Austin Publishing Group

Review Article

Analysis of Two Decades of Research on Marine Protected Areas in Malaysia (2001-2020): Knowledge Gap and Future Research Direction

Ismail MS[1]* and Goeden GB[2]

[1]Fisheries Research Institute, Department of Fisheries, Malaysia
[2]Blue Planet Environment PLT, Malaysia

*Corresponding author: Mohamad Saupi Ismail, Fisheries Research Institute, Department of Fisheries, 11960 Pulau Pinang, Malaysia

Abstract

The Marine Protected Area (MPA) in Malaysia was first recognised through the establishment of marine parks in the 90's. This study provides analyses of the scientific literature on Malaysia's MPAs published from 2001 to 2020, and discusses research trends, major knowledge gaps and directions for future research. To do so, a total of 113 selected scientific publications were analysed. The volume of research has increased rapidly in the last decade with the number of publications per year increasing from 1 in 2001 to 11 in 2020. Three main research indicators i. e. Biophysical, Socio-economic and Governance were used. The Biophysical indicator reveals great disparity with the majority of research focused on aspects of coral biology. Results also indicate that academic research has shown significant advances in the number of Socio-economic studies. Research was concentrated in three locations, i. e. Pulau Tioman, Pulau Redang and Pulau Payar. According to the bibliometric analysis, the top productive institutions were led by the Universiti Putra Malaysia. This study also addresses the research gap, explores new research opportunities and suggests future research directions for MPAs. The innovative technology element was identified as one of the priorities in future research. The current analysis highlighted the importance of collaboration and suggested that partnerships promoting synergistic activities between academic research institutes and the government sector could be the key to enhance and optimise the function of MPAs. In carrying out this review, the authors hope to 1.) Provide insight into the studies performed in MPAs of Malaysia, 2.) categorize areas where research has been conducted and also areas of concern or lacking data, and 3.) assist in guiding future research programs, for better understanding and management of the marine parks.

Keywords: Marine park; Academic research; Bibliometric; Biophysical; Socio-economic; Governance

Introduction

Globally, the future of coral reefs is threatened with environmental degradation affecting the sustainability of reef ecosystems. Broad expectations have been placed on Marine Protected Areas (MPAs) as instruments to protect and/or restore marine biodiversity and ecosystem function [1]. Thus, research is vital in MPAs if Malaysia is to achieve these goals.

At present, there are 42 islands and their surrounding waters that have been gazetted as MPAs in Malaysia. These MPAs are being managed using the Fisheries Act of1985 [2,3] and form huge warehouses that host treasures like coral, fish, unique habitats, etc. that help to define the health and wealth of the nation [4]. The Government of Malaysia plans to establish more marine parks to conserve these marine treasures. With more than 3, 600 km^2 of coral reef areas, the main objectives of MPAs are to protect the coral reef ecosystems from fishing and other harmful activities and safeguard the sustainable development of marine resources [2,5].

For successful MPA plans and actions, the perception of marine conservation issues must raise awareness on a broader management level. One of the factors that restrict effective decision-making in adaptively managing MPAs is a lack of information about the status and natural conditions of the MPAs [1]. After more than 20 years of MPA operation, there was a need to review the scope of studies carried out and designate priority areas for future research. Bibliometric analysis is an approach that analyses the worldwide scientific production of research findings, providing information on the research trends and future directions within specific research field [6].

Earlier investigations on Malaysian reefs, before the year 2000, focused on coral reef ecosystem [7]. In-depth research on reefs was restricted to the studies of selected marine park areas, such as Pulau (= island) Payar [8]. Previous studies of MPAs have been limited by the lack of sound designs and the absence of long-term monitoring data.

The goal of this study is to provide insights into the current status of research in MPAs by grouping topics into clusters of research areas. Also, this study aims to illuminate the impacts of academic research in these protected areas, to highlight potential challenges

and to identify research priorities that can enhance the relevance of research in current and future studies for sustainable management of coral reefs. The review could serve as a basis in fortifying the future direction of research on MPAs.

Materials and Methods

A literature search was conducted, from April to December 2021, using two commonly used databases of Web of Sciences and Google Scholar to collect all references related to Malaysia's MPAs. Additionally, searches of the Department of Fisheries' internal databases were carried out to ensure all relevant papers were acquired. Keywords are fundamental to the bibliographic search of academic literature. The terms of search were the 42 names of the marine park islands (e.g., Payar, Redang, Tioman etc.), "Marine Park" and "MPA". More than two hundred publications were retrieved. However, only peer-reviewed scientific journals, published between 2001 to 2020, were used for the analyses. Each was screened individually to determine whether it was within the scope of this study and focused on research directly related to MPAs. Excluded references were non-relevant studies that had been conducted outside the context of the coral reef ecosystem (e.g., terrestrial flora and fauna), conference papers and duplicated studies published in different journals.

Data for each publication was imported into Microsoft Excel for further analysis. These were included in a table containing date of publication, area of study, subject matter, author's affiliation, title and other related information. Each paper was then categorised using indicators used by the IUCN [1]. Three indicators were selected for assignment to each reference; Biophysical, Socio-economic and Governance. These indicators were also used by Kamil et al. [9] to assess the marine management strategy for MPAs in Southeast Asia. For the purposes of this report, the Biophysical indicator is further divided into the following topics; coral, fish, water quality, other reef community and other studies.

Studies addressing several MPAs (more than three) and "broad scope" publications addressing MPAs in a general way (e.g., did not specify any MPA in particular), were registered as "ALL". It should be noted that several publications discuss more than one MPA, and thus such sources were utilised in multiple sections.

Overall scientific production on MPAs per year was used to assemble charts showing annual frequency distribution histogram and cumulative production. The percentage of the most studied area and research fields was calculated, as well as the total number of publications produced. Additional histograms of frequency distribution were made to highlight the agencies producing the greatest number of publications, as well as which MPAs have been addressed in scientific literature across different research fields.

As the result of this review, knowledge gaps and research opportunities were identified and guidelines for future studies are presented.

Results

From 2001 to 2020, a total of 113 journal articles were published that related to this search. In the first decade, a smaller number of publications per year were observed, (3 or less papers), except in 2009. Entering the second decade, the annual publication rate increased adding significantly to the cumulative total publications. In 2013, the number of annual publications exceeded 10 for the first time. The greatest number of publications was in 2019 (Figure 1). The last decade's publication on MPA corresponded to 84. 07% (95 publications) of the total publications since 2001. Importantly, the last 5 years (2016 to 2020) recorded more than 50% of the total publications. These findings depict the strong and growing interest in MPA research in recent years.

The three indicators (Biophysical, Socio-economic and Governance) were utilised to categorize the topics explored by
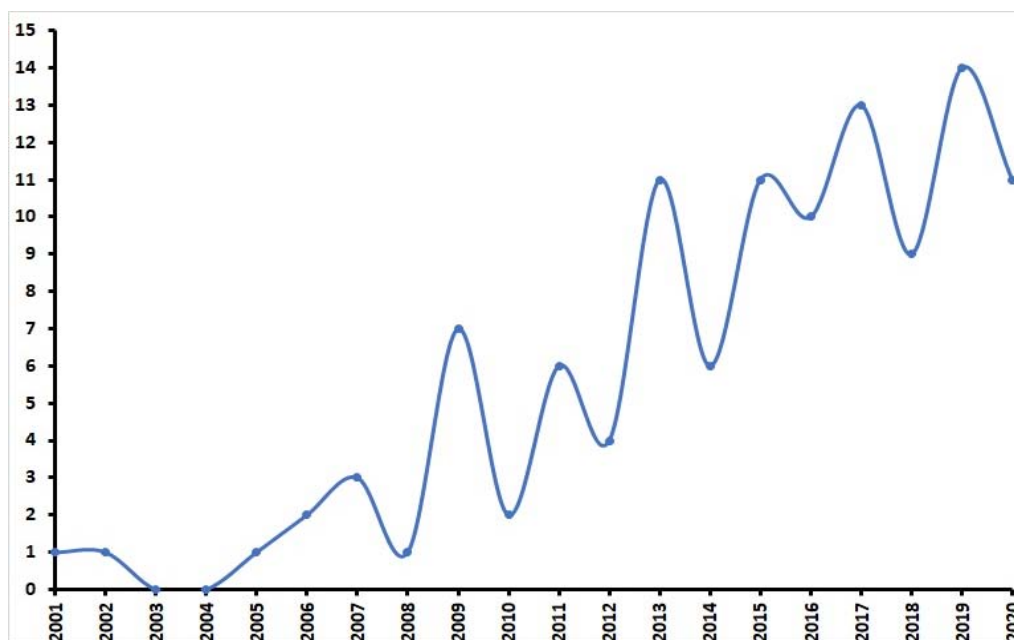

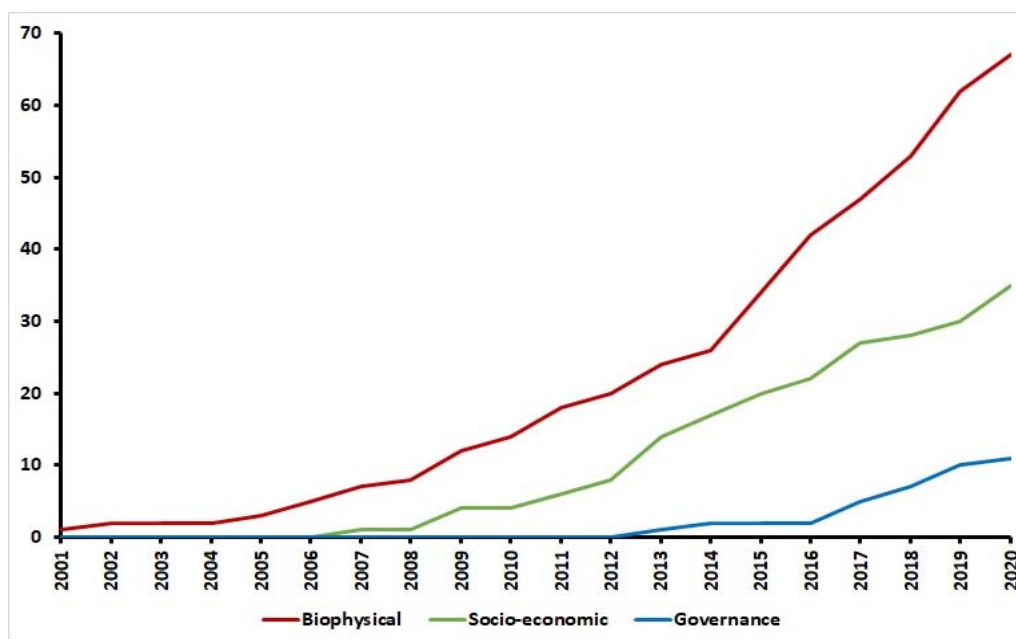**Figure 1:** The annual numbers of publications from 2001 to 2020.

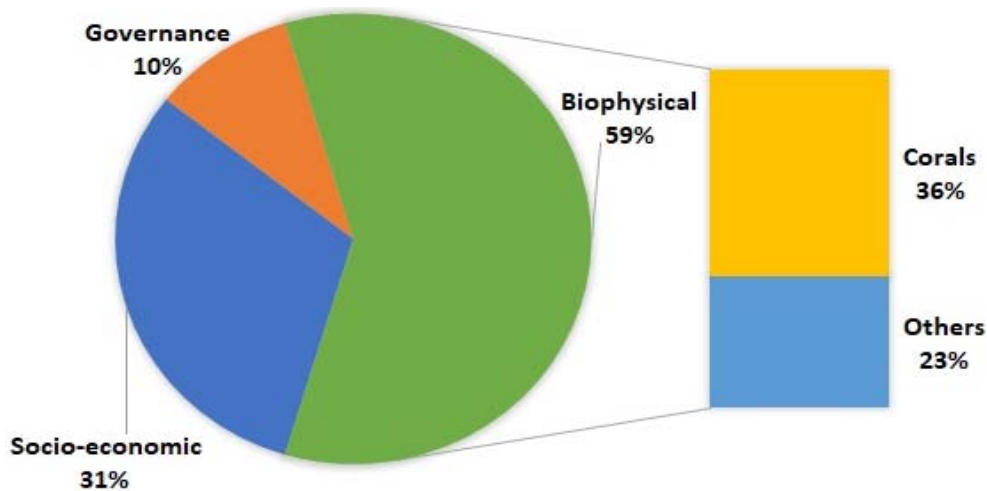**Figure 2:** The growth trends of the three research indicators.

Figure 3: Distribution of types of publication.

researchers in order to analyse the research trends from 2001 to 2020 and to see what patterns emerged over the years.

In the first five-year period (2001 to 2005), all research was focused on the Biophysical component. In the second period (2006-2010), research on the Biophysical component increased four times compared to the first period. During the same period, studies on the Socio-economic component emerged while, the Governance component remained at zero. Research related to Governance only emerged in the third period (2011-2015), while Biophysical and Socio-economic components demonstrated substantial growth in numbers of publications in the third and fourth (2016-2020) periods (Figure 2).

Throughout the years 2001 to 2020, Biophysical research constituted 59.3% of the total publications (Figure 3). This was followed by Socio-economic (31.0%) and Governance (9.7%). The high proportion of Biophysical publications demonstrates the high level of scientific interests in the fundamental knowledge of coral reef ecosystem. Subdivision of the Biophysical category classifies this interest showing the dominance of coral research over other areas.

Research Indicators

Biophysical

The Biophysical component has dominated research for the past two decades. Fifty-nine percent of publications were classified under the Biophysical category. For this study, the authors chose to investigate several aspects of the Biophysical literature. Thus, this category was separated into 5 subjects. The journals varied considerably in type of

Table 1: Publications on Biophysical subject.

Subject	% of the total publication
Coral	36.3
Fish	3.6
Other reef community	14.2
Water quality	0.9
Other studies	4.4
Total of Biophysical component	59.3

subjects over this two-decade period. However, despite this division, the most frequent subject in this category dealt with corals. Results shows that 36. 3% of the published academic research was focused on corals, where as less than 4% were related to fish, while 14. 2% carried out studies on other reef communities (Table 1). Since coral reefs are the backbone of Malaysia's MPAs, this could easily explain the dominance of this subject.

Among the earliest Malaysian studies related to coral community structure was one conducted by Toda et al. [10]. Since then, many more studies have focused on coral community structure (e.g., 11-13). The two most common methods used for coral assessments were the Coral Video Transect (CVT) method [14-15] and Reef Check method [16-17]. Both methods have their own advantages, however, in order to classify and compare coral reefs sites, a standard coral reef evaluation technique and methodology is needed, as suggested by Praveena et al. [18].

Reef Check Malaysia (RCM) has conducted annual monitoring programs in Malaysia since 2007 [16]. The contribution of the RCM project to MPAs of Malaysia was discussed by Lau et al. [17]. Much of the research on corals stemmed directly or indirectly from this project.

The biology and taxonomy of certain groups of corals have been studied [19] however, many other groups have not been investigated. Extensive information on coral species, especially in marine park areas, can be found in Mazlan et al. [20]. Also, the study of coral diseases is an emerging field and one which has contributed considerably to the understanding of coral reef decline in other parts of the world and to its potential relationship with anthropogenic activities. There has been little research on coral diseases in Malaysian reefs, despite these reefs being exposed to multiple natural and anthropogenic threats [21]. These researchers identified 6 types of coral disease in Pulau Tioman.

While studies on coral have been increasing, there has been a steady decline of coral reef health over the last two decades. For instance, live coral cover in Pulau Perhentian, Terengganu has been decreasing since 2009 [16]. Praveena et al. [18] concluded that poor to fair conditions of coral reefs in Peninsular Malaysia were due to increases of sedimentation and tourism impacts. This critical situation has led to the growing interest in coral restoration and conservation. In Malaysia however, restoration has not achieved the same interest as general conservation [22].

Based on peer-reviewed journals, four papers were focused on coral restoration in Malaysia's MPAs. Bin et al. [22] studied the effectiveness of coral restoration in Pulau Perhentian, and concluded

that the overall effectiveness level of the restoration was 67%, which can be considered as effective. The other three papers [23-25] were focused on enhancing coral recruitment using artificial substrates but effectiveness was not evaluated.

Although numerous studies have been carried out on corals, other biodiversity components are still lacking qualitative, quantitative and biogeographical results.

Studies on the biodiversity and the status of fish in MPAs of Malaysia are limited [16,26]. Despite the importance of sustainable management of fisheries resources, few attempts have been made to study the economic value of reef fish in the marine waters surrounding the MPAs. Only a single study has simultaneously addressed fish community and management considerations in MPA sites [26]. He concluded that understanding the present status of reef fish in terms of their biodiversity and abundance is important for the sustainable use of coral reef species in the future.

There were also limited studies on water quality and sedimentation rates in waters within the marine park areas [27-29]. Amir and Mohamed [30] documented a clear relationship between sedimentation and water quality with corals in turbid waters having slower growth rates than corals in clear waters due to the associated negative effects of high sediment loads and reduced water quality. The sediment resuspension at shallow reefs of PulauTioman [27] may have resulted in the slower growth of its *Acropora* corals [28].

Several other studies on other reef communities have focused on marine invertebrates such as mysids and zooplankton in the sea grass meadows [31-32]. Seagrasses are frequently found in conjunction with coral reef ecosystems, especially off Johor waters, and often serve as nursery and juvenile habitats for many reef-associated animals, including the threatened dugongs [33] and syngnathids [34]. Impacts that affect the integrity and functionality of these ecosystems inevitably affect coral reefs.

More recently, research into biochemical compounds [35-36] and a molecular study [19] have produced new insights into the bio-physiology of selected reef organisms.

Socio-Economic

There was a large proportion of research (31%) that focused on the Socio-economic component. Economic valuations of coral reefs need to incorporate the impact of changes in management on coral reefs biophysical characteristics [18]. Often, the Socio-economic conditions, derived from user attitudes, perceptions and beliefs (APB), can often establish pressures on resources other than those determined by Biophysical research. Annual publications rose steadily from 2007 to a peak of six per year in 2013. The continuing growth of the number of studies published in these two decades indicates that interest in this topic is growing. A total of 35 published studies have investigated the Socio-economic aspects of MPA reefs with researchers framing questions around three broad themes: (1) tourism impact; (2) community involvement/participation; and (3) sustainable development, with 12, 10 and 13 publications respectively. The common keyword to all these studies is tourism.

Tourism activities have increased considerably in Malaysia's MPAs [37]. Therefore, literature on the impacts to coral reefs

associated with tourists are more completely represented than the literature on impacts attributable to the local residents of MPAs. Tourism impact has been documented among the main reasons of the marine life and environmental degradation in MPAs. Such conditions have been observed in the marine parks of Perhentian, Redang, Payar and Tioman [5,37-39]. Islam et al. [5] suggested that the coral reefs in Pulau Perhentian are under serious threat, due to overwhelming pressures from tourism. Mohammed et al. [37] reported that tourists who are satisfied with the marine park attractiveness tend to behave more responsibly toward the environment. Negative impacts or threats to coral reef environments caused by tourism development on islands are pollution and the direct impact of those developments [9,11]. The impacts of scuba diving, however, are less well understood. Mapjabil et al. [40] suggested more educational strategies should be implemented across dive sites, with dive operations as the mediator to provide the information.

There has been a recent increase in the number of publications highlighting sustainable tourism [41-43]. The sustainability of marine parks is highly dependent on the visitors' behaviour, including millennial tourists [44]. Lizana and Mohamad Saupi [45] reported that most tourists visited a marine tourism destination to experience beaches, islands and marine parks. They suggested it is important that each marine tourist destination be distinguished as unique in order to compete and sustain its popularity. Saleh and Hasan [41] and Masud et al. [43] pointed out that community and stakeholder involvement in managing the MPAs must be considered in order to attain the goals of sustainable tourism in the future.

Some studies incorporated models or frameworks, such as Sustainable Livelihood Approach (SLA) [46], Sustainable Ecotourism Indicator System (SEIS) [47] and Structural Equation Modelling (SEM) [37], in order to assess livelihood and tourism sustainability of MPAs. A later paper by Ismail et al. [38] used the concept of estimating the loss of revenue from tourism impact in order to calculate the tourism cost to the environment. Also, it is important to include carrying capacity studies, as suggested by Ramdas and Mohamed [48]. Carrying capacity in tourism is the maximum number or threshold value which can be accepted or accommodated by a tourist destination while maintaining tourist satisfaction with reference to a standard of quality [49].

Several studies examined tourists' Willingness to Pay (WTP) a conservation charge in Pulau Perhentian, Pulau Redang, Pulau Tioman and Pulau Payar [50-52]. The findings indicated that tourists were willing to pay more than double the current conservation fees, for sustainable development, making the increase in fee viable.

Analysis of the Total Economic Value (TEV) characteristics in MPAs has received little attention to date. Chong et al. [53] reported that research on the economic value of coral reefs at present lacks comprehensiveness. An effective management tool, such as the use of a mathematically based simulation model, is needed to simulate more precisely the immediate and long term TEV effects [54]. There is, however, a need for the development and implementation of standard valuation techniques to enable better comparisons between MPAs.

Economic valuation and community participation are directions in future coral reef studies in Malaysia [18]. Economic valuation

via Cost-Benefit Analysis (CBA) can determine the benefits and costs generated by the MPAs [55]. Community participation and awareness towards protecting coral reefs is crucial as this resource is the main contributor to the livelihoods of local communities [5]. By systematically conducting the studies, this better understanding can support efforts to minimise any negative effects towards the MPAs.

Governance

Literature on governance only appeared in publications from 2013 onwards, with most of the articles geared towards management and conservation. Although the number has increased since 2013, it represents less than 10% of the total publications. The low percentage of articles in the Governance category implies that research on the management of MPAs is still in its infancy.

The issues concerning living corals in their reef environment have been discussed by Rudra [56]. These include threats to coral reefs, impacts of tourism, and integrated management of resources. He suggested that protection of biological resources of the reef environment is urgently needed. Aziz et al. [57] discussed the potential of using Marine Spatial Planning (MSP) for marine resource utilisation and conservation. Research on the role of MPAs in Malaysia in supporting the fisheries and tourism sectors is limited and needs to be improved, as reported by [4]. He pointed out that the lack of research in Malaysia on this issue is a cause of concern because of the importance of associated fisheries and coastal tourism sectors. Lim and Osman [58] suggested a philosophy of sustainable development should be introduced in the MPAs management strategies.

In-depth analyses on the involvement and engagement of local communities through collaborative management or community-based management were studied by Islam et al. [59], Noh et al. [60] and Rahman et al. [61]. The efficiency of MPAs management in the past has been inadequate, especially the lack of local community engagement in marine conservation efforts [61]. Lau et al. [17] developed a baseline map for Tioman Island Marine Park to identify distinctive conservation priority zones and concluded that engagement and involvement of local stakeholders is necessary in planning conservation and management strategies. This approach may be able to help safeguard the efficacy of the MPAs.

Another driver that has been identified is the overall effectiveness of MPAs. So far, only a single study assessed the effectiveness of the MPA strategy (i.e. 9). To be an effective fisheries management tool, MPAs should be embedded in broader fisheries management and conservation plans [3]. Whether such research can benefit the MPAs will largely depend on its capacity to provide suitable recommendations for management.

Research Intensity

It is important to consider the locations at which the studies have been undertaken. For this purpose, the selected publications were analysed in order to determine which islands where considered hotspots, keeping in mind that some studies have investigated more than one island. A review of the literature shows that while many MPAs have been represented in the studies, there are a few hotspots where much of the research has been conducted. The islands most cited within these two decades were Pulau Tioman (31.8%) and Pulau Redang (24.6%). The top-cited MPAs are listed in (Table 2).

Table 2: Top-five most cited MPAs in accessed publications.

MPA	No. and (%) of Studies			
	Biophysical	**Socio-economic**	**Governance**	**Total No. & (%)**
Pulau Tioman	26	14	0	40 (31.8)
Pulau Redang	19	10	2	31 (24.6)
Pulau Payar	9	6	2	17 (13.5)
Pulau Perhentian	3	9	2	14 (11.1)
Pulau Tinggi	10	2	0	12 (9.5)

In contrast, only 12 studies (9.5%) have focussed on Pulau Tinggi, which is the biggest MPA in Johor waters [2]. There is considerable unevenness in terms of the amount of research completed within each MPA. There is only a single publication from Pulau Labuan [12]. Even in established MPAs, like Pulau Perhentian, the information available is scant (11.1%).

Research Partners

Studies on Malaysia's MPAs have been conducted by 18 local institutions/agencies. Of all articles published, 15.0% were written by Universiti Putra Malaysia (UPM) and 12.4% were written by Universiti Malaysia Terengganu (UMT), comprising all three research indicators. In terms of ranking, these institutions played dominant roles in MPA research. Other key players in studying MPAs were Universiti Islam Antarabangsa Malaysia (UIAM), Universiti Kebangsaan Malaysia (UKM) and Universiti Malaya (UM) which contributed 11.5%, 10.6% and 9.7% respectively, focussing only on two indicators. These five institutions are responsible for nearly 60% of the total publications. This review also found that UIAM is a major contributor to the Biophysical research. They produced 12 (10.6%) of all articles examined. In the Socioeconomic category, UPM out-produced other research bodies with 11 (9.7%) publications. The top 10 overall research contributors from 2001 to 2020 are listed in (Table 3).

Discussion

Research Gaps and Opportunities

The increasing threats posed to coral reef ecosystems have focused our attention on MPA research. This is particularly the case in Malaysia which is a 'hotspot' of marine biodiversity. Some of the

key issues that could be addressed in future coral reef studies include:

i. Effects of management on coral reef health and impact of pollution on coral reef growth with a standardized coral reef methodology, established legal systems and their ability to reduce threats faced by coral reefs and the role of potential science-driven management with community participation [18];

ii. Long term monitoring of populations and community structure which would permit analysis related to the effects of climate change;

iii. A critical need to maintain expertise in coral reef taxonomy;

iv. Development of mathematical models encompassing Biophysical and Socio-economic components, and

v. More studies should be conducted in other MPAs, besides the ones listed in Table 2.

These are crucial steps toward filling the knowledge gap for coral reefs studies in Malaysia. Action in the next decade will be essential to mitigate the impacts on coral reefs from warming temperatures, through local management while meeting national and international obligations, particularly in the context of the United Nations Sustainable Development Goals, climate action, and the role of coral reefs as a global indicator [62].

For a standard coral reef method, the Coral Health Index, which uses a combination of three ecosystem parameters: (i) benthic cover, (ii) fish biomass, and (iii) microbial abundance [63], has been shown to be a reliable coral reef health assessment. To date, the CHI has been used to assess the health condition of the East Africa reefs and central Pacific atolls [63]. In Malaysia, a CHI study was carried out by Ismail et al. [64] on Pulau Anak Datai, Langkawi on the west coast of Peninsular Malaysia.

It is widely accepted that coral reefs have become increasingly threatened during the last two decades. According to Mazlan et al. [20], today's coral reef threats are combinations of natural and anthropogenic pressures. Significant among the latter is pollution [65]. Praveena et al. [18] point out that analysis of the impact of management on reef health and resilience is needed. Researchers as well as managers need to focus on factors that can support coral reef

Table 3: Top ten local institutions in producing publication on MPAs from 2001 to 2020.

Institution	No. and (%) of Publications			
	Biophysical	**Socio-economic**	**Governance**	**Total**
Universiti Putra Malaysia (UPM)	4 (3.5)	11 (9.7)	2 (1.8)	17 (15.0)
Universiti Malaysia Terengganu (UMT)	10 (8.8)	1 (0.9)	3 (2.6)	14 (12.4)
Universiti Islam Antarabangsa Malaysia (UIAM)	12 (10.6)	1 (0.9)	-	13 (11.5)
Universiti Kebangsaan Malaysia (UKM)	10 (8.8)	2 (1.8)	-	12 (10.6)
Universiti Malaya (UM)	6 (5.3)	5 (4.4)	-	11 (9.7)
Universiti Sains Malaysia (USM)	4 (3.5)	6 (5.3)	-	10 (8.9)
Universiti Utara Malaysia (UUM)	-	3 (2.6)	2 (1.8)	5 (4.4)
Universiti Tun Hussein Onn Malaysia (UTHM)	4 (3.5)	-	-	4 (3.5)
Reef Check Malaysia (RCM)	3 (2.6)	-	-	3 (2.6)
Universiti Teknologi MARA (UiTM)	-	2 (1.8)	-	2 (1.8)

resilience, in order to improve their health [18,30]. It is imperative that the coral reefs be monitored over the long-term. Most of the studies considered examined impacts over the short (months to years) to medium (one to five years) terms. Long-term studies can provide more meaningful, trend-based information, which is otherwise lacking. Long-term monitoring of coral reefs can provide critical data that helps coastal residents and the authorities understand the health of the reefs, their dependence on this health for their well-being, and the economic and social consequences of reef decline [62]. This becomes of particular importance when past studies are evaluated critically. Without these long-term views, results can be skewed towards static, or snapshot findings. So far, the Reef Check survey has been the only long-term, systematic, quantitative monitoring program of the reefs and their organisms. Unfortunately, from a realistic point of view and despite all the progress made, the research effort in this area remains to date very expensive and time consuming. While programs such as Reef Check provide an assessment of current coral reef conditions, there remains the need to objectively and accurately link a coral reef's health with MPA management.

It is also crucial to focus on other reef species, such as fish, in the future. Although the literature relating to reef fish is currently sparse, there are many areas to which we can look to fill in the gaps in our understanding of MPA management. A better understanding of the roles played by reef fish in MPAs will lead to greater understanding of the "spill over effect" to nearby commercial fishing grounds and broader concepts of coral health.

Research has been limited in the past due mainly to logistic difficulties but recent technological developments are expanding the horizons of studies. New and innovative technologies, involvement of local stakeholders and citizen scientists, legislation, and issues related to coral health now impact the direction of future research. An example is environmental DNA (eDNA) technology. This new technique is capable of facilitating non-invasive, economical and rapid monitoring of marine biota stocks [66]. It offers the potential to identify and better estimate species diversity by sampling the DNA of entire reef communities. Biotechnology was identified as the potential future direction as the number of these studies increased tremendously worldwide [67].

Research on MPAs is dominated by individual researchers working largely independently over a wide range of topics. Due to limitations on funding, there is a need to prioritize research, so that more effort is directed toward knowledge gaps. Multidisciplinary activities and multilateral collaboration networks among researchers are crucial in broadening the applicability of results. We see the beginnings of collaborative research studies in Biophysical areas in the last decade. The higher production of the top five institutions can be attributed to the formation of effective research teams via co-authorship networks. Similarly, there are opportunities to link academic research and government sectors. Interactions between academic research and the government sector such as funding and graduate students working for government agencies assist in more effective technology transfer. The gap in coral reefs studies can be minimized via collaborative research and networks, as supported by Praveena et al. [18] and Rudra [56]. For the effective direction of research, it is necessary to bring together the policy makers, researchers and stakeholders on a national level. To date, all parties

have managed their own data without data centralization for analysis or archival. Currently, the Department of Fisheries is involved in data compilation and centralization from a variety of data sources.

Future studies should be viewed as a means of establishing realistic benchmarks to be used by MPA managers to gauge and to boost the effectiveness of MPAs. Regular integrated studies of published literature using the three indicators (Biophysical, Socio-economic and Governance) will provide greater knowledge and assist the future implementation of MPAs [9]. The authors believe that prioritised studies can help research-management discussion, and will contribute to healthy and well-functioning MPAs.

Conclusions

The present bibliometric analysis offers valuable insights into the research trends on MPAs, from 2001 to 2020. In early 2000s there were very few articles on MPAs, however, a significant increase in publications, especially in recent years, was observed. Most recent reports on the MPAs concern corals, whereas reef fish have received relatively little attention. It is clear that extensive research and data gaps exist regarding Biophysical fields in the MPAs. The diversity of research present and absent in the MPAs is the central theme of this study. It is hoped that future research can address these gaps.

The analysis of MPA literature over two decades illustrates that researchers have largely been descriptive and not dealt with the practical issues facing MPAs in the future. There has however, been a significant advancement in technology in almost every aspect of research during these decades. Research has been limited due mainly to financial and logistic difficulties coupled with a long-standing need to develop expertise in coral reef taxonomy. Increases in multidisciplinary research and multilateral collaborations in Malaysian MPAs is essential to boost communication, merge goals and areas of future study, and importantly fast-track MPA research in Malaysia.

The current findings are fundamental to constructing impactful research programs for MPA ecosystems and expanding our knowledge on these unique environments. Periodic re-evaluation of the literature is worthwhile because it provides additional snapshots in time of research trends. Hopefully, in the future, more numerous and integrated studies will be conducted in the MPAs. Although this analysis focuses on MPAs, most of the issues addressed can be applied to other coral reef areas in Malaysia.

Acknowledgements

References

1. Pomeroy RS, Parks JE, Watson LM. How is your MPA doing? A guidebook of natural and social indicators for evaluating marine protected area management effectiveness. IUCN. 2004: 215.

2. Asian Development Bank (ADB). State of the Coral Triangle: Malaysia, No RPT146476-3, ADB Reports, Asian Development Bank (ADB). 2014: 109.

3. Weigel J-Y, Mannle KO, Bennett NJ, Carter E, Westlund L, et al. Marine protected areas and fisheries: bridging the divide. Aquatic Conserv: Mar Freshw Ecosyst. 2014; 24: 199–215.

4. Ali J, Ariff S, Viswanathan KK, Islam R. Effectiveness of marine protected

areas as a management tool for the management of the seas of Malaysia. Aust J Basic & Appl Sci. 2013; 7: 658-666.

5. Islam GMN, Noh KM, Yew TS, Noh AFM. Assessing Environmental Damage to Marine Protected Area: A Case of Perhentian Marine Park in Malaysia. The Journal of Agricultural Science. 2013; 5: 132-141.

6. Duan P, Cao Y, Wang Y, Yin P. Bibliometric analysis of coastal and marine tourism research from 1990 to 2020. Journal of Coastal Research. 2022; 38: 229-240.

7. Talib Z, Karim AKA, Wagiman S, Ramli MN. Marine parks Malaysia - management strategy. In Proceedings of the 1st Regional Workshop on Enhancing Coastal Resources: Artificial Reefs, Stationary Fishing Gear Design and Construction and Marine Protected Areas, 2003. Samut Prakan, Thailand. 2004; 129-136.

8. Ali A, Ilias Z, Arshad MA, Sah SAM. Proceedings of national symposium on PulauPayar Marine Park. Fisheries Research Institute, Penang. 2000: 218.

9. Kamil KA, Hailu A, Rogers A, Pandit R. An assessment of marine protected areas as a marine management strategy in Southeast Asia: A literature review. Ocean & Coastal Management. 2017; 145: 72-81.

10. Toda T, Okashita T, Maekawa T, Abdul Aziz KA, Mohd Khusairi MR, et al. Community structures of coral reefs around Peninsular Malaysia. J Oceanogr. 2007; 63: 113-123.

11. Shahbudin S, Akmal KF, Faris S, Normawaty MN, Mukai Y. Current status of coral reefs in Tioman Island, Peninsular Malaysia. Turk J Zool. 2017; 41: 294-305.

12. Safuan CDM, Ismail K, Khalil I, Ali A, Chong WS, et al. Quantification of coral reef benthos for coral health assessment in Labuan Marine Park, Malaysia. Journal of Sustainability Science & Management. 2018; 13: 101-112.

13. Khodzori FA, Saad S, Mohammad-Noor N. Coral community structure in Payar Island Marine Park, Malaysia. Journal of Sustainability Science & Management. 2019; 14: 29-39.

14. Safuan M, Boo WH, Siang HY, Chark LH, Bachok Z. Optimization of coral video transect technique for coral reef survey: Comparison with intercept transect technique. Open J Mar Sci. 2015; 5: 379-397.

15. Crehan O, Mair M, Yii SH, Safuan CDM, Bachok Z. Effect of tourism and sedimentation on coral cover and community structure. Tropical Life Sciences Research. 2019; 30: 149–165.

16. Hyde J, Yee CS, Chelliah A. Five years of Reef Check monitoring data for Tioman, Perhentian and Redang Island. Malaysian Journal of Science. 2013; 32: 117-126.

17. Lau CM, Kee-Alfian AA, Affendi YA, Hyde J, Chelliah A, Leong YS, Low YL, MegatYusop PA, Leong VT, MohdHalimi A, Mohd Shahir Y, MohdRamdhan R, Lim AG, Zainal NI. Tracing coral reefs: A citizen science approach in mapping coral reefs to enhance marine park management strategies. Front Mar Sci. 2019; 6: 539.

18. Praveena SM, Siraj SS, Aris AZ. Coral reefs studies and threats in Malaysia: a mini review. Rev Environ Sci Biotechnol. 2012; 11: 27–39.

19. Akmal KF, Shahbudin S, Hadry NNF, 'Ulwan KSKU, Amira MZK. Taxonomic status of Euphylliidae corals in Peninsular Malaysia based on morphological structures and phylogenetic analyses using mitochondrial COI gene. Russian Journal of Marine Biology. 2017; 43: 118–126.

20. Mazlan AG, Zaidi CC, Wan-Lotfi WM, Othman BHR. On the current status of coastal marine biodiversity in Malaysia. Ind J Mar Sci. 2005; 34: 76–87.

21. Akmal KF, Shahbudin S. Baseline assessment of coral health and disease in Tioman Island Marine Park, Malaysia. Community Ecology. 2020; 21: 285-301.

22. Bin LC, Salleh NHM, Bin LK. The evaluation model for coral reef restoration from management perspective for ensuring marine tourism sustainability. Journal of Sustainability Science & Management. 2020; 15: 93-104.

23. Shahbudin S, Hafiz ZH, John BA, Kamaruzzam BY, Jalal KCA. Distribution and Diversity of Corals on Artificial Reefs at Pasir Akar and Teluk Kalong, Redang Island, Malaysia. Journal of Applied Sciences. 2011; 11: 379-383.

24. MohdFauzi M, Ang SY, Saiful Bahri H, Mohd KHS. Colonization of marine epibiota around WABCORE artificial reef at Panuba Bay, Tioman Island, Malaysia. APCBEE Procedia. 2013; 5: 416-422.

25. Muhammad Faiz MH, Shahbudin S, Mukai Y. Coral recruitment success and sessile benthic colonisation estimation in Tioman Island Marine Park, Malaysia. J Coast Conserv. 2017.

26. Arai T. Diversity and conservation of coral reef fishes in the Malaysian South China Sea. Rev Fish Biol Fisheries. 2015; 25: 85–101.

27. Lee JN, Mohamed CAR. Accumulation of settling particles in some coral reef areas of Peninsular Malaysia. SainsMalaysiana. 2011; 40: 549–554.

28. Nakajima R, Yoshida T, Fuchinoue Y, Okashita T, Maekawa T, Kushairi MRM, Othman BHR, Toda T. Sedimentation impacts on the growth rates of the scleractinian coral Acropora formosa from fringing reefs of Tioman Island, Malaysia. SainsMalaysiana. 2013; 42: 1201–1205.

29. Mohamed KN, May MSY, Zainuddin N. Water quality assessment of marine park islands in Johor, Malaysia. Bulletin of Environmental Science and Management. 2015; 3: 19-27.

30. Amir Y, Mohamed CAR. A short review of coral resilience in a changing marine environment. Poll. Res. 2017; 36: 693-708.

31. Tan HS, Rahim AA. Diversity of coastal mysids from Pulau Tinggi, Sultan Iskandar Marine Park, Malaysia. Nauplius. 2018; 26: e2018037.

32. Shuaib N, Mohamed M, Rusiman MS, Matias-Peralta HM, Rahim A. Preliminary studies on the fluctuation of the biomass of size-fractionated zooplankton in sea grass bed of Pulau Tinggi, Malaysia Jordan J Biol Sci. 2020; 13: 715-719.

33. Ponnampalam LS, Izmal JHF, Adulyanukosol K, Ooi JLS, Reynolds JE. Aligning conservation and research priorities for proactive species and habitat management: the case of dugongs Dugong dugon in Johor, Malaysia Oryx. 2014; 49: 743-749.

34. Ooi JLS, Lim ACO. Seagrasses and syngnathid fish of PulauSibu, Johor. Malayan Nature Journal. 2019; 71: 361-365.

35. Shahbudin S, Deny S, Zakirun AMT, Haziyamin TAH, Akbar John B, Taher M. Antioxidant properties of soft coral Dendronephthya sp. International Journal of Pharmacology. 2011; 7: 263-267.

36. Marican H, Edros R, Mohammad M, Salleh S. Antimicrobial activity of tropical soft corals found in the Northern Straits of Malacca. International Journal of Engineering Technology & Sciences. 2016; 6.

37. Mohammed N, Aziz YA, Khairil Wahidin Awang KW, Samdin Z. Influence of destination attractiveness on place satisfaction and environmentally responsible behaviour in marine parks. Journal of Sustainability Science and Management. 2020; 15: 52-67.

38. Ismail R, Khalid K, Jaafar H, Ismail R. Perhentian Islands' cost of environment: Estimating the loss of revenue from tourism impact. International Journal of Academic Research in Business and Social Sciences. 2020; 10: 826-842.

39. Sharif NM, Lonik KAT. Physical environment and residents' perception towards tourism impacts: A case study of Tioman Island. International Journal of Academic Research in Business and Social Sciences. 2020; 10: 215-228.

40. Mapjabil J, Yusoh MP, Zainol R. Implikasi sosioekonomi pembangunan pelancongan penyelaman scuba terhadap komuniti pulau di Malaysia: Satu tinjauan awal. Geografia – Malaysia Journal of Society and Space. 2012; 8: 26-38.

41. Saleh MSM, Hasan NNN. Ecotourism and coral reef: Analysis of coral reef conservation awareness among stakeholders in Perhentian Island, Malaysia. American Journal of Tourism Management. 2014; 3: 7-12.

42. Ramli MF, Idris H. Pembangunan mampanpelancongnmaritim di PulauPerhentian, Terengganu. JATI. 2016; 21: 108-124.

43. Masud MM, Aldakhil AM, Nassani AA, Azam MN. Community-based ecotourism management for sustainable development of marine protected areas in Malaysia. Ocean & Coastal Management. 2017; 136: 104-112.

44. Abdullah SINW, SamdinZ, Ng SI, Ho JA. Marine parks as a destination

choice of millennial tourists: The role of consumption values and responsible environmental behaviour. Journal on Tourism & Sustainability. 2019; 3: 6-21.

45. Lizana R, Mohamad Saupi I. Factors affecting the performance of visitation to a marine tourist destination: The case of FRI Aquarium, Penang. Malaysian Fisheries Journal. 2013; 12: 35-53.

46. Masud MM, Kari F, Yahaya SRB, Al-Amin AQ. Livelihood assets and vulnerability context of marine park community development in Malaysia. Social Indicators Research. 2016; 125: 771-792.

47. Ng SI, Chia KW, Ho JA, Ramachandran S. Seeking tourism sustainability – A case study of Tioman Island, Malaysia. Tourism Management. 2017;58:101-107. doi:10.1016/J.TOURMAN.2016.10.007.

48. Ramdas M, Mohamed B. Impacts of Tourism on Environmental Attributes, Environmental Literacy and Willingness to Pay: A Conceptual and Theoretical Review. Procedia - Social and Behavioral Sciences. 2014; 144: 378-391.

49. Kostopoulou S, Kyritsis I. A tourism carrying capacity indicator for protected areas. Anatolia: An International Journal of Tourism and Hospitality Research. 2006; 17: 5-24.

50. Ahmad SA, Hanley N. Willingness to pay for reducing crowding effect damages in Marine Parks in Malaysia. The Singapore Economic Review. 2009; 54: 21–39.

51. Mamat MP, Yacob MR, Radam A, Ghani ANA, Lim HF. Willingness to pay for protecting natural environments in Pulau Redang Marine Park, Malaysia. African Journal of Business Management. 2013; 7: 2420-2426.

52. Akhter S, Tai SY. Tourists' willingness to pay for marine resource conservation at Pulau Perhentian Marine Park, Malaysia. {journal}. 2015; 4: 029-041.

53. Chong CK, Cesar H, Ahmed M, Balasubramanian H. Future research directions in coral reef management. In: Ahmed et al. (eds). Economic valuation and policy priorities for sustainable management of coral reefs. WorlFishCenter Conference Proceedings 70. WFC. 2004: 204-209.

54. Osman NH, Mohtar S, Juli AM, Ahmad A, Chan AA, et al. A proposed TEV framework for PulauPayar Marine Park. Journal of Business Management and Accounting. 2017; 7: 77-84.

55. Mokhtar MZ, Adrianza MA, Zulkifli HS. Cost-benefit analysis on marine parks in Terengganu. Journal of Business and Social Development. 2020; 8: 1-12.

56. Rudra T. Coral lives of Malaysian Peninsula - A multifaceted review. Eco Env & Cons. 2018; 24: 1435-1441.

57. Aziz N, Muhammad Z, Ghazali F, Talaat WIAW, Saputra J. Marine spatial planning: The way forward for sustainable development of central Terengganu, Malaysia. Journal of Southwest Jiaotong University. 2019; 54.

58. Lim DD, Osman NH. Kawasan perlindungan marin di Malaysia: Ke arah penerapan konsep pembangunan mampan. Journal of Tourism, Hospitality and Environment Management. 2020; 5: 50-66.

59. Islam GMN, Tai SY, Kusairi MN, Ahmad S, Aswani FMN, Senan MKAM, Ahmad A. Community perspectives of governance for effective management of marine protected areas in Malaysia. Ocean & Coastal Management. 2017; 135: 34-42.

60. Noh AFM, Shuib A, Tai S-Y, Noh KM. Indicators of governance of marine ecotourism resources: Perception of communities in PulauPerhentian, Terengganu. Int. J. Business & Society. 2018; 19: 17-25.

61. Rahman MAA, Ghazali F, Rusli MHM, Aziz N, Talaat WIAW. Marine protected areas in Peninsular Malaysia: Shifting from political process to co-Management. Journal of Politics and Law. 2019; 12: 22-30.

62. Obura DO, Aeby G, Amornthammarong N, Appeltans W, Bax N, et al. Coral reef monitoring, reef assessment technologies, and ecosystem-based management. Front Mar. Sci. 2019; 6: 580.

63. Kaufman L, Sandin S, Sala E, Obura D, Rohwer F, Tschirky T. Coral Health Index (CHI): measuring coral community health. Science and Knowledge Division, Conservation International, USA. 2011: 15.

64. Ismail MS, Ilias Z, Ismail MN, Goeden GB, Yap CK. Coral health assessment of Pulau Anak Datai, Langkawi, Malaysia. Environmental Science and Pollution Research. 2022; 29: 45860-45871.

65. Lachs L, Johari NAM, Le DQ, Safuan CDM, Duprey NN, et al. Effects of tourism-derived sewage on coral reefs: Isotopic assessments identify effective bioindicators. Marine pollution bulletin. 2019; 148: 85-96.

66. Stat M, Huggett MJ, Bernasconi R, DiBattista JD, Berry TE, et al. Ecosystem biomonitoring with eDNA: metabarcoding across the tree of life in a tropical marine environment. Scientific Reports. 2017; 7.

67. Water JAVD, Tignat-Perrier R, Allemand D, Ferrier-Pagès C. Coral holobionts and biotechnology: from Blue Economy to coral reef conservation. Current opinion in biotechnology. 2021; 74: 110-121.