Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 28(5): 929 – 943 (2024)
www.ejabf.journals.ekb.eg

Mangrove Tourism Suitability Index and Ecotourism Sustainability in the Waters of Talengen Bay, North Sulawesi Province, Indonesia

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ARTICLE INFO

Article History:
Received: July 31, 2024
Accepted: Sept. 12, 2024
Online: Sep. 27, 2024

Keywords:
Ecotourism,
Tourism suitability index,
Regional carrying capacity,
Talengen Bay

ABSTRACT

This study examined the potential of the mangrove ecosystem in Talengen Bay, North Sulawesi, Indonesia, for ecotourism development. Mangroves play a crucial role in environmental sustainability by supporting biodiversity, protecting coastlines, and providing habitat for aquatic species. The research aimed to assess the tourism suitability index and the regional carrying capacity of the mangrove areas, crucial for sustainable tourism planning. The study identified six mangrove species, with *Rhizophora mucronata* being the most dominant. The mangrove tourism suitability index (MTSI) was calculated based on parameters such as mangrove thickness, density, species diversity, tidal influence, and associated biota. The results indicate that the Talengen Bay mangrove ecosystem is suitable for ecotourism, with an average MTSI score placing it in the "Suitable" category. Additionally, the carrying capacity for mangrove tourism activities was determined to be 105 visitors per day, ensuring minimal impact on the ecosystem. These findings provide valuable insights for policymakers and stakeholders to promote ecotourism while ensuring the conservation and sustainability of the mangrove ecosystem in Talengen Bay.

INTRODUCTION

The mangrove ecosystem has a very important role in supporting the sustainability of the surrounding environment **(Abidin *et al*., 2021; Ruslan *et al*., 2022)**. Mangroves are coastal ecosystems that have a high level of productivity, hence they are able to support the life of surrounding organisms and maintain ecosystem balance **(Rahmadi *et al*., 2023; Anu*et al*., 2024)**. Apart from that, the mangrove ecosystem also acts as a habitat for various types of biotas, a spawning place for aquatic biota, a coastline protector, as well as a place for foraging and rearing of aquatic biota **(Isroni *et al*., 2019; Islamy & Hasan, 2020; Isroni *et al*., 2023)**.

The concept of ecotourism is defined as a responsible travel to natural areas that preserves the environment, supports the well-being of local communities, and involves interpretation and education **(Chan *et al*., 2021; Huang *et al*., 2023)**. Ecotourism, which emphasizes mindful travel practices aimed at preserving the environment and supporting indigenous communities, has become a center of attention in assessing the suitability of Talengen Bay for tourism ventures **(Satrya *et al*., 2023)**. In developing ecotourism, it is important to analyze the suitability of tourism and the carrying capacity of the area **(Abdillah *et al*., 2020; Ariani *et al*., 2020)**. A study evaluates the tourism suitability index, calculates the area's carrying capacity, and identifies ecotourism activities that can be conducted in mangrove areas **(Ledheng *et al*., 2022; Vipriyanti *et al*., 2022)**. Additionally, research employed the tourism suitability index (TSI) and ecotourism area carrying capacity (ACC) to assess mangrove track exploration tourism **(Nugraha *et al*., 2024)**. Indonesia, home to one of the largest mangrove forests in the world, includes the extensive mangrove forests of North Sulawesi Province. Talengen Bay, located in the Sangihe Islands District, stands out as an ideal site for studying the mangrove ecosystem due to its relatively untouched state and rich biodiversity. The potential for ecotourism development in this region presents a dual opportunity: fostering conservation efforts while delivering economic benefits to local communities.The development and use of mangrove ecosystems for ecotourism is an alternative sustainable development to overcome the problem of destructive use **(Ferreira *et al*., 2022)**. However, in Talengen Bay, the implementation of mangrove ecotourism is not yet fully supported by the availability of physical data, especially information regarding the suitability and carrying capacity of the area. Therefore, there are several things that need attention and a broader and more comprehensive study is needed to determine the ability of the mangrove ecosystem to support all ecotourism activities being developed. This is because mangrove ecosystem resources are limited and vulnerable to both internal and external pressures which can reduce the quality and quantity of the ecosystem. The results of this research are intended to provide valuable insights for policy makers, conservation activists and local stakeholders interested in promoting sustainable ecotourism in Talengen Bay. By understanding the current state and potential of mangrove ecosystems, effective strategies for conservation and sustainable tourism development can be formulated, thereby ensuring long-term benefits for the environment and local communities.

MATERIALS AND METHODS

Study location

The research was conducted in Talengen Bay, North Sulawesi Province, Indonesia. This location is known for its extensive mangrove forests, providing an ideal setting for studying the suitability of mangrove tourism and its sustainability as an ecotourism destination (Fig. 1).

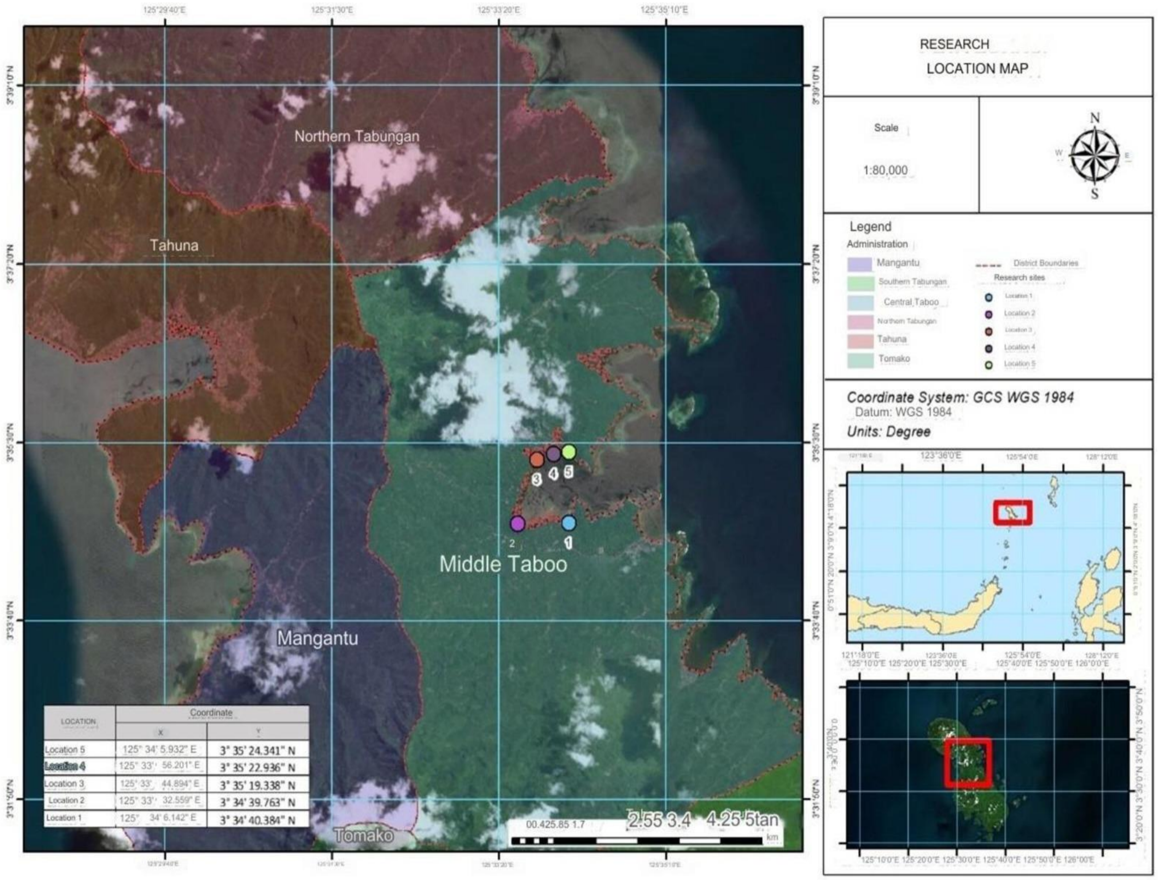

Fig. 1. Research location

Data collections

Data for this research were collected through a combination of field surveys, remote sensing, and secondary data sources. Primary data collection focused on mangrove types, mangrove density, mangrove thickness, associated biota objects and tracking length in the Talengen Bay Mangrove ecotourism area. Secondary data included tidal information for October 2023, obtained from the Naval Hydro-Oceanography Center Institute (PUSHIDROSAL).

Field surveys and remote sensing

Field surveys were conducted in Talengen Bay to assess the density and extent of mangrove forests using two main methods: transect sampling and GPS mapping. Transects, which are made perpendicular to the coastline, function as paths to create plots at regular intervals. In each plot, detailed data on the number of mangrove trees and species composition were recorded. At the same time, GPS devices were used to pinpoint the geographic coordinates of the plots, thereby facilitating the creation of accurate maps illustrating the distribution of mangrove forests throughout the bay.

Complementing these land-based efforts, remote sensing techniques were also being used to improve understanding of mangrove ecosystems. Landsat 8 satellite imagery and aerial photos underwent careful analysis, including image classification to distinguish mangrove areas from other land cover types. Additionally, temporal changes in mangrove forest cover were investigated through change detection methodology, which involves comparing images taken in different years. This multifaceted approach combines field survey data with remote sensing insights, providing a comprehensive understanding of the dynamics and spatial distribution of mangrove forests in Talengen Bay.

Data analysis

Identify types of mangroves

The types of mangrove trees found in the research location were identified using an identification guidebook referring to **Harahab and Setiawan (2017)**, **Beyer *et al.*(2018)** and **Nelly *et al*. (2020)**.

Calculation of the density of mangrove species

The density of mangrove species was calculated using the following formula **(Murniasih *et al*., 2022)**:

$$Di = \frac{ni}{A}$$

Note:
Di = Specific density (ind/m2)
ni = Total number of i-type individuals
A = The total area of the sample observation area (m2)

Mangrove thickness calculation

Mangrove thickness analysis was carried out using the Google Earth application on the Asus Vivobook Core I9 13th Gen Laptop device. Mangrove thickness was measured in the research location where each transect location was located, namely measured from the outermost mangrove vegetation adjacent to the sea to the last (innermost) mangrove vegetation adjacent to land. The obtained mangrove thickness line length values are used to calculate the tourism suitability index value based on published method **(Tjiong *et al*., 2021)**.

Tide calculation

Tidal data, obtained for a specific time period, include the highest and lowest tide levels. These values are summed and divided by two to calculate the average tidal value. These data are then used to assign a score for the tidal parameters.

Biota object identification

Associated biota objects were found and documented in each research location where each transect was located using an android camera, then these biota objects were grouped into the categories of fish, crabs, reptiles and birds. These data were further analyzed into a mangrove ecotourism suitability matrix to obtain a score for these parameters. The identification of biota followed methods suggested in published studies **(Pratama *et al.*, 2020; Jatayu *et al.*, 2023; Islamy *et al.*, 2024a; 2024b)**. The collected organism data can also serve as a reference for regional conservation policies **(Hasan *et al.*, 2020; Insani *et al.*, 2020; Valen *et al.*, 2022; Serdiati *et al.*, 2023)**.

Mangrove tourism suitability index (MTSI)

The mangrove tourism suitability index analysis was based on the method developed by **Hagger *et al.* (2022)**, which requires the calculation of five parameters to determine the score and category. These parameters include mangrove thickness, mangrove density, mangrove types, tides, and associated biota.The formula used is as follows:

$$IKW = \sum_{i=1}^{n} Bi \; x \; Xi$$

Note:
N = Number of Conformity Parameters
Bi = Parameter Weight i-th
Si = Score of the i-th Parameter

After the TSI value was obtained from each transect, the value was categorized according to the value provisions set by **Yulianda (2019)**:

Very suitable = > 2,5
Suitable = 2,0 < TSI < 2,5
Not Appropriate = 1 < TSI < 2,0
Very Inappropriate = < 1

Regional carrying capacity

The area carrying capacity value (ACC) is essential to determine the maximum number of visitors that can be accommodated by the tourist area without causing disturbance to nature and humans. The ACC calculation followed the formula provided by **Yulianda(2019)** as follows:

$$\mathrm{ACC} = K \times \left(\frac{Lp}{Lt}\right) \times \left(\frac{Wt}{Wp}\right)$$

Note :
ACC = Area Carrying Capacity (people/day)
K = Ecological potential of visitors per unit area (persons)
Lp = The area (m^2) or length of the area (m) used
Lt = Area units for specific categories (m^2 or m)

Wt = Time provided by the area for tourist activities in 1 day (hours)
Wp = Time spent by visitors for each activity (hours)

RESULTS AND DISCUSSION

1. Mangrove species identification

Based on the research results, 6 species were found, namely: *Rhizophora mucronata, Rhizophora apiculata, Bruguiera gymmnorhyza, Sonneratia alba, Avicennia marina* and *Nypa fruticans* and dominated by *Rhizophora mucronata*. Mantehage Island, Bunaken National Park, Manado City, namely 20 species of mangroves (*Acanthus ilicifolius, Avicennia marina, Camptostemon philippinense, Nypa fruticans, Lumnitzera racemosa* Willd, *Cockroach Excoecaria, Sonneratia alba, Sonneratia ovata, Heritieralittoralis* Dryand , *Xylocarpus granatum, Aegiceras corniculatum, Acrostichum speciosum* Willd, *Bruguiera cylindrica, Bruguiera gymnorrhiza, Bruguiera parviflora, Ceriops tagal, Rhizophora apiculata, Rhizophora mucronata, Rhizophora stylosa,* and *Scyphiphora hydrophyllacea*). According to **Rumengan*et al*. (2018)**, differences in mangrove species in an area are influenced by physical and chemical factors in the water.

The diversity of mangrove types in the area is considered one of the key attractions for visitors, who engage in tours and educational activities related to the mangrove ecosystem **(Isroni *et al.*,2019)**. This diversity is viewed as an added value for the development of ecotourism in the Talengen Bay area. According to published method, the diversity of mangrove types in an area is recognized as an important value in supporting the management activities of a tourist area and increasing visitor attraction **(Getzner & Islam, 2020; Ewaldo *et al*., 2023)**. A large number of mangrove species is believed to support overall biota diversity, thereby enhancing the ecological richness and appeal of the area **(Sukuryadi *et al*., 2020; Irwansyah *et al*., 2022)**. This diversity is perceived to contribute significantly to the educational and recreational experiences of visitors, promoting a deeper understanding and appreciation of mangrove ecosystems **(Sariaslan & Langer, 2021)**. Consequently, the management and conservation of these diverse mangrove species are seen as crucial for the sustainable development of ecotourism in Talengen Bay.

2. Calculation results of mangrove type density

Based on the research results, the density of mangrove species isdisplayed in Table (1).

Table 1. Calculation of mangrove species density

Species	T1	T2	T3	T4	T5
Rhizophora mucronata	0.07	0.09	0.10	0.09	0.07
Rhizophora apiculata	0.03	0.03	0.03	0.02	0.00
Bruguiera gymnorhiza	0.01	0.01	0.00	0.01	0.01
Sonneratia alba	0.01	0.00	0.01	0.00	0.00
Avicennia marina	0.01	0.00	0.00	0.00	0.00
TOTAL	0.124	0.114	0.13	0.12	0.09

Based on the type of mangrove, *R. apiculata* is shown to have the highest species density in each transect, with a range value of 0.07–0.10 individuals per 500m² and an average value of 0.08. The smallest density values for mangrove species are reported for *Avicennia marina* and *Bruguiera gymnorhiza*, with respective range values of 0–0.01 individuals per 500m² and 0–0.4 individuals per 100m², and average values of 0.02 and 0.01 individuals per 100m². Studies have indicated that *Rhizophora mangle* species tend to be dominant and abundant in mangrove communities, particularly due to their good adaptability to the typical environmental conditions in mangrove forests **(Fazlioglu & Chen, 2020; Khan *et al*., 2024)**. The relatively high density in *Rhizophora* mangroves is attributed to a combination of the species' adaptability, complex root structure, interaction with the nekton community **(Friess *et al*., 2021**), as well as environmental factors that support the growth and proliferation of this species in the mangrove ecosystem. This dominance and adaptability are considered crucial for maintaining the structure and function of mangrove ecosystems, thus enhancing their ecological value and resilience.

3. Mangrove thickness results

The thickness of the mangroves in the various transects was recorded as follows: 238m in transect 1, 163m in transect 2, 204m in transect 3, 287m in transect 4, and 132m in transect 5. From these data, the average thickness of mangroves in the research location was calculated to be 204.8m. This average thickness reflects the overall density and health of the mangrove ecosystem in the area. Mangrove conditions can serve as a significant attraction for tourists due to their aesthetic appeal **(Murniasih *et al*., 2022)**. The denser the mangrove forest, the more appealing it is considered to be for tourists and visitors. Additionally, dense mangrove forests are known to provide better habitat and protection for various species, contributing to biodiversity **(Borsje *et al*., 2011)**. The thick mangrove stands also play a critical role in coastal protection, reducing the impact of waves and storm surges, which is another aspect that enhances their attractiveness for eco-tourists interested in the ecological and protective functions of mangroves **(Borsje *et al*., 2011; Friess *et al*., 2021; De Silva & Amarasinghe, 2023)**. This combination of aesthetic and ecological benefits makes dense mangrove forests highly valuable for a sustainable tourism development.

4. Tide calculation results

In October 2023, an analysis of tidal data from the Indonesian Navy's Hydro Oceanography Center (PUSHIDROSAL) revealed that the average tidal conditions around Talengen Bay stood at 1.89 meters. This figure represents an optimal value for mangrove tourism activities, as it does not surpass the height of the trail at this particular tourist destination. Consequently, tourists can comfortably engage in tracking and exploration activities. The height of sea tides serves as a crucial indicator of visitor comfort during such endeavors, as noted by published article **(Su *et al*., 2021; Shahrin *et al*., 2024)**. This finding underscores the importance of considering tidal patterns in designing and managing tourist experiences within coastal ecosystems. Moreover, it emphasizes the need for ongoing monitoring and research to ensure sustainable tourism practices that align with natural environmental dynamics.

5. Biota object identification results

The research findings on the biotic components of the mangrove ecosystem in Talengen Bay reveal the presence of six distinct groups of biota, including fish, shrimp, crabs, mollusks, reptiles, and birds. The diversity of these biotic groups within the mangrove association is intricately linked to the thickness of the mangrove itself **(Jacquot *et al*., 2023)**. It is elucidated that as the thickness of the mangrove increases, a corresponding rise in the diversity of associated biota is observed. Conversely, a decrease in mangrove thickness is associated with a reduction in the variety of associated biota **(Palit *et al*., 2022)**. This assertion underscores the significant role of mangrove structure and density in shaping the ecological dynamics of these coastal habitats, as highlighted by Sari's findings. Furthermore, it emphasizes the importance of preserving and managing mangrove ecosystems to sustain biodiversity and support ecotourism activities in regions like Talengen Bay.

6. Mangrove tourism suitability index (MTSI)

The suitability of mangrove tourism considers five parameters, including mangrove thickness, mangrove density, mangrove type, tides and biota objects **(Ledheng *et al*., 2022; Ewaldo *et al*., 2023)**. The results of the calculation of the mangrove tourism suitability index for each transect, namely transect 1 is 2.63, transect 2 is 2.25, transect 3 is 2.63, transect 4 is 2.63 and transect 5 is 1.85, while the average value the mangrove tourism suitability index for the five transects is 2.398, and this value means that the talengen mangrove ecotourism area is categorized as suitable based on the published provisions. The ACC assessment is said to be suitable if it has a value of <2.0. The ACC assessment indicates that the Talengen Bay mangrove ecosystem is suitable for mangrove ecotourism. The calculated parameters, including mangrove types, thickness, density, tides, and associated biota, meet the necessary requirements, making the area ideal for development as an ecotourism attraction.

7. Regional carrying capacity (RCC)

The calculation of area carrying capacity in the Talengen Bay area involves assessing the length of the managed tracking routes by the local community. Utilizing Landsat Image 8 calculations, it was determined that the total area of mangrove forest in Talengen Bay spans 440,000 square meters, with the tracking route covering 4,500 square meters (Lp). Additionally, measurements of the tracking length revealed a distance of 300 meters (Lt). The time allocated for touring the attraction within a day is set at 10 hours (07:00-17:00 WITA) (Wt), with each visitor spending approximately 2 hours navigating the mangrove (Wp). Consequently, the area carrying capacity for Talengen Bay's mangrove ecotourism is estimated at 105 people per day. This calculation accounts for existing facilities such as gazebos, toilets, culinary offerings, washing areas, waste disposal facilities, and picturesque photography spots, with an entrance ticket selling at Rp. 5,000 per person.

The daily visitor count derived from area carrying capacity calculations serves as a crucial benchmark for regulating tourist influx, thereby mitigating adverse impacts on the ecological sustainability of the ecotourism site **(Jamin & Rahmafitria, 2022)**. This practice aligns with sustainable tourism principles by ensuring that visitor numbers are maintained at levels that the ecosystem can support without degradation. By implementing such measures, stakeholders **(Islamy, 2024ab)** can safeguard the long-term viability of Talengen Bay's mangrove ecotourism while simultaneously offering memorable experiences to visitors.

Table 2. Mangrove tourism suitability index (MTSI) result

Parameters	**Value weight**	**Transect 1**			**Transect 2**			**Transect 3**			**Transect 4**			**Transect 5**		
		C	**S**	**C*S**	**C**	**S**	**C*S**	**C**	**S**	**C*S**	**C**	**S**	**C*S**	**C**	**S**	**C*S**
Mangrove thickness	0.38	>200-500 (m)	3	1.14	50-200 (m)	2	0.76	>200-500 (m)	3	1.14	>200-500 (m)	3	1.14	50-200 (m)	2	0.76
Mangrove type density	0.25	>10-15 (100 m^2)	2	0.5	>10-15 (100 m^2)	2	0.5	>10-15 (100 m^2)	2	0.5	>10-15 (100 m^2)	2	0.5	5-10 (100 m^2)	1	0.25
Type of Mangrove	0.15	>5 (types)	3	0.45	>5 (types)	3	0.45	>5 (types)	3	0.45	>5 (types)	3	0.45	>5 (types)	2	0.3
Tidal	0.12	1.89	2	0.24	1.89	2	0.24	1.89	2	0.24	1.89	2	0.24	1.89	2	0.24
Biota objects	0.1	Fish, crabs, mollusks, birds	3	0.3	Fish, crabs, mollusks, birds	3	0.3	Fish, crabs, mollusks, birds	3	0.3	Fish, crabs, mollusks, birds	3	0.3	Fish, crabs, mollusks, birds	3	0.3
ACC				**2.63**			**2.25**			**2.63**			**2.63**			**1.85**
Category	**Sufficiently Sustainable**				**Sufficiently Sustainable**			**Sufficiently Sustainable**			**Sufficiently Sustainable**			**Less Sustainable**		
Average ACC	**2.398 (Sufficiently Sustainable)**															
Category (ACC) Yulianda 2019	**Appropriate = 2.0 < ACC < 2.5 Sufficiently Sustainable**															

Table 3. Area carrying capacity parameters

Parameter	Obtained data	Area carrying capacity
Ecological potential of visitors per unit area (persons)	1	105 persons/day
Usable area (m^2)	4500 m^2	
Area unit (area or length) for specific categories (m^2 or m)	150 m	
Time provided for activities in one day (hours)	7	
Time spent by visitors for each activity (hours)	2	

CONCLUSION

The types of mangroves found in the Talengen Bay mangrove ecosystem area include *Rhizophora Mucronata*, *Rhizophora apiculata*, *Bruguiera gymmnorhyza*, *Sonneratia alba*, *Avicennia marina* and *Nypa fruticans* and are dominated by *Rhizophora mucronata*. Based on the tourism suitability index (TSI) for mangrove ecotourism in the Talengen Bay mangrove ecotourism area, it is included in the suitable category with an average ACC value of 2.398. The carrying capacity of the mangrove forest area for tracking is 105 people/day.

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