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Research article

Deficiencies in monitoring practices of marine protected areas in southern European seas

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ABSTRACT

Worldwide, states are gazetting new Marine Protected Areas (MPAs) to meet the international commitment of protecting 30% of the seas by 2030. Yet, protection benefits only come into effect when an MPA is implemented with activated regulations and actively managed through continuous monitoring and adaptive management. To assess if actively managed MPAs are the rule or the exception, we used the Mediterranean and Black Seas as a case study, and retrieved information on monitoring activities for 878 designated MPAs in ten European Union (EU) countries. We searched for scientific and grey literature that provides information on the following aspects of MPA assessment and monitoring: ecological (e.g., biomass of commercially exploited fish), social (e.g., perceptions of fishers in an MPA), economic (e.g., revenue of fishers) and governance (e.g., type of governance scheme). We also queried MPA authorities on their past and current monitoring activities using a web-based survey through which we collected 123 responses. Combining the literature review and survey results, we found that approximately 16% of the MPA designations (N = 878) have baseline and/or monitoring studies. Most monitoring programs evaluated MPAs based solely on biological/ecological variables and fewer included social, economic and/or governance variables, failing to capture and assess the social-ecological dimension of marine conservation. To increase the capacity of MPAs to design and implement effective social-ecological monitoring programs, we recommend strategies revolving around three pillars: funding, collaboration, and technology. Following the actionable recommendations presented herein, MPA authorities and EU Member States could

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improve the low level of MPA monitoring to more effectively reach the 30% protection target delivering benefits for biodiversity conservation.

1. Introduction

The Kunming-Montreal Global Biodiversity Framework, adopted in December 2022, calls for effectively conserving and managing at least 30% of coastal and marine areas by 2030 through marine protected areas (MPAs) and other effective area-based conservation measures (CBD, 2022). Similarly, a couple of years before, the European Union (EU) developed the Biodiversity Strategy for 2030 that aims to put Europe's biodiversity on the path to recovery by 2030, protecting 30% of its land and seas (EC, 2020). Several nations have now set the so-called 30x30 conservation goal in their national biodiversity strategies and action plans creating new MPAs or expanding existing ones. Like in previous biodiversity conservation initiatives under the umbrella of the Convention on the Biological Diversity (CBD), quantitative targets are accompanied by important qualitative aspects such as effective conservation and management, equitable governance, representativeness, and connectivity. However, these qualitative aspects have received much less attention than the quantitative area targets (Gurney et al., 2023; Hermoso et al., 2022; Visconti et al., 2019).

Conservation scientists and practitioners warn that designating new protected areas without implementing regulations and management actions in the existing ones is meaningless. Protection, and its benefits, do not begin until an MPA is implemented with activated regulations or actively managed with ongoing monitoring and adaptive management (Grorud-Colvert et al., 2021). Worldwide, a plethora of designated MPAs lack implementation and monitoring (Claudet et al., 2020; Gill et al., 2017). In Europe, this is particularly the case for Natura 2000 sites (i.e., sites of EU conservation interest for rare and threatened species, and some rare natural habitat types) which less than 40% have management plans and need national funds to be implemented (Mazaris et al., 2017). Previous evidence suggested that reinforcing the capacity of existing MPAs to achieve their conservation objectives would result in high returns on investment for both nature and human societies (Gill et al., 2017). Moreover, the direct monetary benefits of MPAs largely outweigh the operational costs of implementing monitoring programs (Villaseñor-Derbez et al., 2023).

A key component of MPA management is an effective monitoring and evaluation program, generating robust data that can inform management strategies to be adopted to reach conservation targets considering benefits for local people (Maxwell et al., 2020). Long-term data are essential for evaluating ecosystem responses to disturbances (including global changes), providing baselines to evaluate local changes, and assessing the effectiveness of management measures in securing ecosystem structure and function (and consequently services provision), and potential benefits to local communities and the wider society (Davis et al., 2019; Marcos et al., 2021). The collection of high quality ecological and socio-economic data is necessary for both the design of new MPAs and the active management of existing ones. In the first case (i.e., MPA design), such data can drive the identification of priority areas for conservation (e.g., Giakoumi et al., 2011) while in the case of MPA management, monitoring data allows for the evaluation of MPA effectiveness in achieving its objectives (e.g., Magdaong et al., 2014). Furthermore, and most importantly, monitoring data can be used to adapt current management to new conditions and stressors that impact an MPA. For example, the exposure of an MPA to biological invasions needs the uptake of new management actions, or the modification of existing ones, such as selectively harvesting invasive species within the MPA (Kleitou et al., 2021; Dimitriadis et al., 2024). Monitoring and assessment should also move beyond the simple assessment of ecological conditions and consider economic, social, and governance dimensions (e.g., Roncin et al., 2008) integrating the human dimension to capture the effect of MPAs on the social-ecological system in which they should fit (Bennett et al., 2017; Di Franco et al., 2020). Yet, in many cases, the absence of rigorous and consistent monitoring protocols and the transformation of raw monitoring data into actionable information limits the MPA's capacity for adaptive management and therefore its success (Fox et al., 2014).

A monitoring and evaluation program is a program that organizes, controls and adapts a set of operations ranging from field data collection to data analysis for impact assessment (Claudet and Pelletier, 2004). Monitoring and evaluation programs should include control areas to allow rigorous testing of hypotheses, such as the effects of MPA enforcement on fish density (e.g., Guidetti et al., 2008) or the impact of sea warming on benthic invertebrates inside and outside MPAs (e.g., Micheli et al., 2012), and focus on elements of human well-being such as food security, resource rights, employment, income (e.g., Mascia et al., 2010). Monitoring and evaluation can even focus on the MPA management structure itself and focus on internal monitoring of the hierarchical system, resources and staff capacity and how that can determine whether or not the MPA can achieve its objectives (Scianna et al., 2019). The monitoring and evaluation program should adopt a robust sampling design, such as the before-after-control-impact (BACI) experimental design (Kerr et al., 2019), and allow for temporal and spatial replication to create spatially explicit time-series that can be used for the expansion of current networks of MPAs (e.g., García-Barón et al., 2021), the assessment of MPA ecological effectiveness (e.g., Magdaong et al., 2014) or the assessment of human impacts inside or outside MPAs (e.g., Calò et al., 2022). Ideally, monitoring should also cover multiple seasons in a year to capture seasonal variations in species populations and habitats (Douglass et al., 2018) or fishers' activities and revenue (Defeo et al., 2016). In monitoring and assessment protocols, it is important to include the measurement of a range of variables that can be used as covariates in data analyses to control for confounding effects (Benedetti-Cecchi and Osio, 2007; Claudet and Guidetti, 2010; Dunham et al., 2020). Furthermore, when aiming to assess the impacts of conservation interventions, relevant logical and analytical frameworks that account for social-ecological systems should be considered (e.g., Mascia et al., 2017). Although the importance of these essential characteristics of monitoring and evaluation programs is widely acknowledged, their adoption is limited in practice (Addison et al., 2015; Fox et al., 2014; Hayes et al., 2019).

To assess if actively managed MPAs (i.e., MPAs with continuous monitoring allowing adaptive management) are the rule or the exception, we used the European Mediterranean and Black Seas as a case study. These areas host a large number of MPAs (Claudet et al., 2020) and encompass a wide range of social-ecological settings, covering ten countries and six marine ecoregions (Spalding et al., 2007), making it an informative context to assess. In this study, we investigated which MPAs have baseline studies and/or monitoring programs that provide information on the following aspects of MPAs: ecological (e.g., assessment of abundance and biomass of commercially exploited species), social (e.g., information on human wellbeing), economic (e.g., revenue of fisheries) and governance (e.g., type of governance scheme). This objective was achieved by reviewing scientific and grey literature and analyzing the replies from a questionnaire that was administered to MPA management bodies regarding their monitoring activities. This study allowed the identification of gaps in quantitative and qualitative monitoring information that are important for achieving biodiversity conservation targets and effective MPA management. Moreover, this work led the authors to identify strategies revolving around three pillars: funding, collaboration and technology that, if adopted, could increase the capacity of MPAs to design and implement effective social-ecological monitoring and evaluation programs.

2. Methods

2.1. MPAs included in the analysis

An initial list of all the MPAs in the European waters of the Mediterranean and Black Seas was compiled. This initial list contained 1224 MPA designations, compiled using the MAPAMED database for the Mediterranean area (www.mapamed.org). It was filtered by country (EU only) and only the areas having a marine part were kept (1191 MPAs). For the Black Sea MPAs, the World Database on Protected Areas (WDPA) was also used, filtering by country and keeping the areas with a marine part (33 MPAs). The lists were combined and then updated using the European Environment Agency (EEA) database to include MPAs that were not available on MAPAMED, leaving us with a total number of 1261 MPA designations. This initial list was sent to relevant national authorities in each of the study countries to verify and edit if needed, to have the most up to date and reliable information available. In two cases, the national authorities were not available to confirm the list, therefore we used official national databases to cross check which MPAs were included. For two other countries, the national authorities either performed a partial check or directed us straight to the national databases available online. It is worth noting that some fishery reserves in Spain, such as Illa del Toro, Ses Negres, and Badia de Palma, were not included in our list because these sites are not officially reported to the EEA as MPAs by the national authority and are not included in the WDPA.

Following this initial cross check, we decided to exclude sites with a marine area that covers less than 5% of the total protected area, sites that concerned mainly wetlands such as Ramsar sites, or other designation types such as Essential Fish Habitats that aim more at fisheries restoration than biodiversity conservation. This filtering resulted in a total of 949 MPA designations (see list in Supplement Table 1). However, a total of 408 MPA designations were found to overlap to some degree. This considers overlap of Natura sites overlapping national designations and national designations overlapping other national designations. More specifically, we found 318 cases where Natura 2000 sites overlapped with national designations, covering 21,225.64 km^2, and 90 cases where national designations overlapped with other national designations, covering 5053.35 km^2. For example, the Delta de l' Ebre in Spain has two overlapping designations, a national (WDPA code: 389097) and a Natura 2000 site (WDPA code: 555722903). In addition, these Delta de l'Ebre designations overlap substantially with the Punta del Fangar national MPA designation. We considered two or more MPAs as fully overlapping when they have $\geq$90% of their areas in common. If monitoring activities are performed in one MPA designation, consequently the overlapping MPA designations are also being monitored. Overall, in the list of 949 MPA designations, we found 82 MPA designations that fully overlapped, as such we must consider these as "labels" but not necessarily as a set of unique MPAs. After merging fully overlapping MPA designations, we consider 878 out of the list of 949 MPA designations to be a more realistic number of unique sites.

2.2. Questionnaire

An online questionnaire was designed and translated into local languages within the framework of the EU project MAPAFISH-Med. The questionnaire which fed into the larger project (MAPAFISH-MED) was divided into different sections covering different aspects such as general MPA information (e.g., size, year of establishment etc.), MPA governance and management, fisheries activities inside MPAs, and one section was dedicated to Monitoring. The questionnaire was then administered via email to MPA managers or MPA management authorities of the 878 MPA designations. To increase the response rate, 3–5 follow-up emails were sent (Dillman and Goodrich, 1979; Relano and Pauly, 2023). Herein, we focus on the questions and information that was provided regarding the existence of baseline studies and monitoring activities inside MPAs and beyond their borders. We asked the MPA staff to reply to the following questions: (1) Which of the following types of data are collected with a well-established timeframe in a monitoring and evaluation program: Ecological (e.g., assessment of abundance and biomass of commercially exploited fish and invertebrate species), Social (e.g., information on human wellbeing and perceptions of fishers operating in the MPA), Governance/management (e.g., type of governance scheme, level of stakeholder engagement into decision making processes), Economic (e.g., revenue and income of fisheries)? (2) Does the MPA have baseline ecological data regarding fish biomass before its establishment? (3) Does the MPA have baseline socio-economic data regarding: a. fishers' catches and their value before its establishment, and b. fishers' socio-economic characteristics (e.g., age, level of education, total revenue) and their fleet (e.g., number of vessels, length of vessel)?

2.3. Literature review

To perform our review, we followed the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement (Moher et al., 2009). The PRISMA flow diagram and results for both the scientific and grey literature review are summarized in Fig. 1. We performed a search on the Web of Science to find scientific literature published in English using the following combination of keywords present in the title and/or abstract and/or keywords of the publications: "protected area*" or "national park*" or "marine reserve*" or "Natura" and "marine" and "monitoring" or "assessment" or "baseline" and "**country**". The search was done for each country separately, and the keyword "country" was substituted with "Italy", "Greece", "France" etc. We also performed two additional searches that instead of a country, used the keywords: "Mediterranean" and "Black Sea". National biodiversity assessments commonly use non-English literature (Amano et al., 2023), thus we performed a search on Google Scholar using the string: "protected area" or "national park" or "marine reserve" or "Natura" and "marine" and

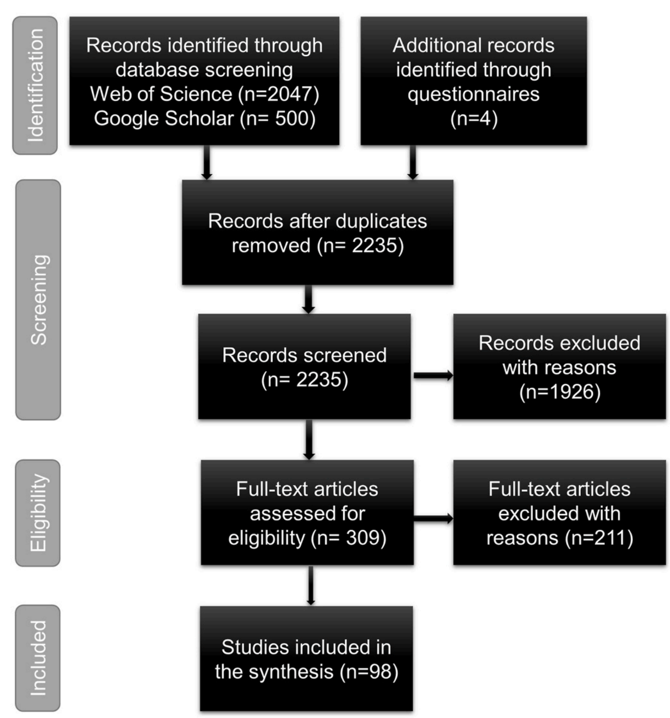

Fig. 1. PRISMA flow chart presenting the articles/documents retained and excluded at each review step. Data for scientific and grey literature are integrated.

"monitoring" or "assessment" or "baseline" and (for example) "Italy" and "Italian" translated into the official language of each country. Native speakers, co-authors of this article, went through the first 50 results that Google Scholar generated and identified documents/reports that are related to the study by reading their (executive) summary or abstract. Fifty has been estimated as a good trade-off between sampling effort and information potentially gathered considering that technical reports and PhD theses that are potentially retrieved through this search are usually very long and time consuming to be assessed (Haddaway et al., 2015).

We retrieved 2047 scientific articles overall (all searches combined), some of which were duplicated items considering that "country"-based and "sea"-based (i.e., "Mediterranean" and "Black Sea") searches could, in some cases, generate the same papers. After removing duplicates, we retained 1731 papers which were screened going through the abstract to decide whether to include or exclude the paper - retaining only papers that were relevant to the topic, i.e., baseline studies and/or monitoring studies using ecological, social, economic, governance variables related to conservation and/or fisheries within MPAs. For instance, a paper that referred to monitoring may actually have focused on the monitoring of chemical substances in coastal waters and thus was not retained for further analysis. Papers were excluded for one or more of the following reasons: the paper did not include a protected area; the protected area was not marine; the MPA(s) were not in the Mediterranean or the Black Sea (e.g., French MPAs in the Atlantic Ocean) or in these seas but not in the EU (e.g., MPAs in Tunisia); the paper did not report relevant variables (e.g., monitoring of plastic debris). The entire text of the 226 papers retained following the abstract screening were assessed in full. The same exclusion criteria were applied for the grey literature documents. After checking 500 grey literature documents, only 83 documents were considered pertinent to our topic and retained for further exploration and potential data extraction. Four additional reports were suggested by MPA managers through their responses to the questionnaire.

After reviewing the documents in their entirety, we retained a total of 98 articles and documents (i.e., 74 scientific articles and 24 grey literature documents) that were pertinent to our topic and extracted relevant information for one or multiple MPAs (list provided in Supplement Table 2). The information collected included: the name and zone of the MPAs included in the study, who conducted the study (research institutes, MPA authorities, NGOs …), whether it was a baseline study, whether it was ecological and/or social and/or economic and/or governance monitoring, the variables investigated, the sampling year(s) and season(s), the sampling methods and unit area, the type of sampling design, the number of sampling sites and replicates within the sites, and whether the data collected is publicly available, and if so,

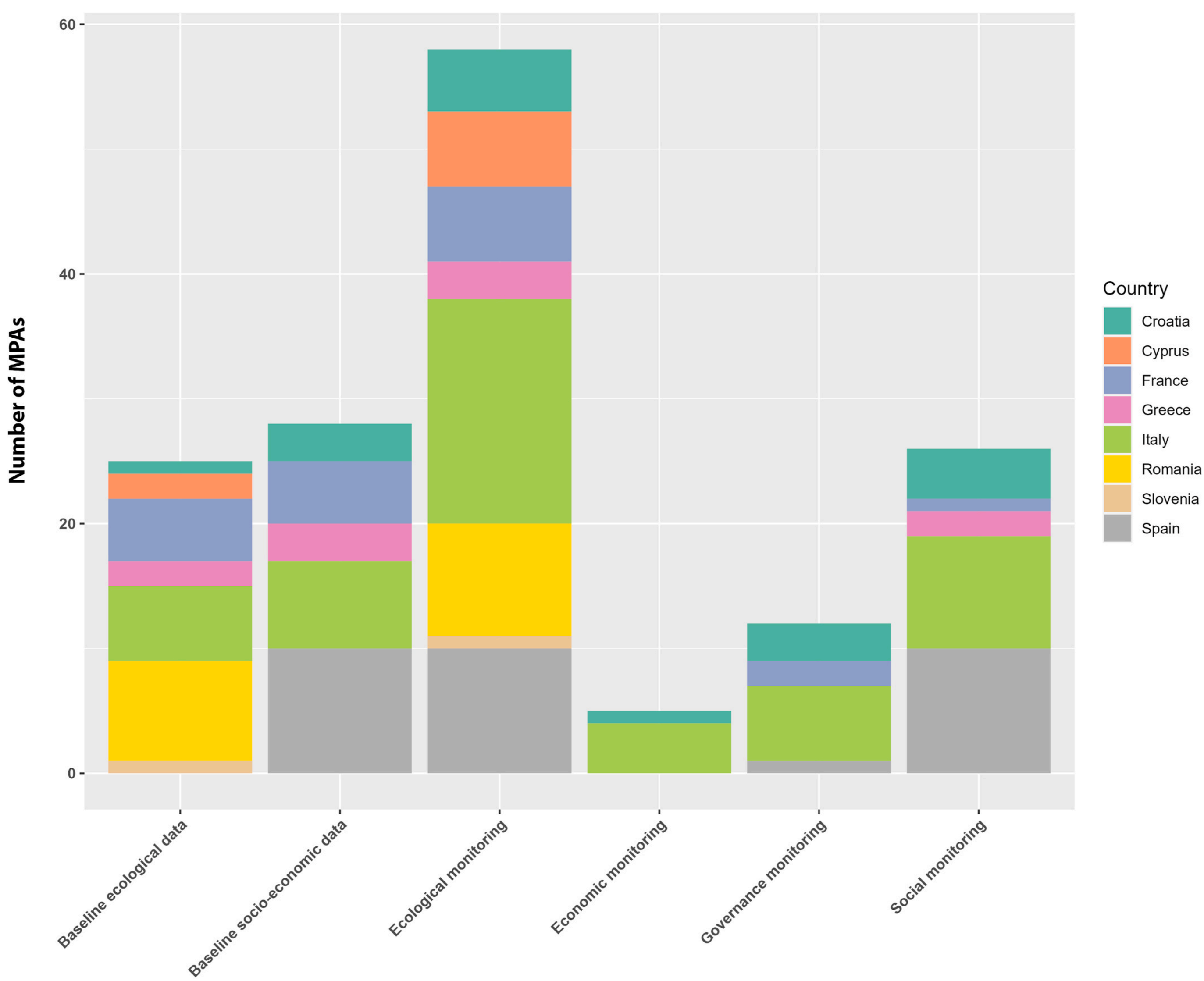

Fig. 2. Number of MPAs reporting monitoring activities (ecological, economic, governance, and social) grouped for each country. Data were collected through the questionnaire administered to MPA managers.

where are they stored.

3. Results

3.1. Questionnaire

As of May 15th, 2023, we received 123 responses to the monitoring section of the questionnaire from nine countries (out of the ten EU member states in the Mediterranean and Black Seas). We received 18 responses from Bulgaria, 20 from Croatia, 9 from Cyprus, 9 from France, 7 from Greece, 40 from Italy, 9 from Romania, 1 from Slovenia, and 10 from Spain (see Supplement Table 1). Overall, authorities managing 81 MPAs in eight countries stated that they perform some sort of monitoring. While the overall percentage of MPA designations performing monitoring activities is low, approx. 10% of the 878 MPAs considered in the study, 65% of the MPAs participating to the survey (n = 123) replied positively. Ecological monitoring was reported most frequently with 58 (47%) of MPAs reporting they carry out such activities followed by social monitoring (25%) (Fig. 2). Economic and governance aspects were reported to be the least monitored, with only 5 (4%) and 12 (10%) respectively, reporting these activities. Only 25 (20%) and 28 (23%) of respondents/MPAs reported having baseline ecological and socio-economic data respectively.

3.2. Literature review

The 74 peer-reviewed scientific articles included baseline and/or monitoring information for 79 MPAs: 44 Nationally designated and 35 Natura 2000 sites. The 24 grey literature documents included information for another 12 MPAs: 2 Nationally designated and 10 Natura 2000 sites. These 91 MPAs, in total, correspond to approximately 10% of all Mediterranean and Black Sea MPA designations (N = 878). The 91 MPAs are located in 8 out of the 10 EU Mediterranean and Black Sea Member States: Croatia (3), Cyprus (2), France (16), Greece (8), Italy (39), Romania (7), Slovenia (1), and Spain (15) (Fig. 3 & Supplement Table1).

We found that 31% of all the scientific and grey literature documents (N = 98) were co-authored by MPA staff, whereas from the acknowledgments section of the articles or documents it appears that MPAs collaborated in 81% of all baseline and/or monitoring studies. It is worth noting that 9% of the scientific literature studies made their data publicly available, whereas for the grey literature this percentage increases 3-fold to 27%.

Out of the 98 documents/articles, 80 included ecological monitoring data, 15 social monitoring data, 11 economic monitoring data, and 11 governance monitoring data (note that the sum is higher than the total number of papers retained as some papers included multiple categories of data). In 22 studies, it was stated that baseline data were included. A total of 70 studies included data on commercially exploited species, six studies included species (fish and mollusks) harvested only by recreational fishers, and 22 studies contained data about a sensitive habitat or species (e.g., *Posidonia oceanica* or coralligenous).

A total of 43 variables were examined/measured in these 98 documents/articles (Full list in Supplement Table 3). It is important to clarify that most studies examined more than one variable. The most measured variables were indicators of the ecological sub-system: abundance/density (in 51% of the studies), species richness (30%), size/size

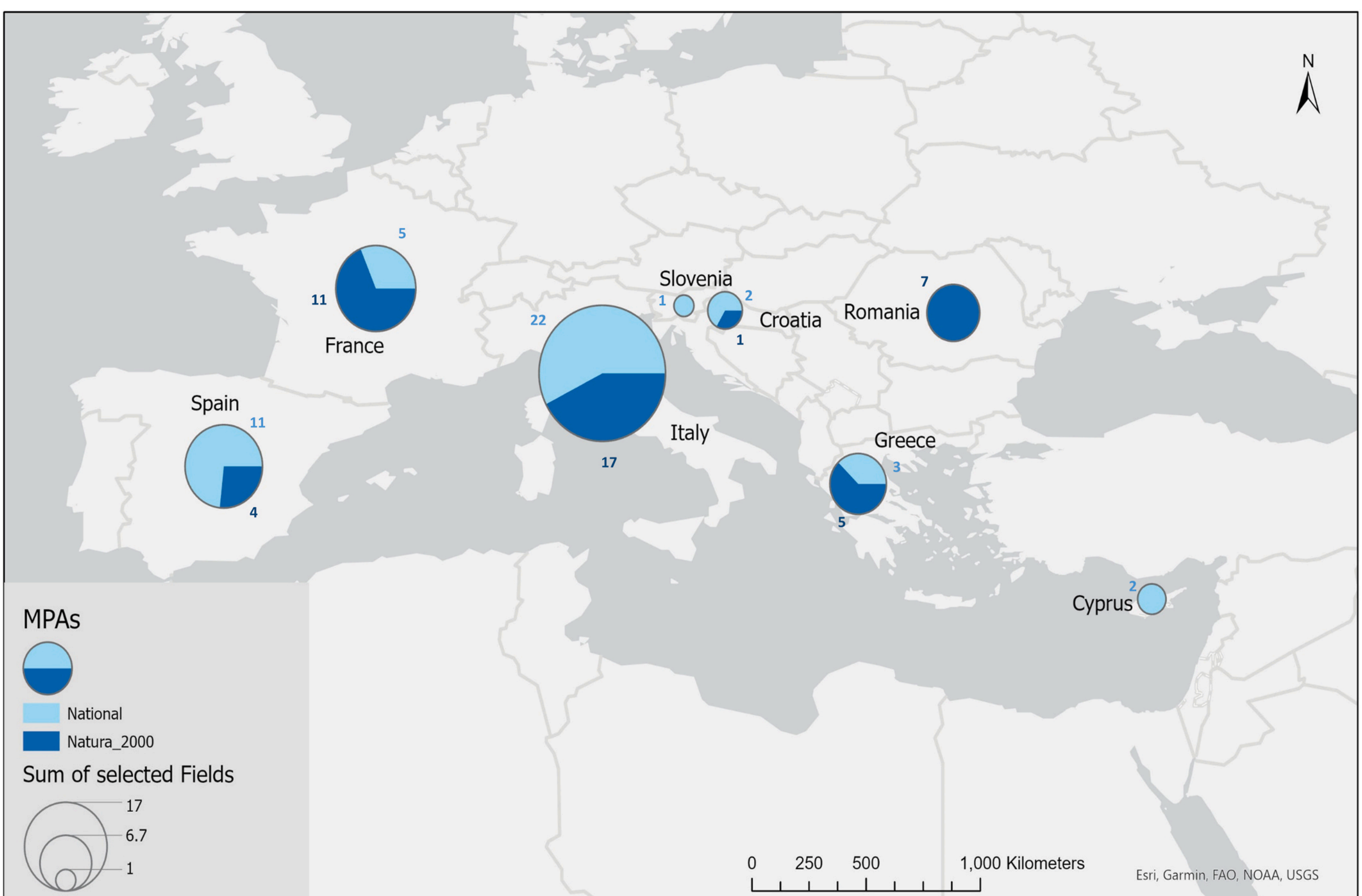

Fig. 3. Distribution of nationally designated MPAs (light blue) and Natura 2000 sites (dark blue) for which baseline and monitoring data were retrieved through scientific and grey literature review. The list of MPAs is provided in Supplement Table 1. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

structure (24%), and biomass (22%). Fewer studies included data related to the socio-economic sub-system (e.g., catch per unit effort (CPUE): 12%), governance (e.g., stakeholder engagement: 8%), social (e.g., human wellbeing: 4%) aspects of MPAs.

To measure the variables mentioned above, half the studies used visual census techniques and one quarter used interviews and questionnaires. Out of the studies using visual census, 60% used transect lines, one third of which used replicates of 25 × 5 m as a sampling area. Other sampling methods included: experimental fishing (15%), landing data assessments and logbooks (12%), acoustics (6%), video surveys and baited cameras (5%), photogrammetric surveys (5%), remote sensing (4%), data from official statistics/markets/auctions (1%), literature review (1%), eDNA metabarcoding (1%), larval collection (1%), side scan sonar (1%), tethering experiment (1%). It is worth noting that some studies used more than one sampling method.

About 70% of the studies including data for ecological monitoring (n = 80) did not account for covariates in their analysis. The ones that did, used mostly depth (18%) and habitat type (16%). Other covariates used in the studies were: temperature (in 9% of the studies), structural complexity/rugosity (8%), latitude and/or longitude (6%), dissolved oxygen (5%), geomorphology (4%), time (4%), salinity (4%), fishing intensity (3%), slope (3%), pH (3%), accessibility (1%), primary production (1%), exposure (1%), spatial scale (1%), bottom current speed (1%), or cumulative human impact index (1%).

In the ecological monitoring studies (n = 80), bony fish (Actinopterygii) were by far the most studied taxonomic group (71%), followed by Mollusca (18%). Other monitored taxonomic groups included: Echinodermata (15%), Cnidaria (15%), Plantae and Chromista (14%), Arthropoda (13%), Chondrichthyes (10%), Tunicata (5%), Mammalia (5%), Bryozoa (5%), Brachiopoda (5%), and Annelida (5%).

Almost half of the ecological studies did not follow a structured sampling (experimental) design and their methods were just descriptive, half of the ecological studies used a Control-Impact (CI) design whereas only one study used a Before-After-Control-Impact (BACI) sampling design (Fig. 4). The majority of the studies collected data during one year and for just one season. Only 5% of the studies used long time-series that covered over 10 years. About 65% of the studies performed sampling in only one season (covering one or more years). Seasonal variations across the year (sampling 4 seasons) were accounted for in only 15% of the studies. Note that two ecological studies with no experimental design were unclear about the sampling years and seasons so they were omitted from this analysis.

The majority of the studies exploring social, economic, and governance aspects of MPAs (70% of the 27 studies) collected information through interviews/questionnaires with stakeholders, mostly fishers but also MPA managers. The most common variables explored by studies focusing on the socio-economic subsystem of MPAs included: CPUE (45%), stakeholder engagement (30%), fisheries revenue/income (18%), human wellbeing (15%), and number of jobs (11%). Like the ecological studies, most socio-economic studies (70%) covered a one-year period. Only two studies included data that covered a period longer than 10 years, revealing the scarcity of long-term socio-economic studies on MPAs in the Mediterranean and Black Seas.

When combining the list of MPAs that responded to our survey, reporting they perform monitoring of some kind (n = 81) with the MPAs for which we found relevant documents reporting monitoring and assessment studies via the literature review (scientific and grey, n = 91), and accounting for duplicates (i.e., MPAs that were identified via the literature review and responses to the survey, n = 33), we found 139 MPAs. This number corresponds to 16% of the 878 MPAs considered in our study.

4. Discussion

4.1. Status of baseline and monitoring activities in Mediterranean and Black Sea MPAs

Overall, we observed a scarcity of baseline and monitoring data for most nationally designated MPAs and Natura 2000 sites in all EU countries of the Mediterranean and Black Seas. This scarcity of data confirms what has been reported in previous efforts to compile data about MPA effectiveness (e.g., Giakoumi et al., 2017) and small-scale fisheries management in Mediterranean MPAs (e.g., Di Franco et al., 2016). Based on the combined literature review and the survey results, we found that only 16% of the 878 MPAs perform some sort of monitoring activities. Italy was the country that presented the largest amount of available data, whereas no data were retrieved for Maltese MPAs. Both the literature review and questionnaires demonstrated that the vast majority of baseline and monitoring data concern ecological and biological variables while most of the monitoring efforts focus on bony fish. Fewer studies included data related to social, economic, and governance aspects of MPAs which is a common finding in different regions of the world (Giakoumi et al., 2018). We also found that often sampling effort is not based on a robust experimental design, with most data coming from snapshot studies that cover only one year and fail to take into account seasonal variations. This finding is perhaps reflective of the tendency for MPAs to rely on short-term projects and project funding to perform monitoring activities which is then dictated by the funders and/or objective of the research topic and does not pertain to a long-term funding strategy supporting monitoring requirements that would be much more beneficial to the MPA and its management (Bohorquez et al., 2019).

Despite our best efforts to produce the most comprehensive literature review possible (with multiple searches, also in local languages), we acknowledge that the literature review we performed may have some gaps, especially when it comes to grey literature as not all information may be made available online. Often, information collected in monitoring surveys is not published or shared but stays "in-house" with the managers and local authorities. In addition, compartmentalization of information collected by regional and national authorities for the same

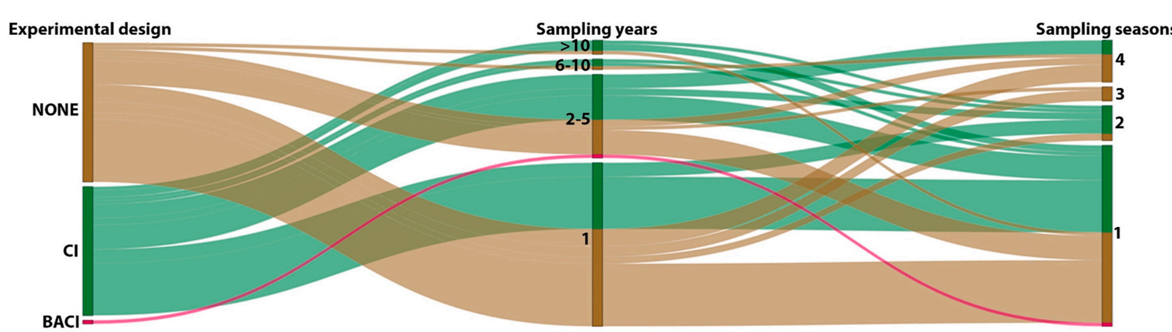

Fig. 4. Sampling design used, and sampling years and seasons covered in studies with ecological baseline and monitoring data (N = 78). CI: Control-Impact; BACI: Before – After – Control – Impact.

MPAs may not be compiled into common databases. These gaps have been partially covered with the questionnaires addressed to MPA authorities and managers, with about 13% of MPAs (123 out of the 878) that replied to our questions. Despite the response rate appearing low, it is difficult to gather this information considering that people are less willing to participate in online surveys and they rather prefer telephone or face-to-face contact (which has significant costs associated given the number of countries and MPAs/MPA authorities to be targeted) (Burgard et al., 2020; Relano and Pauly, 2023). The number of responses is however, in line with similar exercises carried out in other areas (e.g., Batista and Cabral, 2016). In addition, the number of MPAs for which information was gathered is particularly high for the study area considering that a previous assessment carried out a few years ago by the non-governmental organization MedPAN (network of Marine Protected Area managers in the Mediterranean) collected information for 74 MPAs in the entire Mediterranean Sea (including non-EU countries) (MedPAN and SPA/RAC, 2019).

Data collected through questionnaires can have some limitations, particularly those administered online, as they rely on the goodwill of those contacted to complete the questionnaire in the first place and secondly that they fully understand the questions and so answer accurately (Bell et al., 2022). For example, of the 50 links that were provided by respondents in our survey, only four were for reports regarding monitoring. The other links directed us to the MPA webpage, or to the MPA creation decree. This would therefore suggest that there was either misunderstanding or interviewer fatigue. Yet, these limiting factors are common in surveys performed by different organizations in the region. For example, only 46 Mediterranean MPA authorities had replied to the survey conducted by MedPAN stating that they monitor fisheries (small-scale and other) within their MPAs (MedPAN, personal communication).

Furthermore, as already mentioned in the introduction, the majority of the Natura 2000 sites throughout Europe currently lack management plans (Mazaris et al., 2018) and thus such MPA designations are unlikely to have monitoring programs. For example, in Greece, there are over 150 Natura 2000 sites and nationally designated MPAs but less than 10% of these have actual regulations and even fewer are actively managed (Giakoumi et al., 2023). This large number of MPA designations that exist only on paper may in fact distort the percentage of implemented MPAs with active regulations that perform monitoring activities. In fact, out of 123 MPAs that responded to the questionnaire, 65% are performing some sort of monitoring. We can therefore speculate that the results of our survey reflect the situation of the MPAs that are being more actively managed, including a proportion of effectively managed, that would differ substantially from the overall picture emerging from the literature review. This pattern would stress once again, the importance of management capacities in the context of MPAs (Gill et al., 2017).

4.2. Recommendations for improved monitoring and management in MPAs

Besides the need to expand the scope of the assessments carried out in the MPAs from mainly ecological to socio-ecological (Bennett et al., 2017; Mascia et al., 2017), and to ameliorate methods, sampling designs and approaches adopted in assessing socio-ecological outcomes of MPAs (Claudet and Guidetti, 2010; Ferraro and Hanauer, 2014), it is important to reinforce the capacity of MPAs to perform regular monitoring (Gill et al., 2017; Scianna et al., 2019). The following strategies could contribute to increasing the capacity of MPAs to design and implement effective monitoring programs (Fig. 5):

- Ensure that an adequate share of the MPA annual budget is dedicated to the implementation of monitoring activities. This could be reinforced, if national or EU regulations acknowledged the importance of monitoring for the MPA implementation and adaptive management and made such a commitment mandatory for all MPAs. The monitoring program should be designed based on the financial capacity and staff availability of the MPA and include specific measurable metrics (or indices) that will allow the MPAs effectiveness to be monitored over the long-term. In that light, standardization of metrics among different MPAs and countries would be important to allow wider assessments.
- Improve the use of available national funding dedicated to Natura 2000 status reporting to the European Commission by designing monitoring plans and conducting activities with national research centers based on the needs of the Natura managing authorities (when these exist) and sharing the results on publicly available repositories.
- Use of diverse sources of private and public funding including blue carbon and biodiversity offsets (see Bohorquez et al., 2022) to support long-term monitoring activities.
- Establish long-term collaboration between MPA management authorities and researchers/research institutes. For example, the MPA of Torre Guaceto in Italy has been collaborating with the same

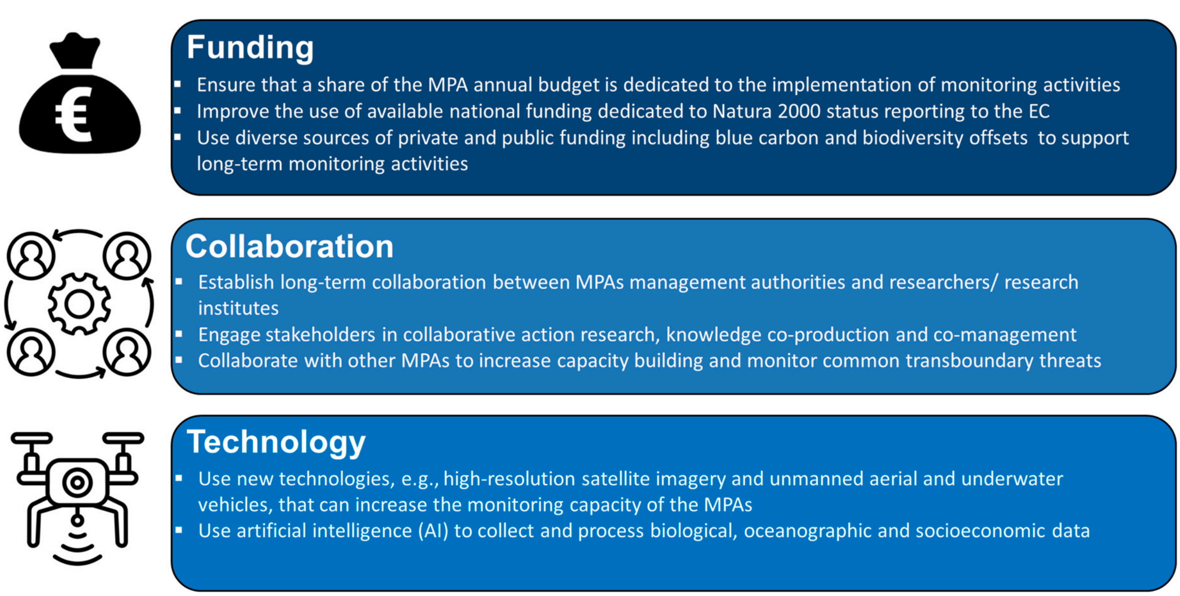

Fig. 5. Strategies for improving the quality of MPA monitoring programs and to increase their capacity to perform monitoring activities.

researchers for over 20 years and consequently has long data series about variables such as the density and biomass of fish, and small-scale fisheries catches within and outside the MPAs' borders (e.g., Claudet and Guidetti, 2010; Russi, 2020). This is the case also in a few other MPAs where long-term data have been compiled (e.g., in Medes, García-Rubies et al., 2013). Both researchers and MPA management authorities can benefit from such collaborations as MPAs are an ideal laboratory for exploring hypotheses related to marine ecosystems and biodiversity.

- Engage stakeholders in collaborative action research, knowledge co-production and co-management. Stakeholders' engagement in MPA management increases trust, builds stewardship, reinforces the acceptance of MPAs by the local community (Di Franco et al., 2016; Masud et al., 2022), and can facilitate the collection of socio-economic data on a regular basis through action research approaches (e.g., Di Franco et al., 2020). For example, by engaging fishers and dive tourism operators in monitoring programs, scientific knowledge is combined with more nuanced local knowledge. It can also make adaptive management easier if stakeholders themselves collect and see the data and see that management changes must be made or that management actions are working (Beier et al., 2017). It can also help identify indicators that are of interest to the local community that will help improve their support/interest in the MPA.
- Collaborate with other MPAs through established networks such as MedPAN (the Network of Marine Protected Areas managers in the Mediterranean) or bilateral agreements to increase capacity building, agree on common metrics for assessing effectiveness, and monitor common threats to marine biodiversity which are transboundary (e.g., plastic pollution; Hatzonikolakis et al., 2022). The creation of a common platform for monitoring data on Mediterranean and Black Seas MPAs with standardized protocols would be a step forward. Some databases, such as MAPAMED (www.mapamed.org) or WDPA (https://www.protectedplanet.net/en/thematic-areas/wdpa?tab=WDPA), provide the foundations for this but the current information included is limited and further efforts are required to increase the usefulness and reliability of these platforms.
- Use new technologies, e.g., high-resolution satellite imagery and unmanned aerial and underwater vehicles, that can increase the monitoring capacity of MPAs with the assistance of researchers who have relevant skills (López and Mulero-Pázmány, 2019) and collect data about human pressures in MPAs that are generally missing (e.g., estimating fishing effort).
- Use artificial intelligence (AI) such as computer vision and deep learning algorithms that can be employed to automatically identify marine life in images, facilitating more efficient assessment. The use of AI can contribute to the collection and processing of biological, oceanographic, and socioeconomic data but should always be done in consultation with scientists and stakeholders to ensure privacy and property rights (see Şeyma, 2023).

Nevertheless, monitoring has little value if the information derived from it is not evaluated and used by the MPA managers and authorities for adopting new management actions or adapting current management practices. Therefore, a further step would be to understand how baseline and monitoring data are being evaluated and used by MPA authorities within a framework of adaptive management. Evidence from different regions of the world show that information generated by monitoring activities is inefficiently used in adaptive management (Addison et al., 2015; Fox et al., 2014; Gill et al., 2017). To avoid key factors that undermine the effectiveness of monitoring programs, Lindenmayer and Likens (2009) suggested an adaptive monitoring framework in which the development of conceptual models, question setting, experimental design, data collection, data analysis, and data interpretation are linked as iterative steps. Furthermore, collaboration and co-production among several actors, including managers, policy makers, scientists, fishers and other stakeholders throughout the process is more likely to lead to actionable science (Beier et al., 2017).

5. Conclusions

Despite its caveats, our study represents a reliable picture of the status of monitoring activities in the EU designated MPAs of the Mediterranean and Black Seas, as it is based on the combination of two distinct scientific approaches: the assessment of scientific and grey literature available online and the administration of questionnaires to MPA managers and authorities. Our thorough search and findings highlight the scarcity of baseline and/or monitoring data regarding various aspects of MPAs across the Mediterranean and Black Seas, and especially for what concerns all the aspects related to the socio-economic dimension of MPAs and their governance. This gap is particularly considerable in MPAs with scarce or absent management. Collaboration of MPA management bodies with researchers/research institutes and key stakeholders, such as fishers, seem crucial for increasing both the quality and quantity of monitoring data. Simultaneously, national governments and/or the EU should continue to provide funding specifically allocated for monitoring activities and assist MPA management bodies in applying adaptive monitoring and management to ensure the best use of monitoring information and the highest return on investment. Ensuring robust data are collected in the MPAs, and that these are then evaluated and used to inform sound and adaptive management is paramount to foster MPAs' effectiveness in delivering social-ecological benefits.

CRediT authorship contribution statement

Sylvaine Giakoumi: Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Katie Hogg:** Writing – review & editing, Validation, Project administration, Investigation, Formal analysis, Data curation. **Manfredi Di Lorenzo:** Writing – review & editing, Validation, Methodology, Investigation, Data curation. **Nicolas Compain:** Writing – review & editing, Visualization, Validation, Methodology, Investigation, Data curation. **Claudia Scianna:** Writing – review & editing, Validation, Project administration, Investigation, Data curation. **Giacomo Milisenda:** Visualization, Investigation. **Joachim Claudet:** Writing – review & editing, Methodology. **Dimitrios Damalas:** Writing – review & editing, Validation, Methodology, Investigation. **Pierluigi Carbonara:** Writing – review & editing, Investigation. **Francesco Colloca:** Writing – review & editing, Investigation. **Athanasios Evangelopoulos:** Writing – review & editing, Investigation. **Igor Isajlović:** Writing – review & editing, Investigation. **Dimitrios Karampetsis:** Writing – review & editing, Investigation. **Alessandro Ligas:** Writing – review & editing, Investigation. **Bojan Marčeta:** Writing – review & editing, Investigation. **Magda Nenciu:** Writing – review & editing, Investigation. **Victor Nita:** Writing – review & editing, Investigation. **Marina Panayotova:** Writing – review & editing, Investigation. **Rosaria Sabatella:** Writing – review & editing, Investigation. **Paolo Sartor:** Writing – review & editing, Investigation. **Vasiliki Sgardeli:** Writing – review & editing, Investigation. **Ioannis Thasitis:** Writing – review & editing, Investigation. **Valentina Todorova:** Writing – review & editing, Investigation. **Nedo Vrgoč:** Writing – review & editing, Investigation. **Danilo Scannella:** Writing – review & editing, Investigation. **Sergio Vitale:** Writing – review & editing, Investigation. **Antonio Di Franco:** Writing – review & editing, Supervision, Project administration, Methodology, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests. All authors reports financial support was provided by European Climate Infrastructure and Environment Executive Agency. 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.

Data availability

The authors do not have permission to share data.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvman.2024.120476.

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