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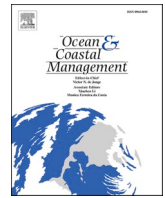


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# From regional effectiveness evaluation and community engagement toward effective marine protected areas

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## ABSTRACT

Marine protected areas (MPAs) are important conservation tools; however, many fail to achieve their full potential because of design and management deficiencies. Evaluating MPA management effectiveness (ME) is essential for identifying deficiency issues in conservations and guiding improvements. This study established an indicator-based framework to evaluate ME tailored to Taiwan's MPAs through literature reviews, expert consultations, and stakeholder workshops. We applied 28 indicators to the ME evaluation of 30 fishery conservation zones (FCZs), utilizing semi-structured interviews with stakeholders, questionnaires, analysis of ecological reports, and on-site visits. Only two MPAs were rated as highly effective; most were poorly managed, with deficiencies in ecological monitoring, enforcement, and stakeholder participation. A case study combined a quantitative ME evaluation with collaborative action research involving governments, scientists, and communities to address issues and accelerate enhancements in the Qimei FCZ. Initial low scores prompted workshops to engage stakeholders in identifying problems such as incorrect boundaries, lack of ecological data, and enforcement challenges. This led to boundary revisions, citizen scientist training, and proposals for no-take zones to improve enforcement. The evaluation revealed management deficiencies in Taiwan's MPAs, while action research catalyzed solutions through participative processes. Region-specific indicator frameworks aligned with local priorities are vital for optimizing MPA benefits. This study provides an exemplary quantitative–qualitative approach, coupling evidence-based evaluations and collaborative action research to improve MPA management.

## 1. Introduction

Marine protected areas (MPAs) have long been advocated and implemented globally as conservation strategies for maintaining marine biodiversity (Lester et al., 2009; Edgar et al., 2014; Baskett and Barnett, 2015). With effective management, MPAs can achieve the ecological restoration of habitats and biological resources by reducing human disturbance, which contributes to the sustainable utilization of marine resources and the provision of ecological services (Bates et al., 2014; Costello, 2014; Relano and Pauly, 2023). Consequently, MPAs can also provide social and economic benefits to the community, including sustainable recreational and commercial use of marine resources and enhanced research and educational opportunities (NOAA, 2023; Sanchezirico et al., 2002).

Realizing these benefits is contingent on the proper design and effective management of MPAs; otherwise, they risk becoming

ineffective “paper parks” (Ballantine, 2014; Relano and Pauly, 2023). Relano and Pauly (2023) assessed 184 MPAs using the “Paper Park Index” and found that 30% are likely “paper parks” - politically easy to establish but offering little protection (Devillers et al., 2020; Relano and Pauly, 2023). Edgar et al. (2014) investigated the extent to which MPAs fulfill their ecological potential by examining the cumulative effects of key planning and management features. Their results showed that most (59%) of the 87 studied MPAs lacked crucial features and were ecologically indistinguishable from fish sites, underscoring the need for better MPA design, durable management, and compliance to achieve the desired conservation value. This highlights the importance of evaluating the MPA management effectiveness (ME) to assess progress, inform adaptive management strategies, and justify their existence.

ME evaluation, as defined by the IUCN, assesses how well a protected area is managed, focusing on design, management system appropriateness, and objective delivery across the six stages of the management

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cycle (context, planning, inputs, processes, outputs, and outcomes) (Hockings et al., 2006). This IUCN-WCPA framework links assessments using common criteria and has global applicability (Coad et al., 2015; Leverington et al., 2010, 2019). Pomeroy et al. (2005, 2004) introduced a four-part process and customizable indicator-based framework structured into major management factors, goals, and indicators, making it adaptable to different MPAs (Fox et al., 2014; Pelletier, 2020; Pomeroy et al., 2005).

Several evaluation methods have emerged based on the frameworks mentioned above (Coad et al., 2015; Wells et al., 2016), including widely used tools such as the Rapid Assessment and Prioritization of Protected Area Management (RAPPAM) (Ervin, 2003) and the Management Effectiveness Tracking Tool (METT) (Stolton et al., 2007; Stolton and Dudley, 2016). These methods utilize questionnaires to quantify MPA management effectiveness by scoring indicators that cover categorical variables and continuous parameters such as enforcement capability and species abundance. RAPPAM offers a quick assessment of management strengths and weaknesses through questionnaires but should be used cautiously because of its reliance on respondent answers (Araújo and Bernard, 2016; Leverington et al., 2010). By contrast, METT requires objective documents and data sources to reduce subjectivity and provide more comprehensive and reliable results (Stolton et al., 2007, 2020; Stolton and Dudley, 2016). However, this method is time-consuming because of the need for extensive background information.

The global community is committed to protecting at least 30% of the ocean and land area by 2030 (Convention on Biological Diversity, 2022). Taiwan's government is aligned with international commitments to marine conservation and implements related plans at the central level to promote healthy and sustainable marine ecosystems. However, inconsistencies have arisen owing to the varying definitions of MPAs and differences in national regulatory levels and authorities, resulting in incongruent conservation outcomes. While national policies can address and assess MPA coverage goals, they may not fully reflect management outcomes.

In 2023, the 46 MPAs in Taiwan are divided into five types according to their characteristics and legislation: fishery conservation zones, recently renamed aquatic organism propagation and conservation zones (FCZs), ecological and cultural environment reserves, national parks, wildlife refuges/habitats, and nature reserves/monuments (Table 1). They are managed by a polycentric authority system (Chung and Jao, 2022). Among them, 30 FCZs have been established under the authority of the Fisheries Act since the 1980s. Therefore, this study focused only on the 30 FCZs because management agencies and legal authorities vary for other types of MPAs. In addition to independent studies on the management issues of some MPAs (Chen et al., 2018; L.-S. Chen et al., 2019; Chung and Jao, 2022; Hung et al., 2021), they have never been officially evaluated under a standard ME framework. Given the diversity of objectives, circumstances, and stakeholder participants, decentralized authorities within MPAs highlight the uncertainty in evaluating ME. Adoption of a universally applicable framework may present some challenges. (Hockings et al., 2006). Therefore, different regions have developed specific indicators and methods to assess MPA ME properly (Ngoc et al., 2012; Muthiga, 2009; Garces et al., 2013; Tempesta and Otero, 2013; Tupper et al., 2015; Maestro et al., 2022; Ocean Conservation Administration, 2022).

In recent years, stakeholders' participation or community participation has been recognized as an essential component in MPA establishment (Oyanedel et al., 2016, 2017; Day, 2017), management, and decision-making (Ban et al., 2008; Havard et al., 2015; Hung et al., 2021; Katikiro et al., 2021; Rahman et al., 2022). Action research fosters collaboration among practitioners, researchers, and residents, enhancing stakeholder involvement and management insights by involving local communities and managers in discussions and taking actions to improve management systems (Hult and Lennung, 1980; Avison, 2002; Ozanne and Anderson, 2010). The central focus is on

**Table 1**

List of the 46 MPAs in Taiwan under five legislations in 2023. The IUCN protected area categories are provided for reference.

MPA Code	Name of MPA	Legislation	IUCN categories
WR1	Mianhua and Huaping Islets Wildlife Refuge	Wildlife Conservation Act	Ia
WR2	Taoyuan Guanxin Algal Reefs Ecosystem Wildlife Refuge		Ia
WR3	Matsu Islands Tern Refuge		Ia
WR4	Penghu County Mao Islet Seabird Refuge		Ia
WR5	Penghu County Wangan Island Green Turtle Nesting Refuge		Ia
WH	Indo-Pacific Humpback Dolphin Major Wildlife Habitat		IV
NP1	Kenting National Park	National Park Law	II
NP2	Dongsha Atoll National Park		II
NP3	Taijiang National Park		II
NP4	South Penghu Marine National Park		II
FCZ01	Suao Aquatic Organisms Propagation and Conservation Zone	Fisheries Act	IV
FCZ02	Toucheng Aquatic Organisms Propagation and Conservation Zone		IV
FCZ03	Keelung City Aquatic Plants and Animals Conservation Zone		IV
FCZ04	Wanghaixiang Chaojing Bay Resource Conservation Zone		IV
FCZ05	Gongliao Aquatic Plants and Animals Reproduction Conservation Zone		IV
FCZ06	Wanli Aquatic Plants and Animals Reproduction Conservation Zone		IV
FCZ07	Ruifang Conservation Zone		IV
FCZ08	Yehliu Aquatic Plants and Animals Reproduction Conservation Zone		IV
FCZ09	Wanwa Venus Clam Breeding Conservation Zone		IV
FCZ10	Shengang Mud Shrimp Breeding Conservation Zone		IV
FCZ11	Wanggong Mud Shrimp Breeding Conservation Zone		IV
FCZ12	Shengang (2) Mud Shrimp Breeding Conservation Zone		IV
FCZ13	Liuqiu Aquatic Plants and Animals Reproduction Conservation Zone		IV
FCZ14	Checheng Aquatic Plants and Animals Reproduction Conservation Zone		IV
FCZ15	Resources Nursing Area of National Museum of Marine Biology and Aquarium		IV
FCZ16	Fushan Aquatic Organisms Propagation and Conservation Zone		IV
FCZ17	Xiaoma Aquatic Organisms Propagation and Conservation Zone		IV
FCZ18	Xiaogang Aquatic Organisms Propagation and Conservation Zone		IV
FCZ19	Yiwan Aquatic Organisms Propagation and Conservation Zone		IV
FCZ20	Ludao Aquatic Organisms Propagation and Conservation Zone		IV
FCZ21	Yanliao Aquatic Organisms Propagation and Conservation Zone		IV
FCZ22	Shuilian Aquatic Organisms Propagation and Conservation Zone		IV

(continued on next page)

Table 1 (continued)

MPA Code	Name of MPA	Legislation	IUCN categories
FCZ23	Gaoshan Aquatic Organisms Propagation and Conservation Zone		IV
FCZ24	Xiaohu Aquatic Organisms Propagation and Conservation Zone		IV
FCZ25	Fengbin Aquatic Organisms Propagation and Conservation Zone		IV
FCZ26	Shitiping Aquatic Organisms Propagation and Conservation Zone		IV
FCZ27	Xiaomen Aquatic Organisms Propagation and Conservation Zone		IV
FCZ28	Qimei Aquatic Organisms Propagation and Conservation Zone		IV
FCZ29	Kinmen Kuningtou Northwest Intertidal Terrain Horseshoe Crab Conservation Zone		IV
FCZ30	Dongao Aquatic Plants and Animals Reproduction Conservation Zone		IV
NR1	Penghu Columnar Basalt Nature Reserve	Cultural Heritage Preservation Act	Ia
NR2	Penghu South Sea Columnar Basalt Nature Reserve		Ia
NR3	Xuhai-Guanyinbi Nature Reserve		Ia
NM	Fanzishi Natural Monument		Ia
SA1	East Coast National Scenic Area (Ludao Haishenping to Fanchuanbi Marine Resources Conservation Area)	Urban Planning Law	IV
SA2	Northeast and Yilan Coast National Scenic Area (Marine Resources Protected Area)		IV

‘action’ to stimulate reflective practice, initiate changes in institutions or communities, and develop democratic management and administration (Williamson, 2013). The action research spiral outlined by Lewin (1946) consists of problem identification, planning, implementation, reflection on outcomes, iterative planning, and ongoing reflection in a recurring cycle. This approach is commonly used in social sciences (Lockett et al., 2001; Bradbury-Huang, 2010; Kaur et al., 2020) and has been encouraged to improve MPA governance (Beier et al., 2017; Di Franco et al., 2020).

The current study suggests that the ME evaluation can clarify management deficiencies, and action research can enhance MPA management by resolving these deficiencies. Accordingly, the aim of this study was to improve the FCZ ME by first identifying issues through an indicator-based ME evaluation framework tailored to Taiwan’s MPAs through a process refer to as the IUCN (Stolton et al., 2020) and Pomeroy et al. (2005). Similar to METT, the evaluation used mixed methods, including literature reviews, semi-structured interviews, and on-site visits to evaluate the FCZs. The Qimei Aquatic Organisms Propagation and Conservation Zone (Qimei FCZ) was selected as a case study for action research to foster stakeholder collaboration and engagement.

## 2. Material and methods

### 2.1. Defining evaluation indicators

The ME evaluation process was designed to encompass the considerations of local communities/managers and the varieties of the objectives of the MPA based on the guidelines for evaluating the ME of MPAs issued by the IUCN (Pomeroy et al., 2004). A set of indicators was selected from three perspectives often considered in MPA ME evaluation

(Muthiga, 2009; Pomeroy et al., 2005; Tupper et al., 2015): biophysical, socioeconomic, and governance factors. These choices were made through a thorough literature review, expert consultation meetings (see Appendix III, Table S1), and stakeholder workshops (Fig. 1). We added “Objective of the MPA” as a new factor because many MPAs in Taiwan were established without clear objectives, while the majority of the indicators were adapted or modified from existing methodologies (Table 2). As a result, 28 indicators were established in the form of an evaluation questionnaire, and an Excel spreadsheet was created to aid the scoring process (Appendix I and II).

### 2.2. Evaluation process and data analysis

The authors (as assessors) evaluated 30 FCZs using the following steps. We first evaluated each FCZ through a comprehensive literature review encompassing scientific reports, government documents, legislative acts, and other available sources. Second, the assessors conducted semi-structured interviews with key stakeholders to adapt to in-person and virtual formats during the COVID-19 pandemic. Key stakeholders, including FCZ local managers, experts, scholars, and affected residents (e.g., fishermen associations, fishers, and tourism services in FCZ areas), were selected based on their possession of at least two attributes: power, legitimacy, and urgency (Mitchell et al., 1997). A purposeful sampling method was employed to efficiently select information-rich interviewees and ensure the involvement of the most relevant stakeholders within resource constraints (Patton, 2002). Following the guidelines by Guion et al. (2011), we conducted in-depth semi-structured interviews using an interview guide derived from the questionnaire to facilitate interviewees expressing their opinions within context. Third, we visited each FCZ to gather photographs and gain insights into the current situation. For island-based FCZs, boat trips or land visits were arranged when feasible.

As shown in Fig. 2, we assigned scores ranging from 0 to 3 points for each indicator using a questionnaire and scoring sheet (Appendix II and II). These scores were cross-validated through interview responses, relevant bibliographic materials, and on-site visits to FCZs by the first assessor and verified by the other two assessors to ensure consistency. The arithmetic mean was then calculated and converted into a percentage for each factor. The percentage scores obtained for each FCZ were divided into four ranks, serving as a benchmark for managers to monitor ME in achieving the FCZ goals. The ranks were defined from low to high scores as Very Poor (0–25), Poor (26–50), Medium (51–75), or High (76–100 points) ME.

### 2.3. Action research

After obtaining the ME evaluation results, a list of FCZs ranked as Medium ME was considered to pilot the action research based on observations during the evaluation process. The reason for considering the mid-range score is that there are higher probabilities of improvement in the short term due to time limitations in a government-funded study. FCZs with lower scores, which often lacked community engagement and local government funding, required more time and resources for enhancement. The action research plan included the following steps (Fig. 3): The current situation and management issues of the FCZ were accessed and identified by the research team through the FCZ ME evaluation process; collaboration by organizing a team encompassing stakeholders (most of them also participated in the semi-structured interviews), including scientists, residents, fishers, and management authorities, to discuss the identified issues and challenges in managing the FCZ; and a series of workshops were held with stakeholders to implement solutions and discuss amending the FCZ policy and generate outcomes that meet the requirements of stakeholders.

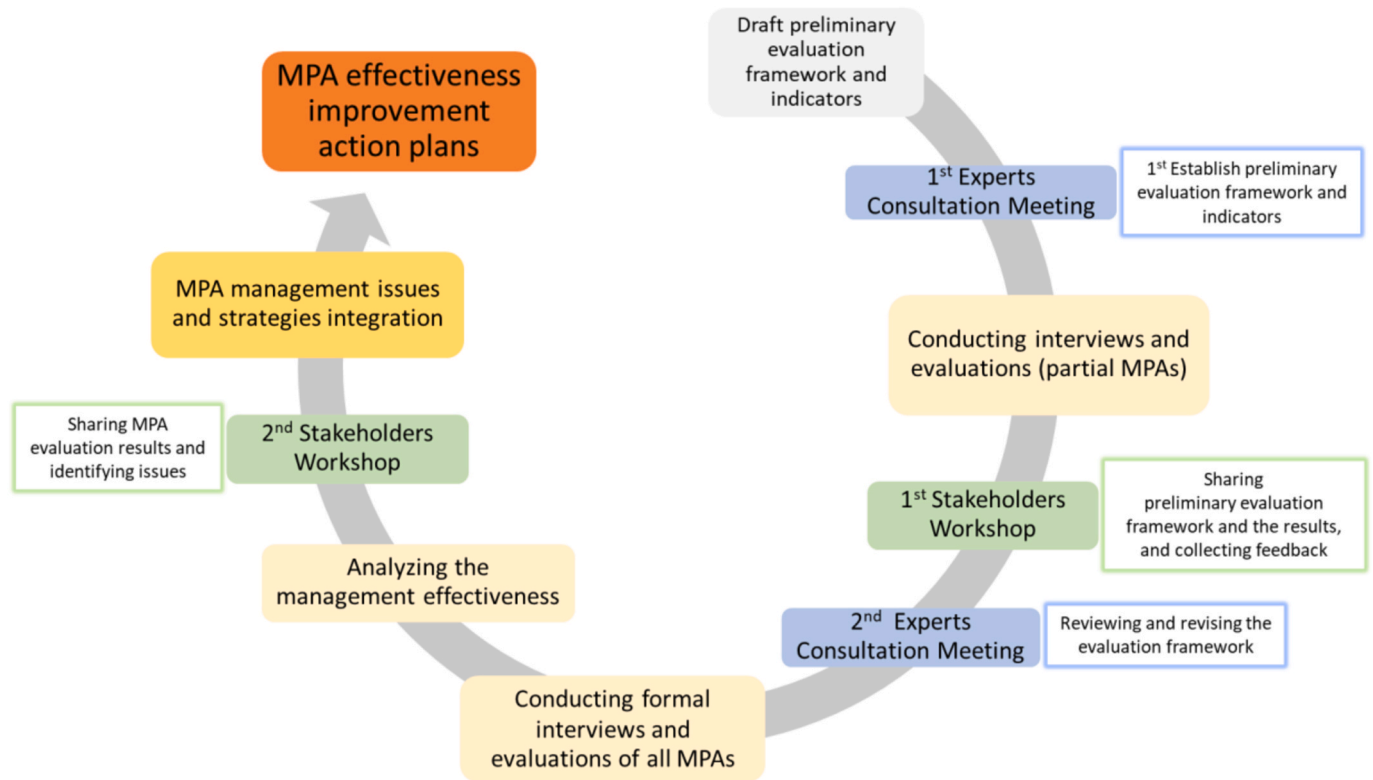


Fig. 1. Flowchart indicating the process for developing evaluation indicators, conducting the evaluation process, and drafting management effectiveness improvement plans.

**Table 2**  
Primary level (four factors) and secondary level (sub-factors) of the indicators and their referred methodologies.

Primary level	Secondary level	References
A. MPA Objective	A1. Objective of the MPA	(Lai, 2018; Staub and Hatzziolos, 2004)
B. Biophysical factors	B1. Monitoring and Evaluation	(Lai, 2018; Staub and Hatzziolos, 2004; Stolton et al., 2007; Wells and Mangubhai, 2004; Yan, 2014)
C. Socioeconomic factors	B2. Pressure and Threats	(Ervin, 2003; Stolton et al., 2007)
	C1. Multiple-use of marine resource	(Lai, 2018; Stolton et al., 2007; Wells and Mangubhai, 2004; Yan, 2014)
	C2. MPA contribution to environmental education	(Lai, 2018)
D. Governance factors	C3. Participation of the stakeholders	(Lai, 2018; Yan, 2014)
	D1. Legislation	(Lai, 2018; Staub and Hatzziolos, 2004; Yan, 2014)
	D2. Finance	(Ervin, 2003; Stolton et al., 2007; Yan, 2014)
	D3. Planning	(Costa et al., 2016; Lai, 2018; Staub and Hatzziolos, 2004)
	D4. Management	(Costa et al., 2016; Lai, 2018; Staub and Hatzziolos, 2004; Stolton et al., 2007; Wells and Mangubhai, 2004; Yan, 2014)
	D5. Achievement toward objective	(Ervin, 2003; Hennie et al., 2018)

### 3. Results

#### 3.1. Evaluation of the FCZ management effectiveness

During the two-year ME evaluation period from 2021 to 2022, 39 key stakeholders, including 15 managers, 9 experts or researchers, and 14

residents (Appendix III, table S2), were interviewed, and over hundred bibliographic references were analyzed for the 30 FCZs to obtain the score for each indicator. The scoring results are shown in Fig. 4 and were classified into four ME performance levels. Two FCZs were rated as “High ME,” nine as “Medium ME,” eight as “Poor ME,” and eleven as “Very Poor ME”. The current status and suggestions for the four levels are summarized in Table 3. The indicators listed in each ranking can be enhanced, and the ME score can be improved in the short term if future management aligns with the recommendations. The issues and problems identified during the evaluation process are discussed in the following sections.

The evaluation results showed that only two FCZs (FCZ04 and FCZ16) were rated as having a High ME, mainly because they implemented strict no-take zones, had high cooperation with local communities, and showed signs of recovery in species abundance. The other FCZs reflected varied scores across ME levels from “Very Poor” to “Medium.” This revealed variations in management problems among-different local governments, where most FCZs lack clear management objectives, long-term ecological observations, and regular evaluation and amendment plans. First, ecological surveys are usually conducted by different research teams with a weak integration of monitoring data, resulting in a lack of a comparison standard to evaluate variations in abundance and biodiversity. A lack of scientific data and inadequate protection levels lead to low ME performance. Second, limited enforcement authorities have resulted in inadequate protection against illegal catches in FCZs. This is because most FCZs only protect specific species rather than designating them as complete no-take zones for all marine organisms. Consequently, the enforcement of illegal activities is compromised, as people are allowed to fish within FCZs as long as they do not catch the protected species. Third, the authorities responsible for the FCZs are the fisheries divisions in the local government; however, several challenges exist concerning water recreation regulations, zoning plans, and conflicts among tourism industries. For instance, intensive scuba diving activities have inadvertently damaged corals in FCZs,

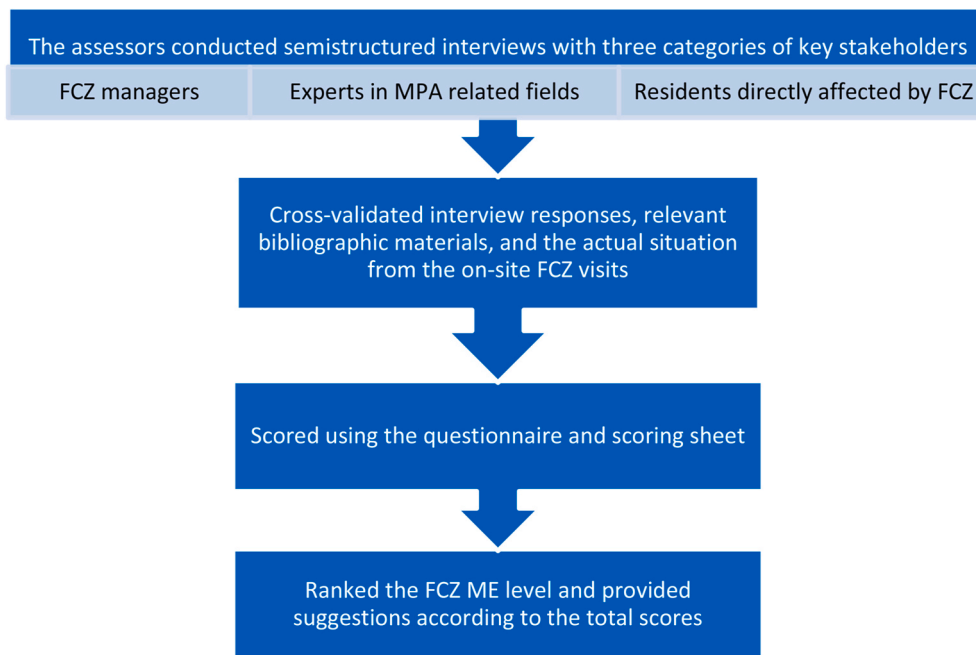


Fig. 2. Flowchart detailing the FCZ management effectiveness evaluation scoring process.



Fig. 3. The participatory action research plan of the pilot FCZ.

reducing habitat coverage.

### 3.2. Action research improved management effectiveness

The Qimei FCZ (FCZ28) was established in 1988 in Qimei Township, Penghu County, and covers a sea area of 4 ha. It is a multipurpose conservation area that partially protects small abalone (*Haliotis diversicolor*), pyramid shell (*Tectus* sp.), collector urchin (*Tripneustes gratilla*), and lobster (*Panulirus* sp.). It received an overall score of 59.42% and was classified as a Medium ME. However, the initial low scores for the biophysical and governance factors (Fig. 4) revealed insufficient enforcement and a lack of ecological observations. In 2019, a volunteer community patrol team was established with assistance from the Ocean Conservation Administration, Ocean Affairs Council (OCA), Taiwan.

Residents actively patrolled and reported violations along the protected zone, contributing to higher socioeconomic scores.

We selected Qimei FCZ (FCZ28) to conduct the participatory action research as a pilot test because of the highly active local community participation observed during field trips and semi-structured interviews. The residents' and local governments' willingness to collaborate enabled short-term improvements and effective collaboration. Based on this finding, we conducted the action research with a team of scientists, residents, fishers, and management authorities from 2021 to 2023. According to a detailed examination of ME evaluation, issues of insufficient management were identified and further discussed through workshops to address improvement strategies. The results of the action research process are shown in Fig. 5, and the issues addressed are outlined in the following sections.

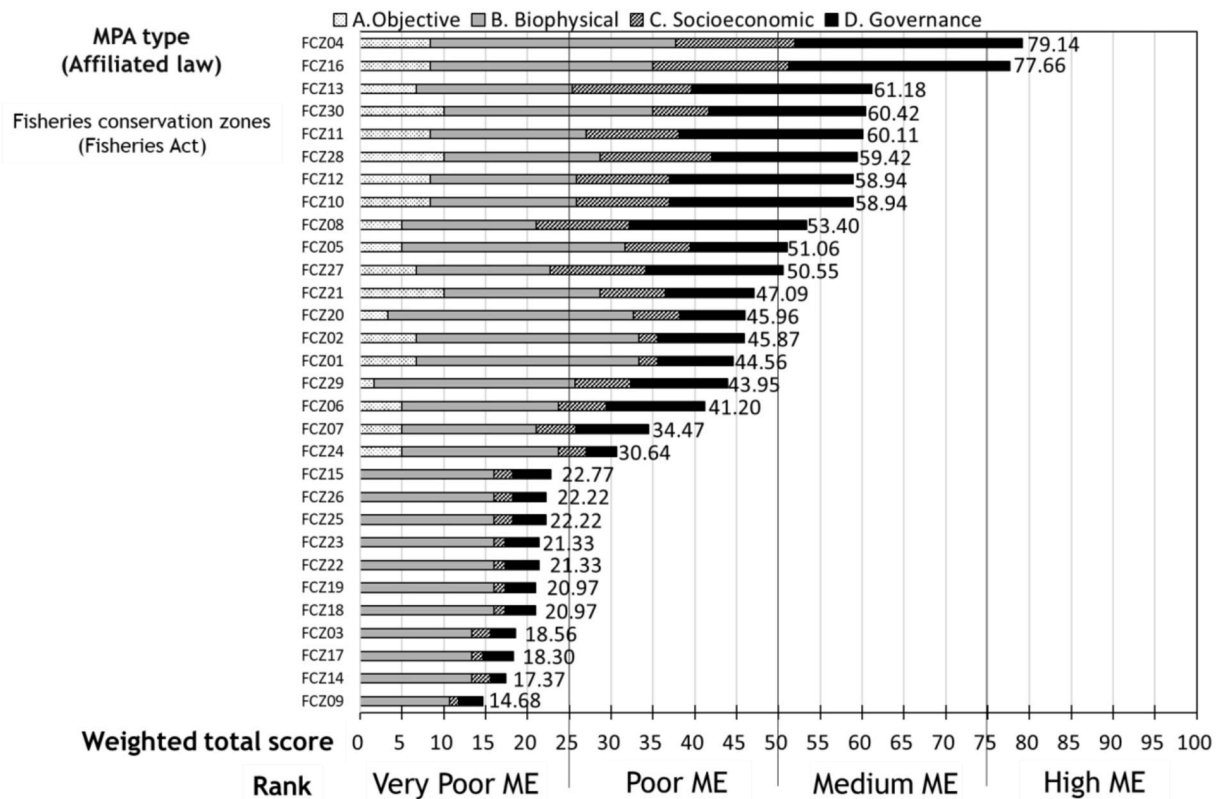


Fig. 4. Evaluation results of management effectiveness of 30 FCZs in Taiwan. The results are grouped according to the legislation and arranged from high to low scores.

3.2.1. Issue 1: incorrect mapping resulting from lacking communication between researchers and stakeholders

This discrepancy was identified through our ME evaluation interviews, highlighting the deficiency of researchers in relying on official documents for their survey plans without communicating with local stakeholders. According to their non-standardized observations, residents claimed that sea urchins have increased, but that the pyramid shell population has decreased since 2019. However, scientific surveys have indicated that the population of protected sea urchins is small and has significantly declined compared with previous ecological surveys (T. Chen et al., 2019). The inconsistency between scientific surveys and resident perceptions arose from differences in survey locations. The officially published MPA boundary was inaccurately positioned 1.5 km from the actual protected zone (gray rectangle in Fig. 6a) due to early Global Positioning System technology errors. Consequently, researchers conducted intertidal surveys close to the coast in 2012 and 2018 (black points in Fig. 6a) because the initially designated protected zone was too deep for scuba diving. In contrast, the resident observations made by snorkeling were in the correct area because the billboard was on the coast within the protected zone. This issue was reported to the local and central authorities in the first workshop in 2021. Local authority corrected this mistake and republished official documents (including central government websites) in November 2022.

3.2.2. Issue 2: lacking long-term and comparable scientific data for ecological monitoring resource

The local authority recognized the need for citizen scientist training, especially in remote areas such as the Qimei FCZ, which lack long-term monitoring data (due to issue 1). A central government-funded program to train local volunteers for ecological surveys was initiated after the first workshop. From 2021 to 2023, ten dedicated local volunteers, primarily the elderly and those lacking professional education, eagerly participated in training courses twice a year (Fig. 6b and c). Notably,

these volunteers were former fishers with strong snorkeling skills, well-suited for sea urchin and large organism surveys (Fig. 6d and e) within the protected zone within the protected zone. Therefore, the researchers suggested training the volunteers, simplifying the observation method within fixed subregions, and focusing on only a few representative species. Beginning in August 2021, volunteers commenced irregular sea urchin observations, maintaining continuous records of temporal variations in the observed sea urchin populations (Fig. 6f). These observations serve as a valuable indicators of the ME evaluation process.

3.2.3. Issue 3: specific species protection leads to poor surveillance and enforcement

Most FCZs have been established to protect these four species. In Qimei FCZ, the general public can collect non-protected species within the MPA. During coastal surveillance, patrollers find it difficult to distinguish between protected and unprotected species, leading to conflict and enforcement challenges. Therefore, a recommendation was proposed in the first workshop to change the restrictions from a specific species-protected zone to a no-take zone to improve monitoring and management.

3.2.4. Issue 4: ignoring the needs of the local community obstructs the development of conservation

Action research in Qimei FCZ commenced with a workshop in 2021, bringing together scientists, local stakeholders, and authorities from local and central governments. During this workshop, discussions on training local citizen scientists and developing an amended management plan reached a consensus. This resulted in the correction of an erroneous conservation zone designation and secured funding for a citizen training project for ecological observation (Fig. 6). Additionally, the local community advocated changing the protection category from specific species protection to a no-take zone. Three workshops were held in 2022 and 2023, involving more than 118 stakeholders to discuss management

**Table 3**  
Summary of the current status and suggestions of the four protection levels of 30 FCZs in Taiwan.

Ranking	MPA	Current status	Suggestion	Relevant Indicators
Very Poor ME	FCZ03	1 Lack of human resource and management funding 2 No management plans, clear conservation objectives, schedules, or regular effectiveness evaluation 3 Low stakeholder participation or involvement 4 Declining of keystone species or unsuitable habitat for protected species (FCZ09, FCZ14)	1 Input funds and human resources to assist in the improvement of ecological monitoring and management plans 2 A decommissioning system should be formulated for areas with declining ecological resources or unsuitable habitats for protected species, or the boundary should be redesigned.	A1.1
	FCZ09			B1.1
	FCZ14			D1.1
	FCZ15			D2.1
	FCZ17			D3.1
	FCZ18			D4.4
	FCZ19			D5.1
	FCZ22			
	FCZ23			
	FCZ25			
Poor ME	FCZ01	1 There are insufficient human resources and funds 2 No management plan, clear conservation objectives, schedules, or regular effectiveness evaluation 3 Most areas are for protecting specific species only instead of for comprehensive habitat conservation 4 Traditional fishery activities are common in most areas; thus, upgrading the ME level is difficult	1 Continue to carry out ecological resource surveys and regularly monitor resource trends 2 Establish a joint management model with community residents, encourage community self-management, and reduce human resources requirements for management 3 Assess zoning plans and designate strict no-take zones to enhance fishery management	A1.1
	FCZ02			B1.1
	FCZ07			C1.3
	FCZ06			C3.1
	FCZ20			D1.1
	FCZ21			D2.1
	FCZ24			D3.1
	FCZ29			D4.4
				D5.1
Medium ME	FCZ05	1 The controlled intensity is high, and some areas are no-enter or no-take zones 2 The input funds and human resources are relatively high, or there is high stakeholder participation or involvement 3 Most areas have relatively comprehensive and long-term ecological monitoring data	1 Assist in the establishment of local scientific investigation human resources and improve the capacity of ecological monitoring 2 Increase the control intensity of fishing activities or the range of no-take areas 3 Strengthen the effectiveness of law enforcement against illegal acts	A1.1
	FCZ08			B1.1
	FCZ10			C1.3
	FCZ11			C3.1
	FCZ12			D1.1
	FCZ13			D2.1
	FCZ27			D3.1
	FCZ28			D4.1
	FCZ30			D4.4
				D5.1
High ME	FCZ04	1 The controlled intensity is the highest, and most of the areas are no-take areas or conditionally no-entry areas	1 Conduct assessments of the socioeconomic impact of MPAs on surrounding communities	C1.1
	FCZ16			C1.2
				D3.2

**Table 3 (continued)**

Ranking	MPA	Current status	Suggestion	Relevant Indicators
		2 Management human resources and funds are relatively abundant, and high stakeholder participation	2 Plan to expand the boundary of MPAs to protect more habitats	
		3 Most areas have management plans, clear conservation objectives, schedules, and regular effectiveness evaluations		
		4 There are comprehensive and long-term ecological monitoring data		

modifications. These efforts garnered support from stakeholders, including managers and policymakers at local and central government levels, leading to revised conservation plans for a no-take zone by 2023. New zoning plans were formulated based on consensus in a series of stakeholder workshops and approved by the central government of the OCA.

As shown in Fig. 7, most residents supported the local authorities' decision to transform the Qimei FCZ into a no-take zone and expand its southern area by 150 m (red dashed rectangle). Local fishers participating in citizen research discovered an abundance of sea urchins in the extended zone. However, stakeholders have also proposed that the intertidal area between the low- and high-tide lines (green line extending to the coast) should remain accessible to local citizens for artisanal fishing. Academic experts agreed with this suggestion and recommended the implementation of licensing for residents as part of a new management plan, which would aid in surveillance efforts. Consequently, the local authority has been amending the management plan for the Qimei FCZ, with financial support provided for ecological observations and comanagement counseling from the central level, specifically the OCA, since November 2023.

#### 4. Discussion

In Taiwan, MPA governance has faced the challenges of polycentric authorities, financial instability, and limited enforcement capacity (Chung and Jao, 2022). This study further revealed the lack of ecological monitoring and inappropriate design of protection strategies for Taiwan's MPAs through ME evaluation. The limitations of polycentricity and decentralization in MPA governance are also found in MPAs worldwide (Jones and Long, 2021). Inconsistencies among decision-making centers, challenges in enforcing rules without an organized hierarchy, and resource-limited contexts hinder effective governance (Fortnam et al., 2022). Polycentric governance risks crowding out and diminishing rule compliance, especially with capacity limitations in higher-level government decision-makers (Carlisle and Gruby, 2018). The effectiveness of MPAs is limited by insufficient management capacity, inappropriate sizing concerning ecological needs, and the risk of poorly designed areas, thereby creating a false sense of protection. (Jameson et al., 2002; Agardy et al., 2011; Hung et al., 2021). Accordingly, the regular application of a comprehensive review of MPAs through ME evaluation offers insights into the weaknesses of management plans. This process helps to identify issues that can be effectively addressed through participatory action research to

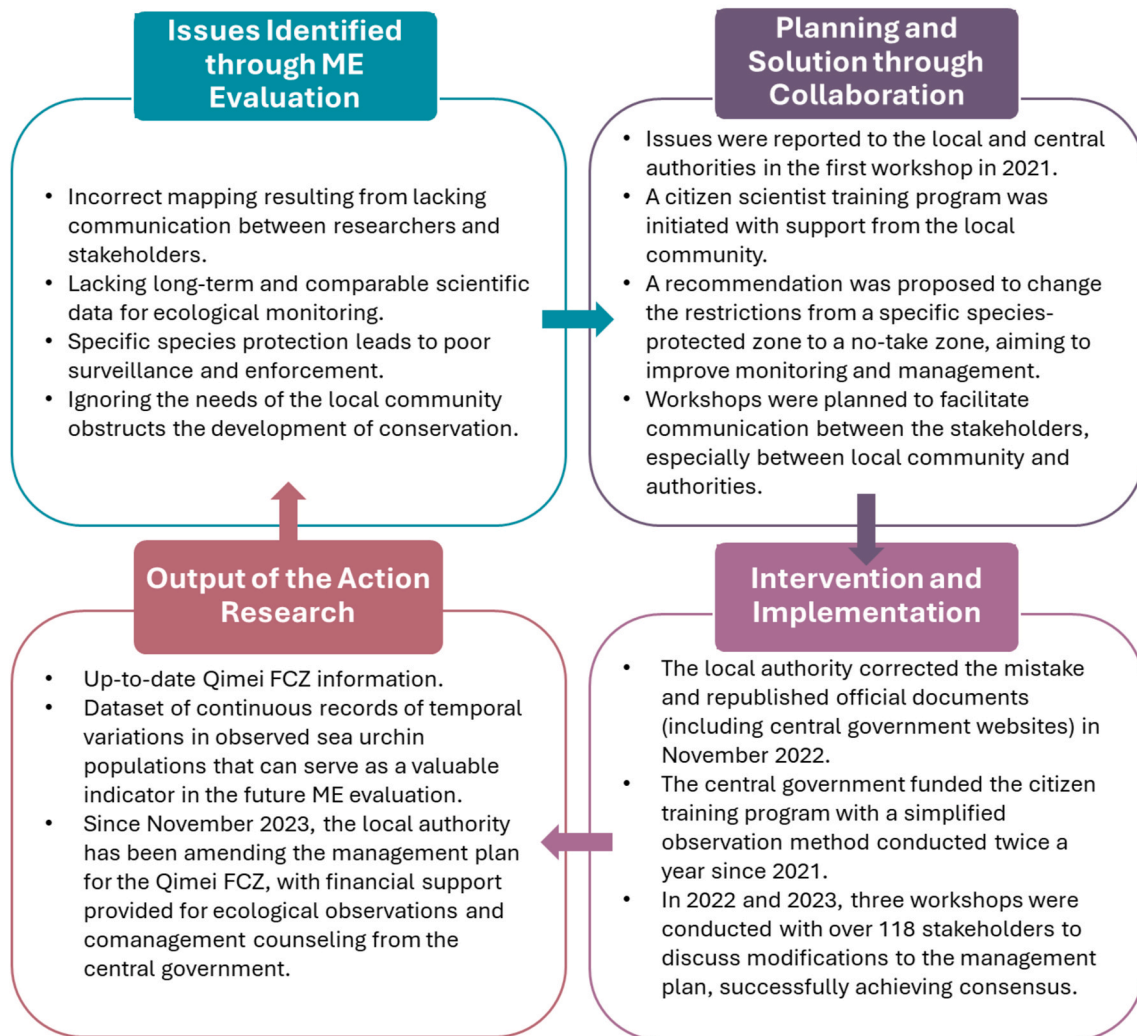


Fig. 5. The action research process conducted in the Qimei FCZ.

enhance management effectiveness. Our case study, for instance, will increase the ME score in future evaluations while we documented management plans, continuous species composition survey, and part of no-take zone with highly regulated fishing activities (under legislative processing), the score will rise according to the indicators A1.1, B1.1, B1.5, D3.2, and D4. This change encourages the central government to participate in conservation policymaking and collaborate with local communities.

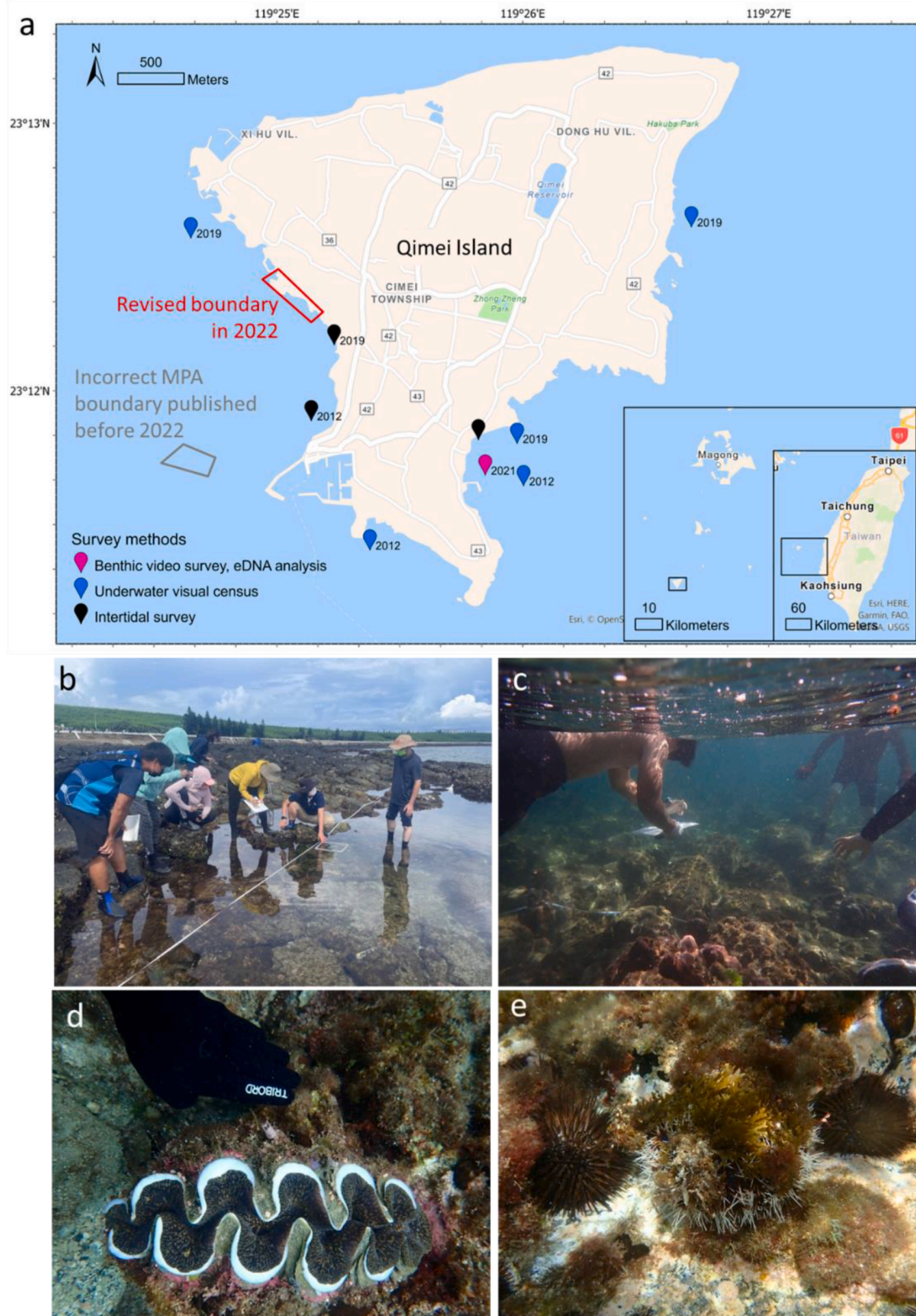
#### 4.1. Regional MPA ME evaluation structure is necessary

The MPA ME evaluation is commonly used to monitor management and conservation outcomes. Nevertheless, diverse methods pose challenges, particularly in local MPAs, which may require extensive scientific data and analytical skills, making them impractical with limited investigative capacity (Hockings et al., 2006). During the evaluation process, we found that some indicators may not be suitable for MPAs in Taiwan. For example, most methods include assessing pressure and threats using indicators related to climate change (Ervin, 2003; Hockings et al., 2006; Stolton et al., 2007), whereas continuous observations exceeding 30 years are needed but are lacking in Taiwan. We suggest that climate change-related indicators should not be a priority in ME evaluation, as limited ecological observations may affect the scoring. The inconsistency in MPA categories between individual nations and IUCN standards also poses challenges to the adoption of international

methods. Hence, a region-specific evaluation approach is essential to address these challenges and ensure alignment between international methods and local conditions for the effective assessment of regional MPAs.

#### 4.2. Design of no-take zones in MPA improves the surveillance ability

The evaluation results of the FCZs revealed that only 7% exhibited high management effectiveness (High ME), whereas the majority (63%) were poorly managed (Poor and Very Poor ME). Enforcement issues are prevalent in most FCZs owing to specific species protection measures, despite the recognized effectiveness of no-take marine reserves for marine ecosystem conservation (Sala and Giakoumi, 2018; Strain et al., 2019; Albano et al., 2021). Compared to the Conservation Park and Buffer zones of the Great Barrier Reef, FCZs in Taiwan are also classified as IUCN Category IV, which offers less protection owing to the range of fishing gear allowed. If robust enabling conditions exist for management plans and designs, highly protected MPAs with low-impact extractive activities and traditional resource use can yield better outcomes than fully protected areas devoid of extractive or destructive activities (Gorud-Colvert et al., 2021). FCZs often permit high-impact gear types, aquaculture, anchoring, or infrastructure, suggesting that implementing no-take zones as sub-regions/or entire areas in FCZs is critical for enhancing management effectiveness. As a new zoning plan with small-scale extractive activities for the original residents (Fig. 7), the



**Fig. 6.** The map of the Qimei Aquatic Organisms Propagation and Conservation Zone (Qimei FCZ) and action research workshops. (a) The revised boundary in November 2022 (red rectangle) and the incorrectly announced boundary (gray rectangle) of the Qimei FCZ. Previous ecological survey locations and methods are labeled, and the management effectiveness results are shown in a pie chart. (b, c) Volunteers training courses on citizen research during workshops. (d, e) Surveyed representative species of a Giant Clam (*Tridacnidae* spp.) and collector urchins (*Tripneustes gratilla*). (f) Continuous records of temporal variations in sea urchin populations from irregular citizen research observations.

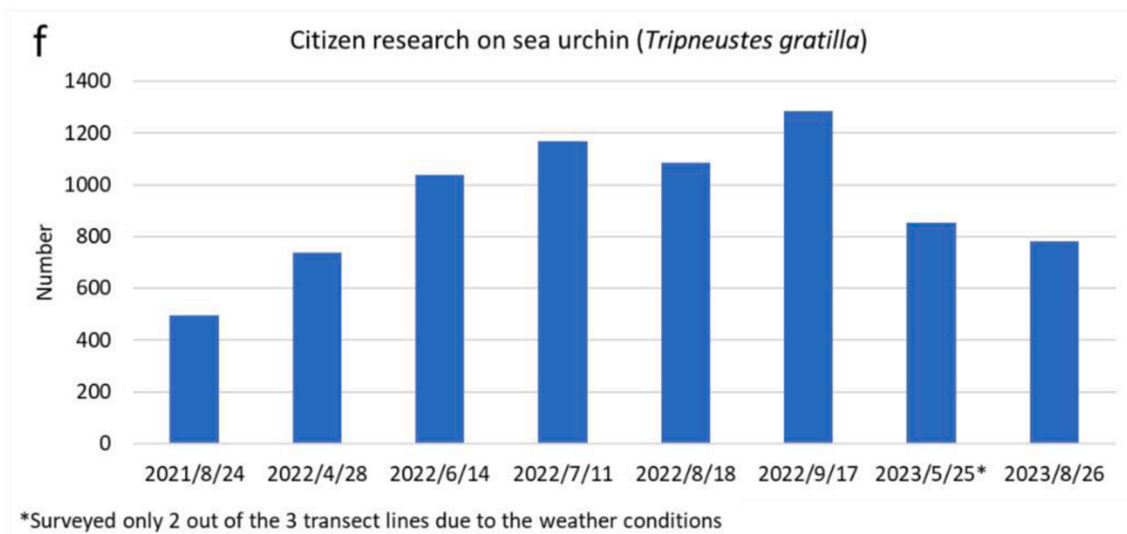


Fig. 6. (continued).



Fig. 7. The 2023 zoning plan introduced no-take areas, including a Core Zone (red rectangle) where all fishing is strictly prohibited. The Buffer Zone (green line) allows traditional shellfish, sea cucumber, and seaweed collection by residents in the intertidal area above the low-tide line, while entry and fishing activities in the subtidal zone beyond the low-tide line are prohibited. The red dashed rectangle indicates the expansion area.

extended no-take zones and easy surveillance by patrols should enhance regulation enforcement.

#### 4.3. Changes in community awareness and enabling conditions accelerate marine conservation

As common-pool resources, marine organisms provide evidence that self-governance institutions, led by local communities and buffered by external influences, can promote sustainable use. (Dietz et al., 2003). Community engagement is an approach that emphasizes the need for

stakeholders to compromise and work together to maximize the overall benefits through ecosystem conservation (Ostrom, 1990). However, it is noticed that the management strategies of FCZs in Taiwan are gradually changing but do not primarily consider the allocation of benefits from commons utilization. Notably, residents in FCZ04, FCZ16 (the highest MEs), and Qimei FCZ were primarily motivated by strong local community demands to modify the FCZs management plans, driven more by nostalgia for the rich ecological environment from their memories rather than economic incentives. This is evidenced in the new zoning plan and intensifying management measures of the no-take zone in the Qimei

FCZ, with high consensus among local communities, although they did not consider a fishing catch or recreational activities. This inconsistency in benefit allocation may change the game theory model widely used for common management strategies (Ostrom, 1990) because local communities are no longer benefit extractors for marine organisms. This awareness change in communities may enhance surveillance and enforcement, while leaders and patrols in local communities will not benefit from extracting the commons that can drive the institution of community self-management to success.

On the other hand, new zoning and governance measures planned through action research receive support from both central and local authorities. The central government, the OCA, acts as an investor to support the action research project and local community patrol program, primarily motivated by key performance indicators (KPIs) such as achieving 30% MPA coverage, species recovery rate, and international compliance. Local governments are the authorities for FCZs, serving as boards and executors, and may face constraints due to financial pressures from central government projects. This MPA counseling strategy was first applied in Taiwan to provide priority issues for improving MPA management outcomes. For example, common mistakes in conservation priority settings, such as poor problem definition, inadequate collaboration with decision-makers, and neglecting prioritization (Game et al., 2013), were addressed by our ME evaluation. Our collaboration with the local government aligns with the Game et al. (2013) strategy of engaging experts, stakeholders, and decision-makers to identify prioritized conservation actions. Furthermore, we found that ME evaluation is a motivational tool for local governments and executing agencies to enhance MPA management, as exemplified by the positive feedback and improvements observed in FCZ04, which ranking first in ME evaluation.

The ME scores do not vary geographically but are more associated with nearby communities' participation levels. For example, FCZ16, FCZ17, FCZ18, and FCZ19 are all in the same county with the same competent authority (Fisheries Section of Taitung County Agriculture Department). FCZ16 obtained the second highest score and ranked "High ME" while the others were ranked as "Very Poor." The local community actively participates in and supports the management of the FCZ16. They established a patrol team to participate in monitoring and giant clam restoration plans. FCZ16 is the only company that charges entry fees to support management, an initiative facilitated by the local community. Similar examples are FCZ04 (High ME) and FCZ03 (Very Poor), which are located in Keelung City and are managed by the City Government. The key difference lies in the high community participation observed in FCZ04 and the lack of participation in FCZ03.

Through action research, researchers and academic institutions can play supportive and bridging roles, facilitating stakeholder collaboration and accelerating the policymaking process. This study demonstrates how government-funded projects can assist in identifying issues and conflicts, establishing communication platforms for resolution, and expediting the promulgation and implementation of legislative amendments, as observed in the case of the Qimei FCZ. In this approach, stakeholder participation and effective communication enhance participant reliability (Djenontin and Meadow, 2018), whereas greater community involvement is essential to protect valued areas and engage locals in managing conservation challenges (Conrad et al., 2019).

## 5. Conclusion

This study established an MPA ME evaluation framework using 28 indicators based on literature reviews, expert consultations, stakeholder workshops, and fieldwork. The evaluation quantified the MPA ME, identified challenges, and offered suggestions for improvement. The key findings emphasize the importance of stakeholder cooperation and recognition for achieving better conservation outcomes. Critical factors in enhancing MPA management include no-take zones, effective enforcement, stakeholder participation and awareness. Smaller, well-enforced MPAs outperform larger MPAs with weaker management.

Effective communication with stakeholders is vital for gaining support, as the successes of MPAs rely on the cooperation and assistance of residents. However, research on the socioeconomic benefits of the fisheries and leisure industries in Taiwan's MPAs is lacking and requires further investigation.

A feasible evaluation process offers valuable insights and feedback for MPA management authorities. This case study highlights the effectiveness of combining evaluation and action research to enhance MPA management efficiency and emphasizes the success of comanagement involving authorities, local communities, and central government support. Our evaluation results resonate with the known governance challenges in Taiwan's MPAs, including insufficient law enforcement capacity, unstable funding sources, and complex governance structures (Chung and Jao, 2022). Additionally, the evaluation process provides a more detailed analysis of the management issues encountered by local practitioners and stakeholders. Furthermore, the quantified evaluation results can aid the central government in tracking the progress of each MPA improvement.

As the final step in enhancing the MPA ME, an integrated approach combining qualitative research and action research with multidisciplinary scientists and stakeholders is a feasible way to accelerate progress in ecological and social dimensions. This study demonstrates how government-funded projects can expedite legislative changes and improve MPA management, emphasizing the importance of community involvement in protecting valuable areas and managing conservation challenges. As demonstrated in the Qimei FCZ case study, the mixed method ME evaluation model can be used by government agencies to address low-performing MPAs and strengthen MPA management.

## CRediT authorship contribution statement

**Shu-Chiang Huang:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. **Yi Chang:** Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Writing – review & editing. **Shui-Kai Chang:** Conceptualization, Funding acquisition, Methodology, Resources, Supervision, Validation, Writing – review & editing.

## Declaration of competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Yi Chang reports financial support was provided by Ocean Conservation Administration, Ocean Affairs Council, Taiwan, ROC. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

Data will be made available on request.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ocecoaman.2024.107075>.

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