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Assessment of marine protected areas in the East China Sea using a management effectiveness tracking tool

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Marine protected areas (MPAs) are important tools for maintaining biodiversity, mitigating climate change, and conserving and restoring natural ecosystems. Management effectiveness assessment is an important component of conservation management in protected areas. In this study, we constructed a management effectiveness assessment tool based on publicly available information for China, with a total score of 126. We used the tool to systematically assess 27 national MPAs in the East China Sea. Our results showed that marine nature reserves (MNRs) and marine special reserves (MSRs) could be classified into two and three classifications, respectively, including MNRs I (n = 4, scores = 88-100), MNRs II (n = 6, scores = 75-81), MSRs I (n = 8, scores = 75-90), MSRs II (n = 6, scores = 59-75) and MSRs III (n = 3, scores = 53-56). Factors influencing the management effectiveness of nature reserves were the length of establishment and general public budget revenue, while for special reserves they were the length of establishment and total agricultural output value. Furthermore, protected areas with high management effectiveness scores tend to have a longer establishment time, dedicated management departments, adequate management staff and financial investment compared to those with low scores. In addition, the low-score MPAs require more communication with stakeholders. The study provides an objective and comprehensive systematic scoring of MPAs' management using METT-based framework and multi-source data. It overcomes the challenge of the general lack of data on MPAs and provides a new approach to management effectiveness assessment.

KEYWORDS

marine protected areas, management effectiveness, socio-economic, systematic evaluation framework, influencing factors

1 Introduction

Marine Protected Areas (MPAs) are "any intertidal or subtidal areas preserved by legal or other effective means, together with their overlying waters and associated flora, fauna, historical and cultural features, to protect part or the entire enclosed environment" (Kelleher, 1999). As such, they are a primary resource for managing, protecting, and restoring marine ecosystems (Hockings, 2003; Turnbull et al., 2021). Over the past two decades, the number of protected areas has expanded rapidly worldwide (Maestro et al., 2019). Currently, there are 17,781 MPAs worldwide, covering nearly 30 million km^2 (UNEP-WCMC, 2022). However, the effectiveness of management of the vast majority of protected areas is unknown, and many are suspected of being "Paper Parks" (Halpern, 2014; Geldmann et al., 2015), where ecosystems may still face threats such as declining biodiversity, habitat loss, and increasing human pressure (Butchart et al., 2010; Gaines et al., 2010; Tittensor et al., 2014). For example, in a global network study, only 59% of MPAs meet three of the five success criteria (Edgar et al., 2014). By the end of 2019, only 5.3% of global coastal and marine areas had specific conservation targets and clear geographic boundaries, and were well managed, with protected areas falling short of planned management targets for biodiversity, ecosystem services, representation, connectivity, equitable management, and effective management (Zheng and Zhao, 2020). Studies found that many MPAs fail to deliver positive social and ecological outcomes (Lester et al., 2009; Mascia et al., 2017) and that their management effectiveness is prone to be affected by many factors, such as management capacity (e.g., staff and budget) (Gill et al., 2017). Therefore, protected areas need to be managed effectively under appropriate legal frameworks and governance structures (Leverington et al., 2010), and the actual management effectiveness needs to be evaluated and monitored in a timely manner to facilitate adaptive management.

Management effectiveness assessment is the primary way to understand the extent to which protected areas are being managed in order to protect their corresponding values and achieve their objectives (Hockings, 2006). A timely assessment of management effectiveness can help understand the gaps between current management practices and overall goals, thus improving management practices and enhancing the management effectiveness of protected areas (Hockings, 2003). Management effectiveness assessment tools are now used in many countries, which can help improve conservation projects in these areas (Leverington et al., 2010). According to the Global Database on Protected Area Management Effectiveness (GD-PAME), 72 different approaches to protected area management assessment have been proposed as of June 2022 (UNEP-WCMC, 2022). Among these, the most frequently used method is the Management Effectiveness Tracking Tool (METT) (3945 completions, including 879 adaptations). Compared to other assessment methods, METT is applicable to individual PAs; it focuses on periodic retrospective evaluations and on the management planning, inputs, and process components of PAs (Hockings, 2006). The METT emphasizes process evaluation and dynamic tracking; it is simple and fast and has moderate assessment indicators (WWF and International Bank for Reconstruction and Development, 2007).

In China, the Technical Specification for Effective Management Evaluation of Nature Reserves (LY/T 1726-2008), the Assessment Standard for National Wetland Parks (LY/T 1754-2008), the Management Assessment Specification for Nature Reserves (HJ 913-2017), the Assignment of Points for Supervision and Inspection of National Marine Reserves, and the National Nature Reserve Management Assessment Assignment Table are employed depending on the assessment purpose (National Wetland Park Assessment Standards, 2008; State Forestry Administration, 2008), but management assessment is mostly carried out in terrestrial reserves and less applied in practice in marine reserves.

In the global protected area management effectiveness database, only 19 protected areas and two MPAs (Shankou Mangrove Reserve and Yancheng Wetland Rare Bird National Nature Reserve) in China are listed. An additional literature search revealed that there are few studies on management effectiveness of protected areas based on the METT framework in China, and most of the studies are on terrestrial nature reserves (Feng et al., 2017; Han et al., 2017; Lin, 2018; Qiu et al., 2019). There are only a few scattered studies on marine-based protected area assessment. Wang et al. assessed 81 national marine areas (Wang, 2018); Fu et al. evaluated the management effectiveness of Ma'an Island (Fu and Sun, 2017); Lin et al. (2022) evaluated the management effectiveness of nature reserves in Fujian Province, Zhang evaluated the management performance of the Ximen Island National Marine Special Protection Area in Yueqing City (Zhang, 2017), and Hong (2016) used the Wenchang fish sanctuary to evaluate management effectiveness and cost-effectiveness.

From the results of these studies, it is clear that there is still much room for improvement in the management level of national MPAs in China in terms of planning, input, and process components. Although these studies have generally adapted the assessment framework to the actual national context and the construction of protected areas in China, the established assessment methods are mainly based on data collection by means of questionnaires, interviews with managers, or consultation with experts, with a relatively low level of research on the quantification of scores and weights, and insufficient correlation analysis between indicators (Zheng et al., 2012). Data acquisition has been an enormous challenge, with issues such as the subjective influence of managers' scoring potentially leading to some bias in the assessment results. Therefore, developing a system of evaluation based on objective indicators will give a more accurate picture of the effectiveness of managing protected areas. In fact, the method has also been encouraged for adaptation (Stolton et al., 2019). The ideal adaptation should retain the basic format of METT and add additional points (Stolton and Dudley, 2016). More than 20 organizations and governments have employed or adapted the METT framework (Dudley et al., 2017).

As one of the four major sea areas in China, the East China Sea has rich biological resources in the region and is an important area for offshore protection. At present, the number of MPAs in the East China Sea is 83, the largest number of protected areas in China, including 27 national MPAs accounting for 32.53% of the total number of protected areas in the East China Sea (https://www.forestry.gov.cn). Studies on the effectiveness of protected areas in the East China Sea have gradually increased in recent years. Still, there has yet to be an overall systematic assessment, which is detrimental to the future planning and construction of protected areas in the East China Sea. Therefore, this paper presents a management effectiveness assessment system based on the METT assessment framework for the East China Sea protected areas and evaluates 27 national MPAs in the East China Sea according to the new adjusted system through six management components: context, planning, input, process, output, and outcome (Hockings, 2003). The clustering results were used to classify the 27 national MPAs in the East China Sea, to explore the

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driving forces of differences, and to provide recommendations for adaptive management of the East China Sea protected areas.

2 Materials and methods

2.1 Construction of the assessment framework

As the most widely used method, METT is systematic and operational, and can provide a rapid assessment of protected area management effectiveness, enabling managers to quickly grasp the current situation, determine the direction of management, and provide an effective reference for policy formulation and management work (Stolton and Dudley, 2016; Stolton et al., 2019). METT assessment focuses on the management planning, input and process components of protected areas (Hockings et al., 2006). However, Chinese MPA management also focus on the basic environmental conditions at the time of establishment, the achievement of protection aims (e.g., biodiversity conservation, shoreline and habitat environmental conditions), and the economic benefits of the protected area. Therefore, this study added adaptive indicators in different components to METT (Tables 1, 2). To evaluate MPA according to local conditions, making results more robust.

In the context component, the METT assessment only includes one indicator, legal status. However, in China, all the MPAs belong to the government and are established legally, so it is impossible to distinguish on the basis of this indicator alone. Chinese protected areas are mostly established based on considerations of livelihoods (e.g., small-scale fisheries), distribution of protected animals especially endangered species, and other issues (Huang et al., 2020). Therefore, we added "human activities", "utilization of sea area", and "endangered species" indicators to the context component (Zhang et al., 2017). The first two indicators were assessed as "yes/no", and the latter one was assessed by the number of endangered species.

In the planning component, the assessment indicators are mainly reflected in the objectives, legal regulations, management planning, design, monitoring and evaluation, and land-sea connectivity, and less consideration is given to special planning and management zoning. China's national park system is characterized by conservation-oriented, scientific management, rational use, and multiple parties' participation in implementation and management. Special projects and spatial planning, such as reclamation and other human development or human-sea conflict activities, are often conducted inside and outside protected areas. Therefore, this study added indicators for "master plan" (5- or 10-years' planning), "special planning" (such as mariculture/research and monitoring/ecological space/urban lighting/tourism/eco-environmental protection/cultural monuments/pollution prevention, etc.) and "management unit" (single or multi-management). The functional zoning of nature reserves in China is based on the basic model of the international Man and the Biosphere Programme (MAB), the "core zone - buffer zone - experimental zone" model. Different management strategies are adopted in different functional zones to achieve the purpose of biodiversity conservation and sustainable development. The special reserves adopt the two or four-zone model of "key protection zone - moderate use zone - (ecological and resource restoration zone - reserved zone)". The ratio of functional areas has a significant impact on the conservation effect (Liu et al., 2022). A similar zoning situation exists in China's East China Sea protected areas (Zhang, 2020), and is often an important factor considered in implementation and management. So "functional zoning" also added in the planning component to assess functional zoning by whether it is conducted scientifically.

In the output component, METT indicators are only available for regular programs and tourism facilities, and there is a lack of consideration for environmental conditions, scientific publication, management facility construction, and resource restoration. So, we added indicators for "monitoring report", "science education promotion", "breeding and release", and "scientific research platform". For China, there is an urgent need for more scientific cooperation between protected areas and research institutions (Liu & Liu, 2015). Scientific publications are a tool to visualize research work and can be used as a criterion for the output component of protected area management activities. Therefore, the indicator of "scientific publication" was added, indicating " the number of papers published about ecosystems within the MPA, irrespective of affiliation". The evaluation was divided into levels according to the amount of literature on protected areas.

Protected areas and national park systems also undertake social functions and services such as ecotourism, sustainable development, restorative aquaculture, scientific publication and conservation. Therefore, we added the indicators of "marine engineering" (e.g., cross-sea bridges, undersea tunnel projects, undersea pipelines, undersea cable projects) and "development and utilization" (e.g., mariculture, marine recreation, eco-tourism) in the process section. In the input section, we added "the use of high technology". In the results section, we added the indicators of "species increase", "invasive creatures" and "economic transition". All these indicators were assessed on a yes/no basis (Supplementary Material). Considering that data on some indicators such as internal management system, file management, and biochemical indicators are not available, they were not used as additional scores.

Two scoring approaches were adopted in this study with reference to the METT scoring method (UNEP-WCMC, 2022). The first approach was a graded scoring of "0-3" for the basic METT indicators. A score of 0 was given when the indicator was poorly or not completed, or no public information was found. A score of 1 was given when the indicator was partially completed. A score of 2 was given when the indicator was completed well. When the indicator was completed very well, it scored 3 points. The second approach was a "0/1" scoring for the METT additional points and the indicators newly added by this study. A score of 0 was given when no management activities related to the indicator were conducted. A score of 1 was given when management activities related to the indicator were conducted. Higher scores indicate good management and vice versa. Our adjusted research framework had 30 indicators with 90 score points and 32 additional items with 36 score points, totaling 126 score points.

2.2 Study areas

The study areas were the national MPAs in the East China Sea, with a total area of 7343.23 km^2, as detailed in Table 3. The earliest national MNR was established in Yancheng, Jiangsu Province, 39 years ago, and the last national marine park was established in Hua'ao

TABLE 1 East China Sea marine reserves management effectiveness assessment system.

Component	METT	METT additional points	Additional points in this study
Context	Legal status	None	Human activities, Utilization of sea area, endangered species
Planning	Protected area regulations, protected area objectives, Protected area design, Management plan, Planning for land and water use, Monitoring and evaluation	Affect planning, Periodic review, Scientific Research and Monitoring, Land & Sea, Connectivity, Ecological services	Master plan, Management Unit, Special planning, Functional zoning
Input	Law enforcement, Resource inventory, Staff numbers, Staff training, Current budget, Security of budget, Fees, Equipment	None	the use of high technology, Publicity and education facilities
Process	Protected area boundary demarcation, Research Resource management, Management of budget, Maintenance of equipment, Education and awareness, Government cooperation, Local residents, Local communities, Commercial tourism operators	Stakeholders, mutually beneficial projects, Local support	Development and utilization, marine engineering
Output	Regular work plan, Visitor facilities	None	Monitoring report, Peripheral development, Science Education Promotion, Breeding and release, Scientific research platform, scientific publication
Outcome	Protection system, Economic benefit, Condition of values	Value Assessment, Routine Maintenance, Responding to threats	Species increase, Invasive creatures, Economic transition

TABLE 2 Differences between two frameworks.

Component	METT	This study
Context	There is only one indicator of legal status, which is not discriminative.	Adding three indicators: Human activities, Utilization of sea area, endangered species.
Planning	Focus on objectives, laws and regulations, management planning, design, monitoring and evaluation, land and maritime connectivity.	Adding four indicators: Master plan, Management Unit, Special planning, Functional zoning.
Input	Focus on staff and funding.	Adding two indicators: Publicity and education facilities.
Process	Focus on cooperation, protection, and education.	Adding two indicators: Development and utilization, marine engineering.
Output	There are only two indicators of regular work plan and visitor facilities, and there is a lack of consideration for environmental monitoring, scientific and educational publicity, and resource restoration.	Adding six indicators: Monitoring report, Peripheral development, Science Education Promotion, Breeding and release, Scientific research platform, scientific publication.
Outcome	The focus is on ecological value assessment and other aspects.	Adding three indicators: Species increase, Invasive creatures, Economic transition.

Island, Xiangshan, Ningbo, Zhejiang Province, only six years ago. The largest area is 2,472.60 km^2 in the Jiangsu Yancheng Wetland Rare Bird National Nature Reserve, while the smallest area is only 3.03 km^2 in Fujian Chengzhou Island National Marine Park. Most of these protected areas are managed at the divisional level, with 22 protected areas having established independent management units and the remaining five protected areas being administered by the marine fisheries administration of the municipality in which they are located. The study covers five sites in Jiangsu Province, two in Shanghai, nine in Zhejiang Province, and 11 in Fujian Province.

2.3 Data sources and selection

The data for the assignment of protected areas used in this study were obtained from publicly available information on the internet (as of May 13, 2022) and databases provided by the Forestry and Grassland Bureau. The search included the official website of each protected area and its other public and external windows, the websites of local municipalities, the websites of statistical bureaus, the websites of the Ministry of Agriculture and Rural Affairs, and news websites. The literature was obtained from China National Knowledge Infrastructure (https://www.cnki.net) and Web of Science (https://www.webofscience.com/wos/alldb/basic-search), and the literature was collected by searching keywords (name of each protected area/marine park, location municipality and protected area). After screening and exclusion, a total of 2700 items of data were finally collected from 847 sources (Table 4). The corresponding indicators of protected areas were assigned according to Supplementary Material, and there were no null values in the assignment results.

According to the study of factors influencing the effectiveness of protected area management (Yang et al., 2012; Xu et al., 2020), we selected 25 indicators, including resident population, primary/secondary/tertiary sector as a percentage of GDP, seafood yield et al. The data on mariculture yield, seafood yield, and GDP were from the statistical yearbook of 2016–2020 of the municipality where the protected area is located. The population and gender ratio data were from the statistical yearbook and the 7th population census, and the data on duration of establishment, area, MPA category were from the database provided by the Forestry and Grassland Bureau. Data on management unit levels and zoning details were from publicly available information on the internet (Table 5).

2.4 Data analysis and testing

2.4.1 Management effectiveness evaluation

The indicator scores were summed by the six management components to obtain the total score for each management component of each protected area. Normalizing the above results, to ensure that the result is between 0 and 1. When the results in the interval [0.75,1], this indicates the management measures of the component are relatively robust; when the results in the interval [0.5,0.75), this indicates that the component has some management measures in place, but needs improvement; when the results in the interval [0.25,0.5], this indicates that the component has some management measures in place, but there are significant defects; when the results in the interval [0,0.25), this indicates that the management measures in this component are clearly inadequate (Leverington et al., 2010; Lin et al., 2022). It is worth mentioning that this method is designed to compare relative scores between protected areas, not absolute scores.

2.4.2 Statistical analysis

To explore the relationship between protected areas and the drivers of effectiveness, this study used PRIMER-e to perform cluster analysis using Euclidean distance for MNRs & MSRs separately based on the assignment results of six components of protected areas. To further explore the reasons behind the differences in the management effectiveness of these protected areas. We constructed a model of 25 potential influencing factors (Table 5) and management assessment scores through DistLM (Distance-based Linear Model). Then we selected the influencing factors through a stepwise approach (screening criteria using the Bayesian Information Criterion, BIC). Finally, we visualized the fitted values using Distance-based Redundancy Analysis (db-RDA) ranking.

3 Results

3.1 Comparison of the two results

In this study, we added additional points(n) for context(n=3), planning(n=4), input(n=2), process(n=2), output(n=6), and outcome (n=3) components respectively, to compare the different results assessed by this study and the METT method (Figure 1). The level means the number of total points in each component of the protected area, and the same total number of points will not be counted repeatedly. From the evaluation results, this study was able to produce a clearer distinction between the context, planning, input, output, and outcome components. Among them, the distinction is mainly reflected in the context and output components. In the context component, the results were increased from 1 level (METT) to 4 levels (this study), and this change was mainly caused by the "endangered species" indicator. In the output component, the results were increased from 4 levels (METT) to 8 levels (this study), and this change was mainly caused by the " scientific publication " indicator.

3.2 MPA assessment

For the normalized results of the six components of the MNRs (Figure 2A and Table 6), the MPA in the interval [0,0.25) accounted for 50%, 10%, 30%, 20%, 10%, and 30%, respectively. And the MPA in the interval [0.75,1] accounted for 10%, 30%, 20%, 20%, 40%, and 30%, respectively. It shows that the management measures in the context component of MNRs are clearly inadequate, while the management measures in the output component are relatively

TABLE 3 Basic information of 27 MPAs in the East China Sea.

Marine Nature Reserve
Jiangsu Yancheng Wetland Rare Birds National Nature Reserve: "JSYC" Area: 2,472.6 km^2; Est: March 1983; Management: Jiangsu Yancheng National Rare Birds Nature Reserve Management Office
Jiangsu Dafeng Milu National Nature Reserve: "JSDF" Area: 780.0 km^2; Est: February 1986; Management: Jiangsu Dafeng Milu National Nature Reserve Management Office
Shanghai Jiuduansha Wetland National Nature Reserve: "SHJDS" Area: 423.2km^2; Est: March 2000; Management: Shanghai Jiuduansha Wetland Nature Reserve Administration
Shanghai Chongming Dongtan National Nature Reserve for Birds: "SHCM" Area: 241.6km^2; Est: November 1998; Management: Chongming Dongtan Bird Nature Reserve Management Office
Zhejiang Jiushan Archipelago Marine Ecology National Nature Reserve: "ZJJS" Area: 484.8km^2; Est: April 2003; Management: Zhejiang Xiangshan Jiushan Archipelago Marine Ecology National Nature Reserve Administration
Zhejiang Nanji Archipelago National Marine Nature Reserve: "ZJNJ" Area: 201.1km^2; Est: October 1990; Management: Nanji Archipelago National Marine Nature Reserve Administration
Fujian Shenhu Bay Submarine Ancient Forest Relics National Nature Reserve: "FJSHW" Area: 31.0km^2; Est: October 1992; Management: Fujian Shenhu Bay Submarine Ancient Forest Relics National Nature Reserve Management Office

(Continued)

TABLE 3 Continued

Marine Nature Reserve
Fujian Xiamen Rare Marine Species National Nature Reserve: "FJZX" Area: 330.9km^2; Est: April 2000; Management: Xiamen Rare Marine Species National Nature Reserve Management Committee Office
Fujian Zhangjiang Estuary Mangrove National Nature Reserve: "FJZJK" Area: 23.6km^2; Est: January 1992; Management: Zhangjiang Estuary Mangrove National Nature Reserve Administration
Fujian Minjiang River Estuary Wetland National Nature Reserve: "FJMJK" Area: 22.6km^2; Est: June 2013; Management: Fujian Minjiang River Estuary Wetland National Nature Reserve Management Office
Marine special reserves
Jiangsu Haimen Oyster Aphid Mountain National Marine Park: "JSHM" Area: 15.5km^2; Est: October 2006; Management: Jiangsu Haimen Oyster Mountain Oyster Reef Special Marine Reserve Management Office
Haizhou Bay National Marine Park, Lianyungang, Jiangsu: "JSLYG" Area: 514.6km^2; Est: January 2008; Management: Lianyungang Haizhou Bay Ecological and Natural Relics Marine Special Reserve Management Office
Jiangsu Xiaoyangkou National Marine Park: "JSXYK" Area: 47.1km^2; Est: December 2012; Management: Jiangsu Xiaoyangkou National Marine Park Management Office
Zhejiang Dongtou National Marine Park: "ZJDT" Area: 311.0km^2; Est: December 2012; Management: Wenzhou Dongtou District Marineic and Fishery Administration
Zhejiang Putuo Zhongjieshan Archipelago Special Marine Ecological Reserve: "ZJPT" Area: 218.4km^2; Est: August 2005; Management: Zhejiang Putuo Zhongjieshan Archipelago Marine Special Protected Area Administration
Zhejiang Yueqing Ximen Island Special Marine Reserve: "ZJLQ" Area: 30.8km^2; Est: February 2005; Management: Yueqing Ximen Island Marine Special Reserve Management Office
Zhejiang Shengsi Ma'an Archipelago Special Marine Protected Area: "ZJSS" Area: 549.0km^2; Est: May 2005; Management: Zhejiang Shengsi Ma'an Archipelago Marine Special Protected Area Administration
Zhejiang Yushan Archipelago Special Marine Protected Area: "ZJYS" Area: 57.0km^2; Est: August 2008; Management: Yushan Archipelago National Special Marine Ecological Protection Zone Management Agency
Hua'ao Island National Marine Park, Xiangshan, Ningbo, Zhejiang: "ZJHA" Area: 44.2km^2; Est: December 2016; Management: Xiangshan County Marineic and Fishery Administration
Zhejiang Yuhuan National Marine Park: "ZJYH" Area: 306.7km^2; Est: November 2011; Management: Yuhuan National Marine Park Management Office and Yuhuan National Marine Park Management Committee
Fujian Xiamen National Marine Park: "FJXM" Area: 24.9km^2; Est: May 2011; Management: Xiamen Oceanic and Fishery Administration
Fujian Chengzhou Island National Marine Park: "FJCZ" Area: 3.0km^2; Est: December 2012; Management: Marine and Fishery Administration of Zhaoan County
Fujian Fuyao Archipelago National Marine Park: "FJFY" Area: 67.8km^2; Est: December 2012; Management: Ningde Oceanic and Fishery Administration
Fujian Changle National Marine Park: "FJCL" Area: 24.4km^2; Est: December 2012; Management: Changle National Marine Park Management Office
Fujian Meizhou Island National Marine Park: "FJMZ" Area: 69.1km^2; Est: December 2012; Management: Fujian Provincial Department of Oceanography and Fisheries
Fujian Chongwu National Marine Park: "FJCW" Area: 13.6km^2; Est: December 2014; Management: Fujian Chongwu National Marine Park Construction Leading Group
Haitan Bay National Marine Park, Pingtan Comprehensive Experimental Zone, Fujian: "FJPT" Area: 34.9km^2; Est: August 2016; Management: Haitan Bay National Marine Park Management Organization of Pingtan Comprehensive Experimental Zone

robust. For the normalized results of the six components of the MSRs (Figure 2B and Table 6), the MPA in the interval [0,0.25) accounted for 11.8%, 17.7%, 35.3%, 35.3%, 15.9% and 5.9%, respectively. And the MPA in the interval [0.75,1] accounted for 41.2%, 52.9%, 11.8%, 5.9%, 29.4%, and 52.9%, respectively. It shows that the management measures in the input and process component of MNRs are clearly inadequate, while the management measures in the planning and outcome component are relatively robust.

The average score of the 27 MPAs was 76.3, of which the average score of MNR was 84.2, and the average score of MSRs was 71.6. Among the MNRs, Zhejiang Nanji Archipelago National Marine Nature Reserve scored the highest (100 points), while Shanghai Jiuduansha Wetland National Nature Reserve and Zhejiang Jiushan Archipelago Marine Ecology National Nature Reserve scored the lowest (75 points). Among the MSRs (including marine parks), Fujian Xiamen National Marine Park scored the highest (90 points), and Jiangsu Xiaoyangkou National Marine Park scored the lowest (53 points). In terms of the effectiveness of the different classifications of protection, the average score for marine parks was 71.3; for marine and coastal natural ecosystems this was 83.3; for

TABLE 4 Data sources for each protected area.

MPA name	Website	Yearbook	Literature	Press release
Jiangsu Haimen Oyster Aphid Mountain National Marine Park	5	4	5	5
Haizhou Bay National Marine Park, Lianyungang, Jiangsu	9	5	10	5
Jiangsu Xiaoyangkou National Marine Park	4	4	0	2
Jiangsu Yancheng Wetland Rare Birds National Nature Reserve	5	5	15	6
Jiangsu Dafeng Milu National Nature Reserve	8	5	42	8
Shanghai Jiuduansha Wetland National Nature Reserve	11	4	47	2
Shanghai Chongming Dongtan National Nature Reserve for Birds	9	3	46	4
Zhejiang Dongtou National Marine Park	3	3	9	8
Zhejiang Jiushan Archipelago Marine Ecology National Nature Reserve	7	5	13	4
Zhejiang Nanji Archipelago Marine Nature Reserve	16	3	88	2
Zhejiang Putuo Zhongjieshan Archipelago Special Marine Ecological Reserve	5	5	17	2
Zhejiang Yueqing Ximen Island Special Marine Reserve	6	3	14	7
Zhejiang Shengsi Ma'an Archipelago Special Marine Protected Area	4	5	24	2
Zhejiang Yushan Archipelago Special Marine Protected Area	6	5	7	5
Hua'ao Island National Marine Park, Xiangshan, Ningbo, Zhejiang	5	5	1	3
Zhejiang Yuhuan National Marine Park	4	5	1	3
Fujian Shenhu Bay Submarine Ancient Forest Relics National Nature Reserve	8	5	7	0
Fujian Xiamen Rare Marine Species National Nature Reserve	8	5	29	2
Fujian Xiamen National Marine Park	5	5	2	3
Fujian Chengzhou Island National Marine Park	7	5	0	2
Fujian Fuyao Archipelago National Marine Park	2	5	0	2
Fujian Changle National Marine Park	3	5	3	1
Fujian Meizhou Island National Marine Park	5	5	4	2
Fujian Chongwu National Marine Park	7	5	1	2
Fujian Zhangjiang Estuary Mangrove National Nature Reserve	9	5	63	2
Fujian Minjiang River Estuary Wetland National Nature Reserve	10	5	13	1
Haitan Bay National Marine Park, Pingtan Comprehensive Experimental Zone, Fujian	2	5	1	3

TABLE 5 Potential drivers affecting management effectiveness.

Driving factors	Specific indicators	Data source
Economy	Mariculture Yield, Marine fishing yield, Seafood yield, Seawater yield, GDP, Fishery output value, Mariculture production value, General public budget revenue and expenditure, Total agricultural output value, Disposable income of urban and rural permanent residents, The proportion of the output value of primary/secondary/tertiary industries in the total output value, Port cargo throughput, Container throughput	Statistical yearbook of the municipality where the protected area is located for the period 2016-2020
Society	Population, Gender ratio (M/F)	Statistical Yearbook and the Seventh Population Census
Administration	Duration of MPA establishment, Area, protected object, Type of protected area	Database provided by the Forestry and Grass Service
	Management unit level, Zoning details	Web public information

TABLE 6 Percentage of scores for each component of the 27 protected areas in the East China Sea.

MPA category	Rating Level	Context	Planning	Input	Process	Output	Outcome
Marine nature reserves	[0.75, 1]	1 (10%)	3 (30%)	2 (20%)	2 (20%)	4 (40%)	3 (30%)
	[0.5, 0.75)	4 (40%)	3 (30%)	4 (40%)	3 (30%)	3 (30%)	1 (10%)
	[0.25, 0.5)	0 (0%)	3 (30%)	1 (10%)	3 (30%)	2 (20%)	3 (30%)
	[0, 0.25)	5 (50%)	1 (10%)	3 (30%)	2 (20%)	1 (10%)	3 (30%)
Marine special reserves	[0.75, 1]	7 (41.2%)	9 (52.9%)	2 (11.8%)	1 (5.9%)	5(29.4%)	9(52.9%)
	[0.5, 0.75)	8 (47.1%)	5 (29.4%)	6 (35.3%)	4 (23.5%)	6(35.3%)	5(29.4%)
	[0.25, 0.5)	0 (0)	0 (0%)	3 (17.6%)	6 (35.3%)	5(29.4%)	2(11.8%)
	[0, 0.25)	2 (11.8%)	3 (17.7%)	6 (35.3%)	6 (35.3%)	1 (5.9%)	1 (5.9%)

marine biological species the average was 86.7, and for marine natural heritage and non-living resources the average was 77. Regionally, the highest average score of 84.5 was obtained for Shanghai's protected areas (marine and coastal natural ecosystems), and the lowest average score of 72.1 was obtained for Fujian's protected areas, as shown in Supplementary material.

3.3 Cluster analysis results

According to the clustering results (Figure 3A), the assessment results of MNRs were divided into two classifications: MNRs I scores are high, between 88-100, with an average score of 95, those that had been established for a long time (average 33 years), and those with a better overall assessment result, with the standardized scores of the assessment components from highest to lowest: planning (86), process (81), output (75), result (71), input (58), and context (25), with differences mainly reflected in the two components of input and context. Specifically, these were Jiangsu Dafeng Milu National Nature Reserve, Shanghai Chongming Dongtan National Nature Reserve for Birds, Zhejiang Nanji Archipelago National Marine Nature Reserve, and Jiangsu Yancheng Wetland Rare Birds National Nature Reserve. MNRs II scores are lower, between 75-81, with an average score of 78, and a shorter establishment time (average 22 years). The overall assessment results being at a medium level, with the scores of the assessment components standardized from highest to lowest: planning (43), input (43), output (36), context (33), process (32), and outcome (29), and the standardized score of local residents' participation in protected area management activities was only 22.2, with differences primarily in process and outcome. Specifically, these were Shanghai Jiuduansha Wetland National Nature Reserve, Zhejiang Jiushan Archipelago Marine Ecology National Nature Reserve, Fujian Shenhu Bay Submarine Ancient Forest Relics National Nature Reserve, Fujian Xiamen Rare Marine Species National Nature Reserve, Fujian Zhangjiang Estuary Mangrove National Nature Reserve, and Fujian Minjiang River Estuary Wetland National Nature Reserve.

According to the clustering results (Figure 3B), the assessment results of MSRs are divided into three classifications: MSRs I scores are high, between 75-90, with an average score of 82. That had been established for a long time (average 14 years), and the scores of the assessment components are standardized from high to low: planning (87), results (75), outputs (72), context (69), inputs (68), and process (55). The process components have low scores in indicators such as conservation demarcation, equipment maintenance, and government cooperation. Specifically, these were Jiangsu Haimen Oyster Aphid Mountain National Marine Park, Zhejiang Dongtou National Marine Park, Zhejiang Putuo Zhongjieshan Archipelago Special Marine Ecological Reserve, Zhejiang Yueqing Ximen Island Special Marine Reserve, Zhejiang Shengsi Ma'an Archipelago Special Marine Protected Area, Zhejiang Yushan Archipelago Special Marine Protected Area, Fujian Xiamen National Marine Park, and Fujian Meizhou Island National Marine Park. MSRs II scores are lower, between 59-75, with an average score of 66 and moderate establishment time (average 11 years). The standardized scores of the assessment components were, in descending order, planning (64), outcome (52), context (50), output (50), input (27), and process (25), with lower scores for the input and process components in the indicators of scientific cooperation, equipment maintenance, local residents, local communities, and water-related projects. Specifically, these were Jiangsu Haizhou Bay National Marine Park, Zhejiang

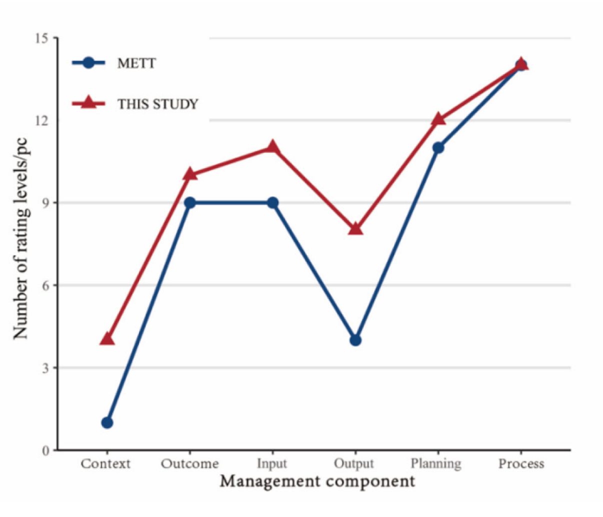

FIGURE 1
Comparison of METT based on 27 protected areas in the East China Sea with the assessment results of this study framework. Scores in the figure are the scores of different components in the assessment of protected areas under different methods.

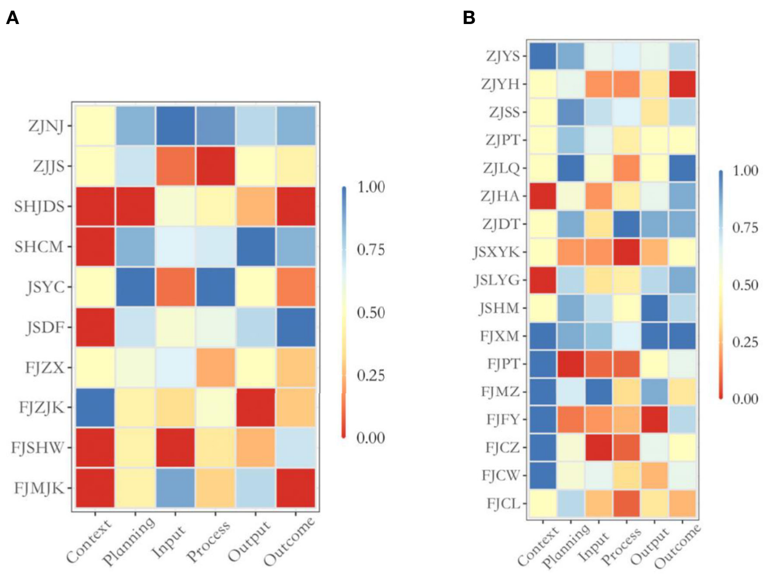

FIGURE 2
Results of the six components assessment of the 27 protected areas in this study: **(A)** MNRs **(B)** MSRs. Abbreviations are the names of the protected areas; see Table 3.

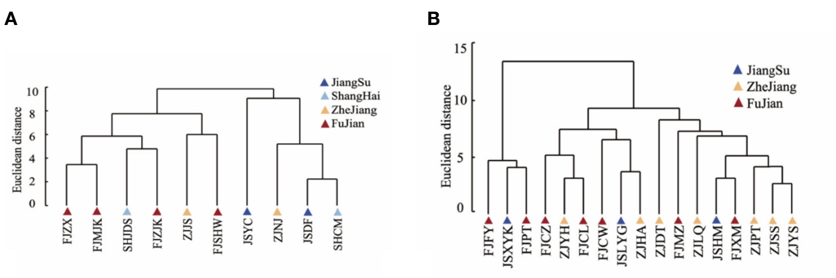

FIGURE 3
Clustering Analysis of Differences in Management Effectiveness of Protected Areas in the East China Sea Based on the Bray-Curtis Distance Algorithm: **(A)** MNRs **(B)** MSRs. Abbreviations are the names of the protected areas; see Table 3.

Hua'ao Island National Marine Park, Zhejiang Yuhuan National Marine Park, Fujian Chengzhou Island National Marine Park, Fujian Changle National Marine Park, and Fujian Chongwu National Marine Park. MSRs III scored the lowest, between 53-56, with a mean score of 54 and a shorter establishment time (average 9 years), and the standardized scores for the assessment components, in descending order, were Context (83.3), Outcome (63), Output (25), Input (15), Process (11), and Planning (10), and only 11 scores after standardization for staff training, with differences mainly in output, input, process, and planning. These were Jiangsu Xiaoyangkou National Marine Park, Fujian Fuyao Archipelago National Marine Park, and Fujian Haitan Bay National Marine Park.

3.4 Analysis of driving factors

Among MNRs, general public budget revenue and duration of MPA establishment were significantly correlated with the management effectiveness of protected areas ($P < 0.05$), and 17 indicators were not significant with the rest of the independent variables and therefore were not included in the model (Figure 4A and Supplementary Material). General public budget revenue (40.2%) and duration of MPA establishment (30.04%) were the most central influencing factors leading to differences in the management effectiveness of protected areas, while the rest were, in order, GDP (18.30%), area (17.50%), protection object (13.7%), disposable income of urban permanent residents (7.15%), type of MNRs (5.52%), and container throughput (3.38%). The contribution volume analysis showed that the management effectiveness of national nature reserves in the East China Sea was positively related to the duration of MPA establishment, negatively associated with the general public budget income of the municipality where the reserves were located, and not significantly related to the remaining factors.

In MSRs, total agricultural output value and the duration of MPA establishment were significantly correlated with protected area management effectiveness ($P < 0.05$), and 23 indicators were not significant with the rest of the independent variables and therefore were not included in the model (Figure 4B and Supplementary

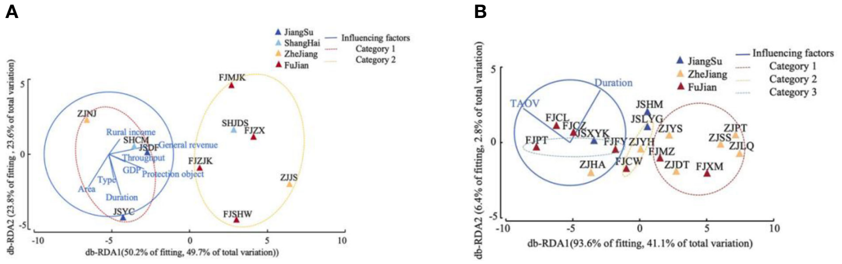

FIGURE 4
Drivers affecting the effectiveness of protected area management: **(A)** MNRs; **(B)** MSRs. ('Rural income' means 'Disposable income of urban permanent residents'; 'General revenue' means 'General public budget revenue'; 'Throughput' means 'Container throughput'; 'Type' means 'Type of protected area'; 'Duration' means 'Duration of MPA establishment'; 'TAOV' means 'Total agricultural output value'.) Abbreviations are the names of the protected areas; see Table 3. Detailed contribution, see Supplementary materials- Appendix 4.3 and 4.4.

Material). Among MSRs, total agricultural output value (29.79%) was the core influencing factor leading to differences in the management effectiveness of protected areas, followed by the duration of MPA establishment (25.92%). The analysis of the contribution of the quantity shows that the longer the duration of MPA establishment, the better the management effectiveness of MSRs, and the management effectiveness of the national MSRs in the East China Sea was positively correlated with the duration of establishment and negatively correlated with total agricultural output value in the municipality where the protected areas were located.

4 Discussion

Management effectiveness is an important aspect of monitoring the progress of protected area organizations (Leverington et al., 2010). As no overall assessment of national MPAs in the East China Sea had been conducted previously, this study developed a robust framework for assessing the management effectiveness of MPAs in the East China Sea (Stolton et al., 2019). The results assist us to sort out the current status of the national protected areas in the East China Sea and make recommendations for adaptive management (Lin & Liu, 2019).

4.1 Limitations of this study

Instead of going to the protected areas to conduct additional questionnaires, more profound research, and interview surveys, this study conducted panel research and assignment assessment with reference to the previous meta-analysis and protected area framework construction, and thus was a tentative exploration. In fact, there are clear explanatory public availed paper for the assignment of each score in this study. So, the use of publicly available papers on the web for assessment ensures that each indicator in this study is judged in a reasoned and informed manner. In this study, the relevant online public data of MPAs include public information published by MPAs, academic papers related to MPAs, and research reports from MPA superior departments and third parties, etc. (e.g., environmental agencies).

In this study, a score of "0" means both "MPA did not do management activities related to the indicator" and "MPA did management activities related to the indicator, but no publicly available data were obtained from online for this study". This means that if data are available through publicly available information online, they must also be available during the field research. The results of the assessment of the indicators are the same. If data are available through publicly available information online, the indicator will be assigned a score of 0. In this situation, we cannot judge whether the data will be available at the time of the field research, and then the score of the indicator assessed at the time of the field study will be greater than or equal to zero. When the study is used as a replacement for field research, the assessment results of this study may be less than or equal to the assessment results of the field research. This is a limitation of this study.

In addition, the MPA's communications or marketing department may want the publicly available information to look good (Markantonatou et al., 2016), leading to high scoring results. This is an unavoidable situation, and it was also the case when interviews are conducted with MPA-related personnel. In fact, this is similar to the traditional assessment of the METT approach, highly dependent on MPAs managing agencies scoring through questionnaires (Dudley et al., 2007). The framework of METT itself is, unavoidably, somewhat subjective. This study builds on the METT by objectifying the data as much as possible. Therefore, when evaluated using publicly available data, it provides an objective indication of the effectiveness of MPA administration. If MPAs could publish more data on the effectiveness of their protection, it would be more beneficial for future research to provide a more comprehensive assessment of MPA management effectiveness (Cinner et al., 2020).

4.2 Management effectiveness

As a whole, the national MNRs in the East China Sea were low in the context and outcome components, high in the planning and output components, and moderate in the input and process components. According to Sun (2018) assessment of Zhejiang Nanji Archipelago National Marine Nature Reserve, the reserve is in the [0.75,1] rank, consistent with the results of this study. However, due to the different selection and focus of the two methods, the indicators that scored lower in the previous study were resource conservation effectiveness and self-sustainability, while the indicators that scored lower in this study were management costs and equipment maintenance. According to the assessment results of Wang (2018) on the national nature reserves of Fujian Xiamen Rare Marine Species National Nature Reserve, Fujian Shenhu Bay Submarine Ancient Forest Relics National Nature Reserve, Zhejiang Nanji Archipelago National Marine Nature Reserve, Zhejiang Jiushan Archipelago Marine Ecology National Nature Reserve. The scores of MNRs are generally high and at the level of good management. However, there are problems such as single-source funding channels and incomplete legislation systems, results that were consistent with the assessment results of this study.

The national MSR in the East China Sea scored low in the input, process, and output components and high in the context, planning, and outcome components. According to Zhang (2017) assessment of the national MSR on Ximen Island, Yueqing, Zhejiang, the area is in the [0.75,1] rating, and the indicators with low scores include local residents and laws and regulations, consistent with the findings of this study. According to the assessment results of Sun (2018) for the National Marine Special Protection Zone of Ma'an Island in Shengsi, Zhejiang Province and the National Marine Special Protection Zone of Zhongjiashan Island in Putuo, Zhejiang Province, they are at the rank of [0.5, 0.75) and [0.75, 1], respectively, while the Protected Area of Zhongjiashan Island in Putuo assessed in this study is at the rank of [0.5, 0.75), lower than the results of this study. The differences in the assessment results mainly came from the lack of some internal information about protected areas in this study, and more publicly available and relevant information would have brought our results closer to those of previous studies.

4.3 Influencing factors

Previous literature has identified five characteristics of highly effective MPAs (Edgar et al., 2014), no fishing, good enforcement, longer establishment time and larger MPA area, which were also shown in this study to be important influencing factors on the effectiveness of protected area management. Except for these factors, the general public budget revenue of the municipalities was a negative factor influencing the MPA management effectiveness for MNRs. In China, the management and economic expenditures of national MPAs generally come directly from the Ministry of Natural Resources, and are theoretically less directly influenced by the municipal governments of the cities where the protected areas are located. But general public budget revenue usually reflected usually reflects the total economic volume and development priorities of a city, and this negative correlation might be due to the imbalance between conservation management and economic development caused by the increased focus on economic development in the cities where the MPAs are located. Besides, the management effectiveness of MPAs is also limited by the capacity of MPA staff and budget (Gill et al., 2017). Studies have shown that economic, social, and management activities cause changes in the management effectiveness of protected areas through complex mechanisms (Gallacher et al., 2016). Protected areas have the complexity and diversity of conservation objectives, conservation types, and protected area management units, and the imperfect digital monitoring system of protected areas leads to the lack of protected area monitoring data (Abell et al., 2007; Fu et al., 2021). The lack of communication and connectivity between protected areas has led to poor information sharing that limits the management, research, and development of MPAs (Bennett and Dearden, 2014b; Feng et al., 2021). In addition, bargaining among stakeholders may lead to asymmetries in management power and responsibility (Bennett and Dearden, 2014a; Wu et al., 2017), leaving protected area managers or local residents in a vulnerable position (Yu and Yu, 2017; Liu and Zhang, 2018). Public participation is also part of the impact management assessment (Voyer et al., 2012). The lack of legal safeguards for goal setting and implementation in different protected areas and the fact that some protected areas are hampered by inadequate funding and ecological compensation (Feng et al., 2017) have led to differentiation in management effectiveness (Hirschnitz-Garbers & Stoll-Kleemann, 2011).

According to previous studies, stakeholder involvement was identified as the most important factor influencing the success of MPAs and was considered in this study (Sylvaine et al., 2018). The planning of protected areas should take into account the diversity of nationally representative species (Xu et al., 2019) and species characteristics (Claudet et al., 2010). The inclusion of endangered species indicators in this study is also intended to provide a more robust and comprehensive consideration of the factors faced in protected area management. Hu et al. (2020) suggested that there is a need to better design and manage the MPA network in China, and the cluster analysis proposed in this study can help analyze the level and rank of protection of MPAs and facilitate the advancement of the management MPA network. The ecological aspects of protected areas, such as depth of water bodies, physicochemical properties and their biodiversity, can be added later to broaden the scope of the study (Bohorquez et al., 2021). Zhao et al. (2022) used 12 performance indicators to assess the management effectiveness of the MPA system in China, and the main issues obtained were relatively similar to the findings of this study, indicating that there are some commonalities in protected area issues that need to be to be addressed (Halpern et al., 2010). The main effectiveness of MPAs is related to MPA governance (e.g., resource use regulations and compliance) (Bennett & Dearden, 2014b).

4.4 Classifications and management recommendations

The previous study indicated that there were different results concerning the management effectiveness of protected areas in the East China Sea under various driving forces (Watson et al., 2014). Therefore, in the following, we will classify protected areas according to their management commonalities by combining government policies, natural environment and socio-economic factors, and make recommendations for adaptive management.

For MNRs I, the general public budget revenue of the municipalities where the first classification of MNRs is located is low, but their management is more effective. The analysis found that the general public budget revenues of the management agency where MNRs I are located represent about 1% of the public budget of their cities, typically 10 times higher than those of MNRs II. They have well-managed legal provisions, as well as a robust management system and advocacy capacity. Regular contact and scientific cooperation between managers and local governments, universities, users of land and water, and tourism operators were actively carried out, and more information was publicly available. However, the protected areas are more disturbed by human activities. In summary, two recommendations are proposed: 1) Summarize successful experiences, explore the advantages of the area, increase publicity, strengthen exchanges and cooperation with other protected areas, and provide feasible recommendations for other protected areas; and 2) Prohibit or restrict human activities in sub-regions (Zhuang, 2020).

For MNRs II, although protected areas have advantages such as management plans and ecological services (Fu, 2007; Portman et al., 2016), active resource management and scientific cooperation, they suffer from insufficient public budget revenues and mutually beneficial programs, and lack of communication with stakeholders (Li & Tang, 2012; Tang et al., 2014). In summary, two recommendations are proposed: 1) A community compensation mechanism should be established to gain the support and cooperation of residents in the surrounding communities (Rosa et al., 2004; Quan et al., 2009); and 2) Communication with stakeholders and community residents should be strengthened, increasing the participation of local residents in conservation management aspects. Creating an environment where the public can express their opinions directly to specific staff (Wei et al., 2017).

For MSRs I, the total agricultural output value is inversely proportional to the management effectiveness, suggesting that the ecological environment of the protected areas is more influenced by fisheries (primary industry) and recreational fisheries (tertiary industry). The management effectiveness of MSRs I is more influenced by the duration of MPA establishment; regular monitoring reports are available, and stocking is reasonably carried out in the area. The ecological value and biodiversity are well protected, but there are still problems, such as residents' unclear knowledge of protected area boundaries, lack of maintenance of equipment in the area, and insufficient cooperation with the government. In summary, three recommendations are proposed: 1) Vigorously carry out education; set up boundary markers and signs at the boundary, to improve stakeholders' awareness of the boundary of the reserve and reduce human activities; 2) Improve the management system; carry out inspection of facilities and equipment, and ensure regular maintenance of equipment; and 3) Allowing local governments to take the lead (Taylor, 2000; Zhuang, 2020), establish an ecological compensation mechanism. Develop information and technical support for community residents to find enrichment projects channels and provide technical support.

For MSRs II, their resource management activities are better, but problems still exist, such as a lack of cooperation in science and education, excessive use of ecological resources by residents and communities around the protected areas, unbalanced economic and environmental development. In summary, three recommendations are proposed: 1) Strengthen scientific research activities and science education advocacy, provide research platforms for research institutes and schools. Popularize ocean-related knowledge for youth, raise citizens' awareness of marine ecological protection, promote public participation. Including citizens in the construction of MPAs so that they can become part of the construction of MPAs (Chen et al., 2019; Zhang, 2020); 2) Considering the balance of local economic and ecological environment development (Zeng et al., 2016), that can avoid over-exploitation of the marine ecological environment by vigorously developing an aquatic product processing industry and guiding fishermen to switch to processing; and 3) Reasonably carry out implementation of marine engineering, strengthen research on the impact of large water-related projects on protected areas (Gao et al., 2007). Discussing and proposing corresponding protection countermeasures, and manage the feasibility demonstration, implementation, and post-project evaluation. The impact on the important ecological barriers of the protected area should be considered in the demonstration process.

For MSRs III, one-third (33%) do not have a particular management organization. There is a need for more staff training, high-tech equipment, and updated information. In summary, four recommendations are proposed: 1) Learning from experience to strengthen their own construction. We recommend learning from the successful experience of other well-protected areas to understand how each component is operated and controlled; 2) Strengthening the capacity building of the MPA management team. It is recommended to provide more professional training opportunities to managers, staff and patrollers, and increase the proportion of professionals in the management team (Nelson et al., 2019; Zhang, 2020), and develop training and capacity building plans for protected area staff and patrollers (Quan et al., 2009); 3) Strengthen daily monitoring, developing high technology, establish regular review mechanisms, and continuously monitor illegal fishing and illegal invasion in protected areas (Fu et al., 2021); and 4) Fulfill the obligation of information disclosure in protected areas, establish a leading group for information disclosure in protected areas. Information disclosed in accordance with the law within the responsibility of the competent authorities should be updated in a timely manner, such as institutional functions, policies and regulations, planning, operational work, and statistical data of protected areas (Wang, 2019).

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material. Further inquiries can be directed to the corresponding author.

Author contributions

This paper is a joint work of all authors. All authors have participated fully and are responsible for the work. All authors have given their consent to the submission. This paper is an original submission and has not been submitted elsewhere. No other manuscript contains the same, similar or related information as presented here.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2023.1081036/full#supplementary-material

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