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Zoning strategies for marine protected areas in Taiwan: Case study of Gueishan Island in Yilan County, Taiwan

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ABSTRACT

According to the United Nations (UN) Millennium Ecosystem Assessment, there has been a dramatic decline in global biodiversity. The UN has made a global appeal for all countries to mitigate their impact on the environment. Marine environmental protection is one of the most critical and urgent issues in the world and many countries have commenced establishing marine protected areas (MPAs) by implementing ecosystem-based management (EBM) concepts. MPA planning has been considered one of the simplest and most effective methods to protect marine environments. Taiwan has recently developed policies that have focused on its marine environment, and there are plans to increase the size of Taiwan's MPAs to 20% of its total ocean territory by 2020, thereby achieving a sustainable ocean. To achieve this goal, the government must address specific difficulties associated with the location of MPAs and relevant zoning strategies. This study establishes MPA protection principles and a zoning framework for MPAs in Taiwan by using Gueishan Island in Yilan County as a case study site to examine specific zoning strategies. The protection of 3 objectives (hydrothermal vents, cetacean, and fisheries resources) is discussed in this paper. Multi-criteria spatial analysis and a geographic information system are applied to identify the most crucial area to protect. To understand the stakeholders' opinions and concerns regarding the proposed zoning framework, this research conducted in-depth interviews with experts and stakeholders. MPAs zoning strategies are formulated at the conclusion of this study that could assist in protecting critical marine resources and avoiding conflicts among various usages of the marine area.

1. Introduction

In addition to the growth in the global population and developments in fishing technology, human activities have extended to ocean areas, and the demand for marine resources has increased. According to the *Millennium Ecosystem Assessment* report from the United Nations (UN), there has been a decline in global biodiversity. All oceans are affected by human activities, including over-fishing, ocean dumping, mining, transportation, aquaculture, and tourism [1]. The UN has appealed to all countries, requesting action to mitigate the impacts of human activities on the marine environment. Researchers have indicated that the traditional methodology for fishing management based on the concept of maximum sustainable yield is unsuitable and inflexible for the complex and multi-use marine space. In addition, the decrease in global capture fisheries production pushes the emergence principle and approach toward the precautionary concept of marine resources protection. Therefore, the protection of marine resources has been discussed from the perspective of ecosystem-based management (EBM). In the past few decades, studies on EBM have focused on the management of fisheries resources and other natural resources. Numerous EBM-based studies have indicated that the zoning of marine protected areas (MPAs) and related network systems is a practical and effective approach to managing and protecting the marine environment [2–5].

The concept of MPAs is based on terrestrial protection, and the term was first proposed in 1962 at the First World Conference on National Parks. The goal of establishing MPAs is to maintain biodiversity, ensure sustainable resource use, and to protect culture and heritage [6]. With a deeper understanding of the marine environment and improvements in technology, previous studies have clarified several substantial differences between terrestrial and marine environments [3,6,7]. Accordingly, the planning, zoning, and management strategies for MPAs should differ from those of terrestrial protected areas. Furthermore, such strategies should consider the tidal and ocean currents, the complexity of oceanology, and the four-dimensional marine characteristics, including 3 dimensional space and time (Table 1). In addition, because MPAs are affected considerably by the surroundings, an effective MPA

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Table 1
The difference between marine and terrestrial protected areas [6,7].

Characteristic	Terrestrial protected areas	Marine protected areas
Spatial concept	• Two- to three-dimensional space	• Three- to four-dimensional space • Zones with various depths need different management strategies
Reserve size	• Small	• Large
Ownership	• Clear	• Viewed as "public property" • Public accessibility and right to use
Boundary management	• Relatively easy	• Hard (even impossible) to control activities on the boundary • Hard enforcement
Seasonal protection	• Relatively low	• Relative high • Need seasonal full protection during the year (fishing propagation grounds)
Species move out after propagation	• Less	• More
Connectivity	• Relatively low	• Relatively high
Predictability	• Relatively high	• Relatively low
Sensitivity	• Relatively low	• Relatively high
Data collection	• Relatively easy	• Relatively hard

must consider its exterior environmental conditions and any related influences. This increases the difficulty of planning and managing MPAs.

Taiwan is located in the center of the Festoon Islands, and has high biodiversity and rich fisheries resources. However, previous research has shown that overfishing, overcapacity, and land pollution have caused the degradation of marine resources [4,8]. In 2006, the MPA concept was proposed in the *Ocean Policy White Paper* in Taiwan. In that paper, several sites (Green Island, Gueishan Island, Penghu Islands, and the Three Northern Islands) were listed as potential MPAs. In 2007, the Marine National Park Headquarters was established, and commenced the establishment of Taiwan's first Marine National Park (Dongsha Atoll National Park). Apart from Marine National Park Headquarters, there are no particular laws and regulations named from MPAs; consequently, marine protection and related regulations have been dispersed across various laws, such as the Wildlife Conservation Act and the Fisheries Act. In 2009, the Sustainable Development Policy Guidelines proposed increasing the size of the MPAs to 20% of Taiwan's territorial waters (inside the 12 nautical miles) by 2020, 50% of which should be marine reserves or no-take zones [9]. Three major challenges for establishing MPAs in Taiwan are (a) location and zoning methodology, (b) conflicts among the various stakeholders, and (c) multi-protection objectives.

In this study, specific zoning strategies are developed to assist in establishing MPAs in Taiwan. To address the difficulties associated with the zoning of MPAs, this study focuses on the following three major issues: (a) the difference between the zoning processes for marine and terrestrial protection; (b) commonalities and conflicts among the various protection objectives and criteria; and (c) the visualization of marine spatial models. The marine geographic information system is applied to analyze and zone the four-dimensional protected areas, and the method of spatial multi-criteria analysis (SMCA) is incorporated into the spatial planning to address the various objectives and criteria. In-depth interviews were conducted to assess the concerns of various stakeholders regarding the potential objectives.

2. Study area

Located off the northeast of Taiwan, Gueishan Island and its surrounding waters are a potential site for establishing MPAs, as proposed in the *Ocean Policy White Paper*. Gueishan Island is approximately 10 km from Taiwan's coast, and the highest point on the island is 398 m above sea level (Fig. 1). Because no specific methods and criteria exist that define and calculate the coverage area of MPAs in Taiwan, it is critical to set a physical study boundary to estimate the covered area of the MPAs in Taiwan's territorial waters [10]. Based on considering both the administrative boundary and border of various stakeholders, the study area includes Gueishan Island and its surrounding waters according to the Toucheng Township fishing rights and the delineation of territorial waters in Taiwan. The Toucheng Township fishing rights area is 3 nautical miles from the high-tide line, which includes Gueishan Island. Therefore, the northern and southern boundaries of the study area are extensions of the fishing rights area (north from the SanDiaoJiao and south to the Lanyang Estuary), and the eastern boundary extends 12 nautical miles from the baseline (Fig. 1). The study area covers approximately 732 km^2, including the territorial waters, inner waters, and Gueishan Island, and its maximum depth is approximately 800 m.

The Kuroshio current and diverse geographical features along the east coast of Taiwan provide abundant fisheries resources in proximity to Gueishan Island. From an economic perspective, the study site is one of the major fishing grounds in Taiwan, and various highly economically valuable fishery species inhabit this area for feeding, spawning, or migrating along the current. The abundant food resources and geographic location between the continental shelf and slope also attracts whales and dolphins.

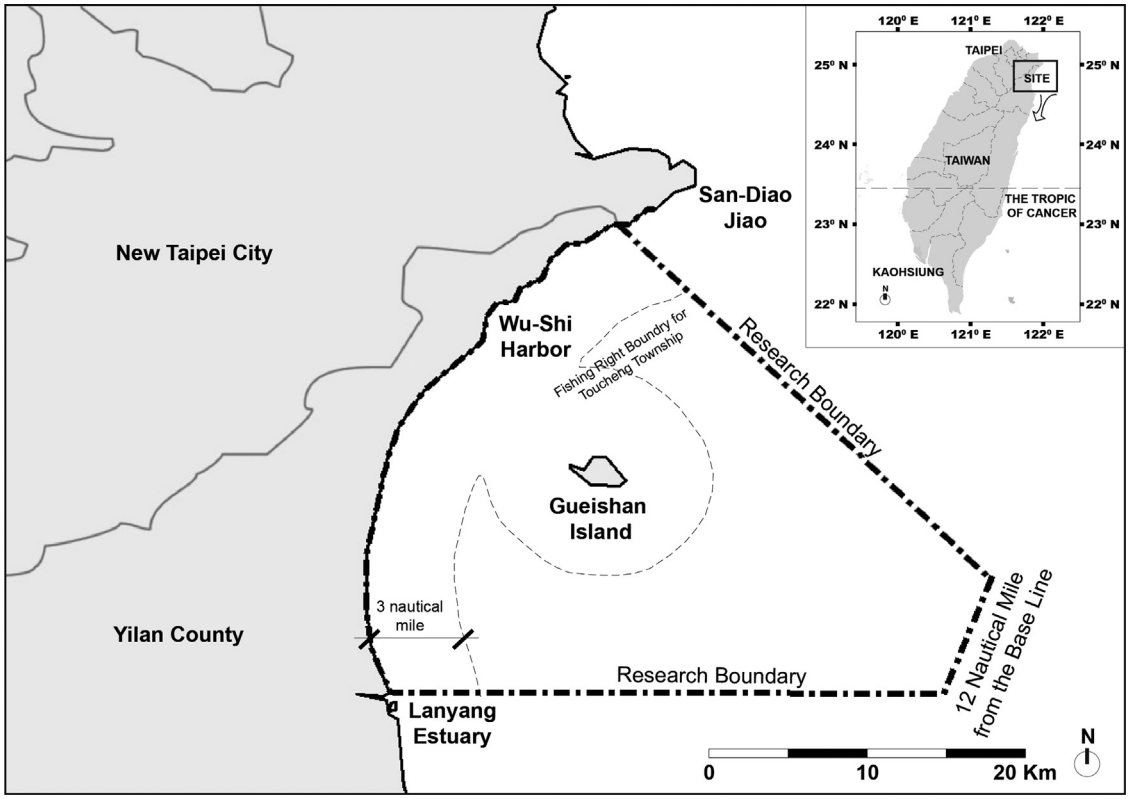

Fig. 1. Location of Gueishan Island and study area.

Gueishan Island has recently become a famous tourist attraction for whale watchers. In addition, rare hydrothermal vents are located at the southeastern end of Gueishan Island. The scale and number of hydrothermal vents comprises one of the world's largest hydrothermal vent systems [11]. The hydrothermal vent crab *Xenograpsus testudinatus*, an endemic species with a unique lifestyle and chemolithotrophic food web has not been observed in any other hydrothermal vent ecosystem [12]. This discussion shows the distinguishing characteristics and complexity of establishing an MPA around Gueishan Island.

The enhancement of fishing technologies and the development of marine tourism has affected the catchment area [13], and the behavioral patterns of whales and dolphins has also been influenced [14]. To minimize the degradation of marine resources, researchers and the government have been advocating the Gueishan Island MPA, and certain local communities have expressed their willingness to cooperate with the MPA concept [15]. However, the agreement to establish the MPAs is conceptual. Consequently, because the proposed Gueishan Island MPA involves numerous stakeholders and protection objectives, a long debate is anticipated concerning the boundary delineation, size, regulation, and limitations of the MPAs. Few studies have researched the MPA zoning strategies according to various interests in Taiwan. In an effort to maintain sustainability and minimize conflicts, this study addresses critical issues concerning Gueishan Island and proposes potentially suitable zoning strategies.

3. Analytical framework and methods

3.1. Protection objections and strategies

Based on the perspective purported by the International Union for Conservation of Nature (IUCN), the goal of establishing MPAs is to conserve biological diversity and productivity [6]. Both of these prospects are viewed as equally crucial to maintaining the health of the ocean environment and ensure the economic stability of affected communities. To achieve this goal, specific, tangible, and concrete objectives must be established, although these objectives might be internally conflicting. For example, the expectation of high productivity might be incompatible with the size of the no-take zone. Therefore, before commencing the MPA selection process, defining clear objectives and understanding the potential relations among stakeholders is the first and one of the most critical steps [16]. The importance of the proposed Gueishan Island MPA can be detailed from various perspectives. After comparing case studies, reviewing extant literature, and conducting in-depth interviews with various stakeholders such as experts, local authority officials, local communities, and fishermen's associations, a multiple criteria structure based on each objective is introduced and applied for the subsequent spatial analysis (Fig. 2). Three major objectives, detailed as follows, are selected in this study to compliment the MPA guidelines discussed by the IUCN [16].

3.1.1. Objective to protect unique ecosystems

This objective is aimed at protecting the critical biogeographical features that have unique and representative characteristics. Several previous studies have asserted that hydrothermal vents possess key features that provide biogeographic, ecological, scientific, and social value [11,12]. Because there are numerous unknowns factors associated with the hydrothermal vent ecosystem, and because the water body has distinctive properties, such as high temperatures (45–60 °C) and acidity (1.75–4.6 pH) [17], the protection strategy and criteria should focus on protecting the core area by maintaining a buffer zone that ensures minimal disturbance.

3.1.2. Objective of productivity

Effective sustainable fishing practices must balance local economic needs and ecological system resilience. Therefore, an EBM

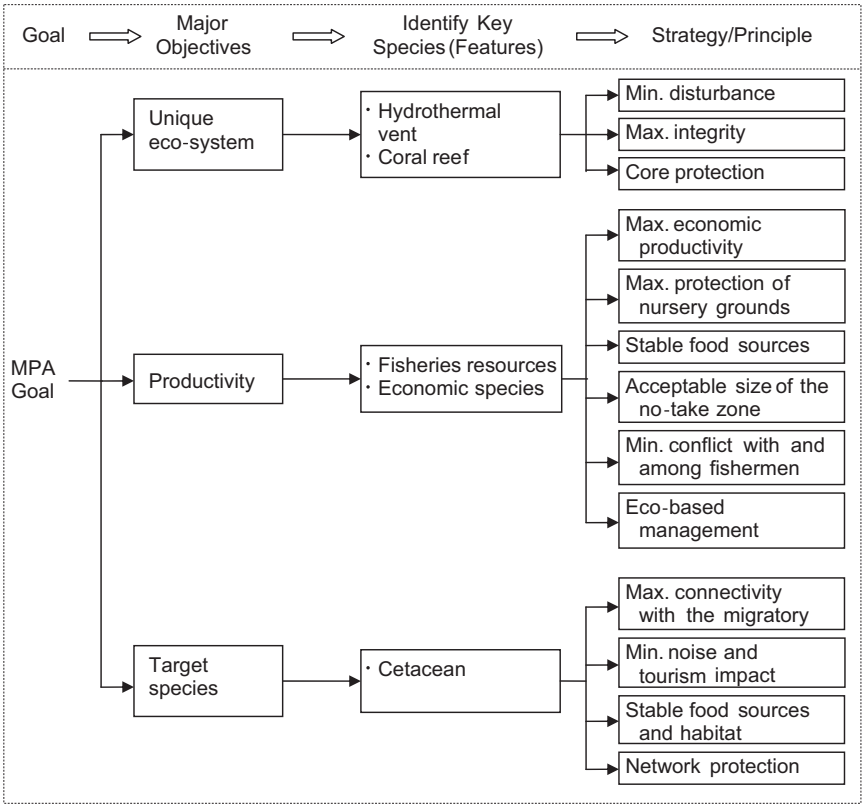

Fig. 2. Graphic illustration of the hierarchical structure of goals, objectives, strategies, and principles.

approach is suitable for protecting the nursery grounds, providing stable food sources, and maintaining an abundance of plankton, larvae, and other highly valued species. To delineate the acceptable location and size of the no-take zone and minimize the conflict and competition among fishermen, this objective requires regular negotiation among planners, decision-makers, and stakeholders.

3.1.3. *Objective to protect target species*

In addition to the unique hydrothermal vent ecosystem and critical ecosystem-supporting productivity (e.g., juvenile, feeding, breeding, or rest areas), this objective aims to support critical ecological values on a regional scale. Whales and dolphins have been identified as key species in this region; accordingly, their migratory route and the surrounding habitat must be considered as an integrated ecosystem that is associated with other protected areas in proximity to the Festoon Islands. Therefore, simultaneously maximizing the connectivity of migratory routes while minimizing the impact of recent blossoming marine activities (e.g., whale watching) should form the basis of the protection strategy and principle for this objective.

3.2. *Data analysis tools*

Delineating MPAs requires a substantial volume of basic data. When the initial protection objectives comprise multiple criteria, an increasingly large data volume is required to assist in making decisions. Unfortunately, data collection and monitoring in marine environments is difficult, which affects many MPA authorities worldwide. Socioeconomic data from local and expert systems provide substantial assistance for data-poor regions [18]. Because it is difficult to obtain all of the required data for the Gueishan Island region, this research compiled related literature, the Ocean Data Bank (ODB) in Taiwan, and in-depth interviews with local associations and experts. Table 2 shows the data used in this study. The observation data of whales and dolphins was collected from a local professional whale-watching fleet.

To provide protection of critical species and separate conflicts among stakeholders, developing an effective zoning plan to establish MPAs is a critical step. However, it is difficult to define boundaries for the protection of a marine environment. With the development of technology, increasing numbers of tools and methodologies have become available that assist in analyzing spatial data for decision-making processes and applications. MARXAN software was developed to map the Great Barrier Reef in Australia [19]. The Gwaii Haanas National MPA applied Ecopath with Ecosim to model and simulate the critical areas for protection [20], and ArcGIS® was employed to develop a marine planning framework in South Australia [21]. These tools facilitate the visualization and clarification of complex spatial information for the general public and decision-makers, and the zoning process for planners. In addition, the practice of spatial analysis can assist in visualizing and examining the relationships among various usages and stakeholders in a single marine space [2]. In this study, the functions of 3D spatial analysis and statistics are integrated into a geographic information system (GIS) that considers time factors to define the proposed Gueishan Island MPA. AcGIS 10 was combined with several relevant functions in the MolderBuilder application.

3.3. *Spatial multi-criteria analysis*

The protection of 20% of the water territories around Gueishan Island is the primary objective of this study. Because multiple protection objectives are identified in this study, the zoning plan can vary based on different scenarios. Table 3 shows the zoning criteria based on each protection objective listed in Fig. 2. Under each objective, the critical criteria for limitations are based on the

Table 2
Data for zoning MPA in the Gueishan Island Region.

Data category	Data type	Data source
Physical info.	• Water depth • Current speed and direction at various depths • Water temp. in various depth	• Ocean Data Bank (ODB), Taiwan • Data from 1999–2000
Hydrothermal vent info.	• Location of vents • Temp. and pH • Species	• [11,12,17] • Data from 1999–2001
Cetacean info.	• Location, number, and species observed • Moving direction of observed species	• Blue Whale fleet • Data from 2010–2011
Biology info.	• Plankton • Larvae	• R/V Ocean Researcher 2 – no. 1278, 1297, 1306 • Data from 2005

Table 3
Zoning criteria for various protection objectives.

Protection objective	Zoning criteria	Zoning methodology and related reference
Hydrothermal vent		
Core	C1: endemic species and related habitat	Vents and surrounding environment (20–200 m of water depth) for *Xenograpsus testudinatus* [12]
	C2: criteria for similar cases of hydrothermal vents globally	500 m for core in the endeavor hydrothermal vents MPA management plan [22]
Buffer	Area affected by vents	Based on water temp., satellite images, and other water quality information
Fisheries resources		
Core	C1: plankton resources	10% coverage of high plankton abundance
	C2: larval resources and spawning grounds for economic species	10% coverage of high larval abundance for identifying local economic species (strict protection from April to May for the spawning period) [23]
Buffer	High richness of plankton, larval resources	Protect 10–20% coverage for maintaining fishing production; protect 30–50% coverage for greater diversity and productivity [24]
Cetacean		
Core	C1: intense distribution for whale and dolphin populations	Coverage of the densest distribution for cetacean population based on the observation data
	C2: distribution for rare species and protected species	Coverage of the densest distribution for rare and protected species
Buffer	Potential route along the edge of the continental shelf	Distribution for various species, especially highly mobile species, and potential migratory routes [25]

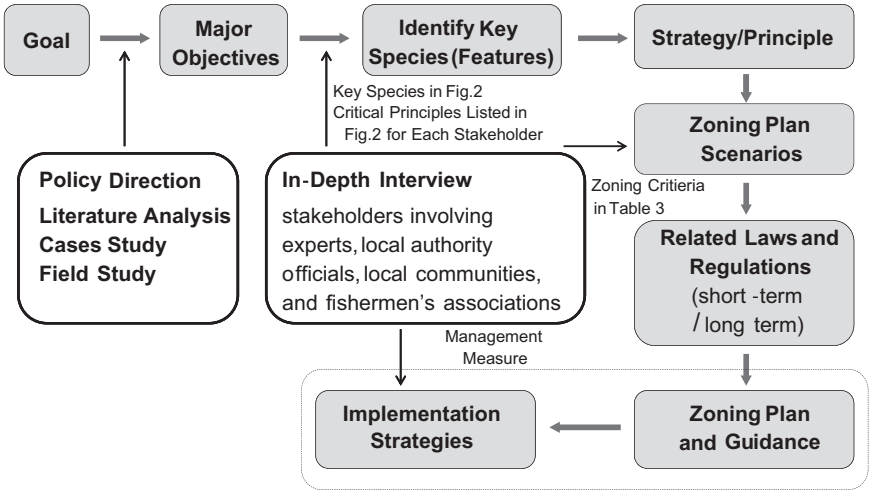

Fig. 3. Graphic illustration the bottom-up strategy, and involvement in various stages from stakeholders.

reviewed literature and in-depth interviews. If more than one criterion is selected, the largest or combined coverage should be set as the core protection area based on the precautionary principle. Various alternatives are anticipated based on different combinations of the core and buffer areas. For example, inside the 20% protected water territory, 5% of the area could be a protection zone for the hydrothermal vent, 9% for fisheries resources, and 6% for the cetacean protection. The various alternative scenarios are based on the priorities of protection objectives, policy orientation and scenario setup. One scenario can be the maximum protection

on fisheries resources, and another scenario can be the maximum protection on cetacean species. This methodology of multiple criteria can help decision-makers to better understand the different scenarios, protected zones and potential impact.

For this study, in-depth interview is used to elucidate the issues associated with the proposed Gueishan Island MPA and the priorities of zoning alternatives. The interviewees were requested to review the proposed protection objectives, zoning criteria, alternatives, and to provide their opinions on the zoning plan, recommended scenarios, management strategies, and implementation of the proposed MPA. The interviewees included MPA experts, local authorities in fisheries management, local non-government organizations, and members of fishermen's associations.

4. Results and zoning plan

4.1. Selection of priorities

Previous studies have shown that many MPAs have achieved their ecological goals after implementing their corresponding zoning plans, although they are typically confronted with managerial difficulties and conflicts. To ensure the efficient management of the MPAs the planning and zoning process includes interviews, discussions with stakeholders, and the acquisition of local knowledge. Several previous studies have asserted that the stakeholders' involvement is a key factor for the successful implementation of MPAs [26,27]. Other research has considered the perspectives of local fishermen as an index for the social acceptance of MPAs, and as tools for performance monitoring [28]. The involvement of stakeholders can be set in various stages of the research (Fig. 3). The majority of the interviewees agreed at an early stage to set several smaller protected zones based on existing laws instead of a single large protected zone. The key species, critical principles, zoning criteria, and the selection of alternative scenarios are based on extant literature and the in-depth interviews.

4.2. Zoning plan

The zoning plans for the Gueishan Island MPA can be proposed following (a) the spatial multi-criteria analysis, (b) defining the alternatives to the core protection and buffer areas, and (c) conducting in-depth interviews to establish the priorities selection. The percentage of the protected zone within the study area and the delineation differ based on the criteria of various scenarios. Fig. 4 and Table 4 show various alternatives, determined by examining the following scenarios: (a) minimum protection on these three resources (16.9%); (b) maximum protection on cetacean resources (25.9%); (c) maximum protection on fisheries resources (27.4%); and (d) maximum protection on all three resources combined (36.7%). The zoning model is set in the GIS, which assists in altering the parameters of the defined protection priorities. The visualization tool assists in enhancing communications among the

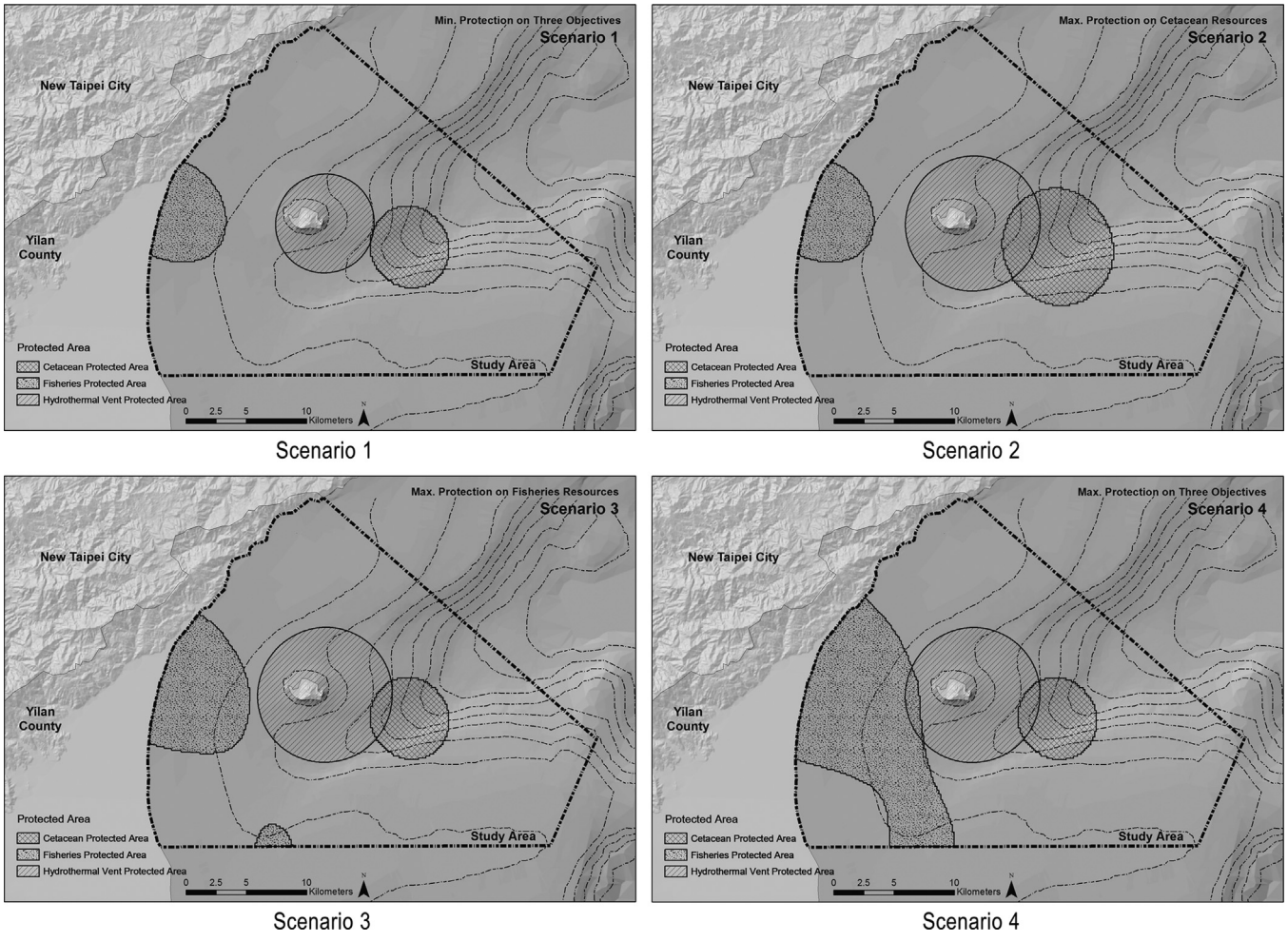

Fig. 4. Alternative scenarios for proposed Gueishan Island MPA.

Table 4
Alternative scenarios for proposed Gueishan Island MPA.

Protected area	Scenario 1 Min. protection on three objectives	Scenario 2 Max. protection on cetacean resources	Scenario 3 Max. protection on fisheries resources	Scenario 4 Max. protection on three objectives
Zone of hydrothermal vent protection	4000 m buffer from the vents = 52.56 km^2	5500 m buffer from the vents = 98.18 km^2	5500 m buffer from the vents = 98.18 km^2	5500 m buffer from the vents = 98.18 km^2
Zone of cetacean protection	10% coverage of the densest distribution for cetacean population = 34.64 km^2	20% coverage of the densest distribution for cetacean population = 69.69 km^2	10% coverage of the densest distribution for cetacean population = 34.64 km^2	10% coverage of the densest distribution for cetacean population = 34.64 km^2
Zone of fisheries protection	5% coverage of richness of plankton, larval resources = 36.38 km^2	5% coverage of richness of plankton, larval resources = 36.38 km^2	10% coverage of richness of plankton, larval resources = 72.90 km^2	20% coverage of richness of plankton, larval resources = 145.84 km^2
Total protected area	123.51 km^2	189.70 km^2	200.44 km^2	268.38 km^2
Percentage of protected area inside the site	16.9%	25.9%	27.4%	36.7%

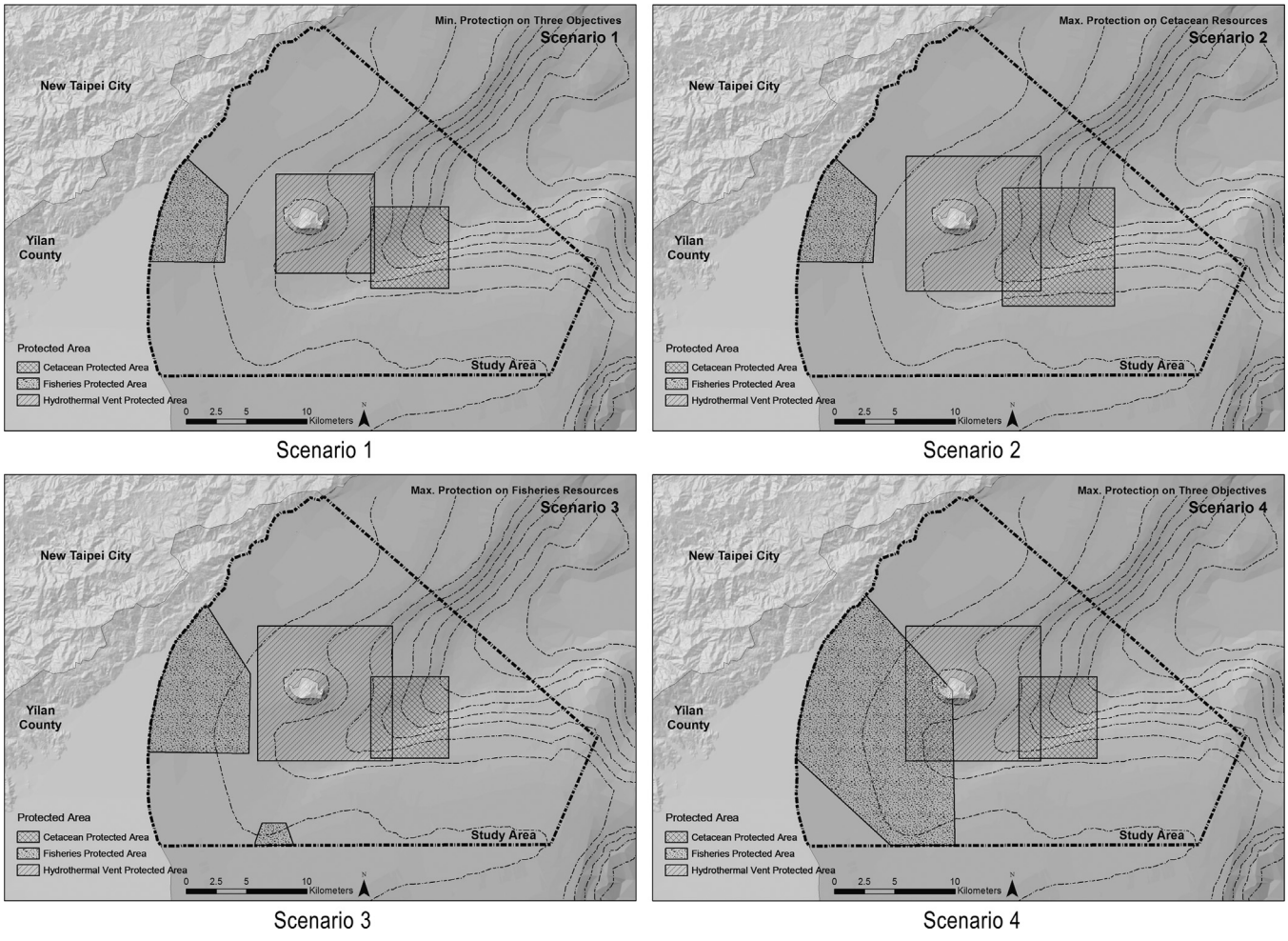

Fig. 5. Alternative scenarios with linear site boundary for proposed Gueishan Island MPA.

various stakeholders in the subsequent phase of the setup of MPA, such as the implementation stage. Previous research has stated that because the shape of the protected areas could affect the implementation and management of the MPA, a linear site boundary with coordinates of turning points is substantially more effective and simpler to manage [29]. Therefore, the shapes and areas of the discussed scenarios are altered based on the tangent line (Fig. 5), and the protected areas are greater than 20% in all of these scenarios (Table 5).

4.3. Enforcement

The majority of the stakeholders in this area agreed that the zoning plan should compliment relevant regulations. Any protected areas that lack effective management and enforcement are susceptible to failure. In the long term, Gueishan Island and the surrounding ocean should establish an MPA that is managed by one authority only. The recommended management zones, permitted activities, involved stakeholders, and related regulations in this study should be

Table 5
Alternative scenarios with linear site boundary for proposed Gueishan Island MPA.

Protected area	Scenario 1 Max. protection on hydrothermal vent	Scenario 2 Max. protection on cetacean resources	Scenario 3 Max. protection on fisheries resources	Scenario 4 Max. protection on three objectives
Total protected area	148.99 km^2	228.25 km^2	235.58 km^2	315.16 km^2
Percentage of protected area inside the site	20.3%	31.2%	32.2%	43.0%

Table 6
Recommended enforcement in each management zone.

	Hydrothermal vent protection zone	Cetacean protection zone	Fisheries resources protection zone
Type of Protection based on IUCN classification	Ia Strict Nature Reserve	IV Habitat/species management area	VI Protected area with sustainable use of natural resources
Major concern in zoning	The area affected from hot spring may vary with current and season. It is critical to monitor the water temperature, marine physical, chemistry data to ensure the hydrothermal eco-system is fully protected.	Whales and dolphins can migrate through current, season, and even different time period in a single day. It is critical to protect not only the densest area for cetacean from observation record, but also set strict regulations for whale-watching activities.	Fishing resources are sensitive to seasonal changes. The spawning and breeding seasons need strict protection. The seasonal protection zone can be set to protect resources, and keep sustainable usage for fishermen.
Conflicts among stakeholders	Conflicts may occur between tourism and conservation.	Conflicts may occur among tourism, fishing and conservation.	Conflicts may occur between fishing and conservation.
Laws and regulations in short term	Cultural Heritage Conservation Law	Wildlife Conservation Law	Fisheries Act

Table 7
Illustrates the zones with overlapping, and the priority to follow.

For the Zones on Top •: Entire Overlay ○: Partial Overlay No Mark: No Overlay		Hydrothermal vent protection zone		Cetacean protection zone		Fisheries resources protection zone	
		Core	Buffer	Core	Buffer	No-Take Core	Buffer
Hydrothermal vent protection zone	Core						
	Buffer			○	○	○	○
Cetacean protection zone	Core		○				
	Buffer		○				
Fisheries resources protection zone	No-Take Core						
	Buffer		○				
Current regulations under Fisheries Act	No-Take on Fish Larval[a]	•	○			○	○
	Limitation on Trawl[b]	•	○		○	○	○

[a] The 500 m near shore is the no-take zone on fish larval during June to August each year under the current Fisheries Act.
[b] The 3 nautical miles from shore is limited on trawling based on the current Fisheries Act.

considered for only the short term (Table 6). During the zoning process, it is anticipated that several zones based on various protection objectives overlap. To minimize any controversy in management and enforcement, a clear priority must be established (Table 7).

5. Conclusion and future development

The zoning of MPAs is a global activity aimed at reducing the impact of human development on the marine environment. The goal for establishing MPAs is to maintain biodiversity and to achieve sustainable development in the marine environment. According to the in-depth interviews and extant literature, the majority of stakeholders and local communities related to Gueishan Island agreed with the goals and concepts of establishing MPAs, although the physical zoning plan could be problematized by conflicts among the various protection objectives and usages. Quantity and quality methodologies, spatial multi-criteria analysis, geographic information systems, and in-depth interviews are employed in this study to delineate the boundaries and various zones for the proposed Gueishan Island MPA. Several conclusions and suggestions for future development are detailed as follows.

Planning for MPAs must address contradictory values from top-down and bottom-up perspectives. Defining the goals, objectives, and related zoning strategies requires top-down policy guidance, although the MPAs could fail if there is insufficient local involvement throughout the planning to implementation process. This study applied both top-down and bottom-up strategies throughout the planning process. The goals, protection objectives, and alternatives were generated based on policies, extant literature, and case studies; however, neither the decision-makers nor the planners can or should decide on the selection priority for the alternatives and subsequent enforcement. During the in-depth interviews, any alternatives and zoning plans can be modified to suit actual events and minimize any conflicts. Throughout the discussion and interview process, visualization proved to be a useful tool for facilitating communication. Because it is difficult to identify landmarks or signs in a marine environment, fishermen and local communities are typically unaware of the proposed MPA boundaries. This compounds the challenges and uncertainties during the negotiation process. Visualization technologies such as ArcGIS, simulated photo images, and videos can improve the understanding of stakeholders, thereby facilitating effective decision-making.

An integrated and well-managed ocean database that includes data for the physical, environmental, biological, and catchment is a critical element for the effective planning of MPAs. An analysis based on scientific information can assist in minimizing mistakes, and in convincing people with differing opinions. Therefore, it is crucial to develop an ocean database in Taiwan. Because there are considerable differences between marine and terrestrial protection systems, four-dimensional information is critical in planning MPAs. For example, information on water depth and current behavior is crucial for fisheries resource management. Varying water depths might contain dissimilar fish species and economic values, and information on ocean currents would be useful in simulating and evaluating the movement of plankton, shoals of fish, nursery grounds, spawning grounds, and other vital habitats.

There are no specific laws and regulations related directly to MPAs in Taiwan. Therefore, the multiple protection targets require suitable laws for further implementation. In the short term, the Cultural Heritage Conservation Law is recommended for addressing hydrothermal vent protection, the Wildlife Conservation Law can be applied for cetacean protection, and the Fisheries Act is suitable for fisheries resource protection. To ensure long term effectiveness, there is an urgent need for the promulgation of integrated laws and regulations, as well as the establishment of corresponding authorities. Planning and establishing a zoning plan for MPAs is only the first step of a lengthy process. Management and enforcement will play critical roles in the subsequent phases. The model of management and local participation in various protection objectives requires further study in the near future.

Because of the high connectivity and complexity of marine environments, the traditional, single protection-oriented methodology is unsuitable for the proposed Gueishan Island MPA plan. This study is an initial study in spatial multi-criteria analysis to facilitate the implementation of an MPA in Taiwan, and provides a framework that considers both top-down and bottom-up strategies. The framework was examined in a small area, and further studies should focus on the connections among MPAs to facilitate the establishment of an MPA network in Taiwan.

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