Marine Protected Areas: A Literature Review of Their Conservation Effectiveness in Safeguarding Marine Biodiversity

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ABSTRACT: Marine Protected Areas (MPAs) are crucial for maintaining marine biological diversity because they safeguarded ecosystems, protected endangered or threatened species, and supported livelihoods, while social and economic security could be achieved by managing marine resources sustainably. This literature review aimed to synthesize related and relevant studies on the effectiveness of MPAs in safeguarding marine biodiversity. The study synthesized twenty (20) published peer-reviewed research articles and reports to scrutinize and provide answers to the questions surrounding the effectiveness, benefits, and challenges in enforcing this global conservation target. The outcomes of the reviewed and assessed papers revealed that well-managed MPAs significantly contributed to habitat restoration, species population recovery, and ecosystem resilience. However, issues such as weak enforcement, stakeholder conflicts, and climate change jeopardized their full potential. This review highlighted the contradictory position of this extensively used management tool at the intersection of biodiversity conservation and emphasized the necessity of adaptive management techniques to enhance MPA design, community involvement, and stronger policy enforcement.

KEYWORDS: MPA's, effectiveness; marine conservation; challenges; current trends

1. Introduction

Oceans were inhabited by a rich diversity of animals and plants [1]. Yet, despite their importance, they faced several threats and challenges caused by human actions. They were not immune to the ongoing impacts of climate change. One of the most serious climate-related threats to the ocean was coastal pollution, which undermined its rich variety of life. A significant contributor to this problem was human activity, which further added to and heightened the risks associated with climate change. For these reasons, it was essential to understand marine biodiversity and the threats to it. One of the key tools for protecting marine ecosystems and biodiversity was the establishment of MPAs.

Marine Protected Areas, or MPAs, had been defined in a variety of ways, but in general, they were designated regions that provided additional protection for conservation purposes. According to Muallil et al. [2], an MPA was a "universal" term for a marine area established

through legislation, administrative regulation, or other appropriate methods, aimed at conserving and protecting a portion or the entirety of the contained environment by developing management principles. Moreover, MPAs were frequently employed as management instruments to preserve ecosystems and species endangered by human activity.

The number of MPAs announced had risen rapidly on a global scale. Marine Protected Areas were very important for managing and protecting marine ecosystems [3]. There were several types of MPAs, which differed in terms of size, conservation goals, governance, and the level of protection they offered. MPAs also served as venues for environmental education, scientific research, and tourism activities [4]. Furthermore, they were considered essential in achieving Sustainable Development Goal 14 (SDG 14). In the Philippines, the national database recorded more than 1,800 MPAs. While some of these were effectively managed, others remained "paper parks" that were not properly enforced, safeguarding barely 1% of the nation's coral reefs. Although not all MPAs were well-documented or managed, they aimed to fulfill conservation objectives within communities, particularly balancing biodiversity protection with livelihood needs. These initiatives contributed to conservation goals even under less-than-ideal circumstances, and they laid the groundwork for the creation of future MPAs [5].

With the aid of scientific knowledge, this study aimed to assess the effectiveness of MPAs in preserving marine biodiversity across geographic regions. Specifically, it sought to address the following research questions: (1) To what extent did MPAs contribute to the conservation of marine biodiversity? (2) To what extent did they aid in the preservation of vulnerable or endangered marine species? (3) What challenges and constraints affected MPAs' ability to successfully protect marine biodiversity? (4) What knowledge gaps existed regarding the effectiveness of MPAs, and what areas of future research should be prioritized?

2. Materials and Methods

2.1. Study design.

A search for documents of scientific merit was part of the study design. ScienceDirect, PubMed, Springer, and Google Scholar were among the multidisciplinary databases searched for relevant studies. The study focused on MPAs and their conservation effectiveness in safeguarding marine biodiversity by using keywords such as "marine protected areas," "marine biodiversity," "marine conservation," "MPA effectiveness," and "current trends."

2.2. Selection of studies.

This study used searches of academic databases to perform a literature review of peer-reviewed articles published in English between 2010 and 2024. To identify pertinent reports that addressed the research questions posed in this study, the review applied inclusion and exclusion criteria. The article selection and screening procedure was guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The detailed selection and screening process is described below and illustrated in Figure 1.
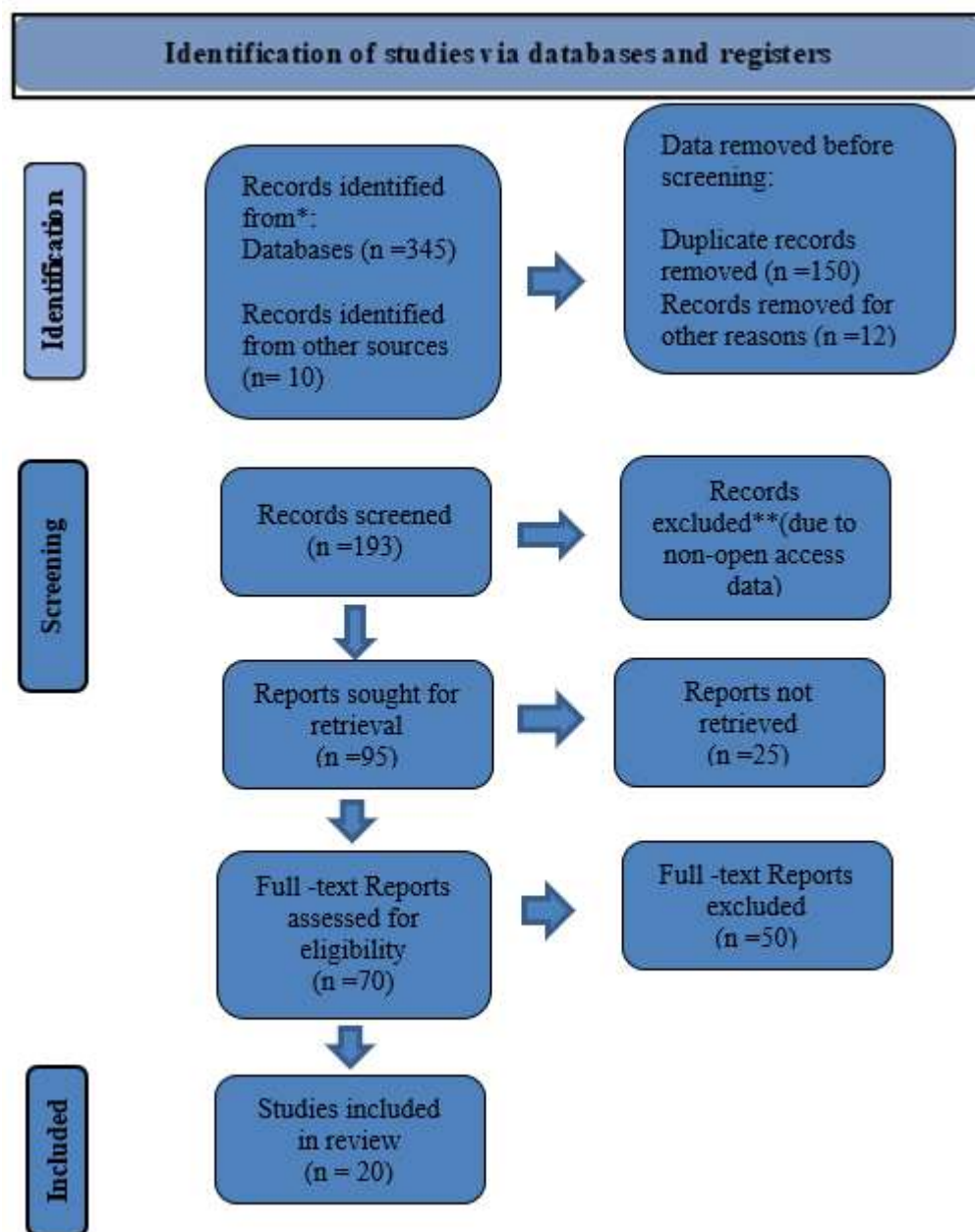
Figure 1. Screening the literature sample, adapted the PRISMA 2020 flow diagram to depict the selection and eligibility criteria.

2.3. Data extraction process.

A total of 355 papers (pre-inclusion criteria) were initially identified as relevant for synthesis from credible local and international research initiatives. These included peer-reviewed, English-language publications that discussed MPAs and marine conservation effectiveness. After applying the predetermined inclusion and exclusion criteria to the articles retrieved from Google Scholar and other databases, only 20 reviewed articles were included in the final synthesis. To ensure clarity and consistency in data extraction, the information was organized into columns (Authors, Study Title, Key Findings, Conclusions, and References). Table 1 presents a synopsis of the studies that were selected and synthesized.

Table 1. Summary of the synthesized articles (authors, title of the study, key findings and conclusion, and reference).

Title of the Study	Key Findings	Reference
"A review of a decade of lessons from one of the world's largest MPAs: conservation gains and key challenges"	Animal monitoring experiments have revealed that several taxa continuously nest and/or forage within the MPA (for example, some reef fishes, elasmobranchs, and seabirds), implying that the MPA has the potential to support long-term conservation	[6]
"From regional effectiveness evaluation and community engagement toward effective marine protected areas"	The review exposed management flaws in Taiwan's MPAs, while action research facilitated solutions through participatory processes. Region-specific indicator frameworks that connect with local goals are critical for maximizing MPA advantages. This project demonstrates an example quantitative-qualitative method to improving MPA management by combining evidence-based evaluations with collaborative action research	[7]
"Marine Protected Areas"	By safeguarding significant global fisheries, enhancing ocean resilience to the effects of climate change, and lowering cumulative impacts and pressures on our oceans, MPAs help to highlight the vital role they play in a future ocean environment that is changing	[4]
"Implications of Community-Based Management of Marine Reserves in the Philippines for Reef Fish Communities and Biodiversity	The study highlighted that fish communities exhibit great site accuracy, supporting the idea that marine reserves and fishery management plans should be examined site by site. The study findings show the significance of site-level dynamics in the success of community-based management.	[8]
"Impact of marine protected areas on temporal stability of fish species diversity"	The results validate the effectiveness of MPAs in maintaining the stability of temporal fish diversity. By stabilizing fish variety, MPA implementation may promote biodiversity resilience in the face of continuous environmental change	[9]
"Evaluating the use of marine protected areas by endangered species: A habitat selection approach"	Roberts et al. (2021) found that, after accounting for depth and productivity, sea turtles favored existing protected areas, particularly multi-use zones, but showed no preference for no-take zones. These findings inform MPA management and highlight the need for robust spatial modeling in planning networks for migratory species.	[10]
"Ecological effectiveness of marine protected areas across the globe in the scientific literature"	To safeguard essential genes, species, and ecosystems, MPAs were largely successful in reducing the primary threats to marine biodiversity, particularly fishing. MPAs should, however, have active, fundamental managerial operations in place and be subject to strict legislative requirements to be most effective. The ecological efficacy of multiple-use MPAs varied significantly more and appeared to be quite context-specific.	[11]
"Marine protected areas in the context of climate change: key challenges for coastal social-ecological systems"	Schmidt et al., considering that, using an integrated, co-developed, and interdisciplinary approach, MPA governance needs to be aware of the interdependence between human and environmental systems as well as their collaborative response to the effects of climate change. The study illustrates some of the difficulties in achieving efficient, flexible, and lawful MPA governance using the UK as a case study.	[12]
"Evaluating the social and ecological effectiveness of partially protected marine areas"	These findings challenge claims that partially protected areas are effective, arguing they provide little ecological or social benefit compared to open areas. In contrast, fully protected regions support greater species richness, biomass, and public trust, with benefits that improve over time.	[13]
"Time at risk: Individual spatial behaviour drives effectiveness of marine protected areas and fitness"	The study findings establish clear connection between individual fish behavior, fisheries-induced selection, and the efficacy of protected areas. These relationships underscore the significance of intraspecific trait variation in understanding population spatial dynamics, as well as the relevance of taking individual behavior into account when developing and implementing MPAs.	[14]

3. Results and Discussion

3.1. Extent of marine protected areas effectiveness in safeguarding marine biodiversity.

Due to the rapid worldwide growth of MPAs, there was a necessity for methods that could assess their true impact on biodiversity preservation [15]. Given the fact that this conservation goals were important instruments for the protection, conservation, and restoration of maritime ecosystems [13], MPAs varied from "partially protected areas" to "fully protected areas" and "no-take marine reserves." Hence, they all aimed to address solutions to the worldwide deterioration of marine life [16]. These ecological benefits improved the biomass of fisheries by increasing egg and larval production and by enhancing the spread of mobile juveniles and adults [17]. Moreover, they helped maintain fish populations, increased the number and reproductive capacity of the breeding stock, boosted juvenile populations, and acted as nurseries and zones for biodiversity protection. Generally, MPAs were extensively promoted as a fishery management device. Additionally, the management of marine protected areas varied between government-managed MPAs and community-managed MPAs.

One significant piece of evidence was titled *"Community- and government-managed marine protected areas increase fish size, biomass and potential value"* [18]. Government-managed MPAs helped restore small fish stocks, playing an essential role in the local conservation of high-value fish, and these impacts were equally powerful in coral reefs and seagrass beds [8]. Similar to larger and more established MPAs, smaller government-run MPAs and recently established community-managed MPAs were essential for protecting valuable local resources such as fish. Consequently, locally controlled MPAs potentially created valuable spillover effects on seagrass and coral reef ecosystems.

Another notable study, titled *"Marine protected areas are a useful tool to protect coral reef fishes but not representative to conserve their functional role"* [19], implied that MPAs could be a beneficial tool for sustaining coral cover and had been used as an important strategy for reducing species loss, increasing biomass, and managing fisheries. The study indicated that, on average, coral cover within MPAs remained stable, whereas coral cover on unprotected reefs decreased.

Furthermore, MPAs were primarily successful in minimizing the main risks to the marine ecosystem, particularly fishing, to safeguard important genes, species, and ecosystems. The success of MPAs and marine ecosystem conservation was based on credible information about the state of the marine environment that was available within a reasonable amount of time [4]. Compliance was critical for MPAs, and there was increasing evidence that stronger protection resulted in better outcomes. Enforcing marine reserves was challenging and costly, yet the benefits of well-protected areas were often overestimated. The majority of the MPA success elements mentioned in this article, describing the conservation effectiveness of MPAs across international research initiatives, are depicted in Table 2.

Table 2. The synopsis of the conservation effectiveness of MPA's across international research initiatives.

Title of the Study	Key Findings and Conclusions	Reference
"Marine conservation beyond MPAs: Towards the recognition of other effective area-based conservation measures (OECMs) in Indonesia"	The study reveals that OECMs could be very important for marine area-based conservation in Indonesia. For example, they could help the Indonesian government meet its national and international conservation goals and targets.	[20]
"Evaluating the evidence for ecological effectiveness of South Africa's marine protected areas"	According to the evidence, South Africa's MPAs now protect all ecoregions and 87% of ecosystem types, but less than half of the assessed species groups. MPAs are generally well-placed, however gaps were discovered along the west coast, in estuaries, the deep sea, and two ecologically and biologically significant areas. Enforcement surfaced as a major difficulty, and many MPAs may be improved by expanding or enhancing no-take zones.	[21]
"Marine Protected Areas: At the Crossroads of Nature Conservation and Fisheries Management"	MPA coverage, as an interesting case study to investigate the role of MPAs in promoting a sustainable management of the ocean.	[22]
"Evidence that spillover from Marine Protected Areas benefits the spiny lobster (Panulirus interruptus) fishery in southern California"	The results show that a 35% reduction in fishing area resulting from MPA designation was compensated for by a 225% increase in total catch after 6-years, thus indicating at a local scale that the trade-off of fishing ground for no-fishing zones benefitted the fishery.	[23]
"Exploring the development of scientific research on Marine Protected Areas: From conservation to global ocean sustainability"	Both bibliometric analyses showed that MPA science has changed from the traditional idea of "marine reserves" to a broader one that includes ecological, economic, and social factors. In conclusion, MPA research is responding to the recognition of MPAs as tools for ocean sustainability by connecting the biological and social-economic aspects of sustainability. This opens up MPA science to research from many different fields.	[24]

3.2. MPAs aid in the preservation of marine species that are vulnerable or endangered.

The primary objective of conservation programs should have been to keep populations and species far from endangered status. Effective management and conservation of endangered species depended on precise knowledge of their range, including migration patterns and interactions with their environment. In the context of conserving migratory marine species and their habitats, MPA networks had to be designed with several important considerations, such as the distribution of anthropogenic impacts and appropriate scale requirements. A fundamental step in conservation planning was often to identify high-use or high-biodiversity areas within a region of interest. In-depth knowledge of animal migration patterns and habitat preferences was necessary to create the most effective MPAs, and conservation plans for threatened or endangered marine species.

To highlight the efficacy of MPAs in assisting vulnerable and endangered marine species, one empirical study, titled *"Evaluating the use of marine protected areas by endangered species: A habitat selection approach"* [10], suggested that MPAs safeguarded turtles, which preferred existing protected areas, notably multi-use zones, after accounting for the impacts of depth and primary productivity. This empirical research generally agreed that there was considerable evidence indicating that MPAs could help endangered species, especially those that had faced historical threats within the boundaries of protected areas. Consequently, based on the articles synthesized in this review, it could be inferred that area-based protections offered by MPAs successfully contributed to the conservation of marine species, provided there was a well-structured and organized approach to conservation planning.

3.3 Challenges and constraints of the implementation of MPAs.

MPAs were a popular management technique for protecting marine species from human influences; however, their effectiveness was generally unverified [25]. A key factor hindering effective decision-making in the adaptive management of MPAs was insufficient information regarding the status and characteristics of conditions (including threats) affecting MPAs and their surrounding areas [10].

One of these challenges, cited in the study titled *"Marine Protected Areas: At the Crossroads of Nature Conservation and Fisheries Management"*, described that MPAs were important conservation and fishery management tools, since individual MPAs sought to achieve a variety of objectives, including the preservation of specific habitats or species, as well as the continuation of some commercial activities such as fishing. However, the establishment of MPAs involved social, ecological, and economic considerations, and the emphasis placed on each of these categories varied significantly when setting actual on-the-ground objectives, often causing serious conflicts among stakeholders [22].

Additionally, according to the scientific evidence presented in *"Avoiding 'Paper Parks': A Global Literature Review on Socioeconomic Factors Underpinning the Effectiveness of Marine Protected Areas"*, when MPAs were established, they often lacked specific goals. Many of these MPAs were little more than so-called "paper parks," with limited financial and personnel resources, rendering them ineffective. However, the study emphasized that by prioritizing stakeholder participation in MPA design, execution, and management, and by enhancing communication between management authorities and stakeholders (primarily fishermen), MPAs could continue to operate efficiently [26].

Furthermore, despite their contributions to biodiversity preservation, MPAs were increasingly impacted by the broader threat of climate change [27]. This included ocean acidification and warming, which prevented marine ecosystems from fully recovering. Although coral reefs within MPAs recovered more quickly than those outside, they continued to deteriorate due to rising sea temperatures despite vigorous conservation efforts. MPAs frequently did not achieve their maximum effectiveness due to issues such as illegal fishing, laws permitting harmful harvesting, or the migration of species beyond designated areas because of ongoing habitat degradation or insufficient reserve size.

Although several factors influencing the performance of protected areas such as location, strictness of regulations, and enforcement, had been studied to some extent, there was no global agreement on their overall effectiveness, as MPAs appeared to work best only in certain contexts. Greater importance should therefore have been placed on improved MPA design, sustainable management, and adherence to regulations to ensure that MPAs realize their intended conservation value.

3.4. The current gaps in knowledge regarding the efficiency of MPAs in safeguarding marine life.

In all its variations, MPAs are an excellent tool for conservation. Scientific evidence demonstrated that MPAs could support the maintenance and recovery of fish populations, enhance the resilience of ecosystems [10], and offer socio-economic advantages. Moreover, evidence for these benefits continually grew. However, the advantages of MPAs could only be achieved if they were properly located, well-protected, and efficiently managed. MPAs served

as an effective means of conservation, yet they required significant resources for their establishment and upkeep. Consequently, it was essential to allocate the available social and financial resources strategically to the most critical areas. With the increased demand for ocean space and resources from numerous industries, the need for such conservation funding has become even more important. Furthermore, the effectiveness of MPAs was still unclear as to how far and how consistently these benefits applied to different species, ecosystems, and geographies.

A significant gap in knowledge was mentioned in the study titled *"Assessing the management effectiveness of China's marine protected areas: Challenges and recommendations"*, which highlighted in its key findings that the lack of a consistent framework, insufficient survey data, financial assistance, and public engagement all provided significant hurdles to evaluating MPA management performance [28]. Some of the main problems described with MPAs included poor design and management, while others included factors such as size, level of protection, management, and enforcement.

Additionally, these gaps were highlighted in the Philippines case study titled *"Small-scale fisheries (SSF) management and conservation schemes and their application in the Philippines"*, which implied that fishermen's reliance on their livelihoods continued to limit the efficiency of management strategies, as pressure from a rising population of highly fishery-dependent coastal communities, food instability, and catch demand rendered measures inefficient. The underlying challenges were deeper and more systemic, stemming from a lack of long-term financing to ensure the survival of developed fishery management plans [29, 30]. Moreover, it was crucial to enhance the management of MPAs, as many failed to achieve their goals, particularly those related to the protection of marine biodiversity.

Although MPAs provided numerous advantages, they also encountered obstacles and misunderstandings. Confusion existed regarding the definition of "protection" and the likely MPA outcomes. This was because not all MPAs were similar. They ranged from comprehensive to minimal protection; some existed only on "paper," not in practice. Evidence for these viewpoints was implied in the study titled *"The MPA Guide: A framework to achieve global goals for the ocean"* [29]. One prevalent misconception was that MPAs only limited human endeavors, resulting in economic hardships for local populations. Nevertheless, with proper management, MPAs encouraged sustainable practices that were advantageous for both the ecosystem and the economy. Integrating marine protected areas into wider ocean planning and zoning projects was a strategic approach that overcame these drawbacks while maximizing the advantages of the MPA tool.

4. Conclusions

MPAs were significant in preserving marine biodiversity, and the importance of this goal across various ecosystems and geographical settings was emphasized in this review. Scientific evidence from local and international research initiatives demonstrated their conservation effectiveness. MPAs, particularly no-take zones and community-managed areas, provided numerous advantages. These advantages included increased biodiversity and resilience, the recovery of fish populations, and protection of coral reef ecosystems. However, this review also highlighted important obstacles that prevented MPAs from reaching their full potential, including problems with enforcement, planning and management, MPA size, and the broader threat posed by climate change. Even though MPAs were a crucial instrument for marine

conservation, their effectiveness was often weakened by issues such as inadequate funding, poor enforcement, and climate-related pressures like ocean acidification and warming. Additionally, the significance of adaptive management techniques such as community engagement and strict enforcement of policies, was emphasized to enhance MPAs' conservation outcomes and lessen the challenges in achieving these conservation goals. Overall, this review emphasized the importance of carefully designed and properly implemented MPAs that involved local communities in the management process. Future studies need to focus on addressing these challenges to optimize their effectiveness. When properly managed, MPAs remained an essential component of marine conservation and a key strategy for maintaining the resilience and well-being of marine ecosystems over time.

Acknowledgments

Author Contribution

The author is primarily responsible for the conceptualization of the manuscript, design, article selection for compilation, synthesis and analysis, writing, editing, proofreading, and validation. Author have proofread and approved the final version of the manuscript.

Competing Interest

The author discloses no conflict of interest related to the publication of this research.

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