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# Evaluating the effectiveness of three national marine protected areas in the Yangtze River Delta, China

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China's coastal areas face serious environmental degradation as a consequence of large-scale economic development. To balance environmental sustainability with economic development, China is currently implementing a strategy of 'eco-civilization', with marine protected areas (MPAs) expected to be one approach to achieving sustainable marine ecosystems. Since the 1990s, China has established over 270 MPAs, but their effectiveness remains unknown, particularly in the Yangtze River Delta. This study modified pre-existing frameworks to evaluate the effectiveness of three national MPAs in the Yangtze River Delta. The modified framework includes conservation outcomes and their potential drivers. Drivers consist of – attributes species or ecosystems within the MPA, attributes of the MPA, institutional design principles, and participation. Five scenarios were proposed based on score combinations of the four drivers: proactive, well designed, well governed, interactive, and learning. All three MPAs achieved a satisfactory level of outcomes and most of the drivers for all three MPAs achieved a satisfactory level. Two of the MPAs were categorized into the learning scenario, and the third into the well-designed scenario, indicating that there is still room to improve institutional design principles and public participation. We suggest developing cost and benefit indicators to more deeply understand proportionality among stakeholders. In addition, the role of participation should be clarified and promoted. We recommend regular environmental performance monitoring and assessment to identify problems and optimize management.

KEYWORDS

effectiveness, framework, drivers, environmental performances, management scenarios

## Introduction

The Earth's oceans are affected by human activities, and over 40% of the marine environment currently faces multiple pressures, including overfishing, climate change, and ocean- and land-based stressors (Halpern et al., 2015). This situation is more pronounced in the coastal areas of developing countries, such as China (McCook et al., 2018). China's coastal areas are of high ecological and socio-economic importance. The country's 18,000 km coastline has four large marine ecosystems (LMEs) – the Yellow Sea, the East China Sea, the Kuroshio Current, and the South China Sea (Qiu et al., 2009). Together, they are home to about 12,000 marine species (Huang, 1994). Marine resources make an important contribution to China's economic development in the areas of fishing, maritime shipping, and oil and gas exploration. In 2019, China's marine economy generated over 8,900-billion-yuan, accounting for 9% of the total GDP (Ministry of Natural Resources (MNR), 2020). Given the importance of China's coastal areas for economic development and the environmental pressures these areas face, effective management to ensure sustainable development is required.

To balance environmental sustainability with economic development, China is currently implementing a strategy of 'eco-civilization'. This strategy calls for the inclusion of environmental protection in the nation's economic, social, cultural, and political systems and establish a long-term mechanism of environmental protection in which stakeholders (the public, businesses, and government officials) can actively participate (United Nations Environment Programme (UNEP), 2016). In the marine environment, this strategy involves "improving the capacity of marine resource exploitation, developing the marine economy, protecting the ecological environment, resolutely safeguarding national marine rights and interests, developing the maritime power" (Xinhua, 2012). Marine protected areas (MPAs) have been adopted as a tool in China's drive towards 'eco-civilization', to conserve biodiversity and the environment. China has two broad categories of MPA: marine nature reserves (MNR), in which extractive activities are highly restricted, and special marine protected areas (SMPA), including marine parks, in which multiple resource use is allowed. According to the importance of their protection targets, MPAs are designated at national and local level (Qiu, 2010). In recent decades, there has been remarkable expansion in the establishment of MPAs, with an increase of 4% annually (Hu et al., 2020). By the end of 2020, there were 271 designated MPAs (106 national MPAs and 165 local MPAs), covering 4.1% of the sea area under China's jurisdiction (Zhao, 2018). Although there is a trend toward increasing the number and coverage of China's MPAs, their effectiveness has not yet been proven. A preliminary assessment found that only 27% of MPAs met three of five success criteria (no-take, enforced, old, large, and isolated) (Hu et al., 2020), which is much lower than the 59% for MPAs globally (Edgar et al., 2014). In addition, many MPAs are unmanaged "paper parks" lacking management administration and funding (Li and Fluharty, 2017). Further research on the effectiveness of China's MPAs is required to improve their conservation outcomes.

The Yangtze River Delta is located near the East China Sea. It supports a population of 225 million people and contributes about one-quarter of China's GDP (Wei, 2020). The region is a strategic location for the sustainable development of China's 'eco-civilization'. At the end of 2020, 34 MPAs had been implemented in the coastal areas of the Yangtze River Delta, of which 41% are MNRs and 59% are SMPAs. These are important environmental management tools. However, the coastal areas of the Yangtze River Delta face a lot of pressure. At present, the total length of continental natural coastline in the Yangtze River Delta is 96,344 km, accounting for 31.2% of China's total coastline (Chen et al., 2018; Wang et al., 2019). Due to the erosion and rapid development, the natural coastline in the Yangtze River Delta is losing (Wang et al., 2019). Besides, the ecosystem health of the Yangtze River Delta is under pressure. According to a 2019 communique on the state of China's marine ecology and environment, the northern Jiangsu shoal (located in the Yangtze River Delta) and the Yangtze Estuary are sub-healthy and Hangzhou Bay is unhealthy (Ministry of Ecology and Environment (MoEE), 2020). In 2019, the Central Committee of the Communist Party of China and the State Council issued the *Outline of the integrated regional development of the Yangtze River Delta*, detailing ongoing social and economic development in the area. To guarantee the sustainable development of the Yangtze River Delta, there is an urgent need to enhance the effectiveness of marine environmental management tools, especially MPAs, which are crucial for the implementation of China's 'eco-civilization' strategy.

Promoting the effectiveness of MPAs is a global requirement. A management effectiveness evaluation (MEE), defined as "the assessment of how well the protected area is being managed – primarily the extent to which it is protecting values and achieving goals and objectives" (Hockings et al., 2006), is an efficient approach to improving the effectiveness of MPAs by identifying the status of management actions, detecting management strengths and weaknesses, and providing information for adaptive management. MEEs have been applied to 60% of MPAs globally (Laffoley et al., 2019), but only a few have been conducted in China (Song et al., 2018).

The first MEE framework for protected areas was developed by the International Union for the Conservation of Nature-World Commission on Protected Areas (IUCN-WCPA). It comprises six key management elements – context, planning, inputs, process, outputs, and outcomes (Hockings et al., 2016). Based on this framework, more than 50 MEE methodologies have been developed (Leverington et al., 2010). The two most relevant frameworks for MPAs are the Marine Score-Card (Staub and Hatziolos, 2004) and How is your MPA doing? (HIYMPAD) (Pomeroy et al., 2005). The former is adapted from the Management Effectiveness Tracking Tool (METT) (Stolton et al., 2003), which is used to evaluate the progress of management in individual protected areas over time. The latter evaluates the biophysical, socioeconomic, and governance of individual MPAs.

Included in MPA MEE frameworks are evaluations of ecological (e.g., fish density) and socio-economic (e.g., typical income of fishers) outcomes. Recently, researchers have suggested that more attention should be given to the drivers likely to lead to successful MPA outcomes so that management actions and the rational allocation of resources can be prioritized (Bennett and Dearden, 2014). Several evaluations focusing on the potential drivers of MPA outcomes have been conducted at global and regional scales, and enforcement, participation, species attributes, capacity shortfalls, and size of the no-take area have been identified as the main factors impacting MPA outcomes (Ban et al., 2017; Gill et al., 2017; Hargreaves-Allen et al., 2017). The selection of potential drivers is key to these evaluations. An evaluation by Ban et al. (2017) identified four key potential drivers (attributes of the species or ecosystem within the MPA, attributes of the MPA, institutional design principles, and participation) for large MPA outcomes. These drivers were identified based on the management of marine resources, the design and management of small-scale MPAs, and the management of common-pool resources. This framework has a solid theoretical basis and can systematically investigate the social, ecological, and governance characteristics of an MPA using both qualitative and quantitative approaches. It has successfully been tested on 12 large MPAs. Using this framework to evaluate the effectiveness of MPAs will help to more deeply understand the social, ecological, and governance mechanisms that contribute to a range of conservation outcomes.

According to Ban et al (2017) framework, fisheries, ecosystem health (trends in the condition of ecosystem health proxies, such as changes in coral cover), and the wellbeing of fishers were selected as outcomes. In practice, environmental performance should be evaluated within the MPA. It has been demonstrated that even no-take areas can be threatened by toxic chemical contamination, such as persistent organic pollutants (POPs) and trace metals originating from surface runoff, partially treated effluent, freshwater discharge from polluted rivers, and/or contaminated atmospheric deposition (Campanella et al., 2001; Terlizzi et al., 2004). Given that most of China's MPAs are near urban areas and are continuously influenced by anthropogenic activities such as industrial wastewater discharge (Lu et al., 2020), marine organisms inhabiting such MPAs are at risk. In addition, protecting the ecological environment is a common objective for all of China's MPAs based on the Rules of Marine Nature Reserves and the Rule of Special Marine Protected Areas (SOA, 1995; SOA, 2010). Therefore, an evaluation that includes environmental performance is necessary for the sustainability of China's MPAs.

In this study, we assessed the effectiveness of MPAs in the Yangtze River Delta, taking three national MPAs as a case study. For this purpose, we modified Ban et al (2017) framework and environmental evaluation. We analyzed the key potential drivers for MPA outcomes and designed five possible scenarios, with priority given various aspects, each of which has consequences on the MPA's social and ecological systems. The evaluation results offer recommendations and lessons on the sustainability and success of MPAs in the Yangtze River Delta, and provide guidance for the evaluation of MPAs elsewhere in China and in other developing countries.

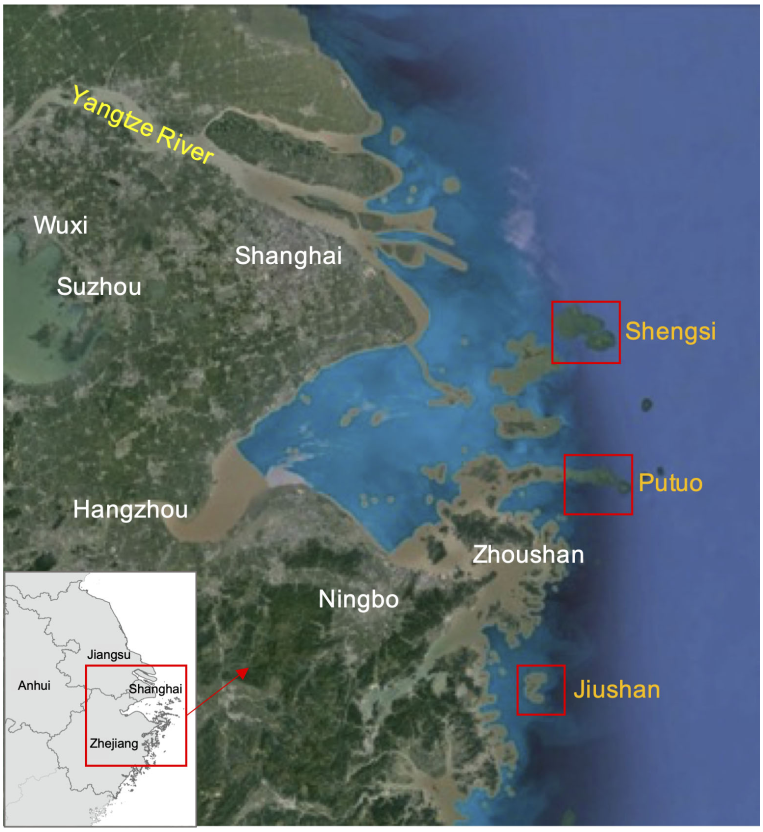
## Description of the case study sites

Three national MPAs in the Yangtze River Delta were evaluated (Figure 1). They were Shengsi National Marine Park, Putuo National Marine Park, and Jiushan Archipelago Marine Ecological National Nature Reserve (Figure 2). These three cases were chosen because they are national marine protected areas, and the resources and ecosystems within them have significant marine ecological conservation, ecotourism, and exploitation values. The state has invested them more than local MPAs, and people are highly concerned about them. Therefore, there is high interest in whether they are effectively managed and protect the marine ecosystems or not. Besides, these three cases include marine nature reserves and special marine protected area (including marine park), ensuring that all types of MPAs in the Yangtze River Delta can be covered. Furthermore, the three cases are different in time of establishment, primary objectives and size, which allows for better validation of the suitability of the framework we developed.

### Shengsi National Marine Park (Shengsi)

Shengsi National Marine Park is located in Ma'an archipelago. It covers an area of 549 $km^2$ and contains 136 islands. It provides good nursery and suitable habitat for many species (Wang et al., 2012) and is home to 96 fish species, 19 shrimp species, 15 crab species, 118 sea algae species, as well as various mollusks and shellfish. Moreover, it has 64 items of listed cultural heritage, including fish food culture, mussel culture, and Shengsi fishing songs (Second Institute of Oceanography (SIO), 2013).

Ma'an archipelago was designated as Shengsi Ma'an SMPA in 2005. Its protection objectives are marine living resources, unique natural island landforms, and intertidal wetlands. The management administration for this SMPA is Shengsi Ma'an Special Marine Protected Area Administration Bureau. The *Shengsi Marine Fishing Management Interim Measures (Trial)* and *Rules for the Implementation of the Interim Measures for the Management of Reef Resources in Shengsi Ma'an Archipelago* were issued for the management of this MPA in 2011 and 2012, respectively. In 2015, this SMPA was designated as Shengsi




Maps Data: SIO, NOAA, U.S. Navy, NGA, GENCO
Image Landsat/ Copernicus
Image ©2022 TerraMetrics

FIGURE 1
The Yangtze River Delta (in the bottom left corner, including Shanghai, Jiangsu, Anhui, Zhejiang) and the locations of Shengsi National Marine Park (Shengsi), Putuo National Marine Park (Putuo), and Jiushan Archipelago Marine Ecological National Nature Reserve (Jiushan).

National Marine Park, with management administration consistent with the previous bureau. However, zones within the marine park were changed into major protected zone, moderate utilization zone, and ecological resources restoration zone (Figure 2). Meanwhile, three management rules issued by the Zhoushan government guide the management of the marine park. These are the *Regulations of National Marine Special Marine Protected Area in Zhoushan*, the *Interim Measures for Marine Fishing in Zhoushan National Special Marine Protected Area*, and the *Interim Measures for Shellfish and Algae Fishing in Zhoushan National Special Marine Protected Area*.

## Putuo National Marine Park (Putuo)

Putuo National Marine Park is located in Zhongjieshan archipelago. It covers an area of 218.4 $km^2$ and contains 151 islands. Mainland runoff and surface current generated by the Yangtze River estuary make this area abundant in nutrients, and it is the site of the Zhongjieshan fishing ground. The marine park is home to more than 35 fish species, 11 shrimp species, and 12 crab species (SIO, 2016). In addition, natural resources include mountains, sea, islands, reefs. The area experiences abundant sunshine and fog and is well-known as a tourist and sea fishing resort. A survey of Asian Fishing Federation experts named Putuo National Marine Park's black sea bream (*Acanthopagrus schlegelii*) the best in the Western Pacific (SIO, 2016). This SMPA aims to protect fish, bird, reefs, and shellfish. Putuo Zhongjieshan Archipelago Special Marine Protected Area Administration Bureau is responsible for the daily management of the park. In 2008, the *Rules for the Implementation of Zhejiang Putuo Zhongjie Mountain Archipelage Special Marine Protected Area* were issued for the management of the SMPA. In 2017, this SMPA was approved as Putuo National Marine Park. Its primary protection objective and management administration are consistent with those of the

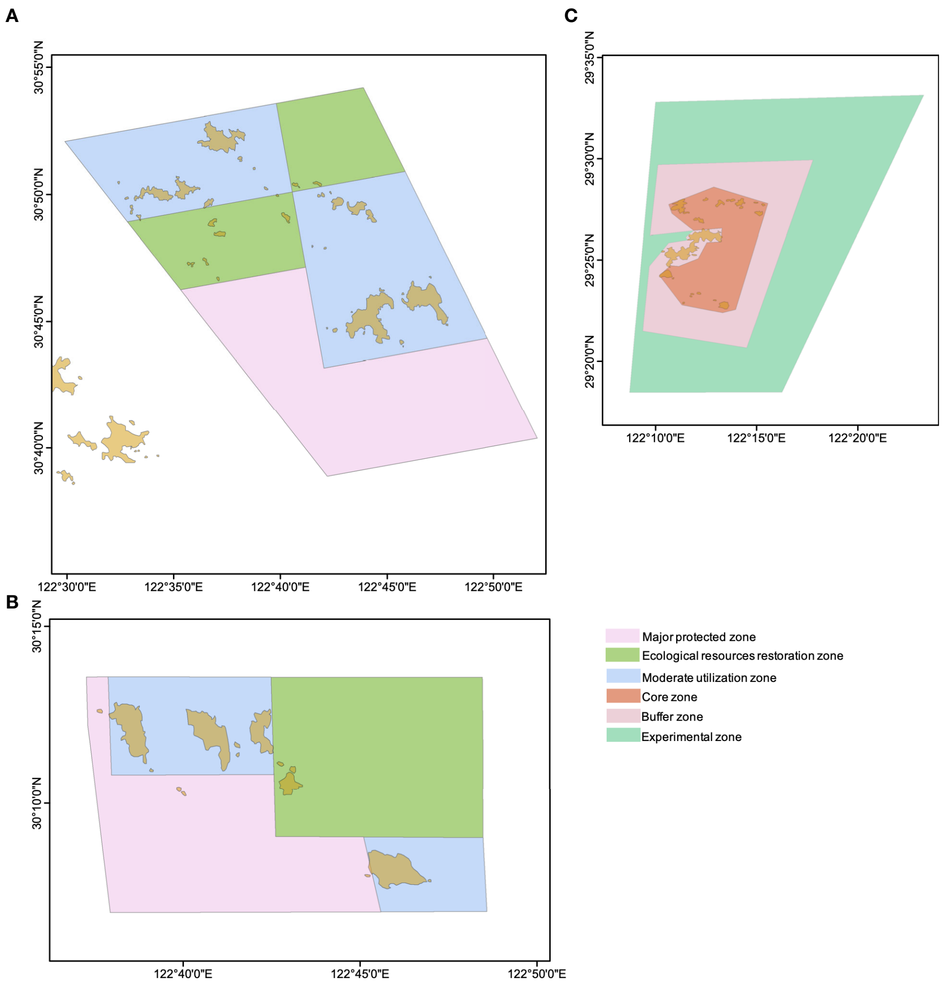



FIGURE 2
Zones in Shengsi National Marine Park **(A)**, Putuo National Marine Park **(B)**, and Jiushan Archipelago Marine Ecological National Nature Reserve **(C)**.

former SMPA. This marine park consists of three zones – major protected zone, moderate utilization zone, and ecological resources restoration zone (Figure 2). It is managed by the *Regulations of National Marine Special Marine Protected Area in Zhoushan*, *Interim Measures for Marine Fishing in Zhoushan National Special Marine Protected Area*, and *Interim Measures for Shellfish and Algae Fishing in Zhoushan National Special Marine Protected Area*.

## Jiushan Archipelago Marine Ecological National Nature Reserve (Jiushan)

Jiushan Archipelago Marine Ecological National Nature Reserve covers an area of 484.8 km$^2$ and is an important seabird breeding site and migratory bird resting point. It has 108 bird species (Ningbo MEMC, 2012), including the Chinese crested tern (*Thalasseus bernsteini*) which is under special protection. Jiushan archipelago also contains suitable habitat for the migration, mating, and reproduction for various marine organisms. It is home to 62 fish species, 49 crustacean species, and more than 30 other species (Ningbo MEMC, 2012). In addition, it is home to the finless porpoise (*Neophocaena asiaeorientalis*) and a variety of waterfowl, making it an excellent place for bird watching, island fishing, and sightseeing.

Jiushan Archipelago was designated as a provincial nature reserve in 2003. It aims to protect the large yellow croaker (*Larimichthys crocea*), cuttlefish (*Sepiella maindroni de rochebrune*), the finless porpoise (*Neophocaena asiaeorientalis*), and the Chinese crested tern (*Thalasseus bernsteini*). Jiushan Archipelago Provincial Ecological Nature Reserve Administration Bureau was established to manage this reserve. In 2006, the *Regulations of Jiushan Archipelago Marine Ecological Nature Reserve* were issued for the management of this MNR. In 2011, this provincial MNR was approved as a national MNR. Its primary protection objectives are consistent with those of the former provincial MNR, but management administration has changed to Jiushan Archipelago National Marine Ecological Nature Reserve Administration Bureau. The *Regulations of Jiushan Archipelago Marine Ecological Nature Reserve*, *Ningbo City* were revised in 2017 to manage this MNR. There are three zones (Figure 2) within this reserve – the core zone, in which all extraction activities are forbidden, the buffer zone, in which non-destructive scientific research, teaching practice, and specimen collection activities are allowed, and the experimental zone, in which appropriate development activities are allowed if approved by the management authority.

## Methodology

In this study, we first reviewed literature on methods for evaluating the management effectiveness of MPAs, including the Marine Effectiveness Tracking Tool (METT), the Marine Score-Card, and How is your MPA doing? (HIYMPAD) (Pomeroy et al., 2005), in addition to other frameworks (Bennett and Dearden, 2014; Ban et al., 2017). Given the purpose of this assessment and the common objectives of China's MPAs, we chose the framework that focuses on outcomes and the drivers of those outcomes, and we added additional indicators for biological and environmental performance.

### Modification of the evaluation framework

The modified evaluation framework is adapted from Ban et al. (2017), which was originally used to assess the social and ecological effectiveness of large marine protected areas. This framework focuses on four key aspects that may drive the social and ecological outcomes of an MPA: 1) attributes of the species or ecosystem within the MPA, 2) attributes of the MPA, 3) institutional design principles, and 4) participation, with a total of 32 indicators (Table 1). Two additional outcome indicators (fisher's income and fisheries) were selected for our modified framework.

The three MPAs are located in important fishing grounds and the conservation objectives of all three include fish species protection. Therefore, fisheries reflect the biological indicator of conservation effectiveness. Fish density, the average fish biomass per survey within an MPA, was used to represent fisheries because it is common practice to evaluate all species within an MPA. In addition, species richness (the number of species) here is used as a proxy of the fish diversity indicating the ecological impacts of MPAs at the community level (Gaston et al., 2008). Therefore, we added the fish diversity to evaluate the ecological outcome of the three MPAs. To assess fish density and fish diversity, we compared current data with data from before the establishment of the MPA, and the greater the increase, the higher the score. The pre-establishment data were obtained from the baseline trawl survey in the planning report, and the post-establishment data were obtained from the trawl survey within the MPA in recent 5 years (Han et al., 2019; unpublished data provided by Liang). These surveys were all in accordance with the Marine Survey Specification (GBT 12763.6-2007) (Standards Press of China, 2007). The fish density data were standardized by the swept area method for comparison (Zhan, 1995). The scores corresponding to the options of fish density and diversity are listed in Table A.1.

Given the urgent need to evaluate the environment performance of MPAs in the Yangtze River Delta, we added the environmental performance indicators of biophysical property, heavy metals, nutrients, and oil, all of which focus on different aspects of seawater quality and are commonly included in environment assessments (Xu et al., 2015). We measured these indicators by comparing their category level changes before and after the establishment of each MPA according to the Seawater Quality Standard of China (GB 3097-1997). There are four seawater quality indicators levels (I, II, III, IV) and each is defined within this standard. The higher the category level, the worse the seawater quality. For biophysical property, heavy metals, and nutrients, we adopted the highest category level from all indicators to represent their category level, because each one includes multiple indicators. Using the highest level guaranteed that our assessment was conducted with the utmost care. For oil, we directly compared the category level before and after the construction of each MPA. The detailed assessment method for environmental performance is defined below:

$$EP_i = \frac{Max(Category\ \ level_i)\_after}{Max(Category\ \ level_i)\_\ \ before} \tag{1}$$

Where $EP_i$ is the environmental performance, and $i$ is one aspect of environmental performances. A category level increase after the establishment of the MPA, the $EP_i$ scored 0, a consistent or higher than category level I after the establishment of the MPA scored 1, a decreased and higher than category level I after the establishment of the MPA scored 2, and a decreased or constant category level I after the establishment of the MPA scored 3.

In total, we identified 39 indicators to assess the effectiveness of MPAs in the Yangtze River Delta. Each was rated on a scale of 0 to 3, with 0 being the least favorable situation and 3 being the optimum situation. The definition and options of each indicator, and outcomes raw data are shown in Table A.1. We calculated the average scores for each type of potential driver, outcome, and environmental performance. The average scores were classified into four levels: (1) [0, 0.5), unsatisfactory; (2) [0.5, 1.5), slightly satisfactory; (3) [1.5, 2.5), satisfactory; (4) [2.5, 3], highly satisfactory.

TABLE 1 Evaluation indicators and data resources for assessing Shengsi, Putuo, and Jiushan; bold indicates newly added indicators.

| Type of indicator | Indicators | Data resource |
|---|---|---|
| Attributes of the species or ecosystem within the MPA | Commons mobility | MPA planning report |
| | Commons productivity | MPA planning report |
| | Ecological resilience | MPA planning report |
| | Resource market value | MPA planning report |
| | Distance to market | MPA planning report |
| Attributes of the MPA | No take area | MPA planning report |
| | Age | MPA planning report |
| | Snapshot age | MPA management plan |
| | Size | MPA planning report |
| | Efficient enforcement | MPA manager |
| | Isolated | MPA planning report |
| | Comprehensive, adequate, representative principles | MPA planning report |
| Institutional design principles | Stakeholder boundary clarity | MPA planning report |
| | Stakeholder boundary fuzziness | MPA planning report |
| | Commons boundaries | MPA planning report |
| | Commons boundary negotiability | MPA manager |
| | Outsider exclusion | MPA manager |
| | Social-ecological fit | MPA planning report |
| | Cost and benefit proportionality | MPA manager |
| | Participation in rule making | MPA planning report/MPA manager |
| | Self-monitoring | MPA planning report/MPA manager |
| | Environmental monitoring | MPA planning report/MPA manager |
| | Self-sanctions | MPA planning report/MPA manager |
| | External recognition | MPA planning report/MPA manager |
| | Multiple levels | MPA planning report/MPA manager |
| | Compliance | MPA manager |
| | Conflict resolution | MPA manager |
| Participation | Participation in rule making | MPA planning report/MPA manager |
| | Participation in protected area siting | MPA planning report |
| | Participation in protected area zoning | MPA planning report |
| | Participation in environmental monitoring | MPA manager |
| | Participation in social monitoring (enforcement) | MPA manager |
| Outcomes | **Fish diversity** | MPA monitoring report |
| | Fish density | MPA monitoring report |
| | Income | Local statistical yearbook |
| | **Biophysical property** | MPA monitoring report |
| | **Heavy metals** | MPA monitoring report |
| | **Nutrients** | MPA monitoring report |
| | **Oil** | MPA monitoring report |
| Total number = | 39 | |

Bold indicators represent the newly added indicators in this study.

## Data collection

Five types of data sources were used for evaluation (Table 1): (1) local statistical yearbooks (Putuo Statistics, 2019; Shengsi Statistics, 2019), (2) MPA management plans (Standing Committee of Ningbo Municipal People's Congress, 2017; Standing Committee of Zhoushan People's Congress, 2017), (3) MPA managers, (4) MPA monitoring reports (Ningbo Marine Environmental Monitoring Center (Ningbo MEMC), 2005), and (5) MPA planning reports (Ningbo MEMC, 2012; Second Institute of Oceanography (SIO), 2013; SIO, 2016). Six managers in total, each with a minimum of three years' management experience, were interviewed regarding indicators that could not be assessed using other data sources.

## Definition of five scenarios

We used the possible average score (rounded up to the nearest whole number) of all indicators to represent the unique score for each type of potential driver. There were different combinations, because the average score for each type of driver varied from 1 to 3. The attributes of the species or ecosystem within the MPA cannot be changed through management after an MPA has been designated. Therefore, we focused our analysis on MPA attributes, institutional design principles, and participation. We proposed five possible scenarios, each of which gives priority to one or other aspect (Figure 3).

This method aims to analyze and predict reality. Alternative (five options) and comparable scenarios are used. This is a tool to understand the potential and limits of management. The average score of each aspect that defines these scenarios can change over time and are, therefore, images of present, future and/or ideal situations (Nygrén, 2019). In addition, we could identify whether certain aspect changes cause significant changes to the scenario. It is also possible to see if certain specific changes (in any indicator) cause significant changes in the general model. We defined these five scenarios as: proactive, well designed, well governed, interactive, and learning.

# Results

## Differences in outcomes between the selected MPAs

Overall, Shengsi, Putuo, and Jiushan had satisfactory outcome levels (Figure 4). Shengsi had the highest average score (2) and Jiushan had the second highest (1.7). In terms of each aspect of conservation effectiveness, both fish diversity and density in Shengsi increased after the park was established, while Putuo and Jiushan only experienced increases in fish density, and the fish density of Jiushan increased more than that of Putuo (Table 2). The income of fishers increased after the establishment of the Shengsi and Putuo, while Jiushan scored 0 for this indicator. According to our assessment, the environmental performances of Shengsi and Putuo reached a satisfactory level, and that of Jiushan was at a highly satisfactory level (Figure 4).

## Assessment of drivers in the selected MPAs

We evaluated four key aspects that may impact outcomes: 1) attributes of species or ecosystems within the MPA, 2) attributes of the MPA, 3) institutional design principles, and 4) participation. Shengsi had the highest total score of these potential drivers (69), Putuo ranked second (66), and Jiushan ranked lowest (64). We also calculated the average score of each key aspect for each MPA (Figure 4). According to the score level settings in section 3.1, the effectiveness of Shengsi corresponding to the four key aspects was satisfactory. The attributes of species or ecosystems in Putuo was slightly satisfactory, and the other three aspects were satisfactory. The attributes of Jiushan were highly satisfactory, and the other three aspects were satisfactory.

Attributes of species or ecosystems within the MPA got the lowest average score of the four key aspects (Figure 4). All three MPAs obtained low scores for ecological resilience and distance to market (Table 2). Of the three MPAs, only Jiushan achieved a highly satisfactory level for MPA attributes (Figure 4), mainly due to its high score for no take area (Table 2). All three MPAs

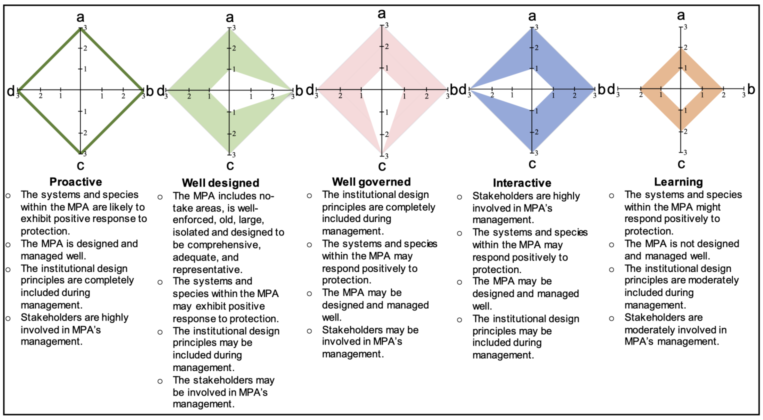



FIGURE 3
Scenario names, definitions, and figures; "a" represents the attributes of the species or ecosystem within the MPA, "b" represents the attributes of the MPA, "c" represents the institutional design principles, and "d" represents participation.

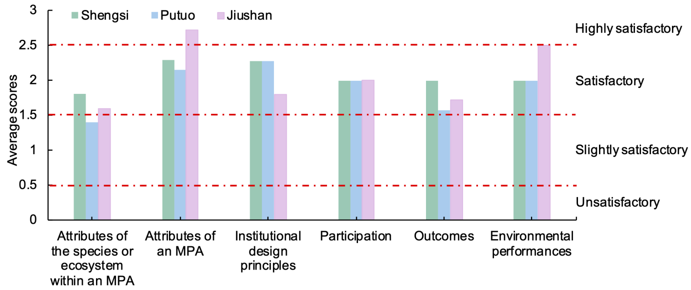



FIGURE 4
The average scores of potential drivers, outcomes and environmental performance within outcomes for the three MPAs in the Yangtze River Delta. The dashed red lines mark score levels; [0, 0.5) = unsatisfactory, [0.5, 1.5) = slightly satisfactory, [1.5, 2.5) = satisfactory [2.5, 3] = highly satisfactory.

scored 0 in the proportionality of their institutional design principles (Table 2). Participation in rule making, protected area siting, zoning, and environmental and social monitoring scored 2 in all three MPAs, indicating that actor groups are moderately involved in MPA management processes (Table 2).

## Scenario evaluation

Shengsi and Putuo scored an average of 1.8 and 1.4, respectively, for attributes of species or ecosystems and 2.3 and 2.1, respectively, attributes of the MPA. They each scored 2.3 for institutional design principles and 2 for participation (Figure 4). The rounding-off method was applied to these average scores. According to scenario definitions, Shengsi and Putuo are currently being managed according to a learning scenario (Figure 5). Jiushan, meanwhile, scored 1.6 for attributes of species or ecosystems, 2.7 for attributes of the MPA, 1.8 for institutional design principles, and 2 for participation and was, thus, identified as a well-designed scenario (Figure 5).

# Discussion

## Applicability of the modified framework

Effectiveness evaluation is to understand the current state of management and to identify problems in management, and thus improve the outcomes of MPAs. A good assessment framework should focus on the management aspects that potentially drive outcomes. In addition, the assessment of effectiveness should also correspond to the objectives of MPAs. The modified framework in this study focuses on those indicators that potentially drive outcomes. These indicators were also successfully applied to assess 12 large marine protected areas and they were found to correlate significantly with indicators of the ecological and economic effectiveness of large marine protected areas (Ban et al., 2017). When we applied these governance indicators to assess three MPAs, we found that data for evaluating these indicators were easily accessible through MPA managers, planning reports, and management plans. According to the Rules of Marine Nature Reserves and the Rule of Special Marine Protected Areas, the common objectives of China's MPAs are to conserve biodiversity, protect the environment, protect ecosystems and their functions within MPAs, and maintain ecosystem services. The indicators of outcomes developed by this study fully covered these aspects (Table 1), which ensures the appropriateness of the assessment.

One advantage of the modified framework is the reliability of the assessment of outcomes. Unlike many frameworks that assess outcomes qualitatively (Stolton et al., 2003; Staub and Hatziolos, 2004; State Oceanic Administration of China (SOA), 2015; Ban et al., 2017), our evaluation of outcomes is based on raw data (Table A.1). On the other hand, our assessment uses a scoring method for the final evaluation of each indicator, which avoids the issue that data from different sources are not easily comparable, or the results of different MPA assessments are hard to be compared. Due to our selection of indicators is derived from existing frameworks, the evaluation results also allow us to complement the global MPA assessment database and contribute to the global scientific study of MPAs. Although there were eight indicators in this framework that were evaluated by the manager's data, they represent only 25% of the total number of indicators. They are from attributes of the MPA, institutional design principles, and participation (Table 1). The qualitative assessment of such management indicators by managers is reliable, and this approach has been used in many studies (Ban et al., 2017; Gill et al., 2017; Hargreaves-Allen et al., 2017). In our study, we interviewed two managers with more than three years of management experience for each MPA to ensure the reliability of the assessment. The assessments of species and ecological attributes within the MPA and outcomes are all derived from MPA monitoring reports or local statistical yearbooks, and these indicators account for

TABLE 2 Evaluation results for Shengsi, Putuo, and Jiushan; bold indicates newly added indicators, *italic* indicates environmental performances indicators.

| Type of indicators | Indicators | Shengsi | Putuo | Jiushan |
|---|---|---|---|---|
| Attributes of the species or ecosystem within the MPA | Commons mobility | 3 | 2 | 3 |
| | Commons productivity | 2 | 1 | 1 |
| | Ecological resilience | 1 | 1 | 1 |
| | Resource market value | 2 | 2 | 2 |
| | Distance to market | 1 | 1 | 1 |
| Attributes of the MPA | No take area | 0 | 0 | 3 |
| | Age | 3 | 3 | 3 |
| | Snapshot age | 2 | 1 | 2 |
| | Size | 3 | 2 | 3 |
| | Efficient enforcement | 2 | 3 | 2 |
| | Isolated | 3 | 3 | 3 |
| | Comprehensive, adequate, representative principles | 3 | 3 | 3 |
| Institutional design principles | Stakeholder boundary clarity | 2 | 2 | 2 |
| | Stakeholder boundary fuzziness | 3 | 3 | 3 |
| | Commons boundaries | 3 | 3 | 3 |
| | Commons boundary negotiability | 1 | 1 | 1 |
| | Outsider exclusion | 2 | 1 | 2 |
| | Social-ecological fit | 3 | 3 | 3 |
| | Proportionality | 0 | 0 | 0 |
| | Participation in rule making | 2 | 2 | 2 |
| | Self-monitoring | 3 | 3 | 0 |
| | Environmental monitoring | 2 | 2 | 2 |
| | Self-sanctions | 3 | 3 | 2 |
| | External recognition | 3 | 3 | 3 |
| | Multiple levels | 2 | 2 | 2 |
| | Compliance | 2 | 3 | 2 |
| | Conflict resolution | 3 | 3 | 0 |
| Participation | Participation in rule making | 2 | 2 | 2 |
| | Participation in protected area siting | 2 | 2 | 2 |
| | Participation in protected area zoning | 2 | 2 | 2 |
| | Participation in environmental monitoring | 2 | 2 | 2 |
| | Participation in social monitoring (enforcement) | 2 | 2 | 2 |
| Outcomes | **Fish diversity** | 1 | 0 | 0 |
| | Fish density | 2 | 1 | 2 |
| | Income | 3 | 2 | 0 |
| | ***Biophysical property*** | 3 | 1 | 3 |
| | ***Heavy metals*** | 1 | 3 | 3 |
| | ***Nutrients*** | 1 | 1 | 1 |
| | ***Oil*** | 3 | 3 | 3 |

The darker the color, the higher the score.
The shade of green indicates the level of the score.

75% of the total number of indicators. Therefore, the results of our assessments can truly reflect the effectiveness of MPA management and conservation.

However, we recognize that the quality of the evaluation data requires further improvement, and particularly the data sources for assessing outcomes. Ideally, a before-after-control-impact (BACI) method should be used when designing MPA monitoring, to provide data that more accurately reflects the impacts of the MPA (Mascia et al., 2017). This method requires baseline surveys and post-establishment surveys at MPAs and control areas with contexts (social and ecological) similar to MPAs. By comparing the differences in data before and after MPAs with the differences in data before and after the control areas, it is possible to determine whether the differences are due to MPAs or natural variations. However, in China, data derived from BACI monitoring is often lacking. We recommend that the

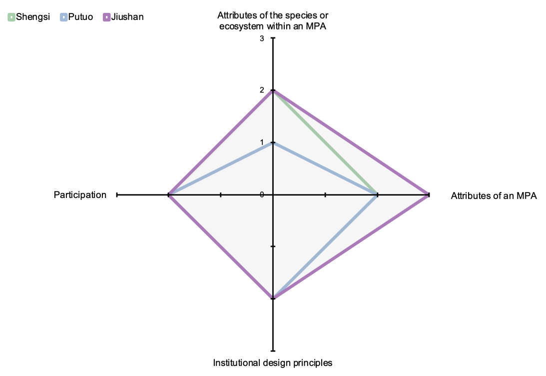



FIGURE 5
Evaluation of the management of Shengsi, Putuo, and Jiushan MPAs.

BACI method should be applied to future MPA monitoring in China, and particularly in the case of newly established MPAs.

## Outcomes

The results of our assessment for outcomes showed that MPAs with a higher average outcome score were associated with higher average scores for two types of potential drivers: 1) attributes of species or ecosystems within the MPA and 2) attributes of the MPA (Figure 4). Existing studies have highlighted the importance of the attributes of species or ecosystems within an MPA; species or systems that are more productive, resilient, less mobile, sheltered from major markets, and have high market value are more likely to exhibit positive responses to protection (Claudet et al., 2010; Collette et al., 2011). An MPA that is no-take, well-enforced, old (>10 years), large (>100 km$^2$), and isolated is more likely to be ecologically effective (Edgar et al., 2014). In addition, MPAs or MPA networks that are comprehensively, adequately, and representatively designed (CAR principles) are also more effective (Margules and Pressey, 2000). Due to limited cases in this study, it is hard to identify the specific indicators that drive outcomes. We recommend strengthening MPA assessment China, and the results will help to compare the effectiveness of different MPA types, identify specific drivers, and promote adaptive management.

The fish diversity and density evaluation results vary between three MPAs after they were established (Table 2). Changes in these two indicators were influenced by a combination of biophysical context, management status, and human activity (Fidler et al., 2021). Future research should establish a long-term MPA monitoring system that includes these three aspects and quantitatively analyzes their effects on biological outcomes. Such studies can reveal mechanisms for ensuring the ecological effectiveness of MPAs and provide evidence-based recommendations for MPA adaptive management.

The income of fishers increased after the establishment of the Shengsi and Putuo MPAs, while Jiushan only scored 0 for this indicator. This is because there are no fishermen living in Jiushan after its establishment. In general, the improvement in fisher's income is beneficial to the enforcement of management actions, as it allows fishers to perceive the benefits brought by the MPA in the places where they carry out their activities. However, caution must be exercised, as this study did not involve an in-depth analysis of fisher's income sources and, therefore, how much of this income increase is related to the MPAs is unknown. Future evaluations could remedy this limitation.

According to our assessment, the environmental performances of Jiushan are better than Shengsi and Putuo (Figure 4). Jiushan is an MNR, which means that tourism and development activities are restricted and it is uninhabited by humans. Therefore, its environmental performance is higher and its seawater quality is better. Shengsi scored low for heavy metals and nutrients (Table 2), implying that concentrations of these two indicators did not decrease after the establishment of the MPA. Two likely reasons for this are: 1) nutrients carried by the Yangtze River and sewage outlets and 2) aquaculture practiced within Shengsi Marine Park. Putuo also had low scores in some environmental indicators (Table 2). Decreased chemical oxygen demand (COD) concentration results in Putuo resulted in a low biophysical properties score, and aquaculture, municiple discharge (e.g., from wastewater treatment plants), fishing companies, and run-off from the Yangtze River caused low COD and increased nutrient concentration (Zhu and Fang, 2014). Differences in environmental performance between the MNR (Jiushan) and the SMPAs (Shengsi and Putuo) suggest that the effectiveness of environmental protection is influenced by management type and human pressures. Given that approximately 41% of China's MPAs are SMPAs, and most are affected by human activities, we recommend more regular monitoring to assess environment performance and to identify problems and optimize management.

## Potential drivers for outcomes

For the attributes of the species or ecosystem within the MPA, the systems within the three MPAs had low resilience to expected threats, suggesting that it will take a long time for the systems within these MPAs to recover from human disturbance. In addition, low scores for distance to market suggests that they are close to the closest markets (10–100 km), which might negatively affect their conservation outcomes. Research conducted in the Indo-Pacific found that reef fish density decreases with decreasing distance from market (Cinner and McClanahan, 2006). A shorter distance leads to lower fish transportation and preservation costs (Claudet et al., 2010), provides incentives and stable prices to continuously exploit fish resources (Scales et al., 2006), and leads to break-down of common resource management. We recommend that future MPA design and evaluation incorporate ecological resilience and distance to market as potential effects on ecological outcomes.

Jiushan achieved a highly satisfactory level for MPA attributes (Figure 4), mainly due to its high score for no take area (Table 2). As an MNR (corresponding to IUCN Ia), extractive activities are highly limited in Jiushan. Although no-take MPAs are more effective than multiple-use MPAs in general, the establishment of no-take MPAs faces obstacles in developing countries because of high living-dependence on marine resources (Sciberras et al., 2013). Multiple-use MPAs are proposed as an alternative tool. Currently, around 40% of China's MPAs are multiple-use, with more being established. The conservation effectiveness of these multi-use MPAs can be improved through the prompt development of management plans and efficient enforcement of regulations (Table 2).

Although the three MPAs were satisfactory in their institutional design principles and participation (Figure 4), there remains some room for improvement. All three MPAs scored 0 in the proportionality of their institutional design principles (Table 2), as the proportion of costs incurred by stakeholders to the benefits received was unknown. Chinese MPA planning reports include government budgets and social-economic benefit forecasts, that do not include exact amounts or beneficiaries. Given this information, we were unable to determine whether costs and benefits were proportionately distributed among stakeholders. Thus, we recommend developing MPA cost and benefit indicators so that proportionality can be better understood and monitored. In addition, Jiushan scored 0 for self-monitoring because it is uninhabited by humans. The communities of Shengsi and Putuo, meanwhile, monitored each other's common resource behaviors. Self-monitoring is a valuable marine conservation tool, as it helps to detect illegal activities in a timely manner, improves compliance with management rules, and reduces enforcement costs. Given the importance of self-monitoring, we suggest that it is promoted in MPAs where actor groups are present.

Public were moderately participate in rule making, protected area siting, zoning, and environmental and social monitoring in all three MPAs (Table 2). In all three MPAs, preparatory groups shared plans with the municipal governments where these MPAs are located, and local government responses to rulemaking, siting, and zoning were taken into account. In Shengsi and Putuo, surveys were conducted with local communities and business employees regarding siting and perceptions of the MPAs. However, participation can be further improved. We recommend that the government increases stakeholder awareness of the importance of participation and participation mechanisms should be more clearly defined in management plans.

### Scenario evaluation

The scenarios evaluation demonstrates that MNRs and SMPAs are managed by different scenarios, indicating that this method can successfully reveal the management characteristics of MPAs. The MNR evaluated in this study falls under the well governed scenario. This management scenario of MPA includes no-take areas, is well-enforced, old, large, isolated and designed to be comprehensive, adequate, and representative. However, it is not perfect in terms of attributes of the species or ecosystem within the MPA, institutional design principles, and public participation (Figure 5). For example, the commons productivity, ecological resilience, and the distance to market of Jiushan were not scored with high level, and it did not perform well in terms of proportionality, self-monitoring, and conflict resolution within institutional design principles. We can combine this method with the results of specific indicator scores to identify certain areas for improvement.

The SMPAs (Shengsi and Putuo) belong to the learning scenario. MPAs under this scenario are not perfect in terms of 1) attributes of the species or ecosystem within the MPA, 2) attributes of the MPA, 3) institutional design principles, and 4) participation. Aspects that should be improved including the establishment of no-take zones and proportionality assessment indicators. Setting no-take zones in multiple use MPAs can make them effective fisheries management tools (Zupan et al., 2018). The highest protection level zone within China's SMPAs is major protected zone, but there are no clear rules for restricting fishing in this zone. In the future, the zoning design of SMPAs may consider upgrading the management of major protected zone to restrict fishing within them, so that its possible spillover effects can enhance the conservation effectiveness of adjacent zones.

## Conclusions and recommendations

The establishment and management of MPAs in the Yangtze River Delta is very important for the implementation of China's 'eco-civilization'. Assessing whether MPAs are effective can promote and improve adaptive management. This study modified a comprehensive framework to evaluate outcomes with potential drivers for MPAs in the Yangtze River Delta. The framework was successfully applied to three national MPAs. The evaluation results show that Shengsi ranked first for four key aspects and Jiushan ranked lowest. The three MPAs achieved almost satisfactory levels for each key aspect. However, the attributes of species or ecosystems in Putuo achieved a slightly satisfactory level, due to poor ecological resilience and proximity to markets. The three MPAs achieved satisfactory levels in outcomes, and higher average scores for outcomes associated with attributes of species or ecosystems and attributes of the MPAs. The SMPAs (Shengsi and Putuo) achieved satisfactory levels for environmental performance, while the MNA (Jiushan) achieved a highly satisfactory level. In general, Shengsi and Putuo are managed according to a learning model and Jiushan is managed according to a well-designed model.

To improve the effectiveness of MPAs in the Yangtze River Delta, we recommend that attributes of species or ecosystems and attributes of MPAs are attached great importance, in particular with regard to the ecological resilience of species or ecosystems and the distance between MPAs and markets. Although all three MPAs achieved satisfactory levels for institutional design principles and participation, there is room for improvement, particularly with regard to proportionality. We suggest that developing cost and benefit indicators for monitoring MPAs will deepen understanding of their proportionality. In addition, public awareness of participation needs to be promoted and the process of participation should be clarified in MPA management plans. Regarding the improvement of environmental performance, we recommend conducting regular monitoring and assessment to identify problems and optimize management.

This study evaluated three MPAs and, therefore, could not quantitatively analyze the specific indicators that affect outcomes. However, the results provide information for adaptive management and design of future MPAs. We recommend using this framework to evaluate more MPAs using statistical methods to identify specific outcome drivers.

## Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## 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.

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## Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2022.911880/full#supplementary-material

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