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Can urban Marine Protected Areas (MPAs) generate effective ecological and management outcomes?

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ABSTRACT

The Mediterranean Sea, a hotspot of biodiversity, is impacted by the urbanisation of its coastlines. Marine Protected Areas (MPAs) play a vital role in safeguarding these urban regions and preserving their marine biodiversity. However, despite the urgent need to protect these populated areas, implementation of MPAs under such conditions remains challenging in terms of policy, financing and governance. Twelve MPAs with different urban scores were assessed in the Western Mediterranean Sea. Our objectives were to compare urban and non-urban MPAs in terms of management performance and ecological effectiveness. We analysed the effect of urbanisation on the management of MPAs and then, the effect of urbanisation and management on the variability of ecological outcomes. Our findings were the following: (1) There is no significant difference in management effectiveness between urban and non-urban MPAs, meaning that MPAs can be effectively managed in both contexts; (2) Urban MPAs are ecologically effective, with at least twice as much fish biomass inside the protected areas as outside; and (3) The implementation of an effective management strategy depends on many different factors, such as staff capacity and access to funding. This study thus provides initial insights into the effectiveness of urban MPAs, showing that they have the potential to be managed effectively, with favourable ecological outcomes. In the context of the 30 × 30 global objective, the framework of urban MPAs can serve as a model for developing new MPAs and promoting policies that encourage action, even in degraded urban ecosystems in need of protection.

1. Introduction

Marine Protected Areas (MPAs) constitute a cornerstone of marine conservation, offering the capacity to mitigate biodiversity loss, facilitate the recovery of ecosystem functioning, and safeguard critical habitats, while simultaneously providing significant socio-economic benefits (Ban et al., 2019; IPBES, 2019; Marcos et al., 2021; Sala et al., 2021). The 30 × 30 target adopted during the Convention on Biological Diversity within the Kunming-Montreal Global Biodiversity Framework (CBD, 2022) aims to increase the coverage of protected marine zones to 30 % by 2030. To achieve this goal, countries are establishing numerous MPAs (Gill et al., 2023) rarely evaluating their level of protection or the quality of the protected area (Pike et al., 2024). The designation of protected areas is not always driven by the imperative to safeguard important ecological ecosystems. Instead, areas that are "high and far" from urban centres are often selected (Joppa and Pfaff, 2009), to ensure that human activities will not be disrupted by the introduction of regulations, while at the same time fulfilling political commitments. The 100 largest MPAs, which collectively encompass 90 % of the total global MPA surface area, are predominantly located far from land, in remote and inaccessible regions (Pike et al., 2024). However, biodiversity is most at risk in coastal ecosystems, owing to their proximity to urban centres and the resulting intense anthropogenic pressures. It is precisely these vulnerable where immediate and effective protection measures are most urgently required (Huijbers et al., 2015; Joppa and Pfaff, 2009; Williams et al., 2022). Nevertheless, there is still no formal definition of "urban MPAs", even though numerous research programmes evaluate the impacts of human activities and urban characteristics on marine ecosystems (Marty-Gastaldi et al., 2025a).

The Mediterranean Sea, recognized as a global biodiversity hotspot

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with high levels of endemism (Coll et al., 2010), is increasingly affected by the intensification of coastal urbanization, reaching 512 million inhabitants in 2018 (UNEP/MAP and Plan Bleu, 2020). Even though the demographic context is very diverse from the north to the south of the basin, almost one third of the population of the Mediterranean Sea lives on the coast and 70 % in urban areas (UNEP/MAP and Plan Bleu, 2020). Natural areas are increasingly being replaced by urban development, rendering coastal zone progressively more artificial (Salvati et al., 2014). Considerable urban sprawl can be observed around the major Mediterranean cities (Schneider and Woodcock, 2008) as a result of the growing population (Doignon et al., 2023), especially near the sea (von Glasow et al., 2013). On top of that, the Mediterranean region is one of the world's leading tourist destinations with over 400 million visitors in 2019 (Plan Bleu, 2022; Weston et al., 2019). The widespread human presence along Mediterranean coasts has led to the accumulation and intensification of anthropogenic threats on marine ecosystems (Borja et al., 2024). Among the primary threats are recreational activities and fishing, which exert significant impacts on coastal areas, both within and beyond MPA boundaries (Mazaris et al., 2019). In an effort to counteract these threats, the urban character of several MPAs, particularly in the Western Mediterranean, has become more pronounced and increasingly necessary (Marty-Gastaldi et al., 2025b). Such urban MPAs are commonly associated with densely populated cities or major tourism infrastructure, are highly accessible through multiple modes of transportation, and attract substantial tourist activity (Marty-Gastaldi et al., 2025b, 2025a).

European MPAs covered 15 % of the Mediterranean Sea in 2024 but those with strong protection (full and high) represented only 1.9 % of the MPA area that is, 0.3 % of the European Mediterranean Sea (Aminian-Biquet et al., 2024). MPAs with strict protection, where fishing and other extractive activities are prohibited (i.e. no-take zones), provide greater ecological benefits than MPAs with lower protection (Sala and Giakoumi, 2018). The effectiveness of an MPA in fulfilling its ecological goals depends on a combination of interrelated factors. Habitat complexity and replication, substrate diversity, MPA age and size, along with effective regulation enforcement and adaptive management, are among the key elements that contribute to ecosystem protection and the generation of ecological benefits (Arneth et al., 2023; Claudet et al., 2008; D.A. Gill et al., 2024; Grorud-Colvert et al., 2021; Maestro et al., 2022). Collaborative governance with involvement of stakeholders increases social support and the acceptability of the protected zones (Cadoret and Beuret, 2022; Di Franco et al., 2020; Enthoven, 2025; Gallacher et al., 2016) coupling marine conservation planning with stakeholders' local knowledge (Boubekri et al., 2023). Yet, as Gill et al. (2017) noted, adequate staff and budget are also important to achieve ecological outcomes.

MPAs must be effective in achieving both socioeconomic and ecological objectives, yet assessing their effectiveness is often challenging. Some research defines management effectiveness as the way in which MPAs accomplish their objectives (Hockings et al., 2006), and others define effectiveness as "optimally sited, under strict protection, well managed and adequately resourced" (Arneth et al., 2023). The effectiveness or the success of MPAs can be evaluated by considering the accomplishment of the goals. These goals may be ecological, socioeconomic or cultural and can be assessed with several indicators (Ervin, 2003; Leverington et al., 2008; Maestro et al., 2022; Stolton et al., 2007). The effectiveness can therefore be measured by the "Management performance" which depends on both the objectives and the strategy employed by the management body to achieve them. Scianna et al. (2019) developed the Management Performance Index (MPI), to assess the management performance of MPAs which influence the management effectiveness. The MPI takes into consideration the vision and the mission of the MPA, formalized through the cultural and goal index (CGI). The strategies implemented by the management body are assessed by the strategy index (SI), which is itself based on four components that are used to evaluate activities such as enforcement, environmental education, monitoring and management of the data.

1.1. Research question and objectives

In this research, we hypothesised that protected areas near urban areas — i.e. areas that are more accessible — are subjected to increased human activity, making access to their resources easier and hence had greater pressure on resources, leading to decreases in fish species targeted by commercial and recreational fishers. At a global scale, terrestrial protected areas (PAs) are often located in remote, elevated, and biased to greater distance from major roads and cities. IUCN Categories I and II are more distant, biased towards steeper slopes and higher elevations than Categories III and IV, which are often closer to cities and more accessible—often receive less intensive management (Joppa and Pfaff, 2009). MPAs are typically established in places where implementation is logistically easier and generates fewer conflicts (Devillers et al., 2015). Similarly, when examining MPAs globally, Mouillot et al. (2024) investigated the socioeconomic and environmental conditions associated with MPA establishment. Accessibility is a key predictor of MPA occurrence: less accessible marine areas are more likely to be protected. This rationale, which echoes Joppa and Pfaff (2009) conclusion, is "the majority of protected areas are biased towards greater distance from roads and cities". Thus, less accessible areas are expected to have greater protection." These studies therefore highlight significant barriers to establishing MPAs along densely populated coastlines, where human density is high. However, this conclusion must be understood in relation to scale: global analyses are typically conducted using 10×10 km grid cells, with accessibility calculated as travel time from marine grid cells to the nearest populated pixel within a 500 km radius (Maire et al., 2016). At finer regional scales, such as the Mediterranean, these dynamics may differ substantially.

Based on a recent study that specifically examining the occurrence of MPAs in urban context within the Mediterranean region (Marty-Gastaldi et al., 2025b) as well as the study of Ventura et al. (2024) on urban MPAs effectiveness, we put forward the following scientific hypotheses: MPAs located in urban contexts can perform as well as, or even better than, their non-urban MPAs. We argue that in order to mitigate the intense pressures of human activities, urban MPAs must reach the same or higher levels of management effectiveness than non-urban MPAs to achieve goals. Therefore, our central hypothesis is that MPAs with a high protection status and active management can be highly effective in both ecological and managerial terms, even in urban environments, across different MPA types (urban versus non-urban). To test our hypothesis, we employed the Management Performance Index (MPI) and the Ecological Management Effectiveness (EME) and compared them in urban and non-urban MPAs setting. We analysed how urban context and management influence the variability of ecological outcomes, and how urban context affects MPA management.

2. Methodology

2.1. MPA selection and study area

We considered twelve MPAs located in the western Mediterranean Sea (Fig. 1) selected from the 20 MPAs assessed by Marty-Gastaldi et al. (2025b). Two key criteria informed the selection of MPAs: presence of a city and the existence of both a management plan and an established team to implement it. Although MPAs may include varying levels of protection, the next selection criterion focused on those that encompass at least one no-take zone being at the implementation or actively managed stage of development (Grorud-Colvert et al., 2021). Finally, the selected MPAs were chosen to be as comparable as possible with respect to factors other than urban status, in order to minimize potential sources of variation.

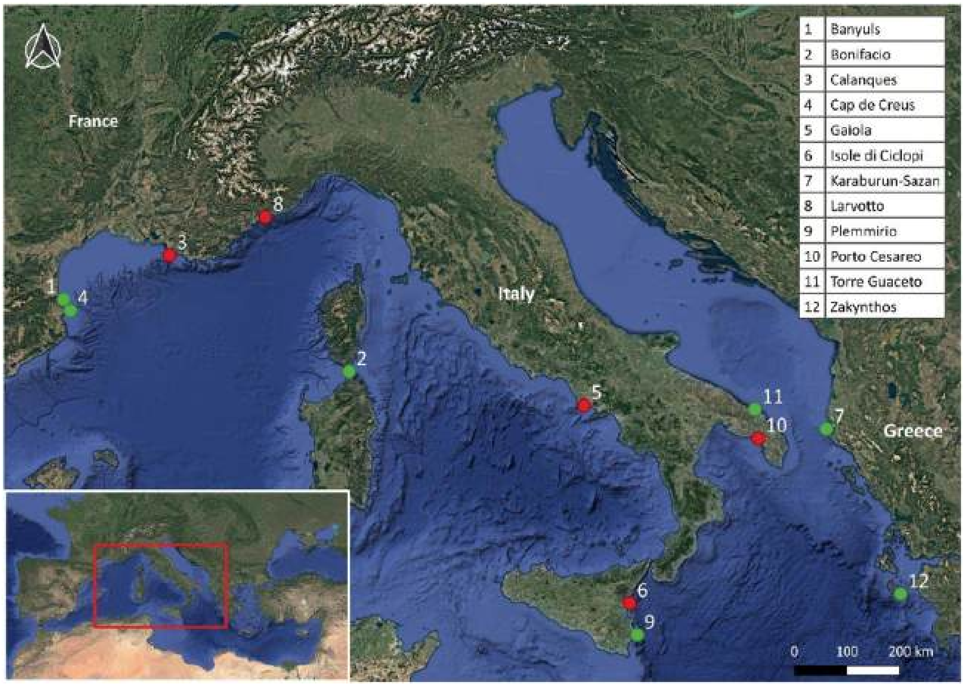

Fig. 1. Location of the Mediterranean marine protected areas (MPAs) included in the present study. Red dots indicate urban MPAs and green dots indicate non-urban MPAs. For details on each MPA see Table S1 in Supplementary Material 1. Map was generated using the open source QGIS software version 3.36.2. Base layer: Google Satellite (2024); EPSG: 3857 (http://qgis.org).

2.2. Data collection

2.2.1. Urban indicator

In our previous study, Marty-Gastaldi et al. (2025b) defined an urban indicator based on nine variables derived from population metrics and satellite images tools: population size, population density, level of tourism, transport access, footpath access, coast access, distance, land cover and infrastructure variables. For each MPA a score from 0 to 5 was assigned for each variable. Then, an overall average was calculated to determine a final score for each MPA, namely the urban indicator, which is intended to measure the level of urbanisation of MPAs (Marty-Gastaldi et al. 2025b). Urbanisation is a process of urban development and population concentration in cities. In this research, we named urbanisation the level of urban context related to the MPA. The calculated urban indicators of the selected MPAs are depicted in Table 1. The indicator is derived from variables that measure: population – "Population size" and "Population Density"; accessibility of the MPA from the city – "Transport Access", "Footpath Access", and "Coast Access"; and attractivity – "Distance", "Infrastructure" and "Tourism".

2.2.2. Management performance indicator

To assess the management effectiveness of each MPA, we used the methodology developed by Scianna et al. (2018), which uses Organization Science (OS) as a framework to assess MPA management performance. These authors define a management performance index (MPI), derived from a hierarchy of other indexes (Fig. 2). $MPI=\sqrt{((CGI^2+SI^2)/2)}$, the quadratic mean of the culture and goal index (CGI) and the strategy index (SI). The strategy index (SI) is the average of the environmental education index (EEI), the enforcement index (EI), the monitoring index (MI) and the management data index (MDI) and ranges from 0 to 8; $SI=(EEI+EI+MI+MDI)/4$.

These indexes were developed to quantify different aspects of management performance and consequently determine its effectiveness. To obtain the necessary data, questionnaires were administered during structured interviews with managers and staff members in each MPA. Data collection also involved consulting documents such as management plans and internal reports. Each MPA has a management plan or an equivalent document that outlines the intended management actions and should be implemented. Questions and scoring system were adapted from Scianna et al. (2018) and can be found in Supplementary Materials

Table 1
Urban indicators for each MPA. The urban indicator can range from zero to five (maximum value).

MPAs	Country	Urban indicator
Banyuls	France	2,28
Bonifacio (France)	France	2,11
Calanques (France)	France	3,44
Cap de Creus	Spain	1,94
Gaiola	Italy	3,17
Isole di Ciclopi (Italy)	Italy	2,94
Karaburun-Sazan	Albania	1,56
Larvotto	Monaco	3,67
Plemmirio	Italy	2,00
Porto Cesareo	Italy	3,39
Torre Guaceto	Italy	1,89
Zakynthos	Greece	2,06

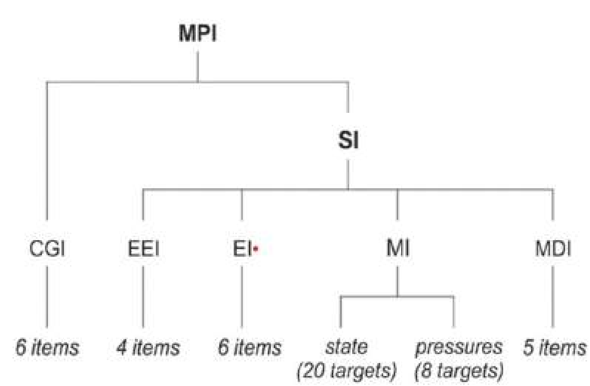

Fig. 2. The hierarchy of the indexes that contribute to the MPI.

1 (Text S1) and Supplementary Materials 3 (sheet "scoring system"), respectively.

Data collection was carried out between November 2023 and May 2025. Twelve MPAs in six countries were visited in field trips totalling 62 days. Two to five days were spent in each MPA to meet the management team, manager, and local stakeholders, and to visit the MPA by land and/or sea. Diving was performed wherever possible. Travelling around each MPA was important to provide a finer understanding of the local specifics, evaluate the situation on the ground, assess the geomorphology of the site, and meet people to gain an insight into the social context.

2.2.3. Ecological indicator

Ecological data were collected thanks to the director or the scientific manager of each MPA. The collection was successful for nine of the twelve MPAs The collection was successful for nine of the twelve MPAs (all except Isole dei Ciclopi, Porto Cesareo, or Karaburun–Sazan). Due to the lack of scientific publications on the ecological effectiveness of some MPAs, grey literature such as MPA activity reports and unpublished data were used (details are available in Supplementary Materials 1, Text S2 & Table S2). Ecological data from within and outside the MPA – similar habitats on rocky substrates – were collected wherever possible; however, when this data was unavailable, data from the most and least protected areas (where fishing is prohibited or regulated/authorised, respectively) were used instead. Detailed information on the location of the sites, type of habitats and methodologies can be found in Supplementary Materials 1 (Text S2 & Table 2) and Supplementary Materials 3 (Sheet 4, "Ecological data"). The ecological indicator used in this study is the log-response ratio (*RR*) for fish biomass, widely used in the literature as a proxy to evaluate the ecological management effectiveness (EME) of MPAs in a meta-analytical concept (Arneth et al., 2023; Di Lorenzo et al., 2020; Gill et al., 2017; Horta e Costa et al., 2025; Scianna et al., 2019; Zupan et al., 2018). The present study relied on biomass data for all fish species because the objective was to assess the production of any ecological benefits, rather than focusing exclusively on commercial or targeted species to evaluate a potential reserve effect or the restoration of lost ecosystem functions and attributes (e.g. top down control by top predators). In other words, this approach provides an overview of how the fish biomass of rocky reef assemblages may respond to protection in urban MPAs, serving as a proxy for overall ecological benefits. All MPAs considered here employ Under-Water Visual Census (UVC) methods (Harmelin et al., 1985) to monitor fish assemblages; however, only some extend to commercial species with heterogeneity in sampling protocols (see Supplementary Materials 3, Sheet 4, "Ecological data"). Consequently, the inclusion of all fish species reflects the methodological limitations associated with using compiled, externally generated datasets rather than data collected directly by the authors. Thus, since the biomass data were extracted from multiple studies, the log response ratio was used to reduce the effects of extreme values, stabilise variability and render comparisons more robust. It was estimated as follows (Hedges et al., 1999):

$$RR = \ln\left(\overline{X}_T / \overline{X}_C\right)$$

where $\overline{X}_T$ and $\overline{X}_C$ are the mean biomass measurements inside and outside the MPA (control), respectively. The variance (v_{RR}) associated with the estimated *RR* was calculated as:

$$v_{RR} = \frac{S_T^2}{N_T X_T^2} + \frac{S_C^2}{N_C X_C^2}$$

where S_T and N_T are the standard deviation and the number of biomass observations, respectively, inside the MPA, while S_C and N_C are the corresponding values outside the MPA.

The corresponding 95 % confidence interval of the *RR* was calculated as follows:

$$\left[RR - z_{\alpha/2}\sqrt{v_{RR}}; RR + z_{\alpha/2}\sqrt{v_{RR}}\right]$$

where $z_{\alpha/2}$ is the $100(1-\alpha/2)$ % percentile of the standard normal distribution and α is the confidence level. If the 95 % confidence intervals overlap with zero, then the calculated *RR* values are not statistically significant and the difference between fish biomass inside and outside the MPA is not significant. Positive *RR* values indicate biomass levels that are higher in the MPA than in the corresponding unprotected area.

2.3. Data analysis

All statistical analyses were conducted in R v4.4.1 (http://www.R-project.org; R Core Team, 2024).

To assess the influence of urban context on the management effectiveness, we performed the PERMANOVA analysis (Anderson, 2001). PERMANOVA tests based on Euclidean distance matrices were employed to evaluate the impact of urbanisation (with all urban variables and with the MPI scores) and management on the ecological effectiveness variable. To assess the influence of management on the ecological effectiveness, we performed linear models (LM) after checking if data are violating normality assumption.

3. Results

3.1. Urban MPAs can be as effective as non-urban MPAs in terms of management

The results of the PERMANOVA test indicate that the difference between urban and non-urban MPAs in terms of management is not significant ($p = 0.954$, Supplementary Materials 2, Table SM1, SM2). In other words, urban context does not significantly influence management effectiveness.

The management performance index (MPI) for all the MPAs ranged from 3.78 to 7.63 (Fig. 3a), with an average of 6.1. The MPA with the lowest management score is Isole di Ciclopi with an MPI of 3.78. The most effectively managed MPA is Banyuls, with a score of 7.63.

A variance in management scores is observable within each MPA category (Fig. 3, a & b). Urban MPAs can achieve a high management score, as evidenced by Gaiola with a score of 7.37/8, or demonstrate suboptimal management, reflected in Isole di Ciclopi with a score of 3.78, which is the lowest among the MPAs examined (Fig. 3a). Similarly, non-urban MPAs have the potential to be managed very effectively, for example Banyuls, noted above as the most effectively managed MPA with a score of 7.64/8, but some are less well managed, for example Karaburun-Sazan, which received a score of 4.29. The analysis revealed no significant differences in the mean of all MPA management index across the two urban categories (Student pair-wise, not significant p-values, Supplement Materials 2, Table SM3; Fig. 3b). All urban MPAs (with the exception of Isole di Ciclopi) exhibit high MPI values, ranging from 5.72 to 7.37. According to the MPA index profiles, there does not appear to be a specific management strategy profile corresponding to each level of urbanisation (Fig. 4). For the non-urban MPAs, the IEE score ranges from 4 to 8, with excellent involvement by the management team in environmental education in the Zakynthos and Banyuls protected areas. The management of data of non-urban MPAs is satisfactory, with an MDI score ranging from 5 to 8. However, data collection is not always optimal in non-urban protected areas, with scores of 2 in Karaburun-Sazan and 3 in Plemmirio. The remaining non-urban MPAs have established collaborative relationships or are actively engaged in the monitoring of marine ecosystems and activities of the protected area, with MI scores of between 5 and 7. Enforcement in the area is not always guaranteed: the EI score can be as low as 3 (Cap de Creus). A high score, such as 7, reflects the presence of a dedicated surveillance team or staff, as well as possibly effective collaboration with the police and a real

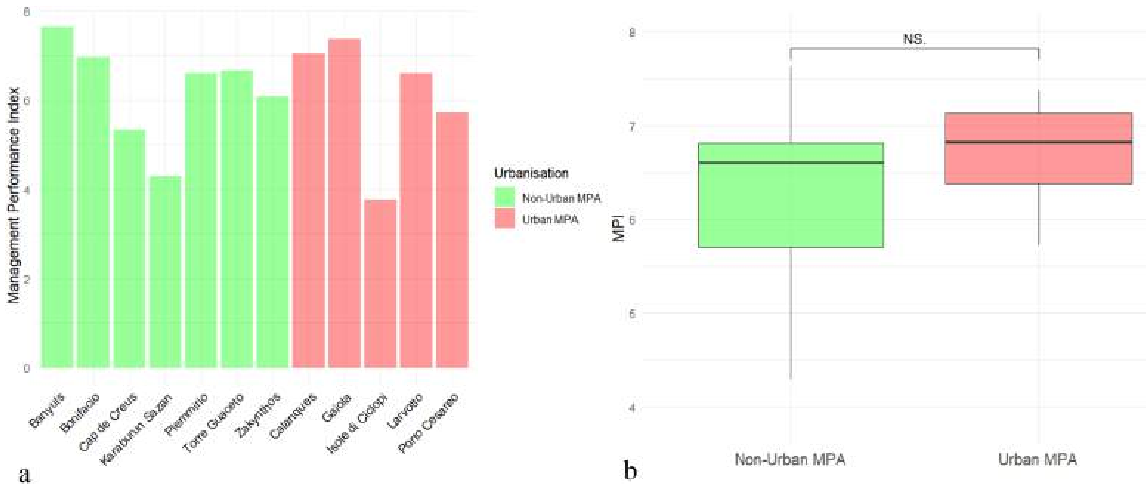

Fig. 3. Management Performance Index (MPI) by level of urbanisation: non-urban MPA in green and urban MPA in red. a) Bar graph MPIs for the MPAs grouped by level of urbanisation; b) Boxplots of MPIs grouped by level of urbanisation. No significant difference exists between non-urban MPAs and urban MPAs.

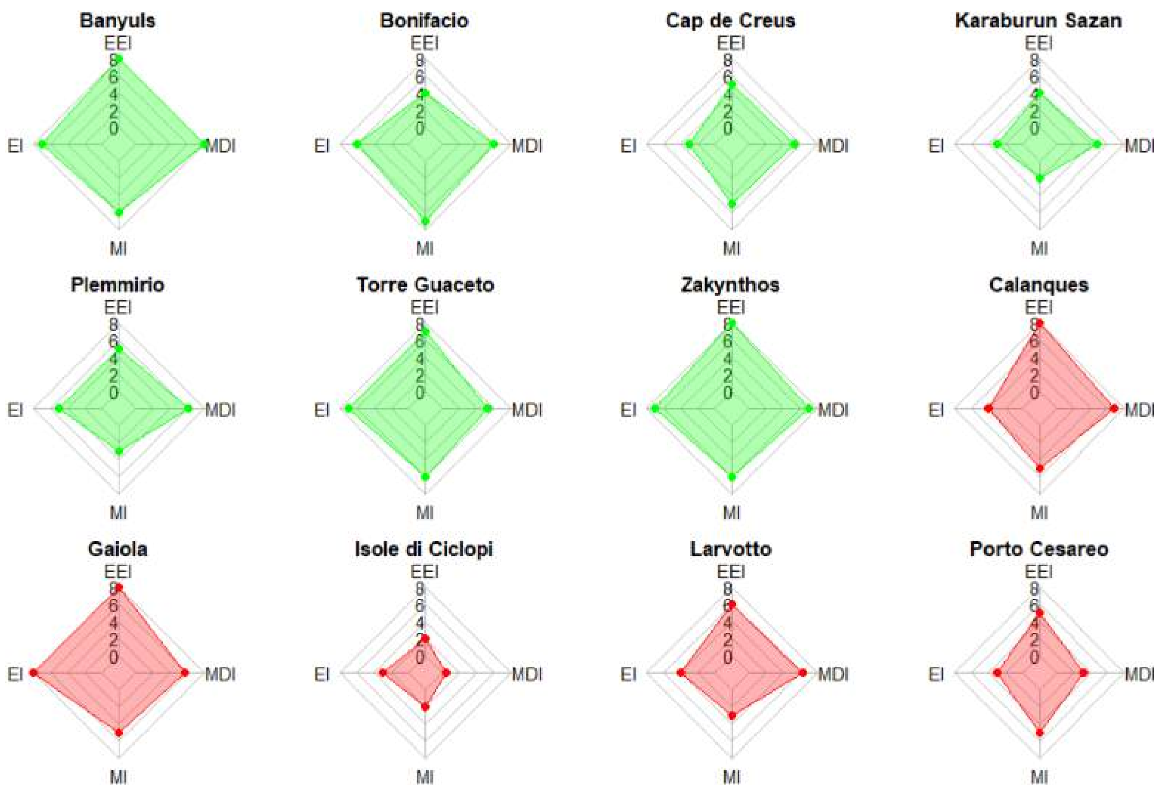

Fig. 4. The management profile of each MPA based on the four indexes: Environmental Education Index (EEI), Management Data Index (MDI), Monitoring Index (MI) and Enforcement Index (EI). The colours represent the level of urbanisation: non-urban MPAs (green) and urban MPAs (red).

willingness to monitor the MPA. The IEE score for urban MPAs generally ranged from 5 to 8, indicating an overall interest in environmental education. The exception was Isole di Ciclopi, which received a score of 2, indicating limited public awareness activity. Management data is, on average, less effectively dealt with than in non-urban MPAs, with heterogeneity ranging from 0.5 (Isole di Ciclopi) to 6.75 for the Calanques MPA. The enforcement of protected areas in the urban environment is found to be heterogeneous, with an optimal enforcement and surveillance effort for Gaiola (score of 8), average score for Calanques and Larvotto (4), and low scores for Porto Cesareo and Isole di Ciclopi (3). The enforcement index is, on average, lower in urban MPAs (mean=4.4) than in non-urban ones (mean = 5.43) but without significant difference (Table SM3, Supplementary materials 2).

3.2. *Urban MPAs can be as ecological effective as non-urban MPAs*

In all the MPAs examined, the log response ratio (RR) was positive, and just one 95 % confidence interval overlapped with zero (Zakynthos) (Fig. 5). Urban MPAs show a biomass log response ratio between 0.5 and 1. The biomass within the urban protected area is 2.04, 2.28 and 2.35 times higher than the biomass in the external unprotected area for Gaiola, Calanques and Larvotto, respectively. This finding indicates that the protective benefits of these urban areas are likely to be substantial. For non-urban MPAs, the ecological effectiveness varies significantly

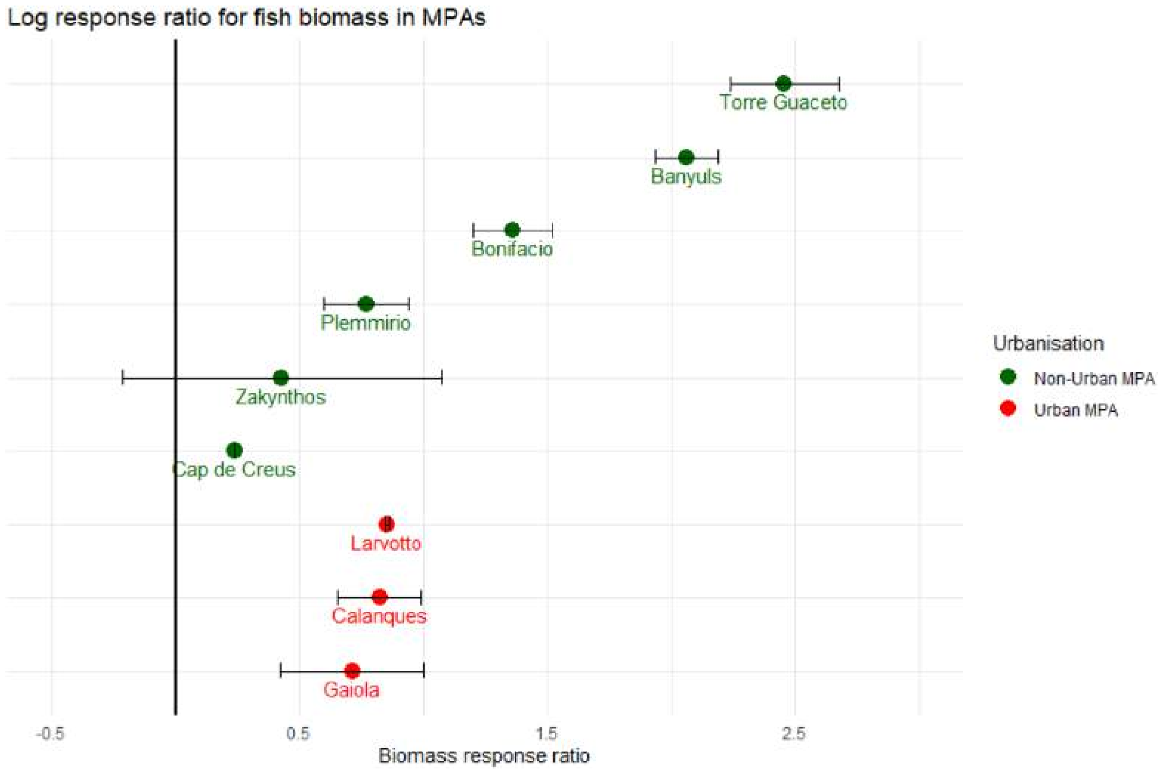

Fig. 5. Log-response ratios and the corresponding 95 % confidence intervals for total fish biomass in the protected areas versus control areas.

between sites, with a log response ratio ranging from 0.24 (Cap de Creus) to 2.46 (Torre Guaceto) (Supplementary Materials 3, sheet “Scores”). An examination of the available data indicates that the fish biomass in the most protected area of Cap de Creus is 1.28 times greater than in the unprotected area, corresponding to an increase of 28 %. In contrast, the Torre Guaceto reserve was found to have a fish biomass more than 11 times greater inside the no-take zone than outside the reserve. Zakynthos has a positive mean ratio, but some results of log response ratio can be negative, indicating the fish biomass outside the MPA may be equal to or greater than that inside. The results of the PERMANOVA test indicate that the differences between urban and non-urban MPAs in terms of ecological effectiveness is not significant ($p =$ 0.542, Supplementary Materials 2, Table SM4). In other words, urban context does not have significant effect on ecological effectiveness.

The analysis revealed no significant difference in the mean of MPA ecological effectiveness across the two categories: non-urban MPA and urban MPA (Fig. 6; Student test, p-value= 0.227, Supplementary Materials 2, Table SM5). An important variance seems to exist in the data group Non-urban MPA: the biomass log-response ratio can be very high (Torre Guaceto) but the measurements of fish biomass inside and outside the reserve can be fairly close (Cap de Creus).

3.3. Relationship between management effectiveness and ecological effectiveness

Linear regression analysis demonstrates an absence of significant relationship between biomass ratio and management performance (Fig. 7) (p-value = 0.132, Supplementary Materials 2, Table SM6), also when the urban indicator is added on the linear regression model (p-value = 0.054, Supplementary Materials 2, Table SM7). The results of the PERMANOVA test indicate that the urban indicator and management effectiveness do not influence ecological effectiveness ($p = 0.127$, Supplementary Materials 2, Table SM8).

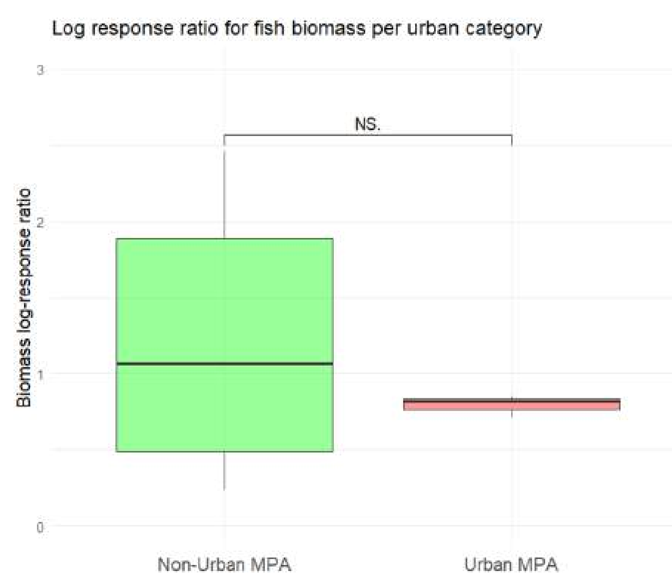

Fig. 6. Biomass log-response ratio per level of urbanisation. No significant difference exists between non-urban and urban MPAs.

4. Discussion

4.1. Urban MPAs can be as effective as non-urban MPAs in terms of management

Our findings demonstrate that MPAs can achieve high management performance index (MPI) scores irrespective of whether they are situated in urban or non-urban contexts. This result supports our hypothesis that urban MPAs require the same level of management effectiveness as non-urban MPAs in order to mitigate the intense pressures of human activities and to achieve conservation objectives in the densely

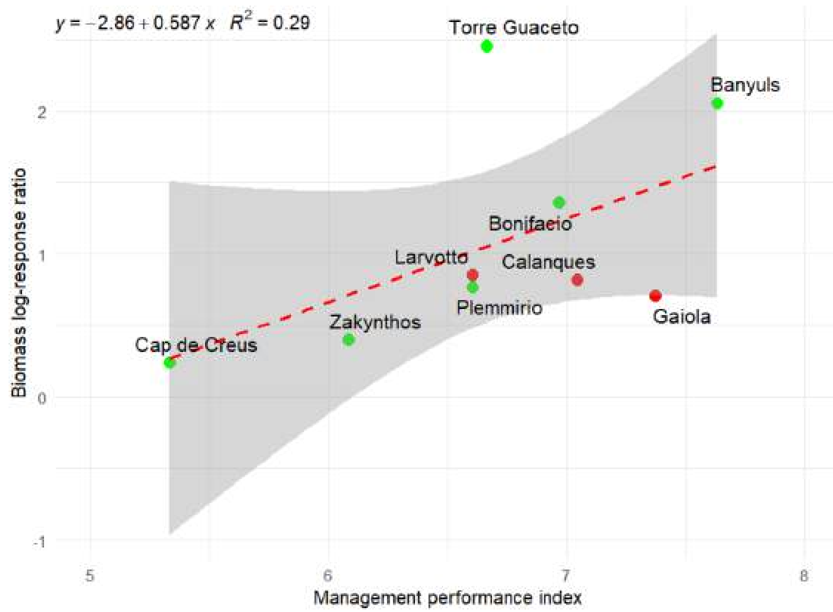

Fig. 7. Linear regression of biomass log-response ratio on Management Performance Index (MPI).

populated Mediterranean Sea.

Applying the MPA Guide (mpa-guide.protectedplanet.net) to the 12 MPAs, Isole di Ciclopi is "Designated", Cap de Creus and Karaburun-Sazan are "Implemented" and the others are "Actively managed". Isole di Ciclopi lacks monitoring and ecological data due to the insufficient budget and staff capacity to achieve its goals, preventing ecological outcomes assessment and effective enforcement implementation of protected areas regulations (Gill et al., 2017; Maxwell et al., 2020). To reach "actively managed", it needs enabling conditions to be met: "Long-term political will and commitment"; "Sufficient and properly organized staffing and funding"; and "Compliance and enforcement" to cite a few. Cap de Creus MPA currently fails to meet the conservation objectives of the management plan, due to the poor implementation of management measures for the marine part of the park. Nevertheless, a new management plan with new legislation and regulation of activities (including mooring zones, fishing bans, AI-powered camera surveillance and research tools) is being developed for implementation in July 2025. Cap de Creus needs to meet enabling conditions to progress to "actively managed": a "stakeholder engagement plan, compliance and enforcement"; "ongoing efforts to build trust, strong local leadership, and ongoing partnerships with local users especially fishermen". Karaburun-Sazan's team is highly engaged in the protection and making significant efforts, but funding financial resources and deficit of personnel (including divers) undermine implementation. To become "actively managed", Karaburun-Sazan needs "sustainable financing", and "an ongoing monitoring, evaluation and knowledge sharing on the ecological data". Literature shows implemented MPAs (here Cap de Creus and Karaburun-Sazan) have worse ecological outcomes than actively managed ones (Fig. 5) (Horta e Costa et al., 2025).

The absence of differences in management performance between urban categories and the variability present within the two categories themselves (Fig. 3a & b), mean that the management is influenced by several factors:

- Differences in the objectives of the MPAs

The objectives of marine protected areas (MPAs) may differ (see Supplementary Material 1, Table S1), leading to the implementation of distinct management measures. The Zakynthos Marine Park was established in 1999 with the primary objective of protecting turtles and preserving the nesting sites in Laganas Bay during the nesting season, which runs from May to October. The management measures implemented are therefore temporary: the no-take zone (A) is closed to professional fishing and shipping zones for six months of the year. Park staff patrol the beaches day and night to raise tourist awareness, and surveillance focuses mainly on boat speeds. In zone B, where professional fishing is regulated for six months, park staff remain present year-round to ensure the beaches stay suitable for turtle egg-laying. Laganas Bay, with its shallow, sandy seabed and sandy coastline, offers ideal conditions for turtle nesting (Dimitriadis et al., 2018). It is one of the most important nesting sites in the Mediterranean region, particularly for the *caretta* species (Simantiris et al., 2024). In another context, Bonifacio has decided to place greater emphasis on monitoring (MI = 7), devoting more time and staff to data collection than to environmental education (EEI = 4, with no reserve staff specifically dedicated to this activity). Conversely, Banyuls teams have demonstrated a significant commitment to environmental education (EEI = 8), evidenced by the establishment of an underwater trail at Peyrefite beach. The reception point is open all summer with seasonal employees dedicated 100 % to this public awareness activity, with free activities for children.

- Differences in institutional governance between countries

The present study focuses on European Union countries, or candidate countries, that demonstrate similar modes of governance. 11 MPAs out of 12 follow a "top-down" profile, meaning that directives come from the government, which generally initiates the creation of the MPA and is primarily responsible for its management. However, it should be noted that the institutional governance varies significantly between countries, and we believe that these institutional differences affect the quality of management and its implementation, as well as access to the necessary resources for proper functioning. In both Spain and France, the designation of MPAs has been integrated into the national or regional institutional framework financed by government. The Larvotto MPA in Monaco is managed by the Monegasque Association for Nature Protection (AMPN). In Italy, marine protection is governed by Law 394 of 1991, which specifies that MPAs are managed by a consortium of one or more of the following entities: public authorities, a public research institute and an environmental NGO. The problem with this law is the limit on employability and funding, which are annually proscribed by the Ministry of the Environment. Another salient issue concerns the surveillance of protected areas; this function is performed by the police forces (i.e. the carabinieri, state police, coast guard or local police) and not by the MPA management team. However, in practice, it is easy to see how this law is being circumvented: either there is a collaboration between the management team and the police but is not actively implemented or there is no collaboration, and the management team lacks the necessary resources for effective surveillance. In Albania, the case of Karaburun-Sazan is distinctive due to the country's historical and cultural context. The establishment of environmental regulatory frameworks for protected areas in Albania is relatively recent: 2015. Finally, in Greece, in contrast to the other 10 MPAs, the Zakynthos Marine Park, was governed by a "bottom-up" system, characterised by local management, for a period of two decades. Since 2020, everything has been centralised under the umbrella of the Natural Environment and Climate Change Agency (NECCA) in order to harmonise the 24 Greek protected areas. It is evident that these institutional governance differences do not provide MPAs with an equal opportunity for success.

- Access to financial and human resources

In the "Organisation Science" framework, organisational size is measured by the number of employees available to carry out the work of the company. In their study, Scianna et al. (2019) adapted this tool to apply it to MPAs, defining an organisational size (OS) score as the ratio of full-time equivalent employees to the surface area of the MPA. There is no significant difference in OS scores between the two categories of urban and non-urban MPAs due to the large variance within each category. The high OS score for urban MPAs can be explained by the size of the protected areas: urban MPAs are mostly small, apart from the Calanques National Park and Porto Cesareo. For instance, Gaiola has five Full Time Equivalent (FTE) employees – the equivalent number of employees working full-time in an organization – for a protected area of 41.6 ha, resulting in an OS of 12. In contrast, 56 FTE employees are employed in Calanques, for an area of 141,200 ha: the OS score is 0.04. Enough people working in the MPA is very important for the successful implementation of management plans and the application of the law. This result is very well described in the literature (D.A. Gill et al., 2024) and represents one of the key conditions for an effective MPA (Grorud-Colvert et al., 2021; Horta e Costa et al., 2025). If the MPA management team cannot employ enough people, monitoring and enforcement activities are carried out in collaboration with local services such as the local police or a consultancy firm. According to our feedback on the fieldtrip and the discussions with MPA employees, some MPAs such as Karaburun-Sazan, do not have enough staff or the staff do not have the necessary skills to carry out all the tasks of the protected area. The management body of Karaburun-Sazan MPA is the Regional Administration of Protected Areas (RAPA) Vlora where the team manages several other protected areas within the Vlora Region. To compensate this staffing gap, Karaburun-Sazan MPA is co-managed by RAPA and FlagPine NGOs.

These outcomes clearly demonstrate that management differences between MPAs are not necessarily due to the urban context, but rather to various other factors that are crucial for effective management. Monitoring depends more on the level of management put in place than on the distance to the city or the level of urbanisation. Whether urban or not, an MPA can be well managed and therefore monitor its area effectively. Provided that it has sufficient material, human and financial resources, and good cooperation with the police force (Giakoumi et al., 2024; D.A. Gill et al., 2024), an MPA will carry out surveillance, monitoring and education regardless of its urban context.

It is important to highlight that the management of a protected area can be very effective with high MPIs observed (an average of 6 for all MPAs in our study), even though some have a lower effectiveness of less than 5. Therefore, in conclusion, the absence of a significant difference in management performance between urban and non-urban MPAs demonstrates that management effectiveness can be high regardless of urban context. These new findings suggest that MPAs can be developed in urban contexts if the necessary conditions are met (Gill et al., 2017; D.A. 2024; Grorud-Colvert et al., 2021; Horta e Costa et al., 2025).

4.2. Urban MPA can be as ecological effective as non-urban MPA

Our results show that urban MPAs are ecologically effective: fish biomass was on average twice as high as in control areas (Fig. 5). These findings confirm our hypothesis: if the MPA has a high protection status and is actively managed, it can respond positively to the protection with ecological benefits. This ratio is higher than the global average of 1.6 reported for 218 MPAs by Gill et al. (2017). Urban MPAs in the Mediterranean Sea are comparable to the global mean. A comparison with similar work by Horta e Costa et al. (2025) is not possible due to the methodological differences. They focused on the biomass of fish targeted by fisheries, whereas we considered the biomass of all fish species. This is one of the limitations of our study.

Non-urban MPAs also showed positive responses to protection in 5 of 6 MPAs. The exception is Zakynthos National Park, primarily aimed at sea turtle conservation with seasonal no-take area: the MPA does not demonstrate a positive response to ecological effectiveness based on fish biomass (Dimitriadis et al., 2018). Yet according to Dimitriadis et al. (2022, C. 2024), other exogenic threats such as invasive species may significantly challenge conservation effectiveness as they are capable of causing ecosystem wide ecological changes, degrade rocky reef state and induce cascading effects towards the diminishing of species diversity and biomass. As the eastern most MPA in this study, Zakynthos is more prone to such threats. However, considering the current pace of warming in the Mediterranean Sea and the rapid westward expansion of invasive species (e.g., Lessepsian immigrants) (D'Amen and Azzurro, 2020; Katsanevakis et al., 2014), this threat may also be relevant soon to MPAs in the western Mediterranean.

In urban context, MPAs seem to face more challenges to be effective than those located in non-urbanised areas, probably due to higher human presence and activity. The mere presence of humans has an impact on the environment (Coll, 2020) or low-impact uses such as snorkelling affect fish and algae communities (Claudet et al., 2010). Urban areas represent a concentration of human activities that can have a multitude of impacts. In the Mediterranean, recreational activities are widespread and economically important, as it is a global tourist destination for water sports. Spain, France and Italy host major ports for pleasure boats, (super)yachts and cruise ships, which are highly harmful to the environment and our health (Lloret et al., 2021). All urban MPAs studied are near marinas or in dense maritime routes. Recreational boating caused significant impacts – anchoring in Posidonia (Lloret et al., 2008; Tursi et al., 2022), noise disturbance (Di Franco et al., 2020; González Correa et al., 2019), antifouling products, transport of exotic species (Ferrario et al., 2019) and water, air and waste pollution (Carreño and Lloret, 2021). To limit damage to the environment and economic development, management measures can be created such as defining maximum boat numbers, especially in MPAs during the summer months (Venturini et al., 2016), and creating designated anchorage areas in MPAs and along the coastlines of popular areas. These pressures mainly affect habitats, while recreational fishing has a direct impact on fish populations (Prato et al., 2016). This activity is more intense in urban areas, although it depends on the habits and behaviours of the local community (Cambra et al., 2021). Recreational fishing can be done from the shore, from a boat or by spearfishing. Studies, although marginal due to the complexity of data collection, show that Mediterranean recreational catches seem to be comparable to or even higher than commercial artisanal fishing (Ben Lamine et al., 2018; Font and Lloret, 2014; Pranovi et al., 2016).

A comparison of authorised activities in urban and non-urban MPAs was inconclusive, as regulations depend more on protection status than on urban context. In Italy, MPAs are uniformly (at least those analysed in this study) divided into three zones: A (no-take/no-go); B (regulated fishing), and C (less restrictive fishing). In France, however, rules vary between MPAs type (Supplementary Materials 3, sheet "activities"). For example, diving is allowed in the no-take zone of the Calanques (urban), but prohibited in highly protected zone of Banyuls and Bonifacio (non-urban), These differences reflect protection objectives rather than urban context. National parks in France integrate public access and "cultural heritage" with conservation, which explains such allowances (Calanques National Park, 2025). Moreover, even MPAs with the same protection status may apply different rules, as management is locally autonomous. Each protected zone in France has its own management approach, characterized by an autonomous decision-making structure. As a result, this autonomous management of areas engenders flexibility and adaptability in response to novel challenges over time. It is this highly local, field-connected and adaptive management approach that makes it effective. This adaptive governance enhances effectiveness, as illustrated by the Calanques, which introduced a reservation system in 2022 to limit summer overcrowding at Sugiton (Lavaud and Robert, 2023; Robert et al., 2023).

The ecological effectiveness of MPAs also depends on habitat type, replication and complexity (e.g. (Clausius et al., 2025; Ventura et al., 2024). In the Mediterranean context, for example at Zakynthos Marine Park, the type of habitat can exert a more pronounced influence than protection level on fish biomass, community structure, and functional diversity, while habitat complexity has been recognized as a key factor in the recovery of degraded fish biomass in no-take zones across several Mediterranean MPAs (Di Franco et al., 2021; Dimitriadis et al., 2018). Effectiveness of MPAs is also influenced by the age and size of no-take zones (Claudet et al., 2008; Di Lorenzo et al., 2014; Guidetti and Sala, 2007; Scianna et al., 2019; Vandeperre et al., 2011) with highly enforced and small-sized urban MPAs being capable of generating ecological benefits (Ventura et al., 2024). Fish rely on complex habitats for food, shelter, and reproduction; greater structural complexity supports higher species richness (Ferrari et al., 2018; Gratwicke and Speight, 2005; Komyakova et al., 2021). A complex habitat functions as a refuge from predators and high structural complexity provide multiple ecological niches. However, protection zones are not always optimally located, as seen in Cap de Creus where the no-take area is offshore, current-exposed, and seems to be less diverse.

4.3. No influence of management on ecological effectiveness

The findings, which indicate that effective management does not have significant influence on ecological effectiveness (Fig. 7) are surprising and contradict the literature (Scianna et al., 2019). This phenomenon can be explained by the small sample size ($n = 9$) due to the lack of ecological data accessible, by the similar management scores (ranging from 5.33 to 7.63) and by the fact that urban MPAs have high management scores but biomass log response values below 1.

A comparison of the present data with results in the literature reveals other apparent contradictions. Numerous studies have analysed the distance between protected areas and "urban centres" – defined in various ways – and show that protected areas that are further from urban centres are richer in fish (Cinner et al., 2018), with larger biomass (D'Agata et al., 2016; D.A. Gill et al., 2024) and better protection (Joppa and Pfaff, 2009; Mouillot et al., 2024). It is important to contextualise these studies, which are large-scale (i.e., "near population centre" is up to 100 km and low human impact is more than 20 h travel time) and cannot be directly compared with the heavily populated Mediterranean situation. Moreover, other studies demonstrate equivalent ecological effectiveness for MPAs in proximity to urban areas compared to remotely located reserves (Huijbers et al., 2015), or even higher ecological effectiveness in some cases (Díaz-Osorio et al., 2022), presumably attributable to the intensity of illegal fishing in the remote areas.

In our studied region, the western part of the Mediterranean Sea, greater human impact is significantly associated with a higher level of protection within MPAs (Portman and Nathan, 2015). The heavily populated Mediterranean coastline can host well enforced protected areas with ecological outcomes (Fraschetti et al., 2022; Giakoumi et al., 2017). Coexistence of human presence and marine protection is thus possible. Our research continues in this vein: urban MPAs can be ecologically effective with between 2 and 3 times more fish inside the MPA than outside. Urban MPAs can also be as effective as non-urban MPAs in term of management effectiveness, meaning it is feasible to implement protection in an urban context.

5. Limitations

The present study is subject to certain limitations and one of them is the restricted access to data. Due to obvious logistical and temporal constraints, we were unable to collect the ecological data ourselves. Therefore, data was obtained from fish counts carried out by the MPA teams or their partners, through published scientific articles or internal reports. The issue of data ownership and sharing was identified as a key obstacle that resulted in the failure to obtain all data necessary. The selected MPAs vary considerably in size from 33 ha (Larvotto) to 141,200 ha (Calanques). The surveillance effort, represented here by the Enforcement Index (EI) indicator, was derived from the number of surveillance hours divided by the size of the MPA *via* a surface area score. This methodology results in a dilution of the monitoring effort in large areas such as the Bonifacio and Calanques National Park. To ensure the best possible representation of reality, an investigation was conducted into the existence of fishing management measures in adjacent areas. This investigation enabled us to adapt in this present study the management scoring system by dividing the number of hours by the areas where surveillance is actually needed, as used in the methodology. In the future, it could be more useful to compare MPAs with similar sizes. Moreover, we analyse the influence of urbanisation though two categories: urban and non-urban. The categories may not be the best way to see the effect of urbanisation on management because the values are too similar to create meaningful categories. Furthermore, the addition of MPAs between these categories is recommended in order to ensure continuity in the values and to observe the influence of urbanisation on management in a variety of the urban scenarios. An analysis could then be done on the effects of an increase in urbanisation, rather than a comparison of categories. This could potentially, with more points, demonstrate a trend.

6. Perspectives

Our results suggest that no-take zones should not be avoided in coastal areas, despite these zones being subject to disproportionally high risks and disturbances, as well as challenges related to policy, governance and enforcement. When protected areas meet certain criteria considered fundamental to their success, the urban context appears to have no discernible impact on their ecological effectiveness. These findings open new directions for research at the intersection of urbanisation and protected areas, a topic that has remained largely unexplored to date (Marty-Gastaldi et al., 2025a). Given the influence of urban settings on marine ecosystems, it would be valuable to assess the composition and structure of fish communities in urban MPAs. Such studies can enhance our understanding of ecosystem responses and resilience to cumulative pressures in urbanized areas (Ventura et al., 2024). Despite the numerous marine restoration success stories including various habitat types and species worldwide (Danovaro et al., 2025), a key question remains whether heavily degraded ecosystems in urbanized areas can be effectively restored once critical thresholds have been exceeded (Foley et al., 2015; Hiddink et al., 2023). In other words, very slow—or even absent—responses of ecosystems to MPA establishment after crossing such thresholds pose particular social, political, and economic challenges (Hughes et al., 2013). In this context, effective marine conservation planning should prioritize the allocation of efforts and financial resources to achieve meaningful ecological outcomes within socially and economically acceptable time frames.

7. Conclusion

Our study is the first study of MPAs in urban contexts that links management data and ecological data. It has demonstrated that, within the Western Mediterranean region, MPAs in an urban context can be managed as effectively as non-urban MPAs. A protected area in an urban context has the potential to be very well managed and to implement effective management measures to achieve defined conservation objectives. We also demonstrated that urban MPAs can generate ecological benefits. For example, with fish biomass (all species pooled) inside protected zones was more than twice that observed outside, depending on the management objectives of each MPA. The findings of this study suggest that management outcomes are influenced by multiple factors, such as the goals of the MPA, the institutional governance of the management body, and access to financial and human resources. Sustainable funding for the areas and staff capacity is essential for the success of the protected zone. However, despite the willingness and efforts of the management teams, the institutional governance limitations in the countries under study constrain the scope of management actions. To achieve optimal effectiveness, MPAs are required to adhere to stipulated protection levels, comprehensive implementation requirements, and specific conditions. Urbanisation of MPAs does not impose any limits on their effectiveness, which is promising for the future. This study provides a framework for the designation of new protected areas, particularly in the context of future global objectives.

CRediT authorship contribution statement

Julie Marty-Gastaldi: Writing – original draft, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Charalampos Dimitriadis:** Writing – review & editing, Validation, Software, Formal analysis. **Nathalie Lazaric:** Writing – review & editing, Visualization, Supervision, Conceptualization. **Benoit Dérijard:** Writing – review & editing, Validation, Supervision.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Julie MARTY-GASTALDI reports financial support was provided by Fondation de la Mer. 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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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.envc.2026.101406.

Data availability

Data will be made available on request.

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