

Characteristics of mangrove ecosystems for marine tourism in Pejarakan Village, Buleleng Regency, Bali

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Abstract. High diversities of flora and fauna, biomass potency, and unique landscape are factors that promote mangrove ecosystems in Pejarakan Village, Buleleng Regency, Bali to be marine tourism destinations. Besides its social, economic, and ecological benefits, the opening of the areas for tourism may have some adverse impacts. As preparation in advancing tourism industries in the area, this research aims at determining the type of tourism to be developed and the carrying capacity of the area to receives visitors. Data were collected for assessing the environmental condition, calculating tourism suitability index, and carrying capacity of the area for tourism. The mangrove vegetation consisted of nine species mangroves dominated by *Rhizophora apiculata* and *Rhizophora mucronata*. In general, the mangrove area is characterised with substantial thickness and mangrove density. The ecosystems are suitable for ecotourism development at three points in the area. Provided 1,461 meters of visitor tracks, the area can accept up to 234 visitors per day. The characteristics of mangrove ecosystems in Pejarakan Village indicate significant potential for marine tourism.

1 Introduction

The attractiveness of coastal ecosystems lies in their unique areas with specific characteristics that are highly dynamic in response to biological, chemical, and geological changes [1, 2]. Mangrove ecosystems are among the important ecosystems within coastal and marine environments, influenced by tidal conditions. Mangrove ecosystems have numerous ecological and economic functions and benefits. Ecologically, they prevent coastal abrasion, remediate pollutants before they enter the sea, absorb carbon to reduce carbon emissions, act as breakwaters, and protect residential areas from waves, wind, and storms [3]. The unique characteristics of mangroves, with their fertile substrates, provide habitats for various types of biota. Biota in mangrove ecosystems generally utilize these areas for spawning, feeding, nursery grounds, and as protection shelters from predators. Parts of mangrove trees, such as trunks and fruits, can be utilized economically. Additionally, mangrove ecosystems have significant potential use for marine tourism [4].

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Such mangrove ecosystem areas of 160 hectares have existed Pejarakan Village, Buleleng Regency, in the north most part of Bali. The longest coastline on the island (157.05 km) and existing coastal ecosystems are a great potency for tourism industry. At present, the mangrove ecosystem in Pejarakan Village is managed by the Nature Conservation Forum of Putri Menjangan with ecotourism orientation [5]. In recent years, there is a shift in the its main utilization, i.e. from fisheries oriented utilization to sustainable utilization through development of ecotourism [6].

Ecotourism is one of popular approach to manage and utilize mangrove ecosystems. This approach manages not only natural resources for tourism but also conservation and preservation to promote sustainability of the ecosystem and the tourims [7]. The mangrove areas in Pejarakan Village is concluded suitable ecotourism with an optimal strategy. As an effort for further preparation, the present study was aimed at assessing the environmental condition of the mangrove areas, calculating tourism suitability index to determine tourism spots, and determining carrying capacity of the area for tourism. This study is essential for decision-making in conservation and tourism planning, and effective management of these valuable coastal and marine ecosystems.

2 Methods

2.1 Time and sampling location

This research was conducted with data collection from October to November 2022 in the filed, the location of mangrove areas in the Pejarakan, Pejarakan Village, Gerokgak Sub-District, Buleleng Regency, Bali. Data collection for environmental assessment was carried out at 10 sampling points along the coast of Pejarakan Village (Figure 1).



Fig. 1. Research location of Mangrove Ecosystem Characteristics in Pejarakan Village, Buleleng Regency, Bali.

2.2 Tools and materials

Sampling to determine mangrove density was carried out using 10 m × 10 m transects. GPS, waterproof equipments, and cameras were used to document mangrove-associated biota and

substrate types, and GPS tools to record coordinates for mangrove thickness data. Satellite images were used to identify the extent of the mangrove areas and other coastal features. These data were analyzed using the QGIS application 3.10. A water quality checker (WQC) was used to measure water quality parameters (physical and chemical), including pH, temperature, and salinity. Worksheets, office stationery, and road boards were used to record observations.

2.3 Data collections

The data sources for this study include primary data (collected directly through observation) and secondary data (obtained from previous research). Primary data collection involves identifying mangrove species by observing the dominant family conditions at each station and documenting samples of mangrove branches, leaves, flowers, and fruits for identification. Mangrove species density was measured using 10 × 10 m quadrant transects at each sampling point by recording mangrove trunk circumference, tree height, species identification, and individual density per species. Quadrant transects were placed using the purposive sampling method based on dominant family conditions. Mangrove thickness was measured using the QGIS 3.10 application, measuring from the outermost sea line perpendicular to the land up to the last mangrove vegetation. Water quality parameters (temperature, pH, and salinity), substrate type, fauna associated with mangroves, and overall mangrove ecosystem conditions were also recorded. Secondary data including tidal information from the www.pasanglaut.com, demographic data and conditions of Pejarakan Village, and the area of mangroves obtained from interviews with stakeholders. The presence and number of associated fauna were observed directly, documented for later identification, and discussed with relevant stakeholders.

2.4 Data analysis

2.4.1 Tourism suitability index (TSI)

Tourism suitability analysis can be calculated using the Tourism Suitability Index (TSI), specifically for mangrove tourism, based on ecological potential parameters with categories and scores (Table 1). Data obtained based on observed parameters and the regional suitability matrix for mangrove ecotourism were used to determine the suitability class of mangrove ecosystems. This determination involves the multiplication of weight and score.

Table 1. Tourism suitability index (TSI) matrix.

| No | Parameters | Weight | Category | Score |
|----|--|--------|-----------------|-------|
| 1 | Mangrove thickness (m) | 0.380 | > 500 | 3 |
| | | | > 200 – 500 | 2 |
| | | | 50 – 200 | 1 |
| | | | < 50 | 0 |
| 2 | Mangrove density (ind/100 m ²) | 0.250 | > 15 – 20 | 3 |
| | | | > 10 – 15; > 20 | 2 |
| | | | 5 – 10 | 1 |
| | | | < 5 | 0 |
| 3 | Mangrove species | 0.150 | > 5 | 3 |
| | | | 3 – 5 | 2 |
| | | | 1 – 2 | 1 |
| | | | 0 | 0 |

| | | | | |
|---|--------------|-------|---|------------------|
| 4 | Tidal (m) | 0.120 | 0 – 1 > 1 – 2 > 2 – 5 > 5 | 3 2 1 0 |
| 5 | Biota object | 0.100 | (Fish, shrimps, crabs, molluscs, reptiles, birds) (Fish, shrimp, crab, Mollusca) (Fish, Mollusca) (One of the aquatic biota) | 3 2 1 0 |

Source: Yulianda [8]

After determining the suitability matrix of ecotourism areas, calculations were carried out using a formula to find the Tourism Suitability Index (TSI) based on Yulianda [8].

$$TSI = \sum_{i=1}^n (Wi \times Si) \tag{1}$$

where: n: the multiplicity of conformity parameters; Wi: Weight parameter to – i; Si: Score parameter to – i.

Category explanation: Very suitable = $TSI \geq 2.5$; suitable for $2.0 \leq TSI < 2.5$; Incompatible = $1 \leq IKW < 2.0$; Very incompatible = $IKW < 1$.

2.4.2 Carrying capacity

The carrying capacity (CC) of the area is sought to determine the maximum number of visitors physically accommodated by the area at any given time without disrupting natural and human resources. Carrying capacity uses the calculation formula as follows [8].

$$CC = K \times \frac{Lp}{Lt} \times \frac{Wt}{Wp} \tag{2}$$

where: CC: carrying capacity of the area (person/day); K: ecological potential of visitors per unit area (person); Lp: area/length of usable area (m² or m); Lt: unit of area for a specific category (m² or m); Wt: time provided by the area for tourist activities in one day (hours); Wp: time spent by visitors for any activity (hours).

Mangrove tracks or mangrove tracking paths along the coastline can be made based on the calculation of the carrying capacity of mangrove areas for mangrove ecotourism development. The calculation of carrying capacity looks at the ecological potential of visitors owned in one area of the mangrove area so that it will have a good impact on natural resources in the area (Table 2).

Table 2. Carrying capacity area for mangrove ecotourism.

| Activity | Ecological potential of visitors (K) | Unit Area (Lt) | Time spent by visitors (Wp) | Time provided by the Area for tourist activities in one day (Wt) |
|------------------|--------------------------------------|--|-----------------------------|--|
| Mangrove tourism | 1 person | 25 m (Based on the length of the path, every 1 person) | 2 hour | 8 hour |

Source: Yulianda [8]

3 Results and discussion

3.1 Characteristics of mangrove ecosystems

3.1.1 Mangrove Thickness

Mangrove thickness is a crucial parameter in determining the suitability of tourism for mangrove ecosystems. In the mangrove ecosystem area of Pejarakan Village, mangrove thickness ranges from 83 to 430 meters, with an average value of 237 meters. The highest category of mangrove thickness observed was 430 meters, indicating that the mangrove thickness falls within the suitable category for ecotourism [8]. The high thickness of mangroves will affect the abundance of organic matter and macrozoobenthos available. [9]. The lowest mangrove thickness was observed at the first sampling point, with a mangrove thickness value of 83 meters, located in the westernmost part of the mangrove ecosystem area. The low thickness of mangroves in this area was attributed to community activities such as the establishment of Hindu places of worship (temples) and residential areas for pond workers, which have led to degradation of the mangrove ecosystems and a decrease in mangrove thickness. The highest mangrove thickness value was found at the fifth sampling point, located in the northern part of the area, with a mangrove thickness value of 430 meters, indicating that this location is suitable for tourism.

This results in the higher value of mangrove thickness because this location is closer to the coast, further away from residential areas, and tends to be more secluded compared to the first location. Mangrove thickness was influenced by several factors. The highest mangrove thickness can be influenced by naturally growing mangrove forests with high vegetation density, situated far from residential areas or human activities, and located in more secluded areas. Conversely, low mangrove thickness values may result from human activities such as coastal area development. Mangrove rehabilitation and replanting also offer benefits in increasing mangrove thickness. This is because mangrove thickness serves as a breakwater and impacts mangrove litter production, which forms the primary link in the mangrove ecosystem food chain. Consequently, this increases the abundance of biota associated with mangrove ecosystems, making them more suitable for tourism [10].

3.1.2 Mangrove density

Mangrove ecotourism density data were obtained based on the number of individual mangrove trees per unit area of the observation plot, representing the observation area [11]. In the mangrove ecosystem area of Pejarakan Village, the highest mangrove density value recorded was 19 individuals per 100 m², while the lowest density value was 5 individuals per 100 m². According to Yulianda [8], the number of individual mangrove trees can indicate the feasibility of ecosystem carrying capacity and habitat suitability for associated biota. The density value of mangroves reflects the abundance of species in the mangrove community, higher density values correspond to greater species abundance associated with mangroves [12]. However, the density of mangroves in the PT. Agung Menjangan Mas area has decreased due to land use changes for shrimp and salt farming areas, residential development, and road construction. This is consistent with the findings of Rahman et al. [13], which suggest that anthropogenic activities can significantly decrease mangrove density and hinder individual mangrove growth. These challenges can be addressed through mangrove replanting or rehabilitation programs.

3.1.3 Types and distribution of mangroves

The mangrove ecosystem area of PT Agung Menjangan Mas, Pejarakan Village, with an area of ± 19 ha, exhibits a diverse array of species and distribution of mangroves. The condition of the mangrove ecosystem in this area comprised nine types of mangroves (Figure 2), predominantly dominated by *Rhizophora apiculata*, accounting for 43%, followed by *Rhizophora mucronata* at 27%. The least abundant mangrove species are *Aegiceras floridum* at 3% and *Avicennia alba* at 1% (Table 3). These percentages were calculated by determining the total number of mangrove tree species observed at each designated sampling point and presenting them as proportions of the whole. This observation is consistent with the findings of Giantara et al. [6] in the same location, which indicate that common mangrove species found in the Pejarakan Village area include *Rhizophora* spp., *Bruguiera* sp., *Ceriops* sp., and *Avicennia* sp. The growth zoning patterns and characteristics of the mangrove ecosystem serve as attractions for ecotourism. The mangroves in the PT Agung Menjangan Mas mangrove ecosystem in Pejarakan Village are the result of planting initiatives conducted by private entities in collaboration with the local community and the NGO Nature Conservation Forum of Putri Menjangan.

Table 3. Distribution of mangrove species.

| Scientific Name | Genus (Group) | Local Name | Percentage (%) |
|-------------------------------|-------------------|-----------------|----------------|
| <i>Rhizophora apiculata</i> | <i>Rhizophora</i> | Bakau minyak | 43% |
| <i>Rhizophora mucronata</i> | <i>Rhizophora</i> | Bakau hitam | 27% |
| <i>Sonneratia alba</i> | <i>Sonneratia</i> | Pidada | 9% |
| <i>Aegiceras corniculatum</i> | <i>Aegiceras</i> | Pisang-pisangan | 5% |
| <i>Ceriops tagal</i> | <i>Ceriops</i> | Tingi | 5% |
| <i>Rhizophora stylosa</i> | <i>Rhizophora</i> | Bako-kurap | 4% |
| <i>Bruguiera</i> sp. | <i>Bruguiera</i> | Putut | 4% |
| <i>Aegiceras floridum</i> | <i>Aegiceras</i> | Teruntung | 3% |
| <i>Avicennia alba</i> | <i>Avicennia</i> | Api-api jambu | 1% |

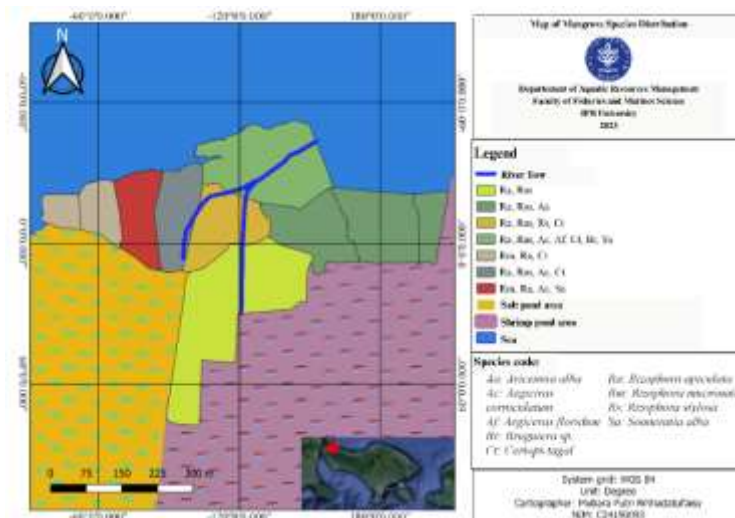


Fig. 2. Mangrove species distribution.

The distribution of mangroves in the mangrove ecosystem area of Pejarakan Village was influenced by several natural factors such as currents, salinity, substrates, and tides, as well as anthropogenic activities such as aquaculture in the surrounding area. According to Urrego et al. [14], the distribution, structure, and composition of mangroves result from the interaction between natural factors and local anthropogenic activities. The geographical location can also impact the distribution of mangrove species in an ecosystem. The distribution pattern of mangroves in this location tends to cluster, with several types of mangroves exhibiting random distribution patterns. Grouping distribution patterns are generally influenced by relatively similar environmental factors and a tendency to select favorable habitats, while random distribution patterns indicate uniformity among mangrove species and a lack of selectivity in habitat choice [15]. The dominance of mangrove species in this mangrove ecosystem may be attributed to the availability of more seeds of *Rhizophora apiculata* and *Rhizophora mucronata* during mangrove planting programs.

3.1.4 Tidal pattern

Tidal data are sought to determine the level of comfort and safety for visitors traveling to the area. Based on secondary data from the pasanglaut.com website, the average tidal range for one month was 1.7 meters, categorizing it as appropriate (>1 - 2 meters) [8]. The type of tide in the mangrove ecosystem area falls under the semidiurnal tide category (Figure 3), which signifies a tidal condition featuring two high tides and two low tides with nearly identical heights within a single day [16]. This condition aligns with the description provided by Maulida et al. [17] that mangroves are referred to as tidal forests because their existence is influenced by tides and predominated by muddy substrates. Tides play a crucial role in shaping sediment characteristics as they are the primary factor in sediment movement between land and sea. Additionally, tides influence changes in salinity; during high tide, salinity tends to increase, whereas during low tide, salinity decreases [18].

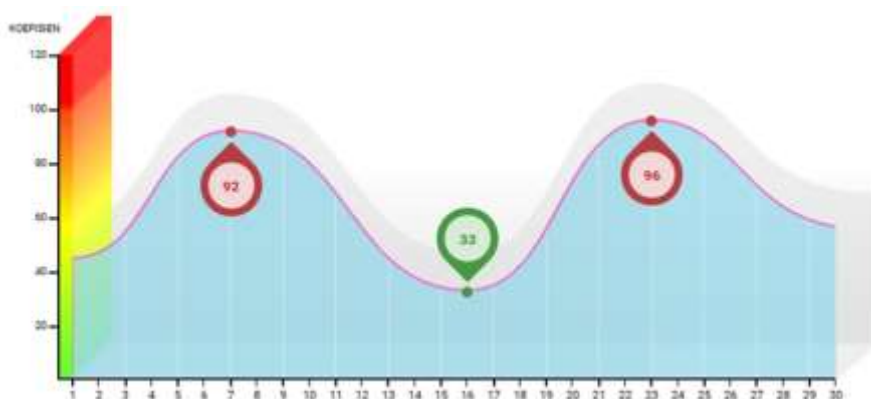


Fig. 3. Tidal of mangrove ecosystems (pasanglaut.com).

3.1.5 Potential biota of mangrove ecosystem

The mangrove ecosystem of Pejarakan Village had variety of potential biotas, including fish, crustaceans, molluscs, birds, and primates (Table 4). The presence of diverse biota is a key attraction for tourists visiting ecotourism sites and serves as an opportunity for education and hands-on learning in the field. As mentioned in Karniati et al. [19], mangrove-associated biota typically utilize mangrove ecosystems as spawning habitats and food sources.

The high potential of biota can indeed be influenced by factors such as mangrove density values, tides, and other environmental conditions. The mangrove ecosystem in Pejarakan Village exhibits a high biota potency, evident from the diverse array of biota observed directly through visual observations in the field. The presence of high biota diversity in a mangrove ecosystem indicates high mangrove productivity. This productivity stems from both the mangrove vegetation itself and the shedding of mangrove leaves, which subsequently become a vital source of organic matter in the food chain within the mangrove ecosystem [20]. The high potential of biota plays a significant role in the biodiversity of an ecosystem area, indicating that the mangrove ecosystem of Pejarakan Village possesses high biodiversity. The highest level of biota diversity is observed in mollusk biota, primarily within the Gastropoda and Bivalve classes. Mollusks typically inhabit substrates or attach themselves to mangrove trees, playing a crucial role in supporting ecological functions within the mangrove ecosystem, serving as primary consumers and decomposers. This is in line with the statement Ginantra et al. [5] in previous studies in the same area, which reported that molluscs exhibit high species diversity. The highest percentage of molluscs was observed in species such as *Pitar citrinus* and *Cerithium* spp., accounting for 100% of the biota found throughout the area. Following molluscs, the next highest diversity of biota was observed bird species. Direct field observations and secondary data provided by the Nature Conservation Forum of Putri Menjangan indicate that the mangrove area of Pejarakan Village hosts various bird species spread throughout the area. These birds typically utilize mangrove ecosystems as migratory shelters, food sources, and breeding grounds [21].

Primates were observed directly at points 1, 2, 3, and points 7, 8, 9. These primates typically utilize mangrove ecosystems as feeding habitats [21]. Fish and crustaceans were also observed in small numbers, while reptile biota was not found in this area. This was attributed to the substrate condition in this mangrove ecosystem area, which was predominantly dominated by mud and sandy mud substrate types that tend to become dry.

Table 4. Percentage of biota potential.

| Groups and Types of Biota | Distribution percentage of potential biota (%) |
|--------------------------------------|---|
| 1. Mollusks | |
| a. <i>Clypeomorus</i> spp. | 40% |
| b. <i>Acanthinucella paucilirata</i> | 40% |
| c. <i>Rapana venosa</i> | 30% |
| d. <i>Pitar citrinus</i> | 100% |
| e. <i>Cerithium</i> spp. | 100% |
| f. <i>Pomacea</i> spp. | 70% |
| g. <i>Coralliophila</i> spp. | 70% |
| h. <i>Batillaria</i> spp. | 60% |
| i. <i>Leptotrophon</i> spp. | 70% |
| j. <i>Conomurex luhuanus</i> | 30% |
| k. <i>Trona stercoraria</i> | 30% |
| l. <i>Nucella heyseana</i> | 40% |
| m. <i>Telescopium</i> | 30% |
| n. <i>Nerita undata</i> | 30% |
| o. <i>Amphissa columbia</i> | 30% |
| p. <i>Bonea bisuturalis</i> | 30% |
| 2. Fishes | |
| a. <i>Periophthalmus</i> spp. | 70% |
| b. <i>Synodus dermatogenys</i> | 60% |
| c. <i>Dermogenys pusilla</i> | 70% |
| d. <i>Oryzias javanicus</i> | 100% |
| 3. Primate | |
| a. Monkey | 60% |
| 4. Birds | |
| a. <i>Egretta</i> sp. | 100% |
| b. <i>Pycnonotus goiavier</i> | 30% |
| c. <i>Charadrius</i> sp. | 40% |
| d. <i>Leptoptilos</i> sp. | 30% |
| e. <i>Himantopus himantopus</i> | 40% |
| f. <i>Stema albifrons</i> | 100% |
| g. <i>Halcyon</i> sp. | 100% |
| 5. Crustacean | |
| a. <i>Scylla</i> sp. | 30% |
| b. <i>Uca</i> sp. | 70% |
| c. Shrimps | 70% |
| d. <i>Austruca perplexa</i> | 60% |
| e. <i>Leptuca subcylindrica</i> | 100% |
| f. <i>Ocypode kuhlii</i> | 40% |

3.2 Suitability of mangrove ecosystems for marine tourism utilization

The mangrove ecosystem area of Pejarakan Village possesses potential use as ecotourism sites, exhibiting a relatively high suitability value. Based on data collected at 10 points, two points, namely points 4 and 6, have a tourism suitability index value in the appropriate category; one point, point 5, falls into the very suitable category; and the remaining seven points were categorized as inappropriate, potentially serving as locations for rehabilitation efforts. (Figure 4). The tourism suitability index (TSI) values at points 1 and 2 were 1.37, point 3 was 1.62, points 4 and 6 were 2, and the tourist suitability index values at point 5 were 2.53, points 7 and 8 were 1.62, point 9 was 1.87, and point 10 was 1.6.

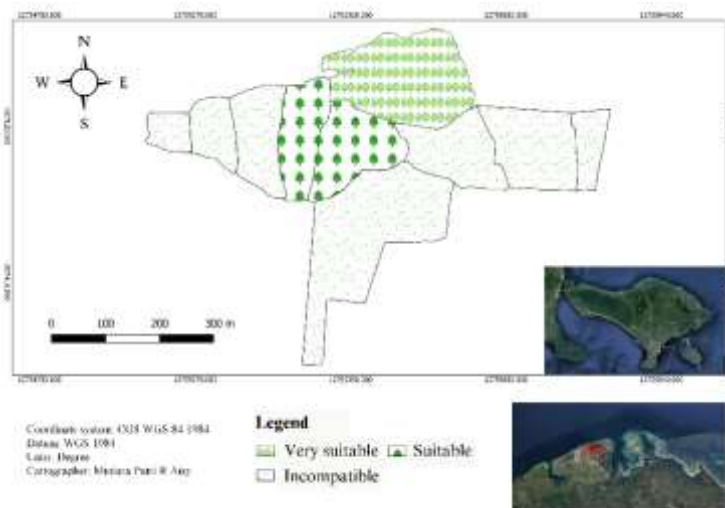


Fig. 4. Tourism suitability index (TSI) for mangrove ecosystems in Pejarakan Village.

The area with very high potential and relatively high suitability value for development into ecotourism in the mangrove area of Pejarakan Village covers 7.11 hectares, while 14 hectares were deemed less potential and unsuitable for development into ecotourism areas. The unsuitability of mangrove ecosystem areas for ecotourism development was attributed to various factors. These include the decline in ecological function of the ecosystem, as evidenced by low mangrove density weights and thickness values at certain points, as well as limited variety in mangrove types. These factors can be influenced by anthropogenic activities surrounding mangrove ecosystem areas, such as the conversion of mangrove areas for shrimp and salt ponds, as well as natural factors like tides, waves, currents, wind, and sedimentation [22].

Mangrove ecosystem rehabilitation activities can serve as an alternative step and an effort to increase the potential of mangrove resources and mitigate physical, chemical, and biological damage within mangrove ecosystems, as outlined in Presidential Regulation Number 121 of 2012 concerning the Rehabilitation of Coastal Areas and Small Islands. According to Nabout et al. [23], the suitability of tourist areas is crucial in the development and management of ecotourism. This is because the suitability of the area is necessary to assess the compatibility of the resources that will be utilized as tourist attractions. These resource characteristics must align with the regulations established in ecotourism management to ensure that tourism activities can be sustainably managed and maintained.

3.3 Carrying capacity of mangrove ecosystems for marine tourism utilization

Carrying capacity assessment is pivotal in the management and development of tourist areas, particularly in ecotourism. Carrying capacity analysis is essential to determine an area's ability to withstand disturbances or stresses resulting from human activities [3]. The mangrove ecosystem in the Pejarakan Village area exhibits significant potential for development as an ecotourism destination. One activity with high potential for development is mangrove trekking.

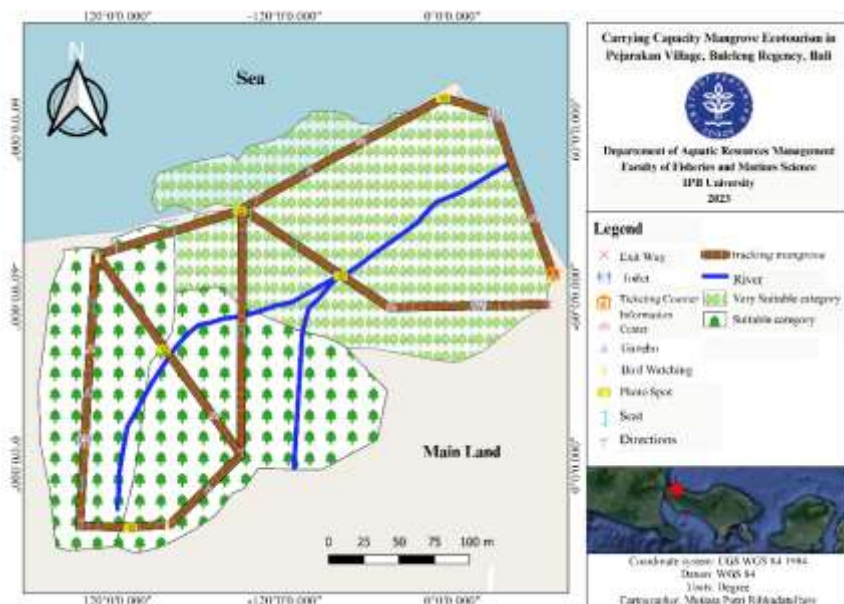


Fig. 5. Carrying capacity for tracking mangrove.

Based on the analyzed results, it is determined that the length of the mangrove trekking track that can be established and developed for mangrove ecotourism in Pejarakan Village is 1,461 meters. Consequently, the carrying capacity derived from the analysis calculation can accommodate up to 234 people per day. This aligns with the assertion made in Yulianda [8] which suggests that the ideal length of the mangrove trekking track suitable for the carrying capacity of mangrove tourism is 25 meters per visitor per day (Figure 5). Mangrove trekking as an ecotourism support facility can aid in educational activities and provide a means to learn about various types of mangroves, flora, and fauna, and mangrove ecosystem associations in the surrounding ecotourism areas through wooden trail or floating deck facilities [24].

The mangrove trekking track can be enhanced with additional supporting facilities for ecotourism activities. These facilities include ticket counters for purchasing entrance tickets before visitors can enjoy the mangrove trekking activities, toilet facilities for convenience, and information centers placed at several points along the track to provide visitors with information and insights regarding the types of mangroves, fauna, and flora associated with the mangrove ecosystem. Gazebos can serve as shelters and resting places in case of sudden rain, while seats can function as temporary resting areas. Photo spots can be placed at several points along the track for visitors to capture memories with beautiful scenery. Directional signs will help visitors navigate the track, and with the many bird species in the area, bird-watching facilities can be added at several points to observe birds from the height of a tower using telescopes. According to [24], the observation of endemic or migratory birds in

ecotourism areas can be scheduled to coincide with the times when birds emerge from their nests. The provision of supporting facilities is crucial in developing an ecotourism area; having comprehensive facilities can add significant value for visitors [25].

4 Conclusion

The characteristics of the mangroves within the mangrove ecosystem area of Pejarakan Village exhibit qualities conducive to marine tourism activities, emphasizing sustainability and ecosystem preservation. With a calculated carrying capacity of 234 individuals per day and a track length extending over 1,461 meters, the area presents ample opportunities for visitors to engage with the natural environment responsibly. To further enhance the mangrove ecosystem's suitability for ecotourism, managers can implement rehabilitation programs designed to align with sustainable tourism practices. By integrating ecotourism principles into mangrove rehabilitation endeavors, managers can not only optimize the tourism potential of the area but also contribute to the long-term health and resilience of the mangrove ecosystem.

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