

Article

Integration of Community-Based Tourism (CBT) Index and Biophysical Assessment for Sustainable Ecotourism Mangrove: A Case Study of Karangsong, Indonesia

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Abstract: Marine ecotourism is one of the pivotal sectors that supports the sustainability of marine ecosystems and elevates the socioeconomic status of the country. Karangsong is located on the northern side of the Indramayu districts, covering approximately 25 hectares of mangrove. The significant number of tourists visiting sites of mangrove ecotourism in Indonesia contributed to the tourist intentions associated with the diversity of mangrove and management strategies. How the community-based tourism (CBT) index aligns with biophysical assessment is still unclear. This study aimed to investigate the interconnectedness between the community-based tourism (CBT) index and biophysical assessment to measure the ratio number of tourists using the carrying capacity and sustainability index in Karangsong. A potential new suitability index for mangrove tourism was created. The various factors such as the mangrove ecosystem, substrate, and suitability that impacted the development of mangrove tourism were quantitatively analyzed. Our study identified that the majority of mangrove ecotourism sites in Karangsong Indramayu Regency consist of rich diverse mangrove species. The biophysical characteristics of the mangrove ecosystem were assessed with a suitability index of 83.7%. Our results indicated that the operations of mangrove tourism in the Karangsong region are well-managed and maintained. The region has a carrying capacity of 803 people/day, which refers to the maximum number of individuals for this area. This finding provides a more detailed understanding of the contribution of the new sustainability index of mangrove tourism and community-based tourism (CBT) approach assessing the potential development and challenges in the management of mangrove forests ecotourism.

Keywords: mangrove; ecotourism; coastal; marine tourism; CBT; coastal zone management; sustainability



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1. Introduction

Indonesia is an archipelago country that is enriched with a diverse marine ecosystem and marine biodiversity. The islands of Indonesia are dominated by various coastal characteristics, including sandy, rocky, cliffs, and mangrove forests. Recently, it was reported that Indonesia has roughly 17,466 islands, with only 16,065 islands registered in the United Nations [1]. Thus, the remaining 1401 islands need to be officially ratified by government consensus [2]. Coastal areas are defined as transitional regions between land and ocean. A coastal region has two boundaries or borders such as parallel borders to the coastline and a boundary that is perpendicular to the coastline (the area near the shore region of the coastline) [2,3]. Coastal areas contain valuable resources that can be utilized by communities to enhance their socio-economic livelihood through marine tourism [4,5]. Marine tourism holds significant importance as it plays a key role in the global tourism industry,

especially in coastal regions. Marine tourism has the potential to elevate the economic growth in local communities by increasing their natural maritime heritage. This can lead to various business opportunities in hospitality, recreation, and conservation efforts, ultimately benefiting both the economy and the people who live in the ecotourism area. There are two limitations that impact the coastline for marine tourism including long-shore (parallel to the coastline) and cross-shore (perpendicular to the coastline) [6]. Marine tourism in Indonesia is mostly concentrated in parallel borders, which have an impact on marine ecosystems due to the high concentration of tourism activities [7,8].

The coastal region of Indonesia has become a potential area for the tourism development sector, consisting of mangrove forest, seagrass meadow, and coral reefs [9]. The Indonesian total mangrove area is approximately 3.5 million hectares. Mangroves provide benefits to ecosystem by serving as a home to unique vegetation, terrestrial, and aquatic fauna, supporting the production of other marine ecosystems (e.g., photosynthesis, nutrient production), and regulate physical and ecological processes that occur in the mangrove environment [10]. Recently, the utilization of a potential mangrove ecosystem for ecotourism has widely attracted tourist interest in exploring the nature of mangrove ecosystems as a nature-based tourism destination [11,12]. The mangrove ecosystem is beneficial for elevating the socio-economics of local communities, as well as serving as a conservation tool to preserve the mangrove forest from damage [10].

Despite the mangrove forest attraction in Karangsang, there are many potential factors of Karangsang as an attractive destination related to ecotourism that can be developed including the beach and diving sites of corals' diversity [13–15]. Ecotourism emphasizes sustainable travel, environmental conservation, and educating travelers about nature. It encourages responsible visits to natural areas, aiming to protect the environment and benefit local communities. Conversely, 'Sun and Sea' tourism involves large numbers of tourists visiting coastal areas for leisure activities like sunbathing and swimming. This type of tourism follows seasonal patterns, with peak visits during favorable weather conditions, resulting in high visitor concentrations. The relationship between the two lies in their impact on destinations and communities. However, we first measure the index of tourism of mangrove forest destination that is essential to examine the factors in developing the attractiveness of the travel and tourism competitiveness in Karangsang. To date, there are 15 areas of ecotourism in Indonesia through the DMO (destination management operation) which were developed for tourist destinations including Pangandaran in West java, Tanjung Puting in East Kalimantan, Komodo Island in Flores, Raja Ampat in Papua, Toba Lake in North Sumatera, Bromo Tengger in Sumeru, Batur in Bali Island, Kota Tua in Jakarta, Rinjani in Lombok, Derawan in Kalimantan, Waktobi in Sulawesi, Bunaken in Manado, Toraja in Sulawesi, Sabang in Aceh [9]. The development of ecotourism and the provision of tourism infrastructure could impact the physical, social, cultural, and economic aspects of the environment. Therefore, the degradation of coastal and marine ecosystems due to overexploitation is a main concern in the context of utilizing resources for marine ecotourism. It is essential to adopt a management framework based on the carrying capacity formulation, which is crucial for the future development of marine ecotourism. This approach aims to formulate management directives conducive to sustainable marine ecotourism. However, Karangsang as a potential ecotourism destination through the index analysis has never been investigated.

Therefore, this research aims to evaluate the biophysical aspects, community involvement, and management potential of the mangrove forest in Karangsang as a possible world-class ecotourism destination. Additionally, the research involves assessing the tourism index using the carrying capacity (CCR) approach and evaluating the index for tourism destination development. We also expand our investigation to address the challenges surrounding ecotourism development in Karangsang. Furthermore, this research offers a comprehensive examination and data analysis of the various obstacles to ecotourism development in Karangsang, with potential implications for practitioners, entrepreneurs, and researchers seeking to develop Karangsang into a world-class ecotourism destination.

2. Materials and Methods

2.1. Study Area

Mangrove Ecotourism Karangsong, Karangsong Village, Indramayu Regency, West Java Province, Indonesia. Indramayu Regency is located at 107°52 east longitude, 108°36 (BT), and 6°15'–6°40' south latitude (LS). The Karangsong mangrove ecotourism is approximately 204,011 hectares, consisting of 31 administrative districts and 302 villages. According to the forest and plantation statistics conducted in 2017, it is among the most severely damaged mangrove ecosystems in West Java. Mangrove ecosystems are vital for the environment, community, and economy, and they have become increasingly popular as ecotourism destinations due to their unique biodiversity and the ecosystem services they provide. Ecotourism could facilitate the balancing of economic activity with conservation efforts. The mitigation efforts for mangrove ecotourism are beneficial to continuously conduct the conservation and restoration of mangrove forests. Based on the analysis of satellite image data, 1103 Ha were recorded in 2008, while 8023 Ha represent conservation forest [16]. Nevertheless, numerous mangroves developed from 2008 to 2017. A map of the mangrove location in Karangsong Indramayu is shown in Figure 1.

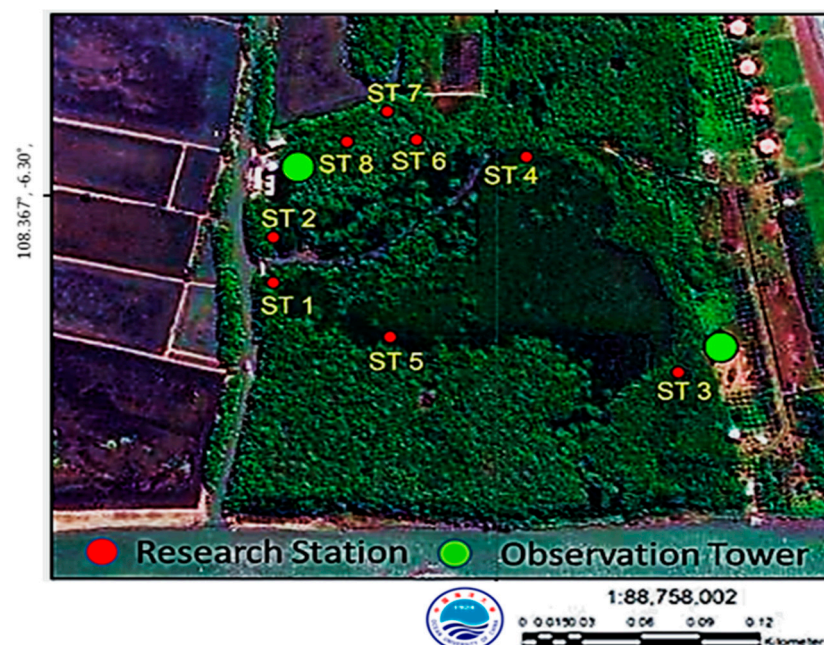


Figure 1. Research stations map of mangrove ecotourism, Karangsong.

2.2. Sampling/Selection

This research was conducted from January 2020 to August 2020. The sampling was conducted using cross-section lines by mapping the specific location of mangrove through a surveying approach. The section lines were drawn from the initial reference point to the outermost mangrove tree perpendicular to the coastline. The length of each transect line was 50 m. The sample cross lines are presented in Figure 2. The mangrove ecosystems' vegetation was analyzed to investigate the relative density of mangrove (Equation (1)). The equation is described below:

$$\text{Density(Ind/ha)} = \frac{\text{Number of individuals of one type}}{\text{Complete plot area}} \quad (1)$$

where Density is the unit of mangrove per hectare, a value of obtained from the number individuals of one type divided by the complete plot area.

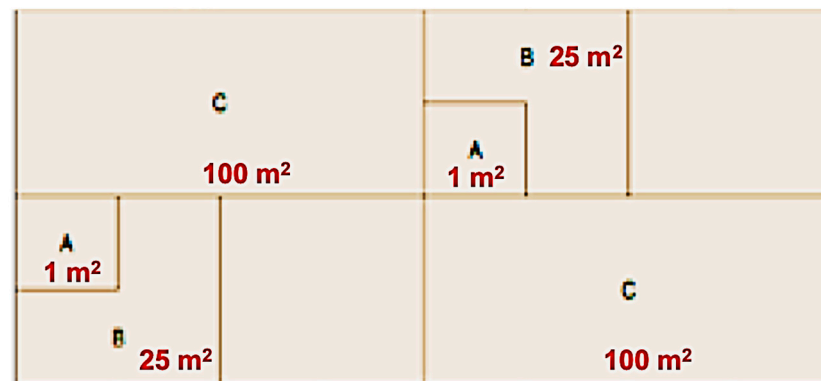


Figure 2. The design of sampling ecosystem. (A) Plot for seedling observation ($1\text{ m} \times 1\text{ m} = 1\text{ m}^2$), (B) Plot for stake observation ($5\text{ m} \times 5\text{ m} = 25\text{ m}^2$), (C) Tree observation plot ($10\text{ m} \times 10\text{ m} = 100\text{ m}^2$).

2.3. Analysis of Substrate

Substrate or sediment was collected from each research station. The samples were collected using a grab sampler and then inserted into a sample bag to analyze sediment particles. The method was conducted by using a sieve with large Wentworth particles following previous studies from [2,17] with some modification. The sediment analysis method was investigated at the Marine Science Laboratory of the Faculty Fishery and Marine Science University, Padjadjaran. The method used for substrate classification followed the previous procedures of [2,17] with some modification.

2.4. Measurement of Carrying Capacity Region (CCR) in Karangsong Mangrove

In this study, the CCR method was used to calculate the supporting power of natural ecotourism development using the concept of the region's carrying capacity (CCR). The CCR represented the maximum number/ population of visitors in the area provided at any given time without causing interference with nature and humans that can be supported or sustained by an ecosystem over time [18–20]. The calculation of CCR was formulated using the Yulianda proposed modification of the CCR model [21].

$$\text{CCR} = K \times \frac{L_p}{L_t} \times \frac{W_t}{W_p}$$

where CCR (carrying capacity region) can be calculated with the parameter of K viewed as the maximum number of visitors per unit area. The K coefficient of carrying capacity refers to the maximum number of visitors a destination can accommodate without compromising the quality of the tourist experience or causing irreversible harm to the environment, society, culture, or economy. It serves as a crucial measure of tourism's impact on space and the environment.

The length of area L_p is the area or length of the area that can be utilized, L_t is the unit area for a specific category, W_t is the time provided by the area for travel activities in one day, and W_p is the time spent by visitors for each specific activity.

2.5. Data Analysis

Data analysis used the statistical descriptive analysis approach. The analysis demonstrated the mangrove biophysical parameters in a table prior to the new suitability index for mangrove tourism and the optimum number of visitors in the mangrove tourism area. The mangrove suitability index in Karangsong was determined based on the 10 criteria, including density, mangrove species, thickness mangrove, association biota, long of river, wide of river, depth of river, substrates, tourist facility, and tourist attributes. Tourist facilities and attributes indicators are described to measure the total amount of well-developed infrastructure necessary for sustainable tourism management in ecotourism areas for tourists.

3. Results

3.1. The Density of the Karangsong Mangrove Ecosystem

The efforts to protect the Karangsong mangrove forest were initiated in 2008. The area of the Karangsong mangrove covers approximately 25 hectares. Our study assessed the mangrove density at eight stations in the Karangsong mangrove area. Our results revealed that the dominant mangrove species in the area were *Avicennia* sp. and *Rhizophora* sp. (Figure 3). Among the stations, Station V exhibited a high density, while the remaining stations were classified as damaged forests due to their density being less than 1200 trees/ha (Table 1). Despite improvements in mangrove density and quality over the years, the Karangsong mangrove forests are still expanding. However, the low density of vegetation and limited number of mangrove species in the waters of Karangsong pose a threat to the ecosystem.

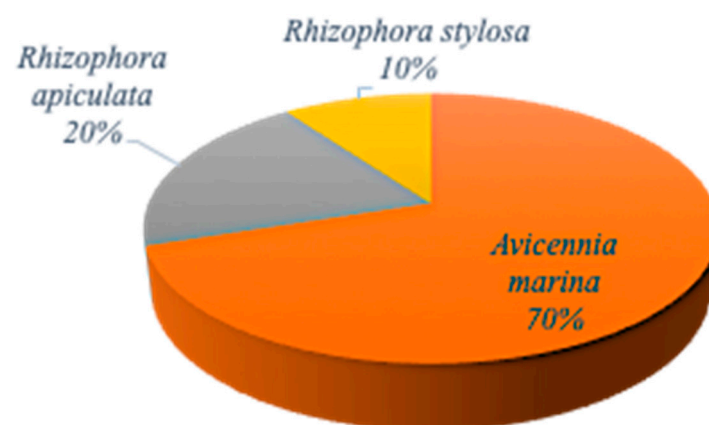


Figure 3. Composition of mangrove species in the Karangsong mangrove forest.

Table 1. The measurement of mangrove density in the Karangsong mangrove forest. Asterisk (*) symbol represents the largest density area.

Stations	Density (Tree/Ha)	Major Mangrove Species
1	1060	Avicennia sp.
2	390	
3	580	
4	640	
5	1200 *	
6	1080	
7	880	
8	940	

To address this issue, it is crucial to promote a general understanding of mangrove ecosystems and disseminate knowledge about their importance. The efforts of mangrove conservation can play a vital role in encouraging key decision-makers to prioritize the sustainability of these valuable ecosystems [22].

3.2. Water Quality and DO (Dissolved Oxygen) Characteristics in Karangsong Mangrove Forest

This study was conducted in the mangrove forest area of Karangsong, which is a designated conservation reserve located in the village of Karangsong, Indramayu District. Our study focused on observing the characteristics of the habitat ecosystem by measuring water quality parameters and substrate types. In recent study, we measured water quality and assessed substrate characteristics at each sampling station with three replicated measurements. Our findings revealed that the temperature ranged from 28.5 °C to 31 °C across the sites (Table 2). Generally, the temperature at each site was consistent and within the normal range to support the mangrove ecosystem. The highest water temperature

of 31 °C was recorded at Station I, indicating relatively warm water compared to other stations. Conversely, the minimum water temperature of 28.5 °C was observed at Station II, suggesting relatively cooler water compared to other stations. These temperature variations across different stations provide strong evidence of spatial differences in water temperature within the Karangsong ecosystem.

Table 2. The measurement of water quality and substrate characteristics.

Criteria	Station							
	I	II	III	IV	V	VI	VII	VIII
Temperature (°C)	31	28.5	30.5	30	30	29	30	30
Salinity (‰)	29	27	28	28	29	28	28	28
DO (mg/L)	6.4	5.2	5.7	5.3	5.4	5.5	5.3	5.3
pH (unit)	7.5	7.4	7.33	7.5	7.4	7.5	7.4	7.4
Type of Substrate	Muddy	Sand	Sand	Sand	Sand	Sand	Sand	Sand

Water salinity is an important factor that affects the growth, survival, and zoning of mangrove species. Our result showed the salinity readings for Stations I–VIII ranged from 27‰ to 29‰. (Table 2). Salinity changes are influenced by a mixture of fresh and seawater. The second station, located on the ship dock and accessible to tourists, had the lowest salinity and was closer to the land. Our results showed lower salinity compared to Station III along the sea, indicating that the mangrove ecosystem in Karangsong is considered a brackish area. It is worth noting the optimal salinity for mangrove growth is within the range of 10–30 ppt [23], and the salinity in Karangsong falls within this range. The dissolved oxygen (DO) values for Stations I–VIII ranged from 5.2 to 6.4 mg/L, which is the minimum threshold. The highest DO value was found at Station I, while the lowest DO value was found at Station II. The content of dissolved oxygen in water is crucial for the survival of aquatic organisms. Oxygen solubility is influenced by water temperature and salinity. It has been reported that mangroves can survive under conditions where the oxygen content exceeds 4 mg/L [24]. However, as temperature and salinity increase, oxygen solubility decreases. It is important to note that DO measurements conducted in the morning may yield lower results due to the absence of photosynthesis and the prevalence of respiratory processes. Acidity, represented by pH, also plays a significant role in the life of mangroves, as it affects the availability of nutrients for vegetation. The pH values of the water at the mangrove stations were within the suitable range for mangrove plants, typically ranging from 5 to 8.5. Station I had a maximum pH of 7.5, while Stations III to VIII had a minimum pH of 7.33 (Table 2).

3.3. Karangsong Mangrove Forest Substrates

The substrate identification results are provided in Table 3. The substrate analysis used statistical descriptive analysis incorporating collection data and the observation of substrate texture. At Station I, the observed substrate consists of mud sand, with 0.1% gravel, 74.3% sand, and 25.6% mud. Station II exhibits a sand substrate comprising 0% gravel, 82.9% sand, and 17.1% mud. Station III shows a sand substrate consisting of 0% gravel, 96% sand, and 4% mud. Similarly, at Station IV, the substrate is primarily sand, with no gravel, consisting of 93.6% sand and 6.4% mud. Station V has a sand substrate of 96% sand and 4% mud, while Station VI has a substrate composition of 93.5% sand and 6.5% mud. Station VII consists of 95% sand and 5% mud, and Station VIII comprises 95.5% sand and 5% mud. Our result showed that the Karangsong mangrove vegetation soil grows better in the mud sand texture.

Table 3. Result of substrates found in the Karangsong mangrove forest.

Station	Textures			Class of Textures
	Gravel (%)	Sand (%)	Muddy (%)	
I	0.1	74.3	25.6	Mud sand
II	0	82.9	17.1	Sand
III	0	96	4	Sand
IV	0	93.6	6.4	Sand
V	0	96	4	Sand
VI	0	93.5	6.5	Sand
VII	0	95	5	Sand
VIII	0	95	5	Sand

3.4. Biota Association in Karangsong Mangrove Ecosystem

The five types of biota found in Karangsong, Indramayu, are closely associated with mangroves. The data collected for this research comprise 17 subgroups representing these five types (Table 4). The presence of various species, including fish, crabs, mollusks, reptiles, and birds, within the mangrove forest enhances the appeal of the habitats in Karangsong, Indramayu. Aquatic wildlife inhabiting the area includes (a) water-dwelling animals, such as various fish and shrimp species, and (b) substrate-dwelling animals, particularly crabs, shells, and various invertebrates [2]. The existence of these diverse biota contributes to the ecotourism potential development in the Karangsong mangrove forest. Protecting the biota residing in the mangrove area is crucial. The mangrove community plays a vital role in the growth, reproduction, feeding, and spawning of these organisms, while also serving as a source of nutrition for wildlife. This interaction with coastal human communities often becomes an economic commodity [2].

Table 4. The biota association in the Karangsong mangrove ecosystem.

No.	Organisms	Type of Biota
1	Fish	Gelodok fish (<i>Periophthalmus</i> sp.); Mullet fish (<i>Mugil dosumieri</i>)
2	Crustacean	Mangrove crab (<i>Scylla serrata</i>); Violin crab (<i>Uca</i> sp.)
3	Mollusc	Conus shell (<i>Conus</i> sp.); <i>Cassidula aurisfelis</i> ; <i>Cerithidea cingulate</i> ; <i>Cerithidea Pomacea</i> ; <i>Telescopium</i> sp.; Mangrove shell (<i>Polymesoda bengalensis</i>)
4	Reptile	Monitor lizard (<i>Varanus salvator</i>); Mangrove snake (<i>Chrysosopolea</i> sp.); Lizard (<i>Emoia crotostata</i>)
5	Bird	White Heron (<i>Bubulcus ibis kuntul</i>); Blekok (<i>Ardeola speciose</i>); Curek (<i>Calidris ruficollis</i>); Kuntul (<i>Egretta intermeding</i>)

Mangrove ecotourism in Karangsong aims to educate tourists and aligns closely with the principles of conservation. The general public receives comprehensive information on the biodiversity found in the mangrove area, including the lifestyles, habits, breeding patterns, habitat formation, and aesthetic beauty of various animals and plants [2]. This knowledge dissemination creates a sense of joy and appreciation. The biophysical relationship with mangrove ecosystem suitability can be explained through the use of a suitability matrix and descriptive analysis that considers parameters such as the density, type, thickness, width, and length of the relevant rivers and substrates [21] (Table 5). Furthermore, this activity can serve as a monitoring tool to prevent the exploitation of mangrove wood and to preserve and protect natural vegetation.

Table 5. The result of suitability matrix for mangrove ecosystem. Maximum suitability value = 98. S1 = Very suitable, with a value 80–100%; S2 = Suitable, with a value 60–80%; S3 = Conditional fit, with a value 35–60%; N = Not suitable, with a value < 35%; Ni = Criteria values to – i (Weight × Score); Nmaks = maximum value from the mangrove tourism category (98).

No	Criteria	Weights	Score 4	Score 3	Score 2	Score 1
1	Density (ind/100 m ²)	3	>15–25/100 m ²	>10–15/100 m ²	5–10/100 m ²	<5/100 m ²
2	Mangrove species	5	>5	3–5	1–2	0
3	Thickness of Mangrove (m)	3	>500 m	>200–500 m	50–200 m	<50 m
4	Associated Biota	5	4	3	2	1
5	Length of River (km)	1	>3 km	3 km	2 km	1 km
6	Width of River (km)	1	>500 m	201–500 m	4–200 m	<4 m
7	Depth of River (m)	3	>3–5 m	>2–3 m	1–2 m	<1m
8	Substrate	1	Rugged, medium and fine sand	Rugged, and medium sand	Fine sand	Common sand
9	Tourist Facility	3	Toilet, restaurant, assesories shop, meeting point, resting point/praying room	Toilet, restaurant, meeting point, resting point/praying room	Toilet, restaurant, meeting point	Toilet, meeting point
10	Tourism Attributes	2	Information board, map of location, sign direction, lighting	Information board, map of location, sign direction	Information board, map of location	Information board

3.5. Assessment Index for Tourist Destination Development

The suitability index results for the mangrove ecosystems, as presented in Table 6, indicate that the research sites in Karangsong have high potential as tourist destinations. With a mangrove ecotourism index of 83.7%, Karangsong is considered an ideal location for planning mangrove tourism, ensuring a satisfying and enjoyable experience for tourists. The presence of mangrove tourism in Karangsong can contribute to the preservation and conservation of the mangrove ecosystem while offering visitors a unique tourist destination. In terms of facilities, it is essential to address certain shortcomings, particularly regarding toilets and meeting points in Karangsong mangrove forest, Indramayu. The existing toilets are often traditional and not consistently clean, posing challenges for some tourists. Therefore, adequate clean water supply is also a primary concern for the tourist destination development system. To address these issues, the questionnaire administered to tourists identified the weaknesses in the current tourist facilities. Tourists expressed their preference for clean and well-maintained toilets and a reasonable number of meeting points within the area.

Mangrove tourism, as a form of ecotourism, offers a range of appealing activities to attract tourists from around the world. These activities may include bamboo trail walks, bird watching, beach trips, exploring the biota, and boat trips [2]. Ecotourism combines sustainable tourism practices with the utilization of natural resources in a manner that generates revenue, fosters an appreciation for traditional culture and the environment, and promotes education. It also encourages the participation of local communities dedicated to protecting natural resources and the environment [25]. Local communities in Karangsong mangrove actively engaged in wildlife protection and habitat restoration activities.

Table 6. Score of suitability area matrix of the Karangsang mangrove ecosystem.

No	Criteria	Weight	Result	Score	Weight × Score
1	Density (ind/100 m ²)	3	8.25	3	9
2	Mangrove species	5	3 species	3	15
3	Thickness of Mangrove (m)	3	>500 m	4	12
4	Associated Biota	5	5 species biota (fish, <i>Crustacea</i> , Moluska, reptile, bird)	4	20
5	Substrate	1	Coarse, medium, and fine sand	4	4
6	Length of River (km)	1	2 km	2	2
7	Width of River (km)	1	4–200 m	2	2
8	Depth of River (m)	3	>2–3 m	3	9
9	Tourist Facility	3	Toilet, meeting point	1	3
10	Tourist Attributes	2	Information board, map of location, sign directions,	3	6
					Total = 82
IKW = $\Sigma(N_i/N_{maks}) \times 100\% = 83.7\%$					

3.6. Carrying Capacity Region (CCR) in Karangsang Mangrove Tourism Destination

The broad calculations and analysis of the ecotourism maps indicate that the mangrove forest in Karangsang can accommodate a tour track of 1.4 km (Lt) within a land area of 25 hectares (Lp). According to the potential ecological and temporal prediction table [21], it is observed that for a 50 m (Lt) runway, the combined unit area of potential ecological visitors (K) for mangrove tourism is 1 person. Visitors typically spend 2 h (Wp) on the mangrove forest tour, while the average time available in the region during a day is 9 h (Wt). Based on these calculations, the tourist carrying capacity (CCR) of the Karangsang ecotourism mangrove in the ecotourism zone is estimated to be 803 people per day. This capacity allows for the provision of necessary facilities such as toilets, mushola (prayer hall), rinsing rooms, and a watchtower. It is important for maintainers to consistently focus on the maintenance of bamboo tracks/roads in the surrounding area of the ecotourism mangroves.

To ensure a satisfactory experience for the daily influx of 803 people and to accommodate potential increases, particularly on weekends, it is advisable for the management to provide various activities and distribute tourists across different destinations. The utilization of coastal areas and sandy beaches, as well as the addition of other activities within the ecotourism area, can help to prevent overcrowding. Additionally, the management may consider implementing limits on the number of incoming tourists on certain days, such as Sundays, to preserve the environment of the mangrove forest. Typically, between 500 and 600 people visit on Sundays/weekends, requiring special attention from the management to maintain the quality of the mangrove environment. Facilities and infrastructure play a crucial role in supporting the successful development of the region [11,26]. The carrying capacity region (CCR) value serves as an indicator for tourism potential and sustainable tourism management. The selection and planning of tourism activities should be aligned with the available resources, focusing not only on mangroves but also on other habitats. Ecotourism should be consistent with environmental protection, community participation, economics, education, and sustainability [27]. Sustainable ecotourism encompasses environmental, social and cultural, and economic sustainability [28]. Considering scientific evidence and knowledge transfer, politics should be guided by scientific information [28].

4. Discussion

4.1. Biophysical Characteristics of the Karangsang Mangrove Forest

We observed that the highest composition of mangrove species (trees) at the observation site is *Avicennia marina* which amounts to 70% of the total number of trees at the observation site. *Rhizophora apiculata* represents 20%, while the lowest is *Rhizophora stylosa* at 10% of the total. Progressive changes in sediments and habitats can affect mangrove zoning. The availability of propagule is suspected to have an impact on the reproductive process. If the environmental conditions are met, the mangroves will be able to complete the reproduction process. This is related to mangroves' ability to adapt to extreme conditions, such as a new mud eruption which will be dominated by the plants whose propagation is highest in that place [29]. Furthermore, our results showed lower salinity compared to Station III along the sea, indicating that the mangrove ecosystem in Karangsang is considered a brackish area. It is worth noting that the optimal salinity for mangrove growth is within the range of 10–30 ppt, and the salinity in Karangsang falls within this range [23].

Our study showed the temperature difference may be due to changes in sunlight intensity. Station III is at the highest temperature because it is near the beach and in an open area, so Station III has a high light intensity, whereas Station I is located in the dock area of the ships and is covered and closed, so the light intensity is low. The temperature measured throughout the site is within the mangrove ecosystem tolerance threshold, and the mangrove ideal seawater temperature is 28–32 °C. Generally, the temperature at each site is in a range that supports marine biota life such as mangrove crabs (*Scylla serata*) and violin crabs (*Uca* sp.) [24].

The pH range observed at the four stations are consistent with the suitable range of mangrove ecosystem (Table 2). The pH values of the substrate at the survey site also support mangrove life. The substrate identification procedure revealed that Station I has a sand substrate, while Stations II–VIII have sand substrates as well. Although mangroves mainly grow in mud, these marine plants can also thrive in various types of substrates such as sand, coral, gravel, and even peat soil [30]. Sand substrates dominate throughout the stations located in Karangsang. The characteristics of the substrate play a significant role in limiting the growth and distribution of mangroves. The distinct physical characteristics and soil chemistry contribute to variations in zoning [31]. The presence of fine sand and mud substrates supports the well-developed growth of mangroves in the research site. The sand substrate dominates all sites in Karangsang due to its proximity to the mainland. The high percentage of sand spread throughout the survey site can be attributed to its proximity to the mainland. As a result, the sand is carried away by the river and rainwater streams. The characteristics of substrates play a crucial role in limiting the growth and distribution of mangroves.

4.2. Management Assessment of the Karangsang Mangrove

Planning and managing mangrove ecosystems for tourism requires the involvement of the local government and manager community-based tourism (CBT) of Pantai Lestari. The criteria for mangrove tourism are established based on the existing condition of mangrove ecosystem conditions, including various species, substrates, tourism facilities, and biota inhabiting the ecosystem [32–34]. Here, mangrove tourism can be classed as ecotourism because tourists receive education from a person from CBT or the manager and tourists can also read all the information from the information board, so that tourists in addition to enjoying the scenery also receive information on how this mangrove ecosystem can grow and know what fauna can live in the mangrove ecosystem [34–36].

Community involvement is essential for the environmentally friendly management of the mangrove ecosystem in ecotourism. The concept of ecotourism itself emphasizes the importance of community engagement in protecting, maintaining, and managing the mangrove ecosystem [37,38]. Local communities in the Karangsang mangrove forest actively engage in wildlife protection and habitat restoration activities. In Karangsang's mangrove ecotourism, the local community organization called "Pantai Lestari" plays a

vital role in its management. Community-based tourism (CBT), such as Pantai Lestari, is considered crucial for achieving sustainable ecotourism [39]. It is widely acknowledged that the community can benefit from long-term sustainable tourism, making the management of CBT beneficial for both the community and ecotourism as a whole [40–43]. However, it is important to reduce the community's dependence on direct incentives to ensure the long-term sustainability of the mangrove ecosystem. One approach is to provide micro-credit to develop small-scale businesses related to mangrove or fishery products. This credit can be provided as a reward for successful rehabilitation and management efforts [44].

By planning and maintaining tourism development through CBT, a more sustainable tourism industry can be created, with a focus on community well-being [40] and community empowerment through tourism, including increasing revenue, expanding employment opportunities, improving social justice, preserving cultural identity, and ensuring environmental sustainability [45]. It is worth noting that as awareness of ecotourism increases globally, there is a need to address potential environmental threats associated with ecotourism and ensure the preservation of natural resources for future generations [46]. In the case of Karangsang mangrove tourism, community-based tourism (CBT) plays an important role. Nevertheless, to attract more tourists and foster the societal development of the area, it is necessary to focus on enhancing the conservation efforts and developing robust infrastructure. This approach will help to preserve the mangroves as a cultural and heritage site, ensuring their long-term sustainability and appeal to visitors. By considering all aspects of mangrove ecotourism, Karangsang can become a thriving destination that satisfies visitors while maintaining its environmental integrity.

4.3. Implication of Development Karangsang Mangrove for Ecotourism

The carrying capacity region in the Karangsang mangrove forest is 803 people/day, demonstrating the potential development for ecotourism. The biophysical elements in the Karangsang mangrove ecosystem make it remarkably valuable as a potential ecotourism destination that requires well-maintained efforts. It has been reported that the development of the ecotourism sector, its various stakeholders, and their involvement can greatly enhance the development of the mangrove ecotourism area in Karangsang and the benefits of the tourism industry, particularly ecotourism, in contributing to environmental conservation efforts [47]. These benefits include:

- A. **Financial Contributions:** Tourism revenue can be directly used by tourism managers for conservation efforts. Funds can be collected from tourists or operators to finance the maintenance or rehabilitation of mangrove, employee salaries, and the establishment of security systems. Indirect taxes from tourist arrivals can also be utilized by the government to support research, conservation programs, and infrastructure development. The taxes generated by tourist sites are managed by the government and distributed to local communities according to governmental regulations.
- B. **Planning and Environmental Management:** Ecotourism can involve local residents and allow for more flexible economic planning. Planners can work to prevent loss or damage to environmental assets in and around the mangrove ecotourism area of Karangsang.
- C. **Raising Awareness and Environmental Protection:** Ecotourism has the potential to connect communities with nature and increase environmental awareness. The development of ecotourism activities can significantly contribute to environmental protection efforts at the local level.
- D. **Alternative Employment Opportunities:** Ecotourism services provide alternative employment opportunities, offering specific types of work. Involving the local community in ecotourism activities is an important aspect of sustainable management. This can help to reduce practices such as mangrove destruction for firewood and other damaging activities resulting from a lack of job options.
- E. **Regulation and Institutionalization:** Ecotourism services should operate in an organized, procedural, and measurable manner. Clear rules and regulations are necessary

to control and limit the activities of tourists, operators, and other stakeholders according to conservation guidelines.

UNESCO and The International Ecotourism Society (TIES) have proposed principles for sustainable ecotourism development. These principles emphasize providing quality experiences and education to visitors, minimizing negative environmental impacts, involving the community in tourism management, providing economic incentives to local communities, and ensuring long-term survival and sustainability [48] (Table 7). There are two standards for dealing with ecotourism: environmental protection and institutional management. Environmental protection includes aspects such as waste management, law enforcement, and improved ecotourism practices [49–51]. Institutional management involves operational planning, institutional coordination, capacity building, economic benefits, and community involvement. The principles for tourism attraction development include upholding religious and cultural values, achieving a balance between development and management efforts, and focusing on conservation for sustainability [11]. To achieve sustainable development of mangrove ecotourism in Karangsang, cooperation between communities, academic institutions, and the government is crucial. This collaborative approach can help to ensure the preservation and sustainable use of resources while providing economic benefits and maintaining cultural and environmental sensitivities.

Table 7. Summary of marine ecotourism development assessed through CBT and biophysical assessment in the world.

No.	Mangrove Ecotourism	CBT and Biophysical Assessment Activities	Location	Source
1	Mangrove Ecotourism Suitability in Sampang	- The mangrove area has a high tourism suitability index - This area exhibits promising potential for transformation into a marine ecotourism destination	Taddan Village, Camplong Subdistrict, Sampang Regency, Indonesia	[52]
2	Mangrove Ecotourism Suitability in view of Biogeophysical Aspect	- The mangrove ecosystem area demonstrates significant potential for ecotourism development, as indicated by the results of tourism suitability analysis - Gonda Beach is classified as highly suitable for mangrove ecotourism, supported by its diverse range of mangrove species and biota, including <i>Bruguiera gymnorrhiza</i>, <i>Rhizophora stylosa</i>, <i>Rhizophora apiculata</i>, <i>Ceriops tagal</i>, <i>Sonneratia alba</i>, <i>Avicennia alba</i>, <i>Avicennia marina</i>, <i>Xylocarpus granatum</i>, and <i>Xylocarpus moluccensis</i>, as well as various fish, reptiles, birds, and crabs	Laliko Village, Campalagian District, Polewali Mandar Regency, Indonesia	[53]
3	The Suitability Index of Mangrove Tourism in the Coastal Area around Budo Village	- Six mangrove species identified: <i>Rhizophora mucronata</i>, <i>Rhizophora apiculata</i>, <i>Bruguiera gymnorrhiza</i>, <i>Sonneratia alba</i>, <i>Avicennia marina</i>, and <i>Nypa fruticans</i> with density ranging from 6.2 ind/100 m² to 11.8 ind/100 m² - Mangrove-associated biota include fish, shrimp, crabs, mollusks, birds, and reptiles - Average tourism suitability index recorded at 54.6%, categorized as “conditionally suitable” - Carrying capacity of Budo Village mangrove tourism area: 116 people/day, operational for 14 h/day	Budo Village, Wori Subdistrict, North Minahasa Regency in North Sulawesi, Indonesia.	[54]

Table 7. Cont.

No.	Mangrove Ecotourism	CBT and Biophysical Assessment Activities	Location	Source
4	Mangrove Forest Ecotourism Suitability in Jailolo Bay Area	- Average tourism suitability index (IKW) determined at 63.5%, categorized as “suitable” - Carrying capacity of mangrove tourism areas in Jailolo Bay: 150 people/day, operational for 12 h/day - Factors influencing mangrove ecotourism suitability in Jailolo Bay: mangrove thickness, type, density, and associated biota	Jailolo Bay area, West Halmahera Regency, Indonesia.	[55]
5	Mapping Ecotourism Potential in Bangladesh	- Various areas in Bangladesh, including Cox’s Bazar, Chittagong, Rangamati, Khagrachhari, and the mangrove region are identified as highly suitable for ecotourism development - Challenges such as the scarcity of limited clean water in coastal areas of Bangladesh and the necessity for integrating safety and security concerns with the mapping of future ecotourism potential have been recognized	Bangladesh	[56]
6	Management of Community Spaces Influenced by Mangrove Conservation and Tourism in Mexico	- Integrating management, conservation, and tourism aspects offers multiple benefits for both the mangrove environment and local communities - A balanced approach fosters conservation awareness and simultaneously creates economic opportunities within the tourism sector	Mexico	[57]
7	Mangrove Restoration to Reduce the Climate Change Impacts on Ecotourism	- Majority of individuals in the Rekawa Coastal Wetlands express willingness to contribute financially to mangrove restoration programs - Factors such as awareness of climate change impacts, recognition of ecotourism benefits, and dependence on mangrove ecosystems influence the extent of willingness to pay - This suggests that implementing mangrove restoration programs can be facilitated with financial backing from the local community	Rekawa, Sri Lanka	[58]
8	Remote Sensing Supports Mangrove Ecosystem Service Valuation in Ca Mau Province, Vietnam	- Economic benefits from mangrove ecosystem services in Ca Mau province, Vietnam, including fisheries, erosion control, carbon sequestration, and timber, total USD 622 million - These benefits are derived from an area coverage of 187 hectares - Proper management of these resources while maintaining environmental balance can significantly improve the quality of life for the local population	Ca Mau Province, Vietnam	[59]
9	Mangroves of Japan	- The total area of mangroves in Japan is 870 ha, less than 0.01% of the country’s total forest area, yet they are protected and are increasing in size and importance for tourism - Mangroves in Japan have significant species diversity, including Rhizophora, Kandelia, and Bruguiera - The conservation status of mangrove forests in Japan varies, with some areas facing threats from coastal development and climate change - The ecological roles of mangrove forests in Japan include coastal protection, carbon sequestration, and habitat for various species	Japan	[60]

Table 7. Cont.

No.	Mangrove Ecotourism	CBT and Biophysical Assessment Activities	Location	Source
10	Sustainability Assessment of Mangrove Forest as a Tourist Destination using GSTC Criteria	- Mangrove conservation efforts in the study area are ongoing, with a focus on sustainable management and economic benefits - Sustainable management and economic benefits exhibit the majority of indicators for sustainability within the conservation efforts - Despite progress, certain conservation efforts may require formalization to enhance effectiveness - Recommendations have been proposed based on identified gaps, aligning with the GSTC guidelines	Kota Belud, Sabah, Malaysia	[61]

5. Conclusions

The development of sustainable mangrove ecotourism must rely on ecological information. Conversely, ‘Sun and Sea’ tourism often leads to issues like over-tourism and environmental harm due to its mass appeal; ecotourism aims to address these concerns by encouraging off-peak travel, offering diverse activities, and prioritizing environmental conservation. Essentially, ecotourism complements ‘Sun and Sea’ tourism by providing sustainable alternatives that strive to balance economic growth with environmental preservation and social well-being. In the areas studied, ecotourism was properly managed and supported by local communities and governments. As a result, environmental damage can be reduced and the mangrove ecosystem as a tourist destination can be made sustainable. The suitability index for mangrove tourism is 83.7%. There are two standards for dealing with ecotourism. The first point is environmental protection, including material recovery, law enforcement, and improved ecotourism. Second, institutional management, including operational planning, institutional management, capacity and coordination, economic benefits, and community involvement, is important. Carrying capacity assessment could facilitate the measurement of marine ecotourism development. Implementing this approach aims to mitigate the degradation of mangrove forests and sustain restoration efforts. Consequently, it can enhance the natural maritime heritage, creating opportunities in hospitality, recreation, and conservation efforts. Therefore, the benefits both the economy, ecosystem, and the residents of the ecotourism area can be sustained.

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