introduced selection bias by favoring experts already engaged in MPA management and conservation, potentially limiting the diversity of viewpoints. While our approach aimed to integrate experts from diverse geographic and disciplinary backgrounds, future research should also consider wider stakeholder and public viewpoints to better capture the full range of values relevant to MPA planning and management.

Although the scenario-based approach used here offers a cost-effective tool compared to more data-intensive assessment tools for exploring alternative options in MPA design and fisheries management, particularly under data-poor conditions, expert assessments were based on hypothetical scenarios rather than empirical studies. While this method allows for controlled comparisons across protection levels and timeframes, it does not fully capture the complexity of real-world MPA implementation, including management challenges (e.g., active implementation, enforced regulations, long-term monitoring, etc.) and governance dynamics. Therefore, it cannot be assumed that assigning a given "protection level" will automatically lead to either the improvement or degradation of specific ecosystem services (Grorud-Colvert et al., 2021).

5. Conclusions

MPAs can influence the supply of ecosystem services and related goods in multiple ways. In the context of the EU Biodiversity Strategy for 2030, which aims to strictly protect 10 % of marine and coastal areas by 2030, it is essential to understand how different MPA protection levels affect both ecological outcomes and the livelihoods of coastal communities. Changes in ecosystem service provision, driven by protection intensity, may directly impact local economies, especially in communities that depend on fisheries. This study complements previous empirical findings suggesting that fully and highly protected MPAs can generate tangible benefits for fisheries, including increased biomass, reproductive potential, and spillover effects, by offering exploratory insights from expert-based assessments. However, such ecosystem services may not be immediately apparent, particularly in the short-term. To address these trade-offs, it is vital that policymakers and MPA managers implement appropriate incentives and public policies aimed at mitigating potential decreases in fisheries income related to stricter conservation measures. In this context, integrating ESA into MPA planning and expansion processes becomes essential for aligning conservation goals with socioeconomic realities. Moreover, beyond the specific case studies analyzed, our findings may provide preliminary guidance to EU and national authorities in implementing coherent, socially acceptable, and ecologically effective MPA networks. This approach offers a practical means to bridge the gap between science,

policy, and local management by translating expert perceptions into decision-relevant information for adaptive marine governance.

Nevertheless, given that the fisheries-related findings are based on a relatively small subsample of experts, the results should be interpreted with caution. This limitation implies that while the observed patterns provide valuable exploratory insights into expert perceptions, they should not be generalised without further empirical validation through broader stakeholder engagement and quantitative field-based assessments.

CRediT authorship contribution statement

Ibrahim Boubekri: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Johanna Schumacher:** Writing – original draft, Visualization, Validation, Software, Resources, Project administration, Methodology, Funding acquisition, Data curation, Conceptualization. **Miriam von Thenen:** Writing – review & editing, Validation, Methodology, Funding acquisition. **Astrid Sánchez-Jiménez:** Writing – review & editing, Validation, Methodology. **Anna A. Lloveras:** Writing – review & editing, Data curation. **Rafael Sardá:** Writing – review & editing, Data curation. **Rachid Amara:** Writing – review & editing, Supervision, Data curation. **Gerald Schernewski:** Writing – review & editing, Visualization, Validation, Supervision, Project administration, Funding acquisition.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Ibrahim Boubekri reports financial support was provided by European Union. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ocecoaman.2025.108061.

Data availability

Data will be made available on request.

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