



Finding harmony in the sea: Resolving conflicts by regional marine spatial planning

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ABSTRACT

Ocean space is of paramount importance to coastal regions worldwide. However, rapid coastal development has led to competition in marine spatial allocation, exacerbating conflicts within maritime domains. Despite significant progress in establishing regulations for coastal governance in Taiwan, conflicts across diverse maritime industries due to a lack of marine spatial planning (MSP) institutions remain a persistent challenge. Potential conflict areas were identified via geographic information system (GIS) maps to assist maritime governance and used in several rounds of coordination meetings with stakeholders for zoning. A regional MSP framework for improving maritime governance is proposed based on a case study, which shows that even without legal MSP institutions, local or certain central government departments can act as the key authorities for implementing the bottom-up planning concept with strong engagement from local communities. The proposed planning process includes: (1) establishing and employing a monitoring system to promptly identify marine activities that can facilitate efficient enforcement; (2) continuous communication with stakeholders led by the local government to improve amendment regulations and aid compliance; and (3) prioritizing the preservation of traditional use rights with community self-management to accelerate regional MSP processes.

1. Introduction

Human activities within marine environments have escalated, including diverse activities such as fisheries, recreation, commerce, and tourism (Frazão Santos et al., 2019). This has produced related conflicts regarding spatial allocation (Ehler and Douvère, 2009) and has affected the ecological equilibrium of these coastal and marine ecosystems (O'Mahony et al., 2009). General methodologies for managing coastal and marine regions have been pursued for an extensive period. Marine spatial planning (MSP) has gained recognition as a viable strategy for mitigating conflicts, particularly in heavily trafficked marine and coastal localities. MSP is increasingly used to manage marine zoning and allocation strategies and address the array of marine-use-related friction (Day, 2002; Ehler and Douvère, 2009). Furthermore, stakeholder participation, inter-organizational cooperation, and effective communication strategies are identified as critical factors in achieving successful outcomes in MSP (Olsen et al., 2014; Smythe and McCann, 2018). The distribution of human activities and natural events within

this intricate framework must be determined comprehensively for the optimal MSP of oceanic activities. Ehler and Douvère (2009) stated that collecting and mapping spatiotemporal distributions, along with human activity densities, offer fundamental data necessary for improving coastal management practices. To achieve this, geographic information systems (GIS) serves as a platform that enables users to create, analyze, visualize spatial or geographic data, and interpret geographic information effectively in the form of maps (Fischer and Nijkamp, 1992). Moreover, GIS offers the integration of diverse spatial datasets and the analytical capabilities required to identify potential conflict areas, which are used for conflict resolution in coastal regions (Gimpel et al., 2018; Stelzenmüller et al., 2013).

Southwestern Taiwan has several essential marine industries including shipping, fisheries, and recreational pursuits, which contribute significantly to regional economic advancement. However, the rapid development of coastal areas has led to competition over marine space allocation, thereby intensifying marine spatial conflicts. In response, the legislative and regulatory framework for coastal

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governance, exemplified by statutes such as the Coastal Zone Management Act and the Spatial Planning Act, has been successfully promulgated by the government of Taiwan. Additionally, the Ocean Affairs Council (OAC) was established in 2018 as a government-sanctioned custodian of marine affairs (Shih, 2020). This demonstrates the governmental commitment to effective marine management. Despite significant progress in establishing regulations for coastal governance in Taiwan, conflicts persist among disparate maritime sectors due to the lack of efficient and comprehensive MSP institutions and governance strategies. This continued predicament highlights concerns about maritime development in Taiwan.

In response to the need for MSP implementation, the Taiwanese government announced the Ocean Basic Act in November 2019, in which Article 4 (Ocean Basic Act, 2019, p.1) stated that:

“The government should enact (formulate) regulations for marine spatial planning, coordinate the use of sea areas and competition, and implement integrated marine management in response to the needs of multi-purpose marine use.”

The highest level of marine governance in Taiwan is the OAC, which delivered the Maritime Management Act (draft) to the legislative department in 2021. The drafted Maritime Management Act would coordinate strategies to address conflicts between marine sectors and preserve the marine environment and ecosystems by implementing integrated management. Accordingly, the OAC would become the marine zoning authority for various sectors and provide marine spatial use plans at the central government level. However, this drafted MSP legislation did not have the capacity to formulate plans for regional governments, such as marine protected areas zonings (Huang et al., 2024) and offshore wind farm development (Hung et al., 2021).

MSP is considered as a collaborative process that integrating spatial data, stakeholder perspectives, and policy considerations to develop a comprehensive framework for marine resource/space-appropriate allocations and sustainable management (Olsen et al., 2014; Twomey and O'Mahony, 2019). The study area in the water off Tainan, Taiwan, is used by diverse maritime sectors including oyster farming, capture fisheries, commercial harbor, and marine conservations. It is notable that oyster farming and capture fisheries were initially existed before the 1980s, while commercial harbor Anping Port extended since the 1990s and Taijiang Natial Park was established in 2009, respectively. Because of lacking MSP institution for the latter sectors, conflicts for sea space and fish resources occurred and remained till present. To resolve the conflicts and create an optimal management plan, the authors of this study were commissioned by the Tainan City Government to provide an optimal management plan. The authors of this this study therefore conducted MSP concept by collecting stakeholder engagement, political processes, and management regulations analysis. The major steps include collecting and visualizing spatial data, mapping information about human activities, and identifying potential conflict areas (Ehler and Douvère, 2009). A new zoning map for the study area concluded from stakeholder perspectives observation, political processes, and management regulations.

2. Background of the study area

Since the 2000s, human activities have increased in coastal areas and ports in Tainan, including shipping, oyster farming, and recreational development, leading to heightened spatial conflicts. The designation of Anping Port (Fig. 1) as an international free-trade zone harbor in 2014 further amplified cargo shipments, tourist ferries, and recreational developments (Chang and Lin, 2016). Tainan City also serves as a major oyster farming area in Taiwan, predominantly employing a floating raft culture system (Yang and Chang, 2017). However, irregularly positioned oyster farming rafts near shipping channels have hampered ship navigation (National Audit Office Taiwan, 2015). Chang and Lin (2016) discovered overlapping areas between floating oyster farming rafts and shipping channels in Anping Port, resulting in conflicts between oyster

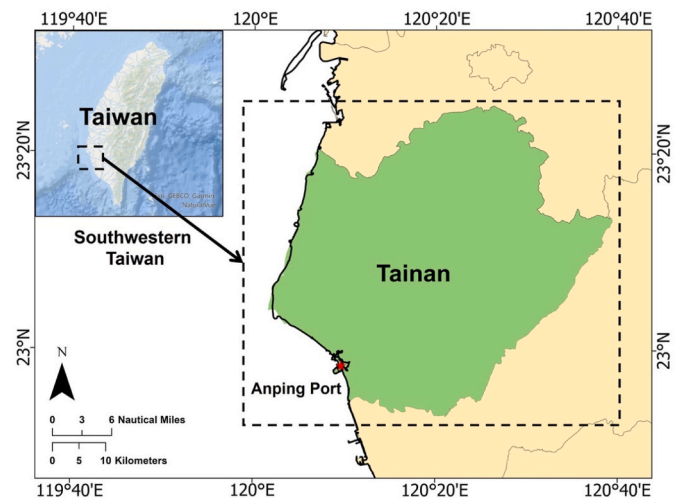


Fig. 1. Anping Port on the southwest coast of Taiwan showcases the focal area of interest, emphasizing the need for effective management strategies and conflict resolution mechanisms.

farming and shipping activities. The waters around Anping Port are crucial for oyster farming, but they also support gill nets and capture fisheries, causing significant conflicts in the sector. In response, the Tainan City Government has been actively c the Self-Government Ordinance of Shallow Water Oyster Farming and enhancing coastal fisheries management by planning fishing rights for the future. These initiatives aim to improve the management of floating rafts, mitigate conflicts related to marine spatial allocation, reinforce oyster farmers' property protection, and address marine environmental pollution. However, the absence of a comprehensive management plan, determination of oyster farming areas, and an efficient monitoring system to identify the precise locations of oyster farms remains challenges (Ocean Affairs Council Taiwan, 2019). Ensuring maritime safety is a critical concern for Taiwan's maritime industry. According to the 2017 Fisheries Statistical Yearbook in Taiwan, a significant proportion (71%) of registered ships in Tainan City are small-scale fishing boats. The majority of these fishing boats weigh less than five tons and lack collision-avoidance systems, posing potential risks to maritime safety (Ocean Affairs Council Taiwan, 2019).

3. Materials and methods

The main steps in the MSP process include pre-planning, defining and analyzing present conflicts, organizing stakeholder participation, and preparing and approving the spatial management plan, that improving decision-making on conflict resolution and allocation of coastal areas (Ehler and Douvère, 2009; Gilliland and Laffoley, 2008). Accordingly, conflict analysis and resolution in the study area followed the MSP process, including spatial distribution of varied types from Automatic Identification System (AIS), oyster farming rafts identified from satellite images (Yang et al., 2022), and spatial zoning and management plan perspectives were archived through stakeholder workshops and coordination meetings (Chang and Lin, 2016; Huang et al., 2024). Finally, the MSP output map (Fig. 2) was proposed by GIS techniques (Gimpel et al., 2018; Stelzenmüller et al., 2013).

3.1. AIS data collection and analysis

The AIS is a radio information reception and transmission system that provides comprehensive ship data, including basic ship information, dynamic ship data, and voyage-related information. The basic ship data contains crucial details, such as Maritime Mobile Service Identity (MMSI), call sign, name, International Maritime Organization (IMO)

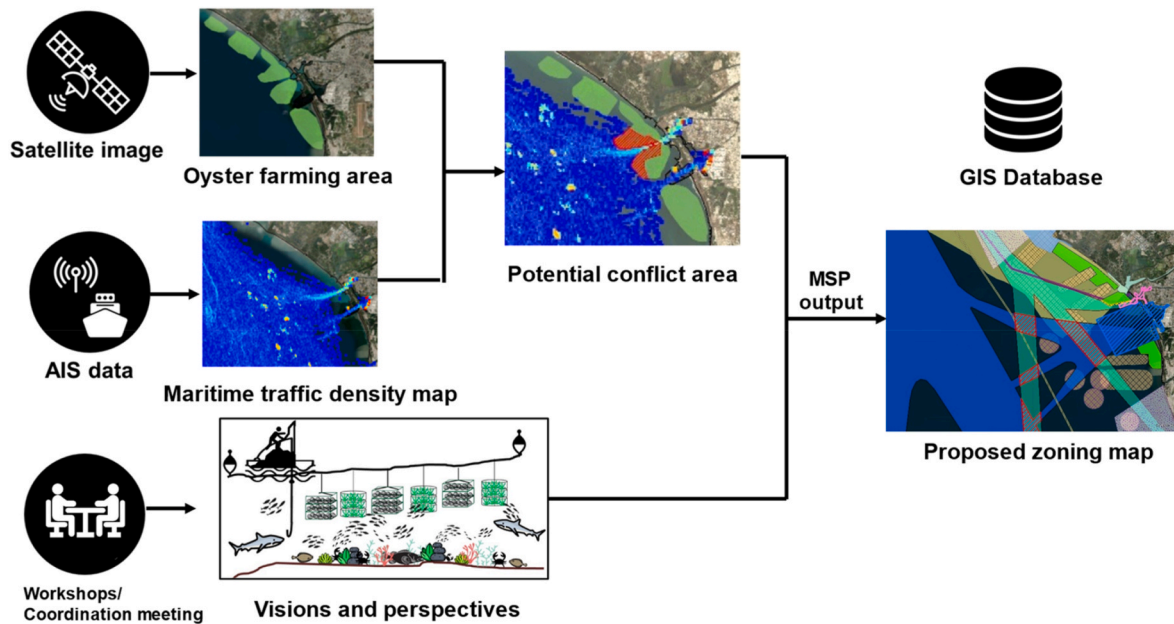


Fig. 2. A flowchart depicting the procedure for creating overlapping and proposed zoning maps using GIS, spatial data, and satellite imagery.

number, length, beam, and ship type. The dynamic ship data included the position, position time stamp, course over ground (COG), speed over ground (SOG), and navigation status. Voyage-related information encompasses the ship draught, hazardous cargo, and destination (Le Tixerant et al., 2018; Liu et al., 2019).

To identify the main shipping lanes, the AIS data provided by Taiwan's Ministry of Transportation and Communications was used to illustrate maritime traffic density maps and estimate vessel routes. The raw AIS data was processed using Microsoft Structured Query Language (SQL) Server software, including filtering vessels by type, such as fishing, cargo, and tankers, followed by conversion into comma-separated value (CSV) files for import into the GIS software ArcGIS Pro. Obtaining a succinct overview of maritime traffic density is crucial within the framework of MSP plans (Le Tixerant et al., 2018). A kernel density analysis approach, which provides a clear spatial representation of maritime lanes, was implemented to identify the main shipping lanes (Le Guyader et al., 2016; Nicolas et al., 2016).

Furthermore, numerous coastal fishing vessels, predominantly representing small-scale fisheries (SSF), actively engage in recreational fishing, gill netting, and pole-and-line practices within the coastal areas of Taiwan (Taiwan Fishery Agency, 2018). To investigate the positions of SSF vessels, real-time positional data from fishing vessels equipped with AIS Class B systems were analyzed. Subsequent analysis was performed using GIS technology to produce points and maps that illustrated the distribution patterns of the SSF vessels.

3.2. Identifying overlaps and potential conflicts

Understanding maritime uses within a spatiotemporal scenario and comprehensively mapping marine activities are crucial for MSP due to the extensive utilization of coastal areas and the accompanying need to identify marine conflict areas (Douve, 2008). Various studies have reported GIS applications in MSP, indicating that GIS can be utilized as a tool for conflict resolution and spatial overlap analysis. (Coccoli et al., 2018; Moore et al., 2017; Prestrelo and Vianna, 2016). GIS also plays a significant role in all geographic and spatial aspects of marine aquaculture development and management (Stelzenmüller et al., 2017).

Mapping and identifying marine and coastal features are essential for MSP, including socioeconomic and environmental uses and values (Shucksmith and Kelly, 2014). In addition, this process provides a clear

visualization of spatial relationships for marine aquaculture development and management (Meade et al., 2016), aiding in conflict visibility and promoting compatibility in ocean use, facilitating potential zoning arrangements (Douve, 2008; Ehler and Douve, 2009; Retzlaff and LeBleu, 2018). Zoning is the principal management measure for MSP, highlighting the importance of ocean zoning maps (Ehler and Douve, 2009). Moreover, zoning maps can be produced using simplified GIS techniques (Chien et al., 2012).

To investigate potential conflicts in the coastal areas of Tainan, data was gathered from specialized portals focusing on spatial data collection within the Taiwanese government, including the OpenData platform, Taiwan Geospatial One Stop, National Ocean Database, and Sharing System. Subsequently, a comprehensive GIS database was constructed using data production, transformation, and classification and incorporating all relevant variables of the study area. The datasets were presented in shapefile format and standardized using the same reference system. In addition, remote sensing images were used to assess the locations of oyster farming areas precisely. High-resolution satellite-derived images sourced from SPOT-7 and employing a Transverse Mercator projection were obtained from the Center for Space and Remote Sensing Research at the National Central University of Taiwan. All maps and images were projected onto the TWD 97 coordinate system and integrated into a GIS dataset focusing on the positions of the oyster farming rafts. A satellite-derived imagery analysis method (Yang et al., 2022) was adopted to detect the positions of the oyster farming rafts and display them as polygons on the area maps to identify potential conflict areas. In addition, AIS data was imported into GIS to create a density map. Subsequently, the overlapping areas were analyzed, and conflict matrices and maps were generated to highlight the areas of potential conflict. Finally, the oyster farming areas and main shipping lanes were seamlessly integrated with a diverse array of GIS data layers sourced from government-provided datasets that encompassed protected areas, geographic information, transport details, ports, fisheries, aquaculture, cable and conduit information, and other anthropogenic activity data. Subsequently, the meticulous digitization and organization of these datasets facilitated the generation of a comprehensive zoning map for this study.

3.3. Stakeholder participation

To resolve marine conflicts and determine the proposed oyster farming fishing rights areas in Tainan, the authors of this study were commissioned by the city government to conduct a new planning process with stakeholder engagement. Table 1 summarizes the detailed

information and major conclusions for each workshop and coordination meeting. The workshops held from 2019 to 2020 focused on understanding the initial marine conflicts among oyster farming, capture fisheries, commercial vessel activities, and marine conservations. The workshops focused on two topics: competition among oyster farming and other maritime activities, and the intention to establish a fishing

Table 1
Summaries of stakeholder workshops and coordination meetings.

Workshop & Meeting #	Date	Location	Invited maritime-related sectors	Finding	Conclusion
Workshop 1	November 7, 2019	Tainan City Hall	<ul style="list-style-type: none"> ● Ocean Affairs Council ●Tainan City Anping Fishing Raft Cooperative Association ●Tainan City Fishermen’s Association ●Tainan City Government ●Tainan City Kunxiwan Oyster Aquaculture Association ●Tainan City Oyster Industry Development Association 	<ol style="list-style-type: none"> 1 Identify the marine conflict among oyster farming, other fishing activities, vessel activities, and navigation channels. 2 Understand stakeholders’ needs for developing the prototype monitoring system. 	Resolve marine conflicts and meet stakeholder needs with a prototype monitoring system.
Workshop 2	October 28, 2020	Tainan City Hall	<ul style="list-style-type: none"> ●Fisheries Agency of the Ministry of Agriculture ●Ocean Affairs Council ●Tainan City Anping Fishing Raft Cooperative Association ●Tainan City Fishermen’s Association ●Tainan City Government ●Tainan City Kunxiwan Oyster Aquaculture Association ●Tainan City Oyster Industry Development Association 	<ol style="list-style-type: none"> 1 Develop the monitoring system for coastal devices. 2 Optimization of the monitoring system in accordance with stakeholder suggestions. 	Enhance and optimize the coastal device monitoring system based on stakeholder input.
Coordination meeting 1	August 11, 2022	Tainan City Hall	<ul style="list-style-type: none"> ●Administration of Kaohsiung Port of Taiwan International Ports Co., Ltd. ●Chunghwa Telecom Co., Ltd. ●Fisheries Agency of the Ministry of Agriculture ●Maritime Port Bureau ●Taijiang National Park Administration ●Tainan City Fishermen’s Association ● The Sixth River Management Office of the Water Resources Agency ● Urban and Rural Development Branch of the Construction and Planning Agency 	<ol style="list-style-type: none"> 1 Redefined the artificial reef zones as a ‘restricted fishing area with net fishing gear’ and revised boundaries for resolution. 2 The submarine cable areas coexist with the fishing rights areas. 3 The wetland areas coexist with the fishing rights areas. 4 The proposition to engage in concurrent utilization within fishing rights areas encountered resistance from other maritime-related sectors. 	Artificial reef zones, submarine cables, and wetlands coexist with fishing rights areas; Face resistance due to high conflicts with Anping Port and national park marine areas.
Coordination meeting 2	September 30, 2022	Legislative Yuan Research Building	<ul style="list-style-type: none"> ● Administration of Kaohsiung Port of Taiwan International Ports Co., Ltd. ● Maritime Port Bureau ● Taijiang National Park Administration ● The Sixth River Management Office of the Water Resources Agency 	<ol style="list-style-type: none"> 1 An adjustment of the fishing rights areas is proposed for resolution due to the relatively confined area of impact. 2 A suggestion was made to consider amending the relevant legal articles or modifying the extent of the harbor area. 3 It was essential to assess if fishing rights could be allocated in the area. The Tainan City Government’s spatial plan must be reviewed to confirm the feasibility of adjusting the area for fishing rights delineation. 	Adjusting fishing rights areas within the jurisdiction of the Zengwen River; amending legal provisions of the Anping port area; reviewing the Tainan spatial plan for feasibility in establishing fishing rights.
Coordination meeting 3	November 4, 2022	Tainan City Hall	<ul style="list-style-type: none"> ● Taijiang National Park Administration ● Urban and Rural Development Branch of the Construction and Planning Agency 	<ol style="list-style-type: none"> 1 A Pointed out the absence of rules prohibiting the establishment of fishing rights areas in the specified zone in the Tainan spatial plan. 2 A suggestion was made to adhere to the regulations outlined in the National Park Law for future applications related to the utilization of fishing rights areas. 	Absence of rules in Tainan spatial plan; Proposed adherence to the National Park Law for establishing oyster farming fishing rights areas.

rights area for oyster farming. The goals of the workshops focused on addressing marine spatial conflict, determining the proposed fishing rights areas for oyster farming, and focusing particularly on achieving coexistence in maritime use. Four types of stakeholders were invited to participate in these workshops and coordination meetings.

- Tainan City Fishermen’s Association and oyster farmers
- Central government legislators
- Maritime-related authorities in local and central governments
- Researchers in marine affairs and fishery science (authors in this study)

To enhance communication during meetings, a new marine spatial map was created using GIS to display both existing and projected uses in coastal waters. In addition, coordination meetings for cross-department authorities held in 2022, that attempted to negotiate the new zoning plan concluded from previous stakeholder workshops that can be certified according to relevant regulations. Central government legislators participated and played a crucial role in coordinating the allocation of sea areas and competition at the local and central levels. Moreover, researchers (authors of this study) attended all the workshops and meetings while a qualitative method of direct observation from meeting was used (Hastings et al., 2012) to conclude solutions proposed in each meeting, and details of stakeholders’ opinions on the conflict between establishing fishing rights area and other maritime activities. The findings and comments from different sectors in the meetings were recorded in a spreadsheet and considered when reviewing possible amendments to the proposed fishing rights area and conflict resolution framework. For the institution of oyster farming fishing right and the role in the management plan, the local government authority and researchers discussed with the leaders of the Tainan Fishery Association.

4. Results

4.1. Maritime traffic in the study area

The collected dataset encompassed an extensive range of information, consisting of over 1.8 million rows covering the period from October 2019 to December 2019. The analysis revealed that the dataset comprised 1,805,776 records of AIS dynamic data originating from 3839 unique MMSI numbers. A detailed examination of the AIS data enabled a statistical assessment of the number of vessels categorized by type in the Tainan Anping region for each month, as summarized in Table 2. For the MMSI numbers recorded in the AIS data, the highest total number of ships, reaching 1,852, was recorded in October 2019, indicating a peak in maritime activity within Tainan. Moreover, since the grey mullet fishing season started in late November and extended until early February in Southwestern Taiwan, an overall increase in the number of vessels involved in fishing activities was observed from October to December. Conversely, the number of Cargo and Tanker ships gradually declined over the same period. An examination of the average marine traffic per vessel, specifically cargo ships, tankers, and fishing vessels, revealed monthly variations within the study area. A visual representation of the vessel traffic density from October 2019 to December 2019 in Tainan, Anping, is depicted in the vessel traffic density map. A marine traffic map categorized by ship type is shown in Fig. 3.

Table 2
The number of vessels identified from AIS in the study area in 2019.

Region	Month	Number of vessels		
		Fishery	Cargo & Tanker	Total
Tainan	October	308	1544	1852
Tainan	November	318	1498	1816
Tainan	December	438	1377	1815

4.2. Potential conflicts between oyster farming and vessels

According to the results of satellite image analysis, in the Tainan region oyster farming rafts were concentrated in waters shallower than 15 m, spanning a distance of 1.5 nautical miles from the coastline, specifically between the Zengwun and Erren rivers (Fig. 4). In addition, the Tainan City Government implemented regulations restricting the oyster farming season from July 1 to September 30, serving as a protective measure against potential typhoon damage during the summer months.

Notably, the areas around Anping Port and Anping Fishing Harbor in Tainan posed a higher risk for oyster farming. Fig. 5 presents a spatial conflict map created based on the dataset of oyster farming areas and vessel trajectories in October, highlighting the presence of a high potential conflict area primarily situated on both sides of the vessel channel at Anping Fishing Harbor (red area in Fig. 5). In addition, a considerable number of floating rafts were cultivated in commercial port areas, with floating rafts near the shipping channels hindering navigation. According to the findings of the workshop in 2019, oyster farmers revealed that farming oysters in outer waters could promote growth but might also result in increased conflicts with navigation channels, as previously described. Moreover, shipping navigation was obstructed by the accumulation of torn and abandoned farming rafts following severe wind disasters and an increase in abandoned and unauthorized oyster rafts near the shipping channel in Anping Port. Furthermore, the results of the AIS data analysis revealed the presence of fishery activities by SSF vessels in the oyster farming area (Fig. 6), as high densities of filter-feeding shellfish, such as oysters, attract wild fish and invertebrates (Barrett et al., 2018). Consequently, SSF vessels frequently utilize oyster farming areas for fishing purposes. However, vessels navigating near oyster farms may sustain damage, potentially escalating conflicts. Insights summarized from a 2019 workshop with oyster farmers suggest that SSF vessels may have been responsible for damage incidents in the past.

4.3. Determining fishing rights areas

Taiwan has a legal system for managing capture fisheries and marine aquaculture sectors (including fish cages, algae, and oysters) by licensing through the Fisheries Act. However, the Tainan City Government started to plan the fishing rights area for oyster farming in the 1990s which continued until the present because the overlapping areas were not released by other authorities. Fig. 7 shows the proposed fishing rights areas (red area) in Tainan following discussions with Tainan governmental authorities and the Tainan Fishery Association.

To resolve the marine conflict, the Tainan City Government held workshops from 2019 to 2020 with the aim of identifying the conflict between oyster farming and other maritime activities, and developing a monitoring system for oyster farming (Yang et al., 2022). Moreover, the Tainan City Government has initiated preliminary consultations with maritime-related sectors to explore the feasibility of coexisting marine area utilization. The fishing rights areas served to initiate correspondence with maritime-related sectors regarding officially announced or potentially restricted areas (Fig. 8a). All maritime-related sectors were responded, indicating an overlap between the maritime areas of the department and the proposed fishing rights areas (Table 3). Consequently, the Tainan City Government held a series of meetings to delineate fishing rights areas for oyster farming while concurrently seeking the resolution of marine conflicts (Table 1).

During the meeting on August 11, 2022 (Fig. 8b), the focus was primarily on negotiating the feasibility of shared maritime space usage and proposing an optimal area for oyster farming fishing rights. Authorities of relevant sectors reached a consensus with the Tainan City Government on the multi-purpose use of areas, which included determining the coexistence of wetlands and submarine cable zones with fishing rights zones but without sea bottom constructions. Furthermore,

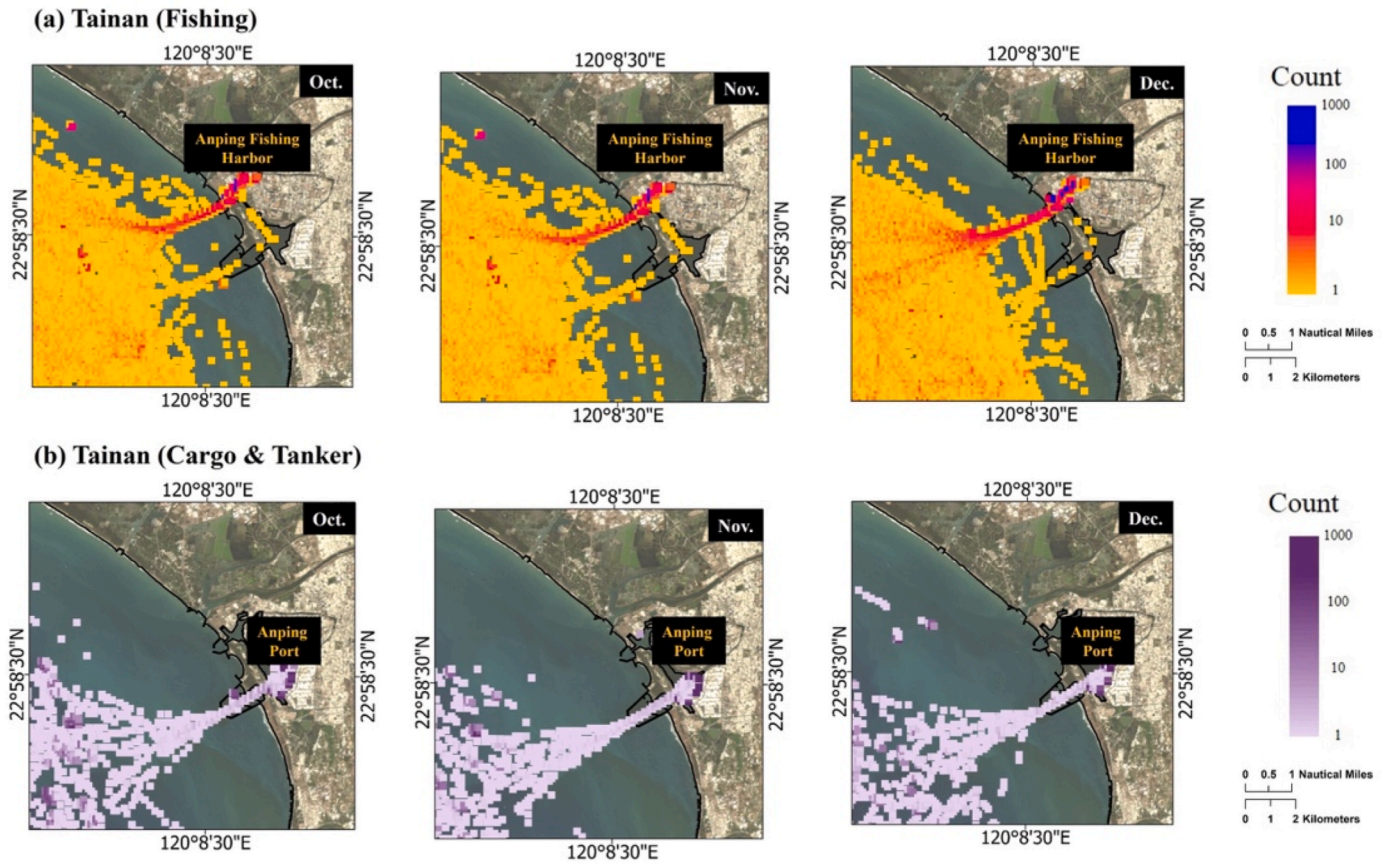


Fig. 3. The marine traffic map according to the ship type around Anping, Tainan. (a) The distribution of fishing boats primarily concentrated around the Anping Fishing Port, with a smaller number of fishing boats operating within the Anping Commercial Port; (b) Tankers and cargo vessels were predominantly found in the Anping commercial port.

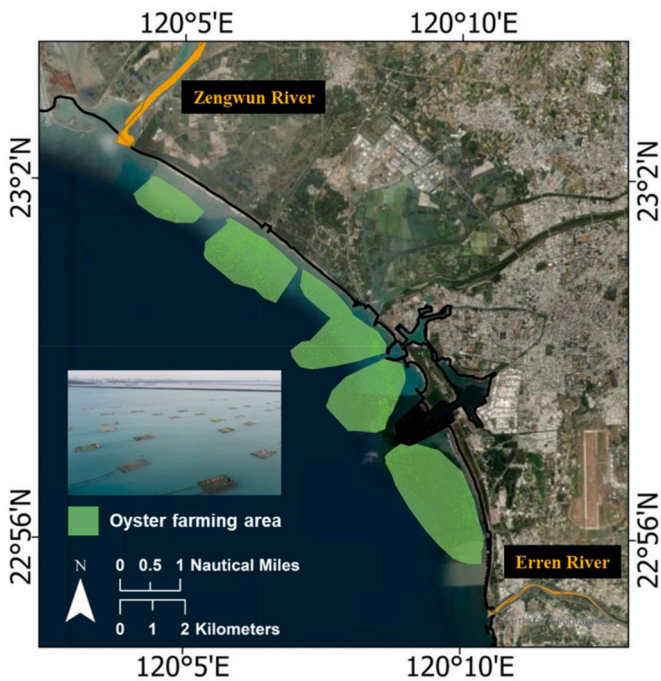


Fig. 4. Extraction results of the floating raft area in Tainan. The satellite image was taken in October 2019 and had a spatial resolution of 1.5 m that covered the Tainan City Coast.

considering the conservation of fishery resources, the boundaries of fishing rights areas should exclude artificial reef zones.

Another coordination meeting was organized due to a lack of consensus, and the central government legislator was asked by the Tainan City Government to invite relevant authorities to the central department (Fig. 8c), which addressed issues regarding the delineation of fishing rights in oyster farming areas. The primary objective of this gathering was to facilitate coordination among pertinent sectors. The authority of the Tainan City Government highlighted that the oyster farming industry had been practiced for four decades and that maritime-related sectors should acknowledge that history and precedent in this case. Even without formally delineated fishing rights, these operations have not ceased. It is crucial to examine the relevant legal provisions and provide assistance to legalize management through the establishment of fishing rights. Establishing fishing rights aims to legalize management, align with natural disaster relief measures, and safeguard the livelihoods of oyster farmers. After the coordination meeting, some contradictions were pointed out in some provisions in The Commercial Port Law mentioned by the Maritime Port Bureau and Administration of Kaohsiung Port of Taiwan International Ports Co., Ltd. An amendment was suggested concerning the relevant legal articles or the harbor area boundary. Regarding the jurisdictional waters proposed by Taijiang National Park, the legality of delineating fishing rights areas must be determined due to the involvement of different regulatory bodies. The directions of the spatial plan issued by the Tainan City Government should also be examined to determine whether the area can be adjusted to delineate fishing rights. Furthermore, because the impact of the Zengwen River jurisdictional areas on the proposed oyster aquaculture zone was not significant, an amendment of spatial boundaries was suggested due to the need to modify fishing rights areas to resolve spatial

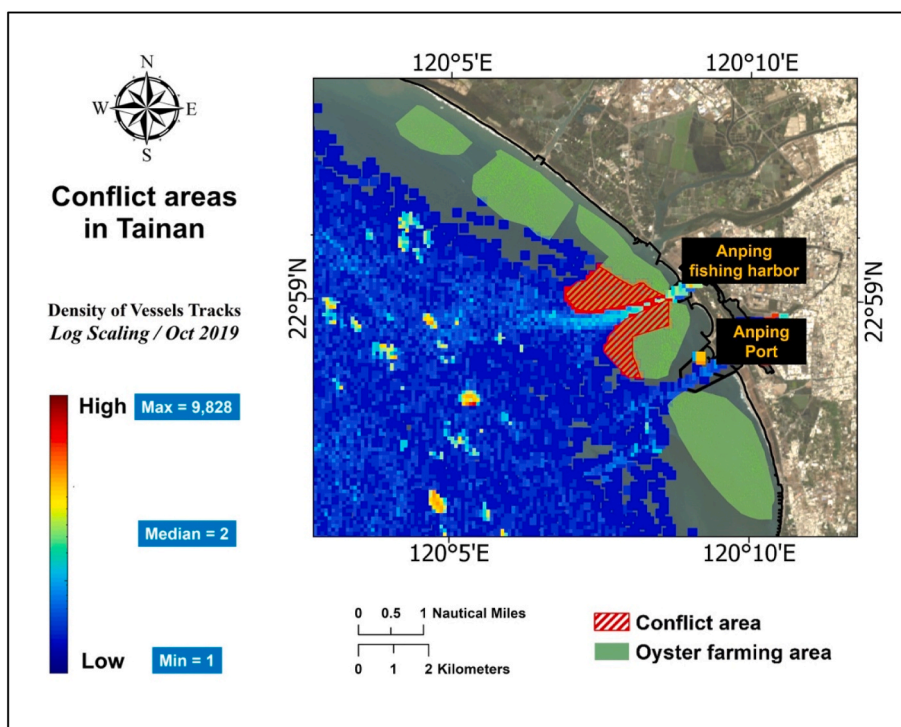


Fig. 5. Potential conflict areas between oyster farming and vessel activities in Anping, Tainan.

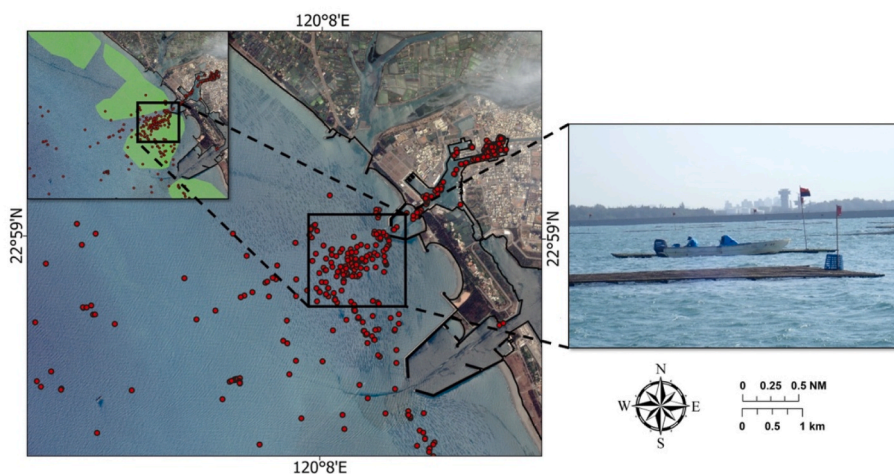


Fig. 6. The AIS positions of SSF vessels over an oyster farming area (fishing boats of less than 5 tons).

conflicts.

The discussions during the third coordination meeting held on November 4, 2022, revealed that the Bureau of Urban Development within the Tainan City Government highlighted the absence of prohibitory provisions for establishing fishing rights areas in the designated zone within the Tainan spatial plan. Adherence to the regulatory framework stipulated in the National Park Law is recommended for subsequent applications concerning the utilization of these maritime areas.

4.4. Proposed zoning map in Tainan

The vessel lanes and determined oyster farming fishing rights areas were integrated using GIS, with which the spatial data of the various maritime-related sectors were combined to create the proposed zoning map for Tainan City, as depicted in Fig. 9. To prevent collision incidents,

a designated vessel speed restriction zone including the channel adjacent to the oyster farming area was recommended (yellow-hatched area in Fig. 9). Furthermore, the installation of navigation aids and conspicuous signs was essential for oyster farms near the aforementioned channel, with the primary objective of enhancing safety measures (Maritime New Zealand, 2018). Moreover, determining a safe separation distance between oyster farms and vessels is crucial to mitigate potential harm (Yoo and Jeong, 2020). Based on the meeting outcomes aimed at determining the proposed oyster farming fishing rights areas, the adjustment of the Anping Commercial Port areas, which included the modification of legal provisions, has raised concerns regarding the proposed establishment of oyster farming fishing rights areas in the shallow waters north of the Anping Port dike. However, the legislative deliberation and revision processes are lengthy, suggesting that the government should consider providing subsidies or incentives for aquaculture equipment and assisting oyster farmers in anchoring oyster

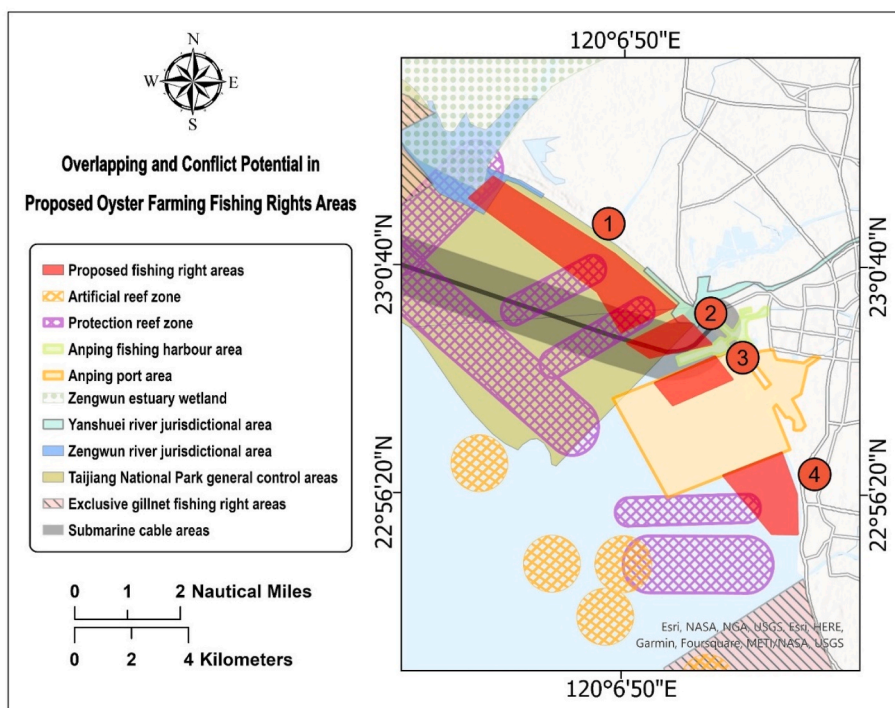


Fig. 7. Proposed fishing rights areas with other sectors in the study area.



Fig. 8. (a) Discussion of proposed oyster fishing areas with the governmental authority and the Tainan Fishery Association; (b) Coordination meeting organized by the Taiwan City government for the proposed oyster farming fishing rights areas beginning in 2021; and (c) Coordination meeting held by a central government legislator in Taipei on September 30, 2022.

Table 3

Overlapped zones and areas between proposed fishing rights areas and other maritime-related sectors.

The maritime-related sectors	Overlapped zone	Area (ha)
Administration of Kaohsiung Port of Taiwan International Ports Co., Ltd and Maritime Port Bureau	Zone 3	215.14
Chunghwa Telecom Co., Ltd	Zone 1, Zone 2, and Zone 3	330.2
Fisheries Agency of the Ministry of Agriculture	Zone 1, Zone 4	269.52
Taijiang National Park Administration	Zone 1, Zone 2	1176.86
The Sixth River Management Office of the Water Resources Agency	Zone 1, Zone 2	70.91
Urban and Rural Development Branch of the Construction and Planning Agency	Zone 1	2.2

farming rafts in outer waters to address this issue in the interim.

Collision incidents contribute significantly to marine accidents in Taiwan. Fishing vessels are frequently involved in collisions primarily within fishing areas, whereas collision incidents involving commercial

vessels are concentrated near ports and adjacent waters (Chou et al., 2018). In this study, the results of AIS data analysis revealed a heightened risk of collision incidents arising from fishing activities within the oyster farming area near Anping Port. SSF vessels operating along the coastline currently do not use AIS equipment in Taiwan, relying instead on immediate detection by nearby commercial vessels. This situation escalates the collision risk, particularly in the zone spanning 3–8 nautical miles from the shore (red-hatched area in Fig. 9). Therefore, heightened vigilance and operational awareness are imperative for fishermen to navigate and conduct activities in this region. To mitigate risk and proactively prevent accidents, mandatory installation and operation of AIS technology on fishing vessels should be enforced. In addition, governmental regulatory measures such as routing recommendations and voluntary vessel speed limits should be adopted (Huntington et al., 2015).

5. Discussion

5.1. Developing an effective performance monitoring system

Developing a monitoring system capable of generating reliable,

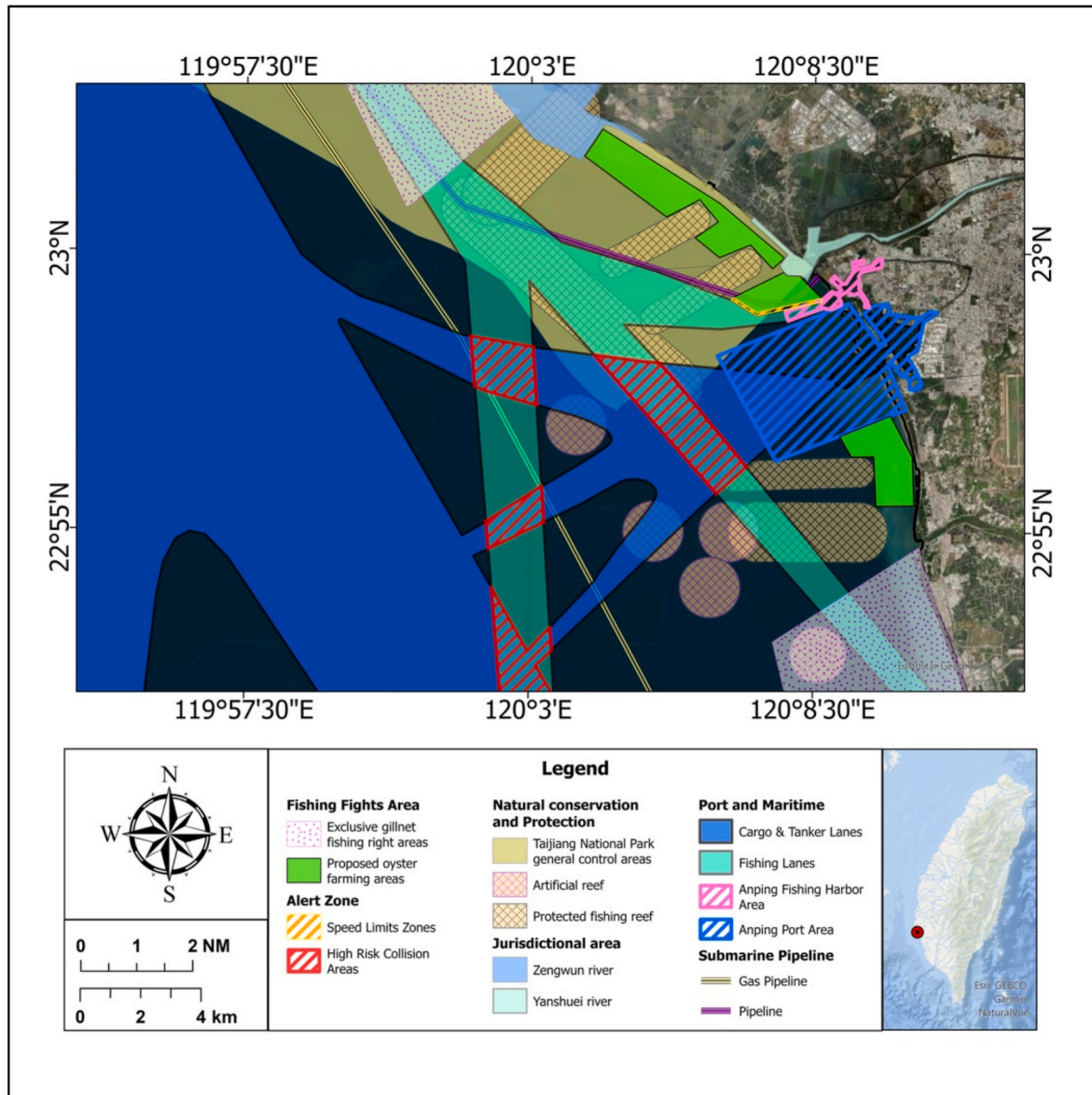


Fig. 9. Proposed zoning map in Tainan.

timely, and pertinent performance information for MSP for assessing the state of the system and evaluating the performance-monitoring results is essential to determine the effectiveness of the monitoring system (Ehler and Douvère, 2009). Evaluation outcomes are valuable for informing decisions when selecting an appropriate monitoring system or expanding or redesigning management actions (Day, 2008). Furthermore, spatial planning objectives may alter during the planning process, thus regular updates in consultation with stakeholders before initiating monitoring activities are crucial (Ehler, 2014).

The current management method for oyster farming in Tainan involves manual inspections conducted by boat inspectors, which requires significant manpower and time and results in low checking efficiency. Therefore, developing a real-time monitoring system to identify relevant information about oyster farms accurately and assist in the implementation of real-name rules is necessary. To address this challenge, Yang et al. (2022) proposed a hybrid RFID-GPS real-time location system that enables automatic monitoring of oyster farming rafts and efficiently identifies oyster raft farms with reduced manpower and time requirements. Supporting the navigation communication and collision avoidance systems of vessels with e-navigation services is essential (An,

2016). E-navigation is a strategy proposed by the IMO that integrates new and existing navigational tools to ensure the safety of ships at sea (International Maritime Organization, 2009). Because SSF vessels often lack adequate space and budget for implementing navigational safety monitoring systems, marine accidents frequently occur in Taiwan. To mitigate marine accidents and enhance the navigation safety of non-SOLAS ships in Taiwan, developing AIS equipment that is economical, compact, proactive, predictive, and equipped with collision-avoidance capabilities specifically designed for non-SOLAS ships is necessary. The AIS equipment actively detects the positions of ships and automatically alerts fishermen. In addition, to ensure the sustained and uninterrupted functionality of the AIS equipment, implementing installation and power provisions that establish a direct interconnection with the vessel's primary switches is imperative, ensuring that the AIS units remain operational whenever the vessel's primary switches are engaged.

5.2. Legislation from local government conflicts with central level

Because of the overlapping with the Anping Port area since the

1990s, the fishing right application for oyster farming was blocked for decades. Instead, the Tainan City Government promulgated the "Oyster Farming Management Regulations" in 2011 according to the Local Government Act at the central level, which regulate the maximum number of rafts for each farmer and the distribution within 1.5 nm from the coast where including waters inside the Taijiang National Park and Anping Port areas. The major goal of this local regulation was to mitigate the conflicts between trap fisheries and maritime traffic (Chang and Lin, 2016). However, the local regulation that allowed oyster farming within the national park and commercial harbors was not recognized by the Taijian National Park and Anping Prot, which are exclusively used and authorized by laws at the central level. The oyster farming fishing rights at the central level was therefore needed, that attempted to have oyster farming either coexist or release the overlapping areas from Taijian National Park and Anping Prot. However, during the workshops, authorities of Anping Port rejected the claim of coexisting or rezoning, where 30% of the oyster rafts existed since the 1990s, because of the need for recreational industries (yacht and tourism) developing plan that approved by the central government in 2021. Taijiang National Park also disagreed with the oyster farming within their park area, where contributed about 40% of oyster rafts, according to their management plan stated the prohibition of artificial devices such as oyster farming rafts in the marine general area.

Because the conflicts remained at regulation levels, coordination meetings were then conducted to find out the solutions while in the third meeting authorities of Anping Port agreed with the coexistence of oyster farming fisheries right because the Tainan City Government purposed to retrieve oyster rafts during June to October that avoiding debris (crashed rafts and buoys) during typhoon season, the national park will then amendment their management plan for the coexistence of original use of oyster farming. However, the Anping Port authorities persisted in the need for recreational development and navigation safety that lacked consensus in zoning. The findings of the coordination meeting came into effect and formed the basis for establishing oyster farming fishing rights that may reduce conflict among maritime activities in the future.

5.3. Local government accelerating regional MSP implementation

Effective MSP relies on the availability of comprehensive data, the presence of a supportive legal framework that facilitates MSP while mandating the establishment of obligatory objectives and priorities, and the implementation of an efficient governance system that enables participatory planning and ensures transparent accountability (Agardy et al., 2012). Legal MSP institutions refer to the planning framework explicitly stipulated by special laws that authorize departments or ministries in local or central governments for implementation. However, legal MSP institutions are yet to be established, not only in Taiwan but internationally (Cook et al., 2019; Panayiotis and Paraskevi, 2020), resulting in reduced efficiency in marine governance. Although the MSP institution still lacks a national legislative framework, the Tainan City Government continued to improve the management of its coastal water with consultation from researchers. The MSP concept was applied without a legal framework but with the support of local authorities who elaborated on a series of workshops and coordination meetings with key stakeholders since 2019, including legislators and relevant authorities in central governments, local fisheries associations, and researchers. The constructive implementation of the regional MSP process led by local authorities can be attributed to the Integrated Coastal Zone Management Plan under the regulations of the Coastal Zone Management Act of 2015. Most local authorities have realized their responsibility for integrated coastal management, and most have leadership abilities and relevant experience because of their professional backgrounds in fisheries or urban planning (Lin et al., 2021). This study further confirmed that local authorities can accelerate the implementation of the regional MSP process to improve management effectiveness in the marine sector, although legal frameworks are still lacking.

Nevertheless, despite its intended characterization as a collaborative and multi-sectoral mechanism for ocean governance, the MSP has faced criticism for its current top-down guidance and its perceived neglect of specific sectors and knowledge systems (Jones et al., 2016). The immediate need for regional marine management is seen to create more sustainable and locally adaptable solutions to marine conflicts (Sievanen et al., 2011a). This bottom-up progress contrasts with the top-down paradigm, where decisions are primarily made by central authorities or local governments that provide overarching legal and policy frameworks but potentially result in lower management effectiveness due to a lack of communication and stakeholder participation (Jones et al., 2016). Therefore, planning and governance capacity for specific contexts must be established to maximize MSP potential (Ehler and Douvère, 2009). Furthermore, linking top-down and bottom-up processes while maintaining an appropriate balance in marine management is essential (Sievanen et al., 2011a). This approach enables stakeholders to participate and build a consensus, thereby enhancing the effectiveness of collaborative efforts to achieve sustainable resource management goals (Agardy et al., 2012).

The Ocean Basic Act of 2019 in Taiwan has clarified the central authority's role in coordinating and integrating maritime powers and responsibilities across various industry-competent authorities. Despite designating the OAC as the highest authority in marine affairs, including the implementation of MSP, the findings revealed a notable absence of OAC involvement in any aspect of MSP. This absence stems from a legislative gap within the MSP framework, which fails to empower the OAC with the necessary legal authority to govern the ocean. Within the Taiwan legal system, current laws prioritize certain sectors and activities, such as the licensing of fishing rights zones overseen by the Fisheries Agency. Consequently, until the enactment of MSP legislation, the OAC's jurisdiction remains confined to non-zoning waters, highlighting a crucial area for future legal development and policy alignment.

5.4. Regional MSP framework for marine governance without legal system

Due to an incomplete MSP legislative framework, implementation led by local governments or certain central departments has been proposed to improve marine governance. Based on MSP and the state of the proposed fishing rights scenario in Tainan, this study proposes a regional MSP framework to resolve conflicts among marine activities and create zones for the sector. Bottom-up requirements may accelerate negotiations and the decision-making process. As shown in Fig. 10, the regional MSP framework can be implemented by local governments or central departments for planning sectoral purposes in Step 1. Researchers should investigate the needs of local communities with the priority of initial use, which should also support the scientific mapping of various maritime activities (Step 2). Coordination meetings at the local level would be Step 3 for conflict resolution between stakeholders within a sector development plan. In Step 4, coordination meetings at the central government level facilitate negotiations with relevant authorities to ensure the legal rights of associated activities. The negotiations involve administrators from diverse sectors who participate in coordination meetings for discussion during the decision-making stages. The primary role of the central coordinator, who provide the capacity in communication and is represented by higher-level government actors (Angst et al., 2018). This step reduces the consensus gap among legal systems, facilitates effective communication, and coordinates the allocation of sea space and competition. Subsequently, numerous solutions were evaluated and consolidated with the principal objective of reaching a compromise that effectively resolved spatial conflicts among human activities. Based on efficient negotiation and consensus, planning organizations could, therefore, design zoning and management plans for various sectors (Step 5), which should be confirmed through coordination meetings at the local level (Step 6). When adjustments are required, the design of the sector development plan should return to Step 2 to

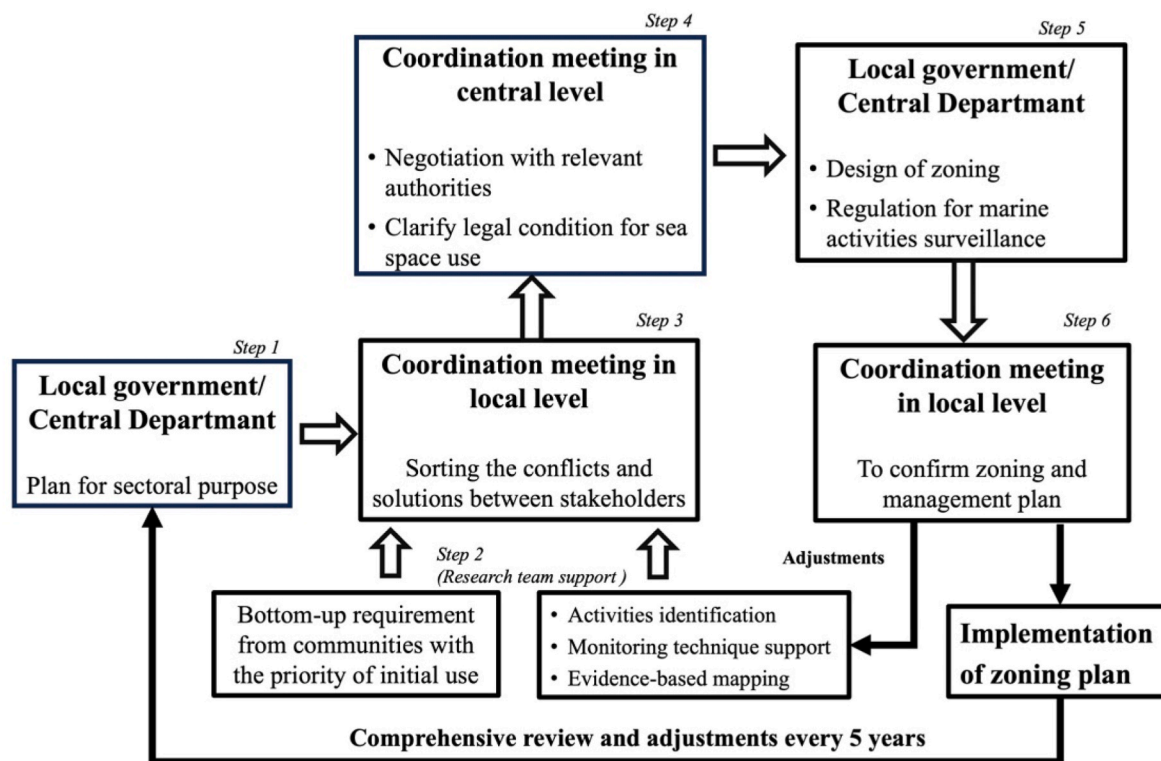


Fig. 10. Marine conflict resolution framework: utilizing top-down and bottom-up approaches to address competition among marine users.

clarify the needs of local communities. Once the final design of the sea-use plan is confirmed and implemented, a comprehensive review of the MSP plan should be conducted every five years to ensure the plan is up to date and identify pertinent adjustments for industrial development.

Engaging in a bottom-up approach with public participation before establishing regulations constitutes an innovative but difficult process (Ferreira et al., 2015). The central government plays a pivotal role in effectively managing multipurpose marine use while addressing the diverse needs of marine users by offering a comprehensive spatial vision and an integrated planning framework tailored to the varied requirements of marine use. However, the lack of a legal framework for MSP has delayed the development of these main sectors. To overcome this, the local government or central department could take the role of MSP authority, even for the sector development plan. Furthermore, the regional MSP planning framework can implement a bottom-up concept by emphasizing strong public involvement and the active engagement of stakeholders (Sayce et al., 2013). Driven by scientific data and stakeholder engagement, the bottom-up approach provides a more localized form of marine management (Gaymer et al., 2014). Additionally, to enhance the effectiveness of marine management, the spatial and temporal distribution of important human activities in the marine management area must be mapped to identify the current conflicts and compatibilities of marine space use (Ehler and Douvère, 2009), and develop an effective real-name monitoring system for coastal devices, which represents a crucial step in marine management. Furthermore, gaining insight into the practical limitations of monitoring systems necessitates the periodic convening of stakeholder meetings or workshops (Twomey and O'Mahony, 2019).

6. Conclusion

Allocating and analyzing the spatial distribution of maritime activities in marine areas is a crucial step in marine management, which indicates current or potential conflicts and provides crucial information

for selecting measures in the spatial management plan. This study integrates maritime traffic and aquaculture data to identify high-risk zones for maritime activities. The proposed spatial representation of these hazardous areas is crucial for enhancing overall maritime traffic safety. Furthermore, integrating various spatial datasets provides diverse spatial information to assist in assessing and resolving marine conflicts and supports management authorities in MSP decision-making. Based on our study, the following should be implemented for MSP units: (1) an effective monitoring system to promptly identify marine activities and ensure efficient enforcement; (2) an improved MSP strategy by implementing amendments to the monitoring system incrementally and communicating regularly with stakeholders as well as management regulations. Regular and effective communication during coordination meetings ensures the transparent elucidation of spatial planning objectives and measures to stakeholders, thereby expediting the execution of management actions; and (3) the assertion of rights associated with traditional uses (e.g., fisheries and marine transportation) is paralleled by the strengthening of communication between governments and stakeholders to achieve consensus, thereby facilitating bottom-up marine management. In addition, the planning process must concurrently consider marine ecological benefits to support the requisite foundation for advancing ocean governance.

CRediT authorship contribution statement

Jen-Han Yang: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Methodology, Investigation. **Yi Chang:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Conceptualization. **Shih-Chun Hsiao:** Supervision.

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 Tainan City Government, Taiwan. Yi Chang reports a relationship with Ministry of Science and Technology of Taiwan R.O.C. that includes: 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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