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Review

Urban Marine Protected Areas (MPAs): A systematic review of governance, management and human impact

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ABSTRACT

The hundred largest Marine Protected Areas (MPAs) are located in remote offshore areas even though human populations are increasingly concentrated in urban coastal regions. Safeguarding coastal marine ecosystems in urban settings, where human populations are densely concentrated, presents challenges due to the need to balance the spatial demands of human activities with the preservation of the natural environment. This article focuses on MPAs located in urban contexts. We conducted a systematic literature review to (1) identify research focused on "urban" MPAs, (2) assess methodologies used to evaluate urban MPA governance and management, and (3) discuss the implications of integrating urban dynamics, management practices, and ecological considerations. Our findings reveal that 1) a clear definition of what constitutes an "urban" MPA remains elusive, while human disturbances are frequently acknowledged. This review therefore includes articles that address the human impact on the coastal environment, but also studies that do not explicitly address MPAs within an urban context. 2) Most studies emphasise the positive effects of management measures or the negative impact of human activities on marine ecosystems. 3) Our review underscores the diversity of approaches employed to evaluate MPA management and governance, highlighting that the concept of effectiveness can encompass social, cultural, and environmental dimensions. We suggest that future studies pay greater attention to the context and scale of MPA governance and management, to identify specific needs for improving MPA effectiveness in urban contexts.

1. Introduction

A Marine Protected Area (MPA) is a geographical area of the sea clearly defined by international, national, or local laws, intended to enhance the long-term conservation of nature within it (Dudley, 2008). MPAs play a crucial role in the management and protection of marine ecosystems (Grorud-Colvert et al., 2021; Sala et al., 2013). Currently, 8 % of the ocean's total surface is protected globally (Pike et al., 2024) and the 100 largest MPAs, covering 7 % of the ocean's surface, are unevenly distributed among marine ecoregions and disproportionately situated in remote offshore areas and overseas territories. MPAs provide multiple ecosystem services, including coastal protection, of genetic diversity, biodiversity and resources, landscape protection, carbon sequestration, and preservation of cultural heritage and traditions (Arneth et al., 2023; Marcos et al., 2021; Sala et al., 2013). They can have ecological as well as socio-economic benefits for fisheries (Vandeperre et al., 2011), by raising incomes (Ban et al., 2019); and tourism (Perera-Valderrama et al., 2020) or recreational non-profit activities, by generating funds (Gelcich et al., 2013). The connectivity of coastal marine zones with other ecosystems plays a crucial role in supporting their ecological functions (Barbier et al., 2011). Human society depends on the marine environment providing its ecosystem services. Many changes and fluctuations are taking place in coastal areas, rendering them particularly vulnerable due to the proximity of human activities (Archana and Baker, 2020; Batista et al., 2014).

Urban coastal marine zones, which are regions with intense human activities, face significant challenges in mitigating adverse impacts such as pollution, artificialization, and overexploitation (Cinner et al., 2018; Micheli et al., 2013). Today, half the world's population lives less than 100 km from a coast (Daeden, 2015; Todd et al., 2019), increasing the amount of human activity in these areas (von Glasow et al., 2013). According to the IPCC report (Intergovernmental Panel on Climate Change, 2023), by 2050, of the expected worldwide population of 10 billion people, more than one billion will reside in coastal areas, and 2.5

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billion will live in urban areas. Urban coastal zones can be defined as areas where human presence and activities are concentrated. Dakar, the capital of Senegal, is a prime example of a coastal city. The region's population is around 4 million, and the city itself has a population of 1.1 million (ansd.sn). Dakar is not only the largest city in Senegal, but also its primary port. Almost 90 % of foreign trade is estimated to pass through its port, and it is also home to a significant fishing fleet (aivp.org). By way of comparison, the Chinese city of Xiamen has a population of over 4 million and attracts almost 60 million tourists annually. Xiamen is located on an island with a busy port and shipping industry. The Xiamen region is characterised by a diverse range of economic activities, including aquaculture, tourism and industrial zones (Carneiro et al., 2017). Both cities are near MPAs. Marine biodiversity is under pressure in urban zones due to the high demand for ocean-based food (Jones and De Santo, 2016; Sullivan-Stack et al., 2022) along with other threats to the ecological ecosystems. Ecosystems in urban coastal areas are affected not only by human activities, but also by the emission of pollutants from urban areas. The concentration of nitrogen and phospherous is correlated with the size of urban population (Smith et al., 2003; Withers et al., 2014). These nutrients can be discharged into the environment via various human activities such as agriculture, industrial discharge and human and animal waste (Todd et al., 2019). Eutrophication has been shown to have a negative impacts on marine ecosystems, resulting in the degradation of services such as fisheries, aquaculture and tourism (Horta et al., 2021). Urban areas are characterised by anthropogenic activities, which are a significant source of pollution and waste. For instance, agriculture employs pesticides, while industry releases untreated industrial effluents and toxic pollutants. Furthermore, vehicular, construction and domestic waste generate different types of pollutants and impact the environment and marine life (Singh et al., 2022).

To preserve fisheries resources and the benefits of ecosystem services, it is imperative to protect urban coastal areas from destructive activities. This protection would benefit neighbouring communities. A protected ecosystem has the potential to be healthier and more resilient in the face of disturbance. However, establishing protected areas in these urban spaces poses a significant challenge (Alves et al., 2019).

To describe and categorise the wide variety of MPAs, scientists and policy experts developed the MPA Guide (Grorud-Colvert et al., 2021). The different levels of protection of MPAs govern their effectiveness. No-take zone marine reserves exhibit greater ecological benefits compared to less protected MPAs (Sala and Giakoumi, 2018) and the inclusion of no-take zones within or in proximity to partially protected MPAs has been demonstrated to enhance the efficacy of protection (Di Lorenzo et al., 2020; Zupan et al., 2018b), even though it may be challenging to implement them (Molina-Hernandez et al., 2018; Schultz et al., 2022). Overall, only 2.6 % of the global ocean surface (Pike et al., 2024) and 0.06 % of the Mediterranean Sea (Claudet et al., 2020) is fully or highly protected. This high level of protection in the Mediterranean Sea is in areas of high human impact (Portman et al., 2012; Portman and Nathan, 2015). Moreover, 51 % of the Mediterranean MPAs are located within 2 km of land, which means that nature conservation and human use of the ocean can overlap. In addition to the level of protection, the quality of management is also a key element in ensuring the achievement of an MPA's objectives (Ervin, 2003; Leverington et al., 2008; Maestro et al., 2020). More than one-fifth of the protected coverage of the Mediterranean Sea is not regulated or managed, as no management plans or associated legal documents could be found for the specific MPAs (Claudet et al., 2020). One of the objectives of this review is to analyse the management of urban MPAs and assess whether it has a positive impact on biodiversity.

Protected areas, whether terrestrial or marine, must be highly protected, well-managed, and strategically sited in order to be effective (Arneth et al., 2023). The type of site selected as a protected area significantly influences its ecological effectiveness, as habitat quality and complexity can play a crucial role, for example in the Mediterranean Sea (Liconti et al., 2022). Current research debates whether it is more beneficial to establish protected areas in regions of high biodiversity value or in areas where the ecosystem has been degraded and needs restoration (García Márquez et al., 2017; Pike et al., 2024; Ventura et al., 2024). Moreover, implementing protected areas in locations with lower human activity is generally more straightforward than in areas with significant human use (Venter et al., 2018). It is crucial to assess the effectiveness of protected areas as conservation tools in urban contexts, both in terrestrial (Rodríguez-Rodríguez and Martínez-Vega, 2018) and marine (Ventura et al., 2024). Currently, the effectiveness of protected areas, whether marine or terrestrial, remains limited and often fails to adequately safeguard biodiversity (Arneth et al., 2023). To address these challenges, robust and effective governance frameworks need to be established.

Protected areas, whether terrestrial or marine, are supposed to be subject to governance for the sustainable use of natural resources. The International Union for the Conservation of Nature (IUCN) defines four types of governance: a) Governance by government (i.e., top-down), meaning governance by a state agency or ministry; b) Shared governance, which includes collaborative, joint (multi-stakeholder management board), and/or cross-border governance (varying degrees across international borders); c) Private governance by an individual owner or non-profit organisation (NGO, university or cooperative); and d) Governance by indigenous peoples and local communities (i.e., bottom-up), in which areas or territories are declared, managed and conserved by indigenous peoples or local communities.

The governance and management of natural resources are grounded in the concept of common goods—resources inherently accessible and available for all to use (Ostrom, 2009; Coriat, 2013). Ostrom's work highlights the viability of local communities managing common resources autonomously, challenging the notion that state intervention is the sole solution. Ostrom describes and conceptualises the functioning, characteristics and rules for sustainable management of marine resources with a bottom-up approach (Ostrom, 2009). Fishing is a perfect example of the governance of common goods and the complexity involved (Ganseforth, 2023; Zhang, 2021).

The success of MPAs as a management tool for biodiversity conservation remains a major challenge, especially in urban areas. Considering biodiversity conservation as an issue of the commons and within the realm of socio-ecological systems is a first step. Many case studies based on commons theory focus on community-based management systems (Botto-Barrios and Saavedra-Díaz, 2020). For example, Marine Extractive Reserves (MER) in Brazil are considered MPAs using a bottom-up approach. The co-management strategy is community-based, involvement of government and local stakeholders (Fortunato et al., 2024). Nevertheless, other management regimes can ensure the sustainable use of common resources. In Brazil, some MPAs are known as Conservation Units and are managed by the stat (Tebet et al., 2018), using a top-down approach.

It would be valuable to examine the contexts and conditions in which management and governance are related to marine biodiversity, as well as how these aspects are effectively integrated within the MPA in urban environments. This article therefore focuses on MPAs in an urban context, which will be referred to as urban MPAs. We conducted a systematic review of the governance and management of urban MPAs. Our objectives were to: (1) identify research focused on "urban" MPAs, (2) assess the methodologies used to evaluate the governance and management of urban MPA, and (3) discuss the implications of integrating

Table 1
Eligibility criteria.

PICO	Key term	Inclusion criteria	Exclusion criteria
Population (P)	Marine Protected Area	All MPAs with a high level of protection, an existing management plan and a local focus	MPAs with global scale, with intervention of different countries or in the high sea
Intervention (I)	Governance	The governance or the management of MPAs	Governance or management of fisheries or spaces not related to an MPA
Comparator (C)	Urban	MPA close to an urban context	Specific focus on direct or indirect impact of human pollution on marine ecosystem (noise pollution, light pollution, invasive species)
Outcome (O)	Biodiversity	Ecological Indicators (biomass, abundance, top predators, species richness of marine ecosystem components).	Single species assessment, state of the art, study on marine mammals or birds, citizen science study

Table 2
Key terms *in French*, English and Spanish.

Population search terms	Intervention search terms	Comparator search terms	Outcome search terms
Aire marine protégée$	Gestion	Centre urbain	Abondance
AMP$	Gouvernance	Cit*	Biodiversité
Parc marin$		Développement côtier	Biomasse
Reserve marine$	Governance	Impact humain$	Densité
Zone de protection forte	Management	Menace anthropique$	Ecosystème
		Impact$ anthropique$	Services écosystémiques
High level of protection	gestión	Milieu urbain	Effet réserve
Marine park$	gobernanza	Pression humaine$	Richesse spécifique
Marine protected area$		Urbain*	
Marine reserve$		Ville	Abundance
MPA$		Zone urbaine	Biodiversity
No*take area$			Biomass
No*take zone$		Anthropogenic activit*	Density
Marine protected site$		Anthropogenic effect$	Ecosystem services
		Anthropogenic pressure$	Species richness
Alto nivel de protección		Anthropogenic threats	Spill*over
AMP		Anthropogenic impact$	Top predator
Área$ marina$ protegida$		Coastal development	
Parque$ marino$		Human impact$	Abundancia
Reserva$ marina$		Urban area$	Biodiversidad
		Urban center$	Biomasa
		Urban*	Densidad
			Desbordamiento
		Amenaza$ antropogénica$	Riqueza de especies
		Centro urbano	Servicios ecosistémicos
		Ciudad*	
		Desarrollo costero	
		Entorno urbano	
		Impacto antropogénico	
		Impacto humano	
		Presión* humana$	
		Zona$ urbana$	

$ symbol is a wildcard representing zero or one character; * symbol is a wildcard representing different character combinations.

urban dynamics, management practices and ecological considerations.

The literature well documents ecological benefits, management and governance types, and the impact of human activities on MPAs. Our review offers insights into potential connections among these three topics. First, we explain the methodology of our systematic literature review. We then present the results and discuss our findings in the same section divided by topics. To start, we describe outcomes regarding the analysis of governance and management methods, and then the influence of management practices on marine ecology. We explore also the impact of human activities on marine ecology, which was followed by the creation of a quantitative urban indicator. We then explore how human impact can be mitigated through good management practices. Finally, we discuss the relationships between management practices, marine protection and urbanisation. Our novel approach expands consideration of urban environments within MPA studies.

2. Methodology

This systematic review uses explicit and rigorous methods to synthetise the literature. It collects and critically analyses studies that address a clear research question (Higgins et al., 2019).

2.1. Definition of research question and terms

Our key question is “Does the governance and management of urban MPAs (with a high level of protection and a management plan) have an impact on biodiversity?” To conduct this review, we used the PICO[1] methodology, a systematic working method from Livoreil (2018), described in Table 1.

In this review we focus only on studies of urban MPAs with i) a high level of protection (i.e., a no-take zone) and ii) an existing management plan. These two characteristics define the scope of our review. We then compare the MPAs depending on urban characteristics and identify the impact of management on ecological biodiversity. The results used here to measure biodiversity are ecological indicators such as the fish biomass (D’Agata et al., 2016), fish abundance (Huang et al., 2017; Suchley and Alvarez-Filip, 2018; Voorberg and Van der Veer, 2020), top predators (Cinner et al., 2018) and species richness (Palacios-Sanchez et al., 2019; Quiros et al., 2017; Venturini et al., 2017).

[1] PICO: Population – purpose of the review, Intervention – what the population is subjected to, Comparator – what will be compared to the intervention, Outcomes – measured effects on the population.

2.2. Eligibility criteria

To perform this review, the PRISMA review protocol was followed (www.prisma-statement.org) (Page et al., 2021). Relevant articles were selected according to the PICO framework, using the eligibility criteria presented in Table 1.

2.3. Information sources

The searches were performed in French, English and Spanish in March 2023. Two bibliographic databases, Scopus (Elsevier) and Web of Science Core Collection (WOSCC, Clarivate), were used to select articles published between January 1, 2015 and March 15, 2023.

2.4. Search strategy

The key terms used are given in Table 2. The specific Boolean search string (adapted for WOSCC) is visible in Supplementary materials 1 (Text SM.1).

2.5. Selection and data collection process

The Zotero software was used for data extraction and processing of the selected articles. We removed records that were too broad or not relevant to the focus of the review, as well as any data that appeared inadequately substantiated or beyond the review's scope. For example, many articles have an interest in management of a large territory or an area bordering several countries (Ceccarelli et al., 2022; Enright et al., 2021; Hameed et al., 2017; Machado et al., 2022) which is not our focus. Informative and non-comparative review articles, as well as meta-analyses and bibliographic reviews, were also excluded from the list. Please refer to Text SM.2 in the "Supplementary Materials 1" for a full list of reasons why articles were excluded from the selection of peer-reviewed literature.

3. Results and discussion

Fig. 1 presents a flowchart of the article selection process. The literature searches initially found a total of 590 articles (269 from Scopus and 321 from WOSCC), which was reduced to 420 after duplicates were eliminated. We assessed the eligibility of all articles based on their titles and selected 249, subsequently retaining 74 after an assessment of their abstracts. The full text of these articles was then examined to determine their eligibility for inclusion, which resulted in 34 articles being selected to include in the review (Fig. 1). The list of full-text articles assessed in this review is available in Supplementary Material 2 as well as the reasons for excluding the other articles.

Of the 34 selected articles, 26 % originated from the Mediterranean region (Italy, France, Spain). The remaining studies focused on South America (26 %, with contributions from Brazil, Colombia, Costa Rica, Mexico), Asia (15 % with contributions from Indonesia, Philippines, China, Vietnam), Australia (3 %), USA (6 %), Portugal (6 %), or the Western Indian Ocean (9 % with contributions from Tanzania, Seychelles) or considered MPA worldwide (9 %). The 34 articles selected for the review are listed in Table 3.

An examination of the published articles highlighted that.

- There is a lack of a clear definition of the term "urban" and recognition of the particular "urban" nature of MPAs located in urban areas. Consequently, no study has specifically investigated the management of urban MPAs and their impact on marine biodiversity. 12 (35 %) articles do not mention the urban nature of the MPAs under study.
- Three studies (9 %) focused on the governance of MPAs, while one focused solely on their management.
- Thirty studies (88 %) examined the relationship between urbanisation, management, and ecology (Fig. 2). Specifically, eight studies investigated the influence of MPA management practices on marine ecology; ten explored the impact of various human activities on marine ecology; six examined the link between management and urbanisation; and six assessed the relationship between urbanisation, management and marine ecology.

We then analysed the contents of the studies in more detail. The articles established connections between three main domains (Tables 2 and 3, Fig. 2).

- Management: this includes all practices related to the management of human activities, including protection.
- Urban or Human-related domain: this encompasses all human-related activities, pressures, and threats at sea and on land, such as pollution.
- Marine ecology: this involves marine species, species assemblages and biodiversity variables.

The salient points of results and discussion have been summarized in Table 4.

3.1. Analysis of the governance MPAs

Studies by Khuu et al. (2021) in Vietnam and Cockerell & Jones (2021) in the Seychelles analysed the governance of specific MPA using the MPAG methodology developed by Jones & Long (2021). Raycraft (2019) examined the literature on the Mnazi Bay-Ruvuma Estuary Marine Park (MBREMP) in Tanzania, analysing the governance of this MPA.

The concept of governance has a polysemic character, depending on the context of the study. It refers to the strategy of actions, processes and laws through which authority is exercised, and decisions are made and implemented. Our results revealed that three articles assessed the governance of different MPAs. Two of these articles, by Cockerell & Jones (2021) and Khuu et al. (2021), are part of the framework of Jones & Long (2021) which facilitates global comparisons and enables the formulation of general conclusions. We highlight that both studies demonstrated an ineffective MPA governance structure, akin to a "paper park" with no substantial impact on the ground. The final article in the series analyses the marine park in Tanzania (Raycraft, 2019). Social conflict and rejection of government protection initiatives have emerged as a consequence of failing to incorporate villagers into governance strategies despite their geographical location within protected areas. In certain instances, disregard for the local population and the imposition of regulations can be perceived by local communities as a loss of freedom, impacting the social acceptance of protective measures (Cadoret and Beuret, 2022). It is important to note that the overarching objective of these three studies was to assess governance rather than measure biodiversity.

3.2. Analyse of the management of MPAs

Only one of the articles in our study deals specifically with the management of MPAs. The other articles measure management alongside marine biodiversity or human impact data. Maestro et al. (2022) assessed the management of three MPAs in Costa Rica by applying their previously developed methodology to identify different management scenarios (Maestro et al., 2020).

Management of MPAs refers to the daily execution of concrete actions and activities in the field, including associated technical and administrative tasks. To clarify the distinction: governance represents the strategic framework, while management constitutes the concrete means by which this framework is applied. Analysing MPA management is crucial for the sustainability of MPAs globally. Our results highlight the panel of methodologies and tools developed to assess the

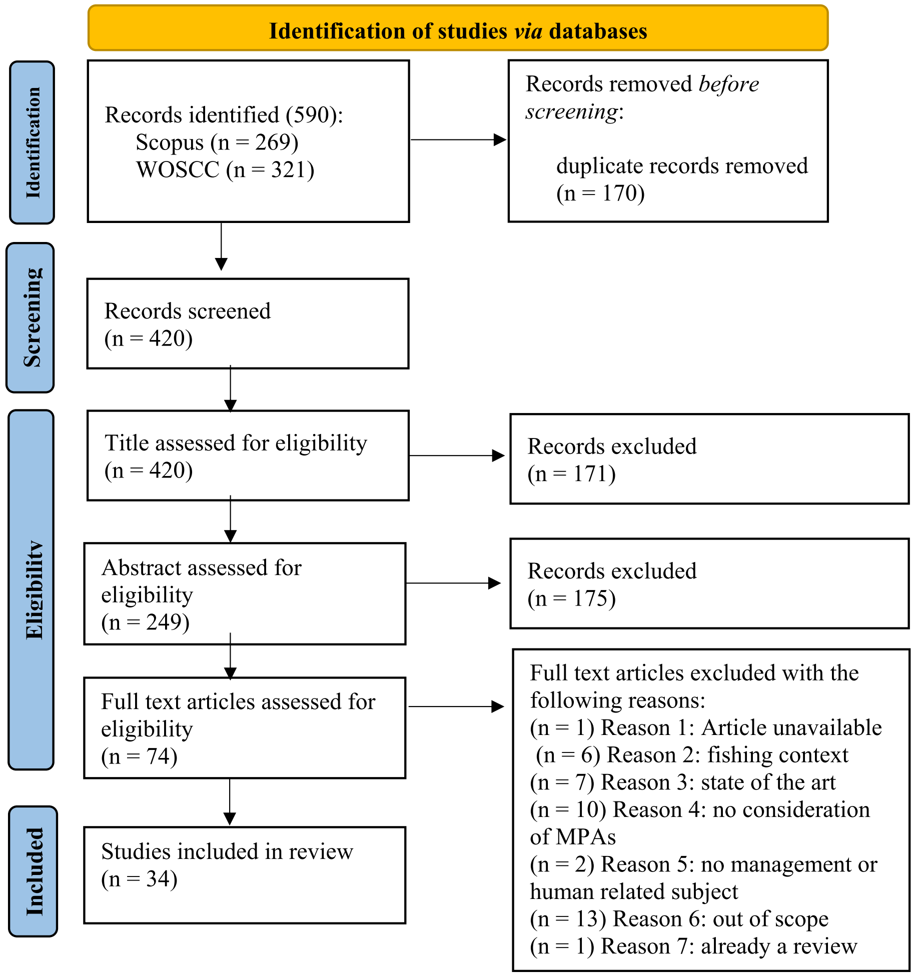

Fig. 1. Flowchart of the studies selection following the PRISMA protocol.
Note: *From:* Page et al., 2021. For more information, visit: http://www.prisma-statement.org/.

management of MPAs. The DPSIR (Driver–Pressure–-State–Impact–Response) framework represents a multi-sectoral approach addressing both environmental and socio-economic impacts on the marine environment. Although the DPSIR model has been utilised by Xu et al. (2015), it is not designed for direct comparison between different MPAs. Nonetheless, the Rapid Assessment and Prioritization of Protected Area Management (RAPPAM) (Ervin, 2003), used by de Almeida et al. (2016) and de Oliveira et al. (2021) in the review can be comparable. Other methods, including the Management Effectiveness Tracking Tool (METT) (Stolton et al., 2007), or How is your MPA doing (Leverington et al., 2008)? share a similar principle: assessing management through workshops with MPA stakeholders. More recently, our results point up the article of Maestro et al. (2022) who developed an additional method employed to analyse MPA management. These approaches typically involve perceptual data collection through expert opinions and the Likert scale.[2] Moreover, to avoid possibility of bias and ensure accuracy, (Scianna et al. (2018) develop a framework based on standardised methods and factual data.

3.3. Influence of the management practices on marine ecology

Twenty-four of the thirty-four studies (71 %) focused on marine biology or ecological variables. Each management measure was associated with a specific human activity, and its impact was evaluated by comparing areas where the activity occurs with areas where it does not. MPAs are designated areas where human activities are prohibited, while areas outside MPAs represent regions where these activities are permitted. Marine ecology measures thus often serve as a positive proxy for management measures. For instance, algae biomass was measured inside and outside MPAs to evaluate the effectiveness of protection efforts (Cannarozzi et al., 2023). Conversely, biodiversity was used as a negative proxy to assess urban impact, for example, the ecological quality of urban and wild areas was compared to determine the impact of urbanisation on marine ecosystems (Fan et al., 2019).

Management encompasses a diverse array of topics, defined by specific management practices such as.

a) Protection: Cannarozzi et al. (2023), Martinez-Ramirez et al. (2021) and Tursi et al. (2022) published studies on the impact of protection (through the establishment of MPAs) on marine species, such as *Ericaria amentacea*, soft-sediment fish species, and *Posidonia oceanica*, respectively.
b) Management of human activities (regulation and prohibition): several studies focused on the influence of the management practices on marine ecology to mitigate the impact of specific human activities on the marine ecosystem. Examples include scuba diving (Calo et al., 2022), recreational fishing (Venturini et al., 2017), and the presence of port structures (Sim et al., 2015).

[2] A Likert scale is a psychometric tool used to measure attitudes in individuals. It consists of one or more statements for which the respondent expresses a degree of agreement, neutrality or disagreement.

Table 3
Classification of the articles included in the review.

Author	Year	Title	Urban domain	Manag. domain	Ecology domain
Alves et al.	2019	Local benthic assemblages in shallow rocky reefs find refuge in a marine protected area at Madeira Island	■		■
Betti et al.	2019	On the effects of recreational SCUBA diving on fragile benthic species: The Portofino MPA (NW Mediterranean Sea) case study	■		■
Calo et al.	2022	Quotas regulation is necessary but not sufficient to mitigate the impact of SCUBA diving in a highly visited marine protected area		■	■
Cannarozzi et al.	2023	Assessing the Effect of Full Protection on the Biomass of *Ericaria amentacea* and Understory Assemblages: Evidence from Two Mediterranean Marine Protected Areas		■	■
Cinner et al.	2018	Gravity of human impacts mediates coral reef conservation gains	■		■
Cockerell et al.	2021	Governance Analysis of St Anne Marine National Park, Seychelles			
D'Agata et al.	2016	Marine reserves lag behind wilderness in the conservation of key functional roles	■	■	■
De Almeida et al.	2016	Evaluating ten years of management effectiveness in a mangrove protected area	■	■	
De Oliveira et al.	2021	Quantifying anthropogenic threats affecting Marine Protected Areas in developing countries	■	■	
Diaz-Osorio et al.	2022	How effective are marine parks in protecting their coral reef ecosystem? A study case in the Mexican Caribbean	■	■	■
Fan et al.	2019	Ecological quality dynamics around marine reserves in the Bohai Sea coastal zone and their relationship with landscape artificialization	■		■
Huang et al.	2017	Can private management compensate the ineffective marine reserves in China?		■	■
Huijbers et al.	2015	Conservation Benefits of Marine Reserves are Undiminished Near Coastal Rivers and Cities	■	■	■
Kemsley & Pukini	2021	Marine Protected Area Watch and Marine Monitor (M2) RADAR Technology: Case Studies in Anthropogenic Use Monitoring in California's Marine Protected Areas	■	■	
Khuu et al.	2021	Governance analysis of Nha Trang Bay and Cu Lao Cham Marine Protected Areas, Vietnam			
Lucas & Smith	2016	Alterations in human visitation patterns and behaviors in southern California rocky intertidal ecosystems over two-decades following increased management efforts	■	■	■
Maestro et al.	2022	Evaluation of the management of marine protected areas. Comparative study in Costa Rica		■	
Martinez-Raminez et al.	2021	Reserve effect of a small North-East Atlantic marine protected area (Arrabida, Portugal) on soft-sediment fish species		■	■
Moreira et al.	2019	Multiple lines of evidence of sediment quality in an urban Marine Protected Area (Xixová-Japuí State Park, SP, Brazil)	■		■
Osuka et al.	2021	Protection outcomes for fish trophic groups across a range of management regimes	■	■	■
Palacios-Sanchez et al.	2019	Anthropogenic impacts in the nearshore fish community of the Yucatan Coastal Corridor. A comparison of protected and unprotected areas	■	■	■
Portman & Nathan	2015	Conservation "identity" and marine protected areas management: A Mediterranean case study	■	■	
Prato et al.	2016	Assessing interacting impacts of artisanal and recreational fisheries in a small Marine Protected Area (Portofino, NW Mediterranean Sea)	■		■
Quiros et al.	2017	Land use is a better predictor of tropical seagrass condition than marine protection	■		■
Raycraft	2019	Circumscribing communities: Marine conservation and territorialization in southeastern Tanzania			
Silva et al.	2021	Threatened marine protected areas in Guanabara Bay, Brazil	■		■
Sim et al.	2015	Sediment Contaminants and Infauna Associated with Recreational Boating Structures in a Multi-Use Marine Park		■	■
Suchley & Alvarez-Filip	2018	Local human activities limit marine protection efficacy on Caribbean coral reefs	■		■
Tursi et al.	2022	The Status of *Posidonia oceanica* at Tremiti Islands Marine Protected Area (Adriatic Sea)		■	■
Uribe-Castañeda et al.	2020	Ecosystems services vulnerability of Uramba Marine Protected Area	■		■
Venturini et al.	2017	Recreational fisheries in Portofino Marine Protected Area, Italy: Some implications for the management		■	■
Voorberg & Van der Veer	2020	Co-management as a successful strategy for marine conservation		■	■
Xu et al.	2015	An integrated environmental risk assessment and management framework for enhancing the sustainability of MPAs: The Cape d'Aguilar Marine Reserve case study in Hong Kong	■	■	
Zupan et al.	2018a	How good is your marine protected area at curbing threats?	■	■	

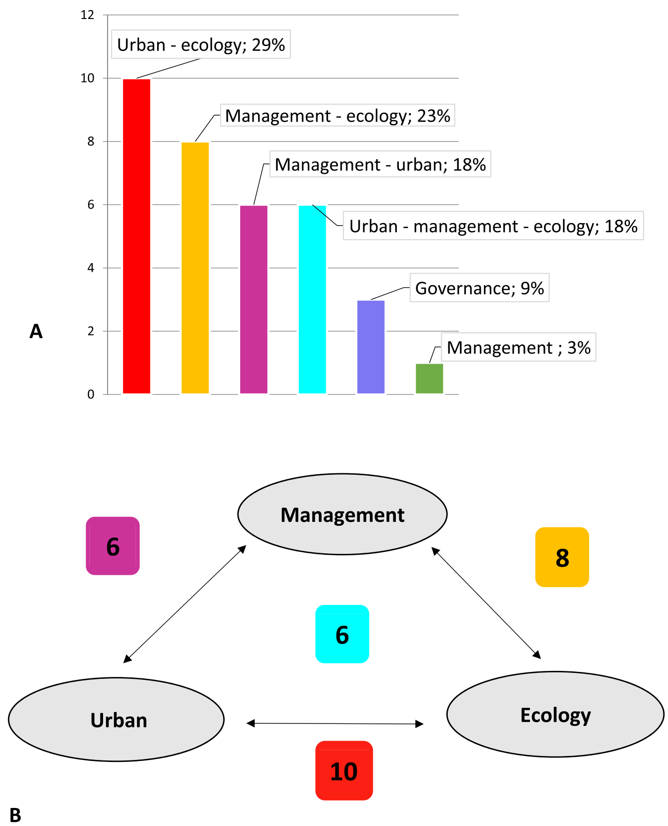

Fig. 2. Links between the themes covered in the articles. A: Number and percentage of articles by subject; B: Number of articles connecting each domain (arrows) and number of articles connecting all three domains: urban, management and ecology (centre).

c) Analysis of management types and their impact on marine ecology: two studies compare fish abundance (ecological indicators) with the type of management or governance for various MPAs (Huang et al., 2017; Voorberg and Van der Veer, 2020).

3.3.1. A single management practice

As previously mentioned, we observed that each management measure is designed to address specific human activities. Enhanced protection zones (management practice) were established within MPAs, in response to fishing pressure (activity). In less restrictive areas of the MPA, recreational fishing (activity) may require a permit (management practice) (Venturini et al., 2017). To reduce the environmental impact of scuba diving (activity) or anchoring (activity), diving quotas and mooring zones (management practices) have been implemented.

Assessing the influence of each management practices on marine ecology enable us to determine its effectiveness. In the Mediterranean Sea, diving quotas have been shown to effectively reduce the impact of scuba diving on false coral (*Myriapora truncata*) (Calo et al., 2022), while mooring zones play a crucial role in safeguarding *Posidonia oceanica* meadows from the impact of boating activities (Tursi et al., 2022). The development of multiple-use areas in marine parks concentrates human activities in a specific zone, limiting the extent to which boating impacts the marine ecosystem (Sim et al., 2015).

While studies analysing the influence of MPA management practices on ecology are emerging, they often focus on specific measures without considering the full spectrum of human activities or the overall management of MPAs.

3.3.2. Multiple management practices

Cannarozzi et al. (2023) examined the reserve effect of two MPAs by investigating macroalgae communities and found no evidence to suggest that full protection leads to an increase in algae biomass. Martinez-Ramirez et al. (2021) assessed fish communities, which serve as an ecological proxy for measuring the reserve effect. While fishing management can effectively boost fish biomass within MPAs (Venturini et al., 2017), Martinez-Ramirez et al., found no evidence of a protective effect on the demersal fish population over time, likely due to the persistence of illegal fishing activities. The type of management also plays a crucial role in the effectiveness of MPAs. Depending on the local context, private management of a marine reserve could be more effective than top-down public management (Huang et al., 2017). Voorberg and Van der Veer (2020) examined the effectiveness of different types of MPA governance (from the IUCN World Database) using a global fish abundance dataset (derived from Reef Check data). They concluded that co-management as part of a formalised strategy is associated with less damage to marine ecosystems, fewer coral bleaching indicators, and higher fish biomass.

3.4. Impact of human activities on marine ecology

The most frequently observed interaction in the articles is between the domain "urban" and the domain "ecology" (29 %). An urban environment is characterised by a high concentration of people and activities.

The impact of human activities on marine ecology can be due to.

a) Urbanisation causing human pressures on land, including the artificialization of coastlines (Fan et al., 2019), urban pollution (Moreira et al., 2019; Silva et al., 2021) and land use changes (Quiros et al., 2017);
b) Human activities at sea affecting benthic assemblages (Alves et al., 2019), coral reefs (Cinner et al., 2018; Suchley and Alvarez-Filip, 2018) and ecosystem services (Uribe-Castañeda et al., 2020).
c) Specific human activities such as scuba diving (Betti et al., 2019) or recreational fishing (Prato et al., 2016), impact benthic species and fish stocks, respectively.

3.4.1. Single human activity

Two articles examine the impact of a specific human activity on coastal communities within the same MPA: Portofino. Betti et al. (2019) compared the benthic communities (i.e., red coral and other species) of diving and non-diving sites. Their observations revealed that the benthic substrates of diving sites exhibited a greater abundance of fragments of these species (sometimes up to ten times more) compared to non-diving sites. This finding serves to underscore the impact of diving activities in marine protected areas. The impact of and interaction between commercial and recreational fishing is also being studied in Portofino. The food web of Portofino's coastal communities is impacted by recreational fishing, which exerts a significant effect on the high trophic level predators (HTPs), which is detrimental to artisanal fishing (Prato et al., 2016). Both these issues must not be neglected and management measures must be applied to regulate harmful activities in the protected areas.

3.4.2. Multiple human activities

Regarding human impacts on the marine environment, particularly within MPAs, several articles address the subject in various ways (Table 5). The literature examines the types and levels of pressures induced by human activities (Alves et al., 2019) on specific territories. Pressures are defined as "forces, activities, or events that have already had a detrimental impact on the integrity of the protected area (i.e., that have diminished biological diversity, inhibited regenerative capacity, and/or impoverished the area's natural resources). Pressures include

Table 4
Summary of our results and discussion.

Study area	Main focus	Articles of the review
Analysis of the governance of MPAs	State of art of the governance	Cockerell and Jones, (2021) Khuu et al. (2021) Raycraft (2019)
Analysis of the management of MPAs	State of art of the management	Maestro et al. (2022)
Influence of the management practices on marine ecology	A single management practice	Tursi et al. (2022) Calo et al. (2022) Venturini et al. (2017) Sim et al. (2015)
	Multiple management practices	Cannarozzi et al. (2023) Huang et al. (2017) Martinez-Ramirez et al. (2021) Voorberg and Van der Veer (2020)
Impact of human activities on marine ecology	Single human activity	Betti et al. (2019) Prato et al. (2016)
	Multiple human activities	Alves et al. (2019) Fan et al. (2019) Silva et al. (2021) Moreira et al. (2019) Quiros et al. (2017) Suchley and Alvarez-Filip (2018) Cinner et al. (2018) Uribe-Castañeda et al. (2020)
Mitigate human impacts though management practices	Solutions to reduce human impacts	De Almeida et al. (2016) Zupan et al. (2018a) De Oliveira et al. (2021) Kemsley and Pukini (2021) Xu et al. (2015)
Interaction between the urban, management and marine ecology domains	Case studies of MPAs with diverse levels of urbanisation and interaction with marine ecosystem	Lucas and Smith (2016) Palacios-Sanchez et al. (2019) Osuka et al. (2021) Huijbers et al. (2015) Díaz-Osorio et al., 2022 Portman and Nathan (2015)

both legal and illegal activities, and may result from direct and indirect impacts of an activity" (Ervin, 2003). The most common approach is to compare indicators of marine biology or ecology between areas that have varying degrees of human pressure: "protected", implying an absence of pressures; "unprotected", indicating human-induced pressure such as fishing or boating; or "urbanised" (Alves et al., 2019). The objective is to observe potential differences and draw conclusions about the detrimental impact of human activities on the environment. Human presence and activities around an MPA can cause disturbances, leading to the degradation or modification of the ecosystem's functional structure or cetacean presence (Castellote et al., 2015; Purdon et al., 2020). For example, in Madeira Island, non-protected areas may suffer a decline in local biodiversity, while urbanised areas might see an increase in opportunistic species (Alves et al., 2019). The level of human pressure likely plays an important role in the health of the marine ecosystem, particularly in the composition of benthic communities.

From a different perspective, the ecological status and habitats of marine ecosystems may be compromised by terrestrial human activities. The ecological state depends on the artificialization of the coastline. The closer a reserve is to the coast, the more its ecological quality diminishes (Fan et al., 2019). Moreover, indirect pollution (e.g., chemical contaminants) from urban areas can discharge into the sea and affect a protected area (Silva et al., 2021). The proximity to an urban bay produces alterations in the benthic communities within the reserve (Moreira et al., 2019). Indirect impacts of land-based human activities, such as urbanisation and land use, were more important in determining the condition of seagrass beds than marine protection measures (Quiros et al., 2017). Protection measures on land near seagrass beds, which involve minimising the human disturbance to the land, have positive effects on the condition of seagrass beds. Conversely, land uses such as agrochemicals in watersheds, livestock and human development (urbanisation) negatively impact the condition of seagrasses. Land occupation and local human activities such as coastal development limit the effectiveness of protection measures on coral reefs (Suchley and Alvarez-Filip, 2018). Keywords such as urbanised areas (Alves et al., 2019; Fan et al., 2019; Moreira et al., 2019) frequently appear, and variables such as population density, tourism, and ports are examined. Quiros et al. (2017) discuss human development and urbanisation, considering factors like housing, commercial development, and infrastructure, showcasing a spatial perspective with movements and interactions across space and time.

In the second group, the term "human impact" is measured through various concepts, including the well-known concept of "Gravity" (Cinner et al., 2018). This is a predictive model for interactions between two locations, such as a city and a coral reef, that assesses the impact one may have on the other based on their distance and the population size. The discourse also encompasses human threats, defined as "processes, activities, or potential events in which an impact is likely to occur in the future" (Ervin, 2003). The concept of human threat is more localised. Various indices emerge to define levels of human threats, combining factors like coastal development and marine pollution (Suchley and Alvarez-Filip, 2018). The concept of anthropogenic stressors is similar to the idea of a human threat, incorporating different activities that impact the marine ecosystem (Uribe-Castañeda et al., 2020).

3.5. *Creation of an urban indicator*

While there is no precise definition of the concept of "urban" concerning MPAs, it generally relates to the presence of a nearby city and the integration of human activities associated with an urban zone. The proximity of an MPA to a city implies greater human activity at sea, meaning that an area can be both protected and urban (Batista et al., 2014; Portman and Nathan, 2015).

To effectively mitigate human-induced threats to MPAs, these threats

Table 5
Designation of "human activities" through human impact indicators.

Article	Designation	Variables
Alves et al., 2019	Human-induced pressures/levels of human pressures: protected, non-protected and **urbanised area**	- Population density - Tourism (annual overnight stay) - Presence of harbour with ships
Cinner et al., 2018	**Human impact** though "gravity" concept: interactions between two places (e.g., cities) are positively related to their mass (i.e., population) and inversely related to the distance between them	- number of people - distance (time travel) (Modelling)
Quiros et al., 2017	Human development or **urbanisation** (houses, commercial development, roads)	- houses - commercial development - roads
Suchley and Alvarez-Filip, 2018	Human activity: The level of **local human threats** was estimated by integrating two component indices developed at a global scale by the World Resources Institute (WRI): (1) coastal development and (2) marine-based pollution and damage threats (= the distance to commercial and cruise ports scaled by shipping and passenger volumes)	Coastal development: - location and size of cities - ports/-airports - population density within 10 km of the coast - coastal pop. growth - tourism growth
Uribe-Castañeda et al. 2020	**Anthropogenic Stressors** identified by a literature review, a story map and boat field trips around Uramba MPA are: human construction, sewage, solid waste, oil pollution, logging, mollusc overexploitation, overfishing, seasonal tourism, marine traffic, improper aquaculture	- Human construction - Sewage - Seasonal tourism - Aquaculture - Marine traffic
Portman and Nathan, 2015	Human impact score from Portman et al., 2012): spatial model that estimates ecosystem-specific differences in the impacts of 17 **anthropogenic drivers** of ecological change.	Modelling
Zupan et al., 2018a	**Extractive threats**: Recreational fishing: hook and line/spearfishing Artisanal fishing: professional fishing (no. of boats/year) Commercial fishing: professional fishing trawlers/purse-seiners (no. of boats/year) **Non-extractive threats**: Tourism: bathing/trampling, scuba-diving, private boating, commercial boating (no./year)	Human threat quantification to define threat intensity index (Ic) to reduce MPA threat
Palacios-Sanchez et al., 2019	**Disturbance categories**: Considering the population size, its main activities, and infrastructure from the National census of population and housing, all sample sites were classified into categories of disturbance.	- Population size - Activities: fisheries and/or seasonal tourism - Infrastructure: urban development and/or port development

must first be quantified. Zupan et al. (2018a) consider all potential human threats within the study area (from extractive to non-extractive activities). Various approaches exist to assess human pressures within a given study area, with scoring methods being particularly common. One widely used approach is the "Human Impact Score", "a spatial model estimating ecosystem-specific differences in the impacts of 17 anthropogenic drivers of ecological change, combining expert-assigned impact weights with multiple drivers" (Portman and Nathan, 2015).

In this context, our systematic review reveals recurring patterns in the way urban characteristics are assigned to MPAs. As summarized in Table 5, urban areas are typically characterized by variables that can be grouped into three main categories.

- Population, encompassing variables such as "population density", "number of people", "size of the city" and "coastal population growth";
- Tourism activity, reflected in indicators like "annual overnight stays", "commercial development", "tourism growth" and "seasonal tourism"; and
- Accessibility and infrastructure, including variables such as "presence of harbour/port", "distance to the city", "house, roads", "human construction", "sewage", "aquaculture" and "port development".

If a protected area is designated using variables from at least one of these three categories, it can be considered urban. These qualitative variables could serve as a basis for representing the urbanisation of MPAs through an urban indicator. However, converting these qualitative variables into quantitative data would allow for a more precise evaluation of the degree of urbanisation of MPAs.

3.6. Mitigating human impact though management practices

Six of the studies focusing on the management of MPAs explored the urban aspect, specifically human-related factors. The authors analysed socio-economic factors that may influence management in a developing countries (de Oliveira et al., 2021) or in the Mediterranean Sea (Portman and Nathan, 2015). Analysis were conducted on all potential threats to an urban marine area in China, Xu et al. (2015) and to MPAs in California (Kemsley and Pukini, 2021). Zupan et al. (2018a) examined the ability of an MPA to cope with urban threats in the Mediterranean Sea while de Almeida et al. (2016) evaluated the management of an MPA over a decade in Brazil.

Within an MPA, the implementation of a management plan enhances conservation efforts (de Almeida et al., 2016). A high level of protection effectively eliminates extractive activities, however non-extractive human pressures persist (Zupan et al., 2018a). Urban growth can further weaken management, and incompatible activities, such as tourism (de Oliveira et al., 2021) and illegal fishing (Kemsley and Pukini, 2021) – the latter being particularly challenging to quantify – pose significant threats to protected areas. The primary factor undermining management measures is the lack of adequate enforcement (Gill et al., 2017). The adoption of an integrated environmental risk assessment and management (IERAM) framework can facilitate decision-making, thereby strengthening marine biodiversity protection within MPAs (Xu et al., 2015).

3.7. Interaction between the urban, management and marine ecology domains

Six articles include the domains of urban, management and marine ecology in their research. The articles explored the implementation of management strategies or practices to mitigate human impact, using different ecological variables. Fish diversity or biomass are the main ecological variables used to assess the impact of management strategies in different urban context (D'Agata et al., 2016; Díaz-Osorio et al., 2022; Huijbers et al., 2015; Palacios-Sanchez et al., 2019). Human impact can be measured by the frequency of detrimental activities such as collection and fishing (Lucas and Smith, 2016) or by measuring population size density (Osuka et al., 2021).

MPAs play an effective role in mitigating human impact (Lucas and

Smith, 2016). For example, biomass within reserves declines less rapidly under the effect of "gravity" compared to fished areas (Cinner et al., 2018). While MPAs positively impact fish communities, they do not improve water quality (Palacios-Sanchez et al., 2019). The primary goal of protection remains crucial. Although management measures within MPAs can enhance biodiversity, their effectiveness may be reduced by the proximity of human settlements and fishing activities in the coastal zone, as observed in the western Indian Ocean islands (Osuka et al., 2021). In Mexico for example, coral cover responds positively to protection, but negatively in areas where local human threats are significant (Palacios-Sanchez et al., 2019).

The literature often reports that protected areas near urban areas are more accessible and subject to increased human activities, leading to a reduction in fish biomass (Cinner et al., 2018) and weaker protection (Joppa and Pfaff, 2009; Mouillot et al., 2024). However, other studies suggest that MPAs close to cities can demonstrate equivalent effectiveness (in term of log response ratios – abundance inside vs. outside reserves) to those of more remotely located reserves (Huijbers et al., 2015) or even more so, particularly due to the illegal fishing in more distant locations (Díaz-Osorio et al., 2022). Proximity to urban centres can facilitate enforcement and surveillance.

In the northern littoral countries of the Mediterranean Sea, higher levels of protection within MPAs are significantly associated with greater human impact (M. Portman and Nathan, 2015). Thus, the coexistence of human habitation and marine protection is possible. The authors suggested that policymakers in urban areas implement restrictions or bans within MPAs to manage the anticipated increase of human activities.

3.8. Context and scale dependency

3.8.1. Definition of urban

The impact and intensity of anthropogenic pressures depend on the geographical, socio-economic, and ecological context. Urbanisation in countries like Indonesia or Costa Rica is characterised by small fishing communities and seasonal tourism. It is vastly different from the constant maritime traffic and mass tourism of the Mediterranean Sea, where intense human use is combined with a strong focus on conservation (Zupan et al., 2018a). Urbanisation therefore needs to be defined within its specific context.

Human impacts are also gradual. How far do they extend? When discussing urban agglomeration, where does the city begin, and to what extent can an area be considered urbanised? Some studies are highly specific and localised (Alves et al., 2019), while other are remarkably global (Cinner et al., 2018). For instance, cities are neither regarded nor studied as a determinant able to influence marine ecology or management.

3.8.2. Marine ecology

Marine ecology is influenced by its geographical context and cannot be compared across different environments. The results of Voorberg & Van der Veer (2020) (see 3.2.2 A multiple management practices) should be interpreted within the specific geographic context, and additional factors that may affect the results should be considered. Huang et al. (2017) found that private MPAs are more ecologically effective than public MPAs in terms of fish abundance. This finding, based on data from China, may be context- and culture-dependent and should not be taken as a general rule.

3.8.3. Management

The management of MPAs should be tailored to the social context, as each country or region has its own specific laws, which can be challenging to compare. A European initiative is fostering collaboration among Mediterranean countries to standardise marine regulations (Eger et al., 2022; Katsanevakis et al., 2020). Furthermore, environmental threats vary between developed and developing countries, for instance, poverty has been identified as a significant threat in Brazil (de Oliveira et al., 2021).

Most studies assessing MPA management or the impact of urban areas have primarily relied on large-scale assessments, using resolutions of 500 m (Batista et al., 2014) or 1 km^2 grid cells (Cinner et al., 2018; Micheli et al., 2013; Nelson and Burnside, 2019; M. Portman and Nathan, 2015). There has been limited focus on mapping specific threats to MPAs at smaller spatial scales, both within the MPA and its surrounding area. MPAs could therefore be used as tools for local spatial management (Zupan et al., 2018a).

4. Conclusion

The main innovation introduced by this review is the concept of MPA having an urban character. We identified various terms and factors related to urbanisation. An MPA may be considered urban if it is located in a so-called "urbanised" area with coastal development, or if it is subject to various human pressures. In the absence of a universally accepted definition of the term "urban" in the existing literature, the creation of an urban indicator that includes population, tourism and accessibility/infrastructure variables is necessary. The influence of management practices on marine ecology has been the focus of extensive research, in terms of both individual measures and more comprehensive investigations. The most common type of research identified in our investigation assessed the impact of human activities on marine biodiversity. The effectiveness of an MPA in reducing human pressure on the coastal ecosystem depends on the protection goal, the scale of the study, the local context and the allocated resources. The proximity of an MPA to an urban area can be a double-edged sword. While it can lead to increased human activity and fishing pressure, which could potentially undermine the protection provided by the MPA, it can also enhance surveillance, thereby benefiting the MPA. Establishing robust protection zones in areas close to population centres demonstrates the potential for a symbiotic relationship between human activity and conservation efforts.

Therefore, balancing protection and human activities is the most promising research avenue for the next decade and the reason that the governance and management of urban MPAs is a "Grand Challenge" (Ferraro et al., 2015; George et al., 2016; Howard-Grenville et al., 2014). Newly identified forms of co-governance (a hybrid of top-down and bottom-up approaches) are well-suited to addressing these challenges. Evaluating the governance types of MPAs in relation to their urban characteristics will be a valuable focus for future research.

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CRediT authorship contribution statement

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

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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Data availability

I have shared my data on supplementary materials.

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