

Suitability Analysis and Carrying Capacity of Marine Ecotourism Based on Swimming, Fishing, and Boating Activities at Marsegu Island, Kotania Bay

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Abstract.

Marsegu Island in Kotania Bay, West Seram Regency, Maluku Province, holds remarkable ecological potential that is worth developing as a sustainable marine ecotourism destination. This study aims to analyze land suitability and carrying capacity and formulate development strategies for marine ecotourism activities covering swimming, fishing, and boating. Data were collected during August–September 2024 through biophysical parameter measurements at three observation stations, supplemented by interviews, questionnaires, and field observations. Tourism suitability was calculated using the Tourism Suitability Index (TSI), carrying capacity using the Carrying Capacity (CC) formula, and strategy prioritization using descriptive integrated analysis. Results indicate that fishing and boating tourism at all three stations fall under category S1 (highly suitable), while swimming tourism at two stations is classified as S1 and one station as S2 (suitable). Carrying capacity ranges from 21–59 visitors/day for swimming, 100–120 visitors/day for fishing, and 144–160 boat units/day for boating tourism. The results of this study recommend that the zoning system be implemented as a policy strategy for the development of marine ecotourism on Marsegu Island, with 4 zoning directions and 6 policy recommendations. Integrated management based on carrying capacity principles and zoning systems is fundamental to ensuring the long-term sustainability of ecotourism in this area.

Keywords: *Marine ecotourism; tourism suitability; carrying capacity; Marsegu Island and analytical hierarchy process.*

I. INTRODUCTION

The Kotania Bay area, astronomically located at coordinates 02°58′–03°06′ S and 128°00′–128°08′ E, represents one of the strategic coastal regions in West Seram Regency, Maluku Province. This area comprises five small islands distributed around the mouth of the bay, namely Marsegu Island, Osi Island, Burung Island, Buntal Island, and Tatumbu Island. Among these five islands, only Osi Island and Buntal Island are inhabited, characterized by stilt-house settlements constructed above seagrass beds and coral reef flats. The coastal waters of this region are dominated by three major ecosystems—coral reefs, mangroves, and seagrass beds—which together form an interconnected and mutually supportive ecological system. The waters of Kotania Bay are generally characterized by fringing reef formations that follow the coastline of Seram Island, creating extensive reef flats, some of which are exposed as intertidal land while others remain shallowly submerged during low tide (Clark, 1996). Administratively, Marsegu Island has been designated as a Marine Nature Tourism Park covering an area of approximately 11,000 hectares through the Decree of the Minister of Forestry and Plantation No. 114/Kpts-II/1999 dated March 5, 1999. Its management falls under the authority of the Maluku Natural Resources Conservation Agency (BKSDA Maluku).

Morphologically, the island exhibits diverse characteristics: the southern part is dominated by mangrove forest vegetation; the northern part consists of forest growing on coral substrates; the northwestern section features coral cliffs rising 8–10 meters; while the northeastern part presents a stretch of white sandy coastal forest extending approximately 1,720 meters, characterized by the *Ipomoea pes-caprae* zone dominated by *Ipomoea pes-caprae* and *Spinifex littoreus*. From an ecological perspective, studies conducted

in the waters of Kotania Bay have identified three locations with distinct microhabitat characteristics, consisting of sites within the bay dominated by seagrass beds and sites outside the bay dominated by coral reefs. These three locations function as spawning and nursery grounds, as well as feeding areas for larvae, juveniles, and young stages of economically important fish species, supported by the abundant availability of zooplankton as a primary food source (Braat & Groot, 2012). The community of adult economically valuable fish inhabiting this area is highly diverse, ranging from carnivorous groups such as the families Serranidae (groupers), Lutjanidae (snappers), and Lethrinidae (emperors), to planktivorous groups such as the family Caesionidae and *Rastrelliger kanagurta*, as well as herbivorous groups including the families Scaridae and Acanthuridae.

The coral reef conditions across the three observation sites are classified as moderate to very good. The presence of such rich ecological potential makes Marsegu Island highly suitable for development as a marine ecotourism destination. Ecotourism represents a conservation-based tourism management approach that does not directly exploit natural resources but instead utilizes ecosystem services and local community wisdom to fulfill tourists' educational, physical, and psychological needs. Although rapid tourism growth can significantly enhance local economic development, it also has the potential to lead to overexploitation of natural resources and degradation of destination quality (Damanik, 2006). Therefore, the concept of carrying capacity becomes a crucial instrument to minimize ecosystem degradation while ensuring the sustained welfare of communities that depend on these resources. However, field conditions indicate that the management of marine ecotourism in the Marsegu Island Nature Tourism Park (TWA) remains suboptimal. Steven J. Cooke (2004) identified several fundamental constraints, including the absence of a management institution capable of accommodating the interests of all stakeholders in a collaborative manner, the lack of integrated regulations governing resource utilization, and weak cross-sectoral coordination among local government authorities, the Tourism Office, BKSDA, and tourism operators.

Although 90% of the 54 surveyed respondents reported awareness of the area's conservation status, this awareness has not been fully translated into environmentally responsible behavior, as evidenced by the continued use of destructive fishing practices such as blast fishing and cyanide fishing in the surrounding waters. Community participation also remains limited to roles such as providers of accommodation, food services, transportation, and tour guiding, without extending to more substantive involvement in area management. Based on these conditions, an assessment of ecosystem suitability and area carrying capacity constitutes a crucial initial step prior to further development of marine ecotourism. The determination of ecotourism land suitability is conducted by multiplying the weights and scores of each measured ecosystem parameter (Lelloltery, 2018). The development of marine ecotourism on Marsegu Island, when aligned with ecological conditions and local socio-cultural contexts, and supported by active community participation, has the potential to become a sustainable driver of local economic growth. Based on the background described above, several key issues require further investigation. First, what are the levels of suitability and carrying capacity of the aquatic area for marine ecotourism development, including swimming, fishing, and boating activities, in the waters of Marsegu Island, Kotania Bay.

Second, what are the perceptions of communities residing around Kotania Bay, particularly on Osi Island, regarding marine ecotourism activities such as fishing, swimming, and boating tourism. Third, what are the appropriate strategies for the integrated and sustainable development of marine ecotourism in the Marsegu Island area of Kotania Bay. In line with these research questions, this study aims to achieve three primary objectives. First, to analyze the suitability and carrying capacity of marine ecotourism in the waters of Marsegu Island, Kotania Bay. Second, to examine the perceptions of local communities living around Kotania Bay regarding the planned development of marine ecotourism in the area. Third, to formulate comprehensive and sustainable development strategies for marine ecotourism in the waters of Marsegu Island, Kotania Bay. The findings of this study are expected to contribute to two main aspects. From an empirical perspective, this research is expected to enrich scientific knowledge and insights related to marine ecotourism development strategies, particularly in the waters of Marsegu Island, Kotania Bay, West Seram Regency. From a practical perspective, the results of this study can serve as a reference for marine

ecotourism development planning, as outlined below. For the government, particularly the Regional Government of West Seram Regency, this study can provide a basis for formulating planning policies and development strategies for marine ecotourism in the Marsegu Island waters of Kotania Bay. For local communities, especially residents of Osi Island and surrounding areas, this research is expected to enhance preparedness in welcoming and serving tourists visiting the marine ecotourism area of Marsegu Island. For academics, this study is expected to serve as a scientific reference and information source for researchers and students interested in further studies on marine ecotourism development in the future.

II. METHODS

The study was conducted from August to December 2025 in the waters of Marsegu Island, Kotania Bay, West Seram Regency, Maluku Province, encompassing three predetermined observation stations (Figure 1).

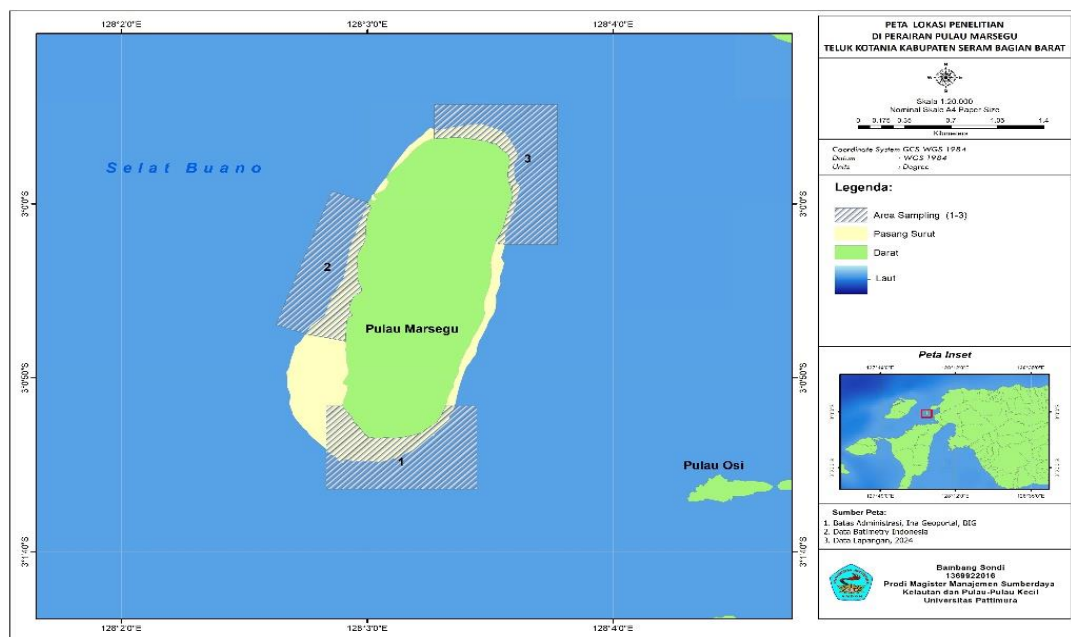


Fig 1. Research Location

Data were collected using two approaches. Primary data were obtained through interviews, questionnaires, and field observations involving local communities, community leaders, and government officials engaged in the management of marine ecotourism in Kotania Bay. Respondents were selected using purposive sampling and accidental sampling techniques, comprising 25–30 individuals. Secondary data were obtained from the Regional Development Planning Agency (Bappeda) of Maluku Province, the Tourism Office of West Seram Regency, scientific journals, and academic reports, including government policies, tourist visitation data, and regional geographic conditions. Environmental parameters measured at each observation station included temperature, salinity, current velocity, depth, and water clarity. The measurement results were analyzed to assess the carrying capacity of the area in supporting sustainable ecotourism development. Ecosystem suitability was evaluated by comparing field measurement results with data from previous studies to identify shifts in environmental conditions across the aquatic zones of Marsegu Island. The ecosystem suitability value was calculated using the Ecosystem Suitability Index (IKE) formula:

$$IKE = \left(\frac{N_i}{N_{max}} \right) \times 100\%$$

Marine ecotourism suitability parameters were assessed for three main activities, namely swimming/snorkeling, scuba diving, and fishing. The observed parameters included coral community cover, life form types, coral reef fish species, water clarity, coral reef depth, current velocity, beach type, beach width, substrate type, the presence of hazardous biota, and the availability of freshwater.

Tourism suitability was calculated using the Tourism Suitability Index (IKW) formula. (Manning R. E, 2011):

$$IKW = \sum \left(\frac{Ni}{Nmaks} \right) \times 100\%$$

The calculation results were classified into four suitability categories: S1 (Highly Suitable, ≥ 2.5), S2 (Suitable, $2.0 < 2.5$), S3 (Conditionally Suitable, $1.0 < 2.0$), and TS (Not Suitable, < 1.0) (Yulianda, 2019). The suitability parameters for each tourism activity are presented in Table 1 and Table 2.

Table 1. Parameters of Suitability of Swimming Activities (Yulianda, 2019)

No	Parameter	Weight	S1	S2	S3	TS
1	Depth of the waters (m)	0,125	0–3	>3–6	>6–10	>10
2	Beach type	0,200	White sand	White sand+coral	Black sand	Muddy, steep
3	Width of the beach (m)	0,200	>15	10–15	3–<10	<3
4	Brightness (%)	0,125	>80	>50–80	20–50	<20
5	Current speed (m/s)	0,080	0–17	17–34	34–51	>51

Table 2. Parameters of Suitability of Fishing Activities (Aziz et al., 2012)

No	Parameter	Bobot	S1	S2	S3	TS
1	Brightness (%)	5	>80	60–80	30–<60	<30
2	Coral cover (%)	5	>75	50–75	25–50	<25
3	Number of types of reef fish	3	>100	>50–100	>20–50	<20
4	Current speed (knot)	1	0–15	>15–30	>30–50	>50
5	Coral reef depth (m)	1	1–3	>3–6	>6–10	>10/<3

The carrying capacity of the area is calculated using the following formula (Yulianda, 2019):

$$DDK = x \frac{Lp}{Lt} \times \frac{Wt}{Wp}$$

The marine ecotourism development strategy was analyzed using an integrated approach to generate data-driven management recommendations. This integrated analysis was conducted descriptively by synthesizing three key components: the level of suitability across all tourism activities, variations in carrying capacity, and stakeholder perceptions. This synthesis serves as the basis for the comparative evaluation of tourism activities, zoning-based management strategies, and evidence-based policy recommendations derived from the collected data. This approach emphasizes carrying capacity-based management, spatial planning, and ecosystem resilience as the fundamental principles for sustainable marine ecotourism development.

III. RESULT AND DISCUSSION

The results indicate that the development of marine ecotourism on Marsegu Island, Kotania Bay, is strongly influenced by variations in biophysical conditions across observation stations. Marsegu Island has a total coral reef area of 1,557.68 ha, with 432.52 ha located within the designated utilization zone (Lelloltery et al., 2018). The analysis of land suitability and carrying capacity across the three stations reveals that not all water areas possess equal capability to support marine ecotourism activities. These findings emphasize that a spatial and carrying capacity-based approach is a fundamental prerequisite in sustainable coastal ecotourism planning, as highlighted in various international and regional ecotourism studies (Hall, 2001).

3.1 Suitability and Carrying Capacity of Swimming Tourism

3.1.1 Suitability of Swimming Tourism

The development of swimming tourism as part of marine ecotourism is highly dependent on the suitability of coastal biophysical conditions and the environmental capacity to accommodate tourism activities without degrading ecosystem quality. The results of the suitability parameter measurements for swimming tourism at the three research stations are presented in Table 3 and Table 4.

Table 3. Values of Swimming Tour Suitability Parameters at 3 Research Stations

Parameters	Station I	Station II	Station III
Depth (m)	3	7	5
Brightness (%)	100	90	100

Current Speed (cm/sec)	16	19	17
Beach Type	White Sand	White Sand + Coral Fragments	White Sand
Width of the Beach (m)	8	4	11
Slope of the Beach (°)	0,05	1	0,5
Aquatic Base Material	Sand	Sand	Sandy Coral
Dangerous Biota	None	There are	None
Distance of Freshwater Source (km)	0,15	1,7	2,3

Table 4. Results of the Suitability Analysis of Swimming Tourism in the Waters of Marsegu Island

Stations	Σ (Weight \times Score)	Indeks (%)	Classes	Limiting Factors
Station I	2,95	98,3	S1 – Highly Appropriate	Insignificant
Station II	2,23	74,3	S2 – Conform	Depth >6 m and dangerous biota
Station III	2,85	95,0	S1 – Highly Appropriate	Long distance of fresh water

Based on Tables 3 and 4, two observation stations fall into the S1 category (highly suitable), while one station is classified as S2 (suitable). This variation in suitability levels reflects differences in coastal environmental characteristics that directly influence the safety, comfort, and sustainability of beach recreation activities. Water depth is a key factor in determining the feasibility of swimming tourism, with the optimal range generally between 0–3 m, as it provides a high level of safety for non-professional visitors (Orams, 1999). Station I, with a depth of 3 m, is categorized as ideal, while Station III, at a depth of 5 m, remains relatively safe under certain supervision. In contrast, the depth of 7 m at Station II represents a primary limiting factor, as it may increase safety risks for visitors, considering that safety is a fundamental component in determining the carrying capacity of coastal recreation, where excessive depth can reduce visitor comfort. Water clarity values ranging from 90–100% across all stations indicate good environmental quality with very low turbidity levels. High clarity enhances the aesthetic value of coastal landscapes and provides a positive visual experience for tourists, while also indicating minimal sedimentation and low anthropogenic pressure—key indicators for sustainable marine ecotourism development (Moberg & Folke, 1999).

Current velocities ranging from 16–19 cm/s reflect relatively stable hydrodynamic conditions, where low to moderate currents facilitate water mass exchange without posing risks to tourists (Simon, 2004). Current stability also contributes to maintaining water quality through oxygen circulation and nutrient distribution within coastal ecosystems. From a coastal morphology perspective, the presence of white sandy beaches at Stations I and III is a major supporting factor for high suitability values, as such beaches offer high aesthetic appeal, better comfort, and lower risk of injury compared to rocky or muddy shores. At Station II, the presence of coral rubble reduces the suitability score due to the increased risk of injury to visitors. A beach width of 11 m at Station III provides more recreational space compared to Station II, which has a width of only 4 m. Gentle beach slopes at Stations I and III indicate ideal conditions, as depth transitions occur gradually, whereas the steeper slope at Station II increases risk for visitors with limited swimming ability (Pitcher, 2002). The presence of hazardous biota at Station II constitutes a significant limiting factor, as such organisms can reduce the perceived safety of the destination. Although the relatively long distance to freshwater sources at Station III (2.3 km) does not directly affect environmental quality, it influences the comfort of tourism facilities, which is an important component in destination development based on the 4A approach (Attraction, Accessibility, Amenities, and Ancillary services).

3.1.2 Carrying Capacity of Swimming Tourism

The carrying capacity for swimming tourism ranges from 21 to 59 persons per day, calculated based on a standard space requirement of 50 m² per person, which is commonly applied in beach recreation management to ensure visitor comfort and safety. Variations in carrying capacity among stations are primarily determined by the extent of effective beach area available. Station III, with the largest area (1,100 m²), yields the highest capacity of 59 persons/day, allowing for a more even distribution of visitors and reducing spatial crowding along the beach. Visitor density is a critical factor in outdoor recreation, as it is directly associated with tourist satisfaction and perceptions of environmental quality.

Table 5. Results of Analysis of the Carrying Capacity of Swimming Tourism on Marsegu Island

Stations	Space Requirements (m ² /person)	Observation Area Area (m ²)	DDK (person/day)	Status
Station I	50	800	43	Height
Station II	50	400	21	Medium
Station III	50	1.100	59	Very High

Station I demonstrates a relatively high carrying capacity of 43 persons/day, with an area of 800 m², indicating that the site still possesses an optimal capacity to accommodate visitors without increasing the risk of coastal environmental degradation. Coastal areas with sufficient spatial capacity are able to maintain ecological functions while providing adequate space and comfort for visitors. In contrast, Station II exhibits the lowest carrying capacity, at 21 persons/day, due to its relatively small beach area (400 m²), making it more vulnerable to tourism pressure if visitor numbers are not properly controlled. Coastal tourism areas with limited space tend to experience more rapid environmental degradation as a result of trampling, sediment disturbance, and waste accumulation. An increase in tourist numbers without consideration of carrying capacity may lead to beach erosion, degradation of coastal vegetation, and increased water turbidity. The principles of ecotourism emphasize that resource utilization should remain below the maximum carrying capacity to allow for ecological recovery (ecological buffer). Based on these findings, Station III is recommended as the primary zone for swimming tourism, Station I as a supporting zone, and Station II as a limited-use zone with the implementation of a spatial carrying capacity approach.

3.2 Suitability and Carrying Capacity of Fishing Tourism

3.2.1 Suitability of Fishing Tourism

All three observation stations in the waters of Marsegu Island fall into the S1 category (highly suitable), with suitability index values ranging from 86.7% to 97.8%. This indicates that the area possesses highly favorable biophysical characteristics to support the development of conservation-based fishing ecotourism. The high suitability values are primarily influenced by a combination of key environmental parameters, including water clarity, coral reef cover, coral reef fish diversity, current stability, and the depth of target habitats. Water clarity is a critical indicator in marine tourism, as it is directly associated with perceived destination quality and visitor experience (Moberg & Folke, 1999), and recreational fishing activities tend to develop optimally in waters with high clarity and low sedimentation pressure.

Table 6. Value of Parameters for Suitability of Fishing Tourism at 3 Research Stations

Parameters	Station I	Station II	Station III
Brightness (%)	100	90	100
Coral Cover (%)	76	63	65
Number of Types of Reef Fish	134	152	142
Current Speed (cm/sec)	16	19	17
Reef Depth (m)	2	2	2

Table 7. Results of Analysis of the Suitability of Fishing Tourism in the Waters of Marsegu Island

Stations	Total Score	IKW (%)	Classes	Interpretasi
Station I	44	97,8	S1 – Highly Appropriate	Stable fish habitat
Station II	39	86,7	S1 – Highly Appropriate	Highest fish diversity
Station III	39	86,7	S1 – Highly Appropriate	Reef conditions are good

Coral cover values ranging from 63% to 76% indicate that the coral reef ecosystems are in good to very good condition. Coral reefs function as spawning grounds, nursery areas, and feeding habitats for various economically important fish species, making them a key factor in the success of fishing tourism. Coral reef ecosystems provide essential ecosystem services, including fish stock availability and the stability of fisheries productivity (Damanik, 2006), and the sustainable development of recreational fishing-based ecotourism depends on the preservation of reef habitat quality. The high number of coral reef fish species, ranging from 134 to 152 species, reflects significant biodiversity, where species richness has been shown to enhance visitor satisfaction and extend the duration of stay in recreational fishing tourism destinations. Stable current conditions support sport fishing activities by maintaining the presence of target fish within reef zones without increasing safety risks for tourists.

The relatively uniform reef depth (± 2 m) indicates that fishing zones are located at optimal depths, facilitating access for small boats and reducing operational costs, which aligns with the characteristics of small-island marine ecotourism that emphasize nature-based experiences. Spatially, although all stations are classified as highly suitable, differences in ecological characteristics are evident among them. Station I exhibits the highest suitability value due to the combination of high coral cover and stable current conditions, making it a potential primary zone for fishing tourism. Station II shows the highest number of coral reef fish species, indicating its role as an important habitat for reef fish communities and its suitability as a premium fishing tourism site. Station III demonstrates a balanced set of biophysical parameters and can therefore function as a buffer zone to distribute tourism pressure across the area.

3.2.2 Carrying Capacity of Fishing Tourism

The results of the carrying capacity analysis for fishing tourism indicate a relatively high capacity, ranging from 100 to 120 persons per day. Station II has the largest area (6,000 m²) and the highest carrying capacity at 120 persons/day, followed by Station III with an area of 5,500 m² (110 persons/day), and Station I with an area of 5,000 m² (100 persons/day). The suitability of fishing tourism at Marsegu Island is presented in Table 8.

Table 8. Results of Analysis of the Carrying Capacity of Fishing Tourism on Marsegu Island

Stations	Effective Area of Fishing Ground (m ²)	DDK (person/day)
Station I	5.000	100
Station II	6.000	120
Station III	5.500	110

The results of the carrying capacity analysis for fishing tourism indicate a relatively high capacity, ranging from 100 to 120 persons per day. Station II has the largest area (6,000 m²) and the highest carrying capacity at 120 persons/day, followed by Station III with 5,500 m² (110 persons/day), and Station I with 5,000 m² (100 persons/day). The availability of fishing space is the primary factor determining utilization capacity, as excessive user density may reduce the quality of the tourism experience while simultaneously increasing pressure on natural resources. Recreational fishing activities have the potential to exert pressure on fish stocks if utilization intensity exceeds the natural regeneration capacity of the ecosystem; therefore, the concept of carrying capacity must consider not only spatial extent but also ecosystem productivity and habitat resilience.

Utilization up to the maximum capacity at Station II is not recommended, as sustainable ecotourism principles require that resource use remain below maximum capacity to allow for ecological recovery (ecological recovery capacity), particularly in coral reef ecosystems that are highly sensitive to anthropogenic disturbances. The relatively balanced capacities of Stations I and III enable a more even distribution of tourism pressure, thereby enhancing visitor experience by reducing competition for fishing space among anglers (Walters, 2001). The implementation of catch-and-release practices, limitations on the number of anglers, and zoning regulations are essential strategies to maintain a balance between tourism utilization and ecosystem conservation.

3.3 Suitability and Carrying Capacity of Boating Tourism

3.3.1 Suitability of Boating Tourism

All observation stations in the waters of Marsegu Island fall into the S1 category (highly suitable) for boating tourism. However, this suitability is seasonally influenced by fluctuating environmental conditions; therefore, boating activities should be selectively managed to minimize safety risks and potential disturbances to coastal ecosystems (Tambunan, 2013). The suitability values for boating tourism on Marsegu Island are presented in Table 9 and Table 10.

Table 9. Value of Suitability Parameters for Boating Tourism at 3 Research Stations

Parameters	Station I	Station II	Stasiun III
Depth of Waters (m)	3	7	5
Current Speed (cm/sec)	16	19	17

Table 10. Results of Analysis of the Suitability of Boating Tourism in the Waters of Marsegu Island

Stations	Total Score	IKW (%)	Classes	Interpretasi
Station I	18	100	S1 – Highly Appropriate	Ideal depth
Station II	16	88,9	S1 – Highly Appropriate	Stable current
Station III	18	100	S1 – Highly Appropriate	Safe for tourist routes

All observation stations in the waters of Marsegu Island fall into the S1 category (highly suitable) for boating tourism. However, this suitability is seasonally influenced by fluctuating environmental conditions; therefore, boating activities should be selectively managed to minimize safety risks and disturbances to coastal ecosystems (Tambunan, 2013). Water depth is a primary parameter, as it is directly related to navigation safety and the risk of vessel grounding. The ideal depth for small-scale tourist boats generally ranges from more than 4 to 8 m. A depth of 7 m at Station II represents the most optimal condition, as it provides sufficient maneuvering space for vessels while minimizing disturbance to the benthic substrate. A depth of 5 m at Station III is also considered suitable for small to medium-sized tourist boats. In contrast, the depth of 3 m at Station I constitutes a limiting factor, as it increases the risk of propeller damage and disturbance to benthic habitats if navigation activities are intensive. Shallow waters are highly sensitive to vessel activities due to water turbulence and sediment resuspension; therefore, the implementation of navigation routes and vessel size restrictions is necessary to maintain the stability of coastal ecosystems. Current velocities ranging from 16 to 19 cm/s indicate hydrodynamic conditions that support boating operations throughout the year, as stable currents enhance travel comfort while reducing the risk of maritime accidents.

3.3.2 Carrying Capacity of Boating Tourism

The results of the carrying capacity analysis for boating tourism indicate a relatively high capacity, ranging from 144 to 160 boat units per day. Station I has the largest area (20,000 m²) with the highest capacity of 160 units/day, followed by Station III with 19,000 m² (152 units/day), and Station II with 18,000 m² (144 units/day).

Table 11. Carrying Capacity Analysis of Boating Tourism at Marsegu Island

Stations	Navigation Waters Area (m ²)	DDK (boat unit/day)
Station I	20.000	160
Station II	18.000	144
Station III	19.000	152

The linear relationship between the extent of aquatic space and carrying capacity indicates that the availability of navigational space is the primary limiting factor, as excessive user density can reduce recreational quality and increase conflicts among users within the area. Boating activities have the potential to generate boat wake, water turbulence, and sediment resuspension, which may trigger coastal erosion, disturb benthic habitats, and reduce water clarity. Therefore, although the carrying capacity values are relatively high, their utilization must still consider ecological limits to avoid exceeding the recovery capacity of coastal ecosystems.

Station I exhibits the highest carrying capacity due to its largest navigational space, allowing for a more even distribution of boat traffic and reducing the intensity of ecological pressure at specific locations, in accordance with the principle of dispersing tourism activities to minimize cumulative environmental impacts. Station II is designated as a limited-use zone or transit route rather than a central hub for boating activities, consistent with the concept of carrying capacity management, which emphasizes regulating utilization intensity based on the ecological characteristics of the area (Simon, 2004). Coastal areas with extensive water space enable the development of marine tourism activities without significantly increasing ecological pressure, provided that zoning-based management is consistently implemented. The fundamental principle of ecotourism emphasizes that the number of operational tourist boats should remain below the maximum carrying capacity to allow for ecological recovery space (Honey, 2008).

3.4. Marsegu Island Marine Ecotourism Development Strategy

3.4.1 Integrated Analysis of Marine Ecotourism Activities (Swimming, Fishing, and Boating).

The development of marine ecotourism at Marsegu Island demonstrates a strong interdependence between ecological suitability and carrying capacity across three primary activities: swimming, fishing, and

boating. Each activity exhibits distinct spatial requirements and ecological sensitivities, necessitating an integrated management approach to ensure sustainability. Swimming tourism shows relatively limited carrying capacity (21–59 persons/day) due to its dependence on coastal morphology, shallow water depth, beach width, and safety-related parameters. This activity is highly sensitive to environmental degradation, particularly in areas with narrow beaches, steep slopes, or the presence of hazardous biota. In contrast, fishing tourism demonstrates a higher carrying capacity (100–120 persons/day), supported by broader spatial coverage and the availability of productive coral reef ecosystems.

However, its sustainability is strongly dependent on fish stock availability and ecosystem resilience, making it vulnerable to overexploitation if not properly managed. Boating tourism exhibits the highest carrying capacity (144–160 boats/day), primarily driven by the extent of navigable water space. Despite this high capacity, boating poses indirect ecological risks through wave generation, sediment resuspension, and disturbance to benthic habitats. Therefore, while boating has greater spatial flexibility, its ecological footprint can be significant if operational intensity is not controlled. Comparatively, swimming represents a high-sensitivity, low-capacity activity, fishing represents a moderate-sensitivity, resource-dependent activity, and boating represents a low-sensitivity but high-impact activity. This differentiation highlights the necessity of spatial zoning and activity-specific regulation to balance ecological protection with tourism utilization.

3. 4.2. Marsegu Island Marine Tourism Policy Development Strategy and Recommendations.

Based on the analysis of suitability and carrying capacity, a zoning system is proposed as the primary management strategy to optimize resource utilization while maintaining ecological integrity:

1. Primary Utilization Zone (Core Tourism Zone)

This zone is designated for high-suitability and high-capacity activities, particularly fishing tourism and controlled boating operations. Station I and Station II are recommended as core zones due to their high ecological suitability and resource availability. However, fishing intensity must be regulated through catch limits and seasonal controls.

2. Swimming Tourism Zone (Recreation Zone)

Station III is recommended as the primary swimming zone due to its optimal combination of beach width, safety conditions, and carrying capacity. Station I may function as a supporting zone, while Station II should be restricted due to safety risks and environmental limitations.

3. Limited-Use Zone (Buffer Zone)

Station II should also function as a controlled-use or buffer zone for certain activities, particularly boating transit routes rather than concentrated activity areas. This approach minimizes ecological pressure on sensitive habitats while maintaining connectivity between tourism zones.

4. Conservation Zone (Protection Zone)

Areas with high ecological sensitivity, such as coral reef hotspots and nursery grounds, should be designated as conservation zones with strict limitations on tourism activities. These zones serve as ecological buffers to maintain biodiversity and ecosystem resilience.

The implementation of zoning should be supported by spatial planning tools, monitoring systems, and enforcement mechanisms to ensure compliance and long-term sustainability.

To ensure sustainable and integrated development of marine ecotourism at Marsegu Island, the following policy recommendations are proposed:

1. Implementation of Carrying Capacity-Based Management. Tourism activities must be regulated to remain below maximum carrying capacity thresholds to allow for ecological recovery and prevent environmental degradation.
2. Establishment of Zoning Regulations. A formal zoning system should be developed and enforced, distinguishing between core tourism areas, recreational zones, buffer zones, and conservation areas.
3. Strengthening Institutional Coordination. Improved coordination among stakeholders, including local government, BKSDA, tourism agencies, and local communities, is essential for integrated management.

4. Community-Based Ecotourism Development. Local communities should be actively involved not only as service providers but also as co-managers of ecotourism resources to enhance sustainability and local economic benefits.
5. Implementation of Sustainable Tourism Practices. Practices such as catch-and-release fishing, limits on visitor numbers, and environmentally friendly boating operations should be adopted.
6. Monitoring and Adaptive Management. Continuous environmental monitoring and periodic evaluation of carrying capacity are necessary to respond to ecological changes and tourism dynamics.

IV. CONCLUSION

The waters of Marsegu Island in Kotania Bay generally exhibit a high level of suitability for the development of marine ecotourism. Swimming tourism at Stations I and III is classified as S1 (highly suitable), while fishing and boating tourism across all three stations are entirely categorized as S1. The carrying capacity ranges from 21–59 persons/day for swimming tourism, 100–120 persons/day for fishing tourism, and 144–160 boat units/day for boating tourism. The results of this study recommend that the zoning system be implemented as a policy strategy for the development of marine ecotourism on Marsegu Island, with 4 zoning directions and 6 policy recommendations.

This study demonstrates that the waters of Marsegu Island, Kotania Bay, possess high ecological suitability for marine ecotourism development, with all observed activities swimming, fishing, and boating falling within suitable to highly suitable categories. However, variations in carrying capacity and ecological sensitivity across activities highlight that not all areas can be utilized uniformly. Swimming tourism exhibits the lowest carrying capacity and highest environmental sensitivity, requiring strict spatial and safety considerations. Fishing tourism offers high economic potential but must be carefully managed to prevent overexploitation of fish stocks. Boating tourism provides the highest capacity but poses indirect ecological risks that necessitate regulation. The findings confirm that carrying capacity-based and spatially integrated management is essential for sustainable marine ecotourism development.

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