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Ecological Suitability and Environmental Carrying Capacity Analysis for Sustainable Mangrove Ecotourism Development in Tungkal 1 Village, Jambi Province

[1]Utomo Soconingrat*, [2]Hutwan Syarifuddin, [3]Hamzah
[1]Master of Environmental Science, Graduate School, Universitas Jambi, Indonesia*;
email: utomosoconingrat@gmail.com
[2] Master of Environmental Science, Graduate School, Universitas Jambi, Indonesia
[3] Department of Forestry, Faculty of Agriculture, Universitas Jambi, Indonesia
*Correspondence

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Abstract
Introduction: *Mangrove ecosystems provide essential ecological, economic, and social functions along tropical coasts. In Tungkal 1 Village, West Tanjung Jabung Regency, Jambi, two mangrove areas, Pangkal Babu and Kelapa Beach, have been developed as ecotourism destinations since 2019 and 2023, respectively, with visitor numbers rising from 180 in 2020 to 22,609 in 2023 at Pangkal Babu alone. Uncontrolled visitation without prior suitability and capacity assessment risks damaging the very ecosystem that sustains the tourism activity.* ***Objective:*** *This study analyzed the tourism suitability and visitor carrying capacity of both mangrove ecotourism areas.* ***Method:*** *Primary data on mangrove thickness, density, species composition, tidal range, and associated fauna were collected using 100–120 m line transects across three stations at Kelapa Beach and four at Pangkal Babu, then analyzed with the Tourism Suitability Index (IKW) and Carrying Capacity (DDK) formulas of Yulianda (2019).* ***Results and Discussion:*** *Kelapa Beach obtained an IKW of 1.75 (Not Suitable), limited mainly by its 121 m mangrove thickness, while Pangkal Babu obtained 2.76 (Very Suitable), supported by 669 m thickness, 338 ind/100 m² density, and ten mangrove species. Carrying capacity reached 200 visitors/day at Kelapa Beach and 255 visitors/day at Pangkal Babu, with mangrove tracking contributing the largest share at both sites (63% and 74.5%).* ***Conclusions:*** *Pangkal Babu is ecologically ready for intensified, capacity-bound ecotourism development, whereas Kelapa Beach requires mangrove rehabilitation before further tourism expansion.*

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Introduction

Mangrove ecosystems provide essential ecological, economic, and social functions, including protection against erosion and flooding, habitat for aquatic species, and carbon storage (Nijamdeen et al., 2023). The Indonesian government has committed to restoring 600,000 hectares of mangroves by 2024 as part of national conservation efforts (Walhi, 2023). This policy supports the development of mangrove-based ecotourism, which integrates environmental conservation with improved well-being of coastal communities (Damiasih, 2017). Maintaining coastal environmental quality is therefore important because mangrove degradation may reduce ecosystem services and increase risks to coastal livelihoods and community health. Tanjung Jabung Barat Regency, Jambi Province, has two mangrove ecotourism sites in Tungkal 1 Village: Pangkal Babu, inaugurated in 2019, and Kelapa Beach, inaugurated in 2023. Visitor numbers at Pangkal Babu increased sharply from 180 in 2020 to 22,609 in 2023. Without adequate ecological suitability assessment and carrying capacity regulation, this growth may increase pressure on mangrove ecosystems and raise the risk of coastal pollution from solid waste, wastewater, and other tourism-related activities

Area suitability refers to the appropriateness of a mangrove area for ecotourism development, evaluated using parameters such as canopy thickness, stand density, mangrove species composition, tidal patterns, and associated biota (Kadriansari et al., 2017; Wulandari et al., 2024). Carrying capacity refers to the maximum number of visitors an area can support without compromising its ecological functions, as stipulated by Law No. 32 of 2009 on the Protection and Management of the Environment and by Regulation of the Minister of the Environment No. 17 of 2009 on Guidelines for Determining Environmental Carrying Capacity. These two parameters are interdependent. An area that is ecologically suitable for ecotourism may not necessarily possess a high carrying capacity, as carrying capacity is also influenced by environmental sensitivity and the effective area available for tourism activities (Falih et al., 2025).

Ecotourism is distinguished from conventional mass tourism by its emphasis on environmental conservation and local community empowerment as fundamental prerequisites rather than supplementary considerations (Damiasih, 2017). This principle is particularly important in coastal areas because healthy mangrove ecosystems contribute to maintaining water quality and fisheries resources, thereby supporting food security, livelihoods, and the health of coastal communities. Conversely, environmental degradation and pollution associated with poorly managed tourism can reduce these ecosystem benefits and potentially increase community exposure to unhealthy coastal conditions. Accordingly, decisions to establish or expand mangrove ecotourism areas should be grounded in objective assessments of ecological conditions, rather than being driven solely by potential attractiveness or market demand. In the absence of such assessments, ecotourism management may inadvertently contribute to the degradation of mangrove resources, as observed in several rapidly developing coastal tourism areas lacking adequate carrying capacity planning.

Extensive research on the suitability and carrying capacity of mangrove ecotourism has been conducted across various coastal regions in Indonesia, including the Baros Mangroves in Bantul (Anandita et al., 2024), the Bintan Mangroves in the Riau Islands (Jocom et al., 2024), Telok Bediri Mangroves in Kubu Raya (Falih et al., 2025), and the Teluk Ambon mangrove ecosystem in Maluku (Alimudi at al., 2025). However, comparative studies focusing on two adjacent mangrove ecotourism areas with distinct biophysical characteristics, such as Pangkal Babu and Kelapa Beach in Tungkal 1 Village, remain scarce. As a result, managers and local governments lack a robust scientific foundation for establishing differentiated priorities and management strategies for each site. This study aims to (1) assess the suitability of the Pangkal Babu and Kelapa Beach mangrove areas as ecotourism destinations, and (2) evaluate the visitor carrying capacity of both areas to inform recommendations for sustainable mangrove ecotourism management in Tungkal 1 Village.

Method

The research was conducted over two months in 2026 at two mangrove ecotourism sites in Tungkal 1 Village, Tungkal Ilir District, West Tanjung Jabung Regency: Kelapa Beach Mangrove Ecotourism Site (0°48′8.96″ S; 103°29′49.98″ E; approximately 4 ha) and Pangkal Babu Mangrove Ecotourism Site (0°49′33.91″ S; 103°32′44.62″ E; 121 ha). Primary data on site conditions, mangrove thickness and density, species, fauna, and visitor activities were collected through field observations, interviews, and questionnaires, while secondary data were obtained from relevant institutions and scientific literature. Mangrove density was measured using line transects. Kelapa Beach used three 100-m transects with three 10 × 10 m plots per station, while Pangkal Babu used four 120-m transects with five 10 × 10 m plots per station. Species density was calculated as Di = ni/A and classified according to Ministry of Environment Regulation No. 201 of 2004 as dense (>1,500 ind./ha), moderate (1,000–1,500 ind./ha), or sparse/degraded (<1,000 ind./ha). Mangrove thickness was measured using Google Earth Pro, while fauna data were obtained through direct observation and interviews and identified according to Noor et al. (2006). (Noor et al., 2006).

Ecotourism suitability was assessed using the Mangrove Tourism Suitability Index (IKW) matrix (Yulinda, 2019), based on mangrove thickness, density, species, tidal range, and biota. The Tourism Suitability Index was calculated as TCI = Σ(Ni × Weight) and classified as Highly Suitable (>2.5), Suitable (2.0–2.5), Unsuitable (1.0–2.0), or Highly Unsuitable (<1.0). Area Carrying Capacity (DDK) was calculated as DDK = K × (Lp/Lt) × (Wt/Wp) for mangrove trekking, leisurely sitting, fishing, and river cruising, using activity-specific values of K, Lt, Wp, and Wt (Yulinda, 2019). Field data were compiled and processed using spreadsheets, and the results for both sites were presented descriptively and comparatively through tables and graphs (Yulinda, 2019). Field measurement data were manually compiled and processed using spreadsheets to ensure traceability and verification of each step in the IKW and DDK calculations. Suitability and carrying capacity information for both areas was presented descriptively and comparatively using tables and graphs to facilitate interpretation of differences between the sites. The analysis referenced results from similar studies conducted in other mangrove ecotourism areas in Indonesia.

Result and Discussion

General Conditions and Physical Characteristics of Mangrove Ecosystems

Satellite imagery measurements of mangrove thickness demonstrate substantial differences between the two study areas. At Pangkal Babu, mangrove thickness is 669 m, which exceeds the threshold for the "Highly Suitable" category (>500 m). In contrast, Kelapa Beach exhibits a thickness of only 121 m, placing it in the lowest category of the IKW matrix (<50–200 m). This disparity in thickness corresponds to the total area of each site: Pangkal Babu encompasses 121 ha, whereas Kelapa Beach covers only 4 ha, resulting in significantly less available space for mangrove development at Kelapa Beach.

Table 1 presents the results of mangrove density and species diversity measurements for both areas. At Kelapa Beach, total mangrove density ranges from 2,100 to 5,900 individuals per hectare (average 3,600), comprising four mangrove species, with Rhizophora apiculata and Avicennia alba as the dominant species. In Pangkal Babu, total density ranges from 6,900 to 10,900 individuals per hectare (average 8,450), with ten mangrove species, dominated by Avicennia alba, Avicennia marina, and Rhizophora apiculata. Both sites are classified as dense mangrove areas (>1,500 individuals/ha) according to Ministry of Environment Regulation No. 201 of 2004. However, Pangkal Babu exhibits substantially greater species diversity than Kelapa Beach. Low mangrove species diversity typically reflects ecological pressures such as erosion, land conversion, or other anthropogenic activities near the coast (Aprianto et al., 2021; Roiska et al., 2026), which aligns with the conditions at Kelapa Beach, where the land-based station is subject to more intensive human activity. From an environmental quality perspective, this difference also indicates that Kelapa Beach requires closer monitoring of coastal conditions because its smaller mangrove belt and more intensive human use may reduce the ecosystem's capacity to buffer disturbances. Although water-quality parameters such as pH, salinity, dissolved oxygen, turbidity, and nutrient concentrations were not measured in this study, these indicators should be incorporated into future monitoring to provide a more direct assessment of environmental quality in both tourism areas

Table 1
Physical Characteristics and Mangrove Vegetation of the Kelapa and Pangkal Babu Beach Ecotourism Areas

Parameter	Kelapa Beach	Pangkal Babu Beach
Area (ha)	4	121
Number of observation stations	3	4
Mangrove thickness (m)	121	669
Density range (ind./ha)	2.100–5.900	6.900–10.900
Average density (units/100 m²)	114	338
Number of mangrove species	4	10
Dominant type	Rhizophora apiculata, Avicennia alba	Avicennia alba, Avicennia marina, Rhizophora apiculata
Tidal range (m)	4	4

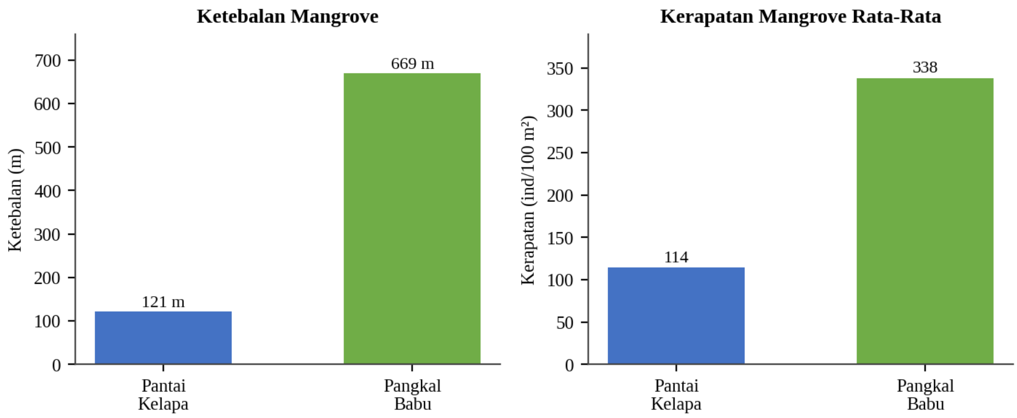

Figure 1. Comparison of Average Thickness and Density of Mangroves in the Kelapa Beach and Pangkal Babu Ecotourism Areas

Figure 1 demonstrates that the difference in mangrove thickness between the two areas (548 m) is proportionally much greater than the difference in density (224 plants/100 m²). Specifically, Pangkal Babu is 5.5 times thicker but approximately 3 times denser than Kelapa Beach. This pattern indicates that Kelapa Beach's primary limitation is its spatial dimensions, specifically the area and thickness of the mangrove green belt, rather than the stand's density per unit area. Consequently, the most effective rehabilitation strategy for this area is to expand the planting area toward both the sea and inland, rather than increasing the density within the existing area. A wider mangrove belt would also strengthen ecological filtering functions by trapping sediments and reducing the movement of land-based pollutants into coastal waters. Thus, mangrove rehabilitation at Kelapa Beach should be considered not only as a strategy to improve tourism suitability but also as an effort to maintain coastal environmental quality.

Flora and Fauna Diversity in Mangrove Ecosystems

1. **Flora Associated with Mangrove Ecosystems**

Vegetation surveys at all observation stations in Tungkal 1 Village identified ten true mangrove species from five families, as illustrated in Table 2. This consolidated checklist accounts for the differences in species numbers presented in Table 1, with four species at Kelapa Beach and ten at Pangkal Babu. Thus, all species recorded at Kelapa Beach are represented in the overall mangrove flora checklist for Tungkal 1 Village, which is more comprehensively documented in the Pangkal Babu area.

Table 2
Flora Diversity of the Mangrove Ecosystem Association in Tungkal 1 Village

Local Name	Latin Name	Family
Api api hitam	*Avicennia alba*	Acanthaceae
Api api kuning	*Avicennia marina*	Acanthaceae
Tumu putih	*Bruguiera cylindrica*	Rhizophoraceae
Tumu hitam	*Bruguiera gymnorhiza*	Rhizophoraceae
Lenggadai	*Bruguiera parviflora*	Rhizophoraceae

Teruntum	*Lumnitzera racemosa*	Combretaceae
Nipah	*Nypa fruticans*	Arecaceae
Bakau	*Rhizophora mucronata*	Rhizophoraceae
Bakau gajah	*Rhizophora apiculata*	Rhizophoraceae
Prepat	*Sonneratia alba*	Lythraceae

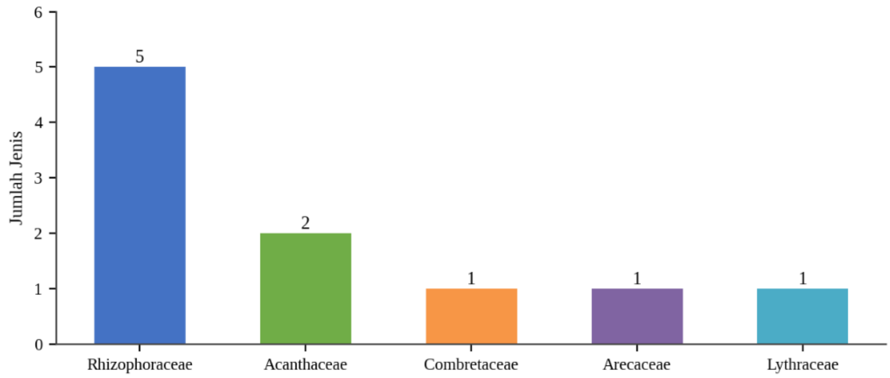

Figure 2. Composition of Mangrove Species by Family in Tungkal 1 Village

Figure 2 indicates that the family Rhizophoraceae dominates the mangrove flora composition in Tungkal 1 Village, comprising 5 of 10 species (50%), including three species from the genus Bruguiera and two from Rhizophora. The Acanthaceae family is the next most prevalent, with two species from the genus Avicennia (20%). In comparison, the Combretaceae, Arecaceae, and Lythraceae families are each represented by only one species. The predominance of Rhizophoraceae aligns with the typical zonation patterns observed in tropical coastal mangroves. Rhizophora and Bruguiera species generally occupy the more stable, inland-facing central zones that experience reduced wave exposure. Avicennia, belonging to the Acanthaceae family, typically acts as a pioneer species in the foreshore zone adjacent to the sea (Noor et al., 2006). The occurrence of Nypa fruticans (nipah) suggests freshwater influence from river estuaries in certain parts of the area. Sonneratia alba (prepat), in the family Lythraceae, commonly serves as a pioneer species on soft, muddy substrates along the water's edge. The considerable diversity of families and the dominance of species that form the primary forest structure, such as Rhizophora and Bruguiera, support the findings presented in Table 1 and Figure 1. These results indicate that the Pangkal Babu area has more mature and diverse mangrove vegetation than Kelapa Beach, providing a foundation for evaluating the mangrove species parameter score in the IKW analysis.

2. Fauna Associated with Mangrove Ecosystems

Field observations and interviews with managers and visitors identified 17 species of fauna associated with the mangrove ecosystem of Tungkal 1 Village, comprising 6 reptiles, 5 birds, 2 fish, 2 mammals, and 2 crustaceans (Table 2).

Reptile species such as Varanus salvator (water monitor) and Trimeresurus purpureomaculatus (black krait) indicate that dense mangrove vegetation provides a moist microhabitat protected from tidal fluctuations. Bird species including Ardea cinerea and Egretta garzetta are primarily waterbirds that forage in shallow waters. Mangrove-associated fish, Boleophthalmus boddarti and Periophthalmodon schlosseri, were observed on mud substrates affected by tidal movements. Additionally, Haliastur indus utilizes the coastal zone for hunting and flight.

Arboreal mammals such as Macaca fascicularis and Trachypithecus cristatus use the dense mangrove vegetation as a foraging ground. Crustaceans including Scylla serrata and Tubuca paradussumieri were observed in open muddy areas. This faunal diversity underscores the ecological role of the Tungkal 1 mangrove as a habitat, foraging site, and refuge for various species. Furthermore, the area functions as a natural ecotourism attraction, consistent with findings from other mangrove regions in North Sulawesi (Wulandari et al., 2024).

Table 3
Faunal Diversity of the Mangrove Ecosystem Association in Tungkal 1 Village

Taxa Group	Total Type	Examples of Species
Reptile	6	Varanus salvator, Trimeresurus purpureomaculatus, Bungarus fasciatus
Aves	5	Ardea cinerea, Egretta garzetta, Haliastur indus
Pisces	2	Boleophthalmus boddarti, Periophthalmodon schlosseri
Mammals	2	Macaca fascicularis, Trachypithecus cristatus
Crustasea	2	Scylla serrata, Tubuca paradussumieri
Total	**17**	

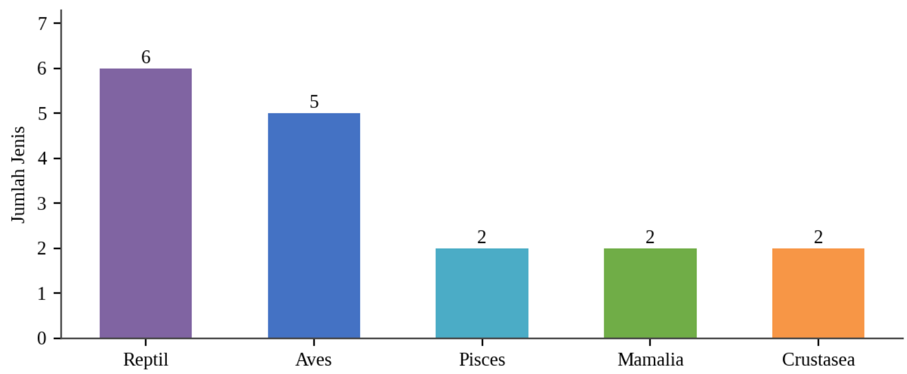

Figure 3. Composition of the Number of Fauna Species in the Mangrove Ecosystem of Tungkal 1 Village by Taxonomic Group

As shown in Figure 3, reptiles and birds dominate the fauna composition of the mangrove association in Tungkal 1 Village, together accounting for 11 of the 17 identified species (±65%). This dominance is understandable, given that semi-aquatic reptiles and waterbirds are the most easily observed fauna in densely vegetated intertidal zones, while fish, mammals, and crustaceans tend to be more hidden within the muddy substrate or the mangrove canopy, resulting in lower encounter rates during the survey. This composition is consistent with the general pattern of fauna in Indonesia’s tropical coastal mangroves, indicating that avifauna and reptiles are typically the main attractions for wildlife watching in mangrove ecotourism areas (Wulandari et al., 2024)

3. Analysis of the Tourism Suitability Index (IKW)

Table 4 presents the IKW calculation results for both areas. Kelapa Beach received a total IKW score of 1.75, categorizing it as “Unsuitable” ($1.0 \leq IKW < 2.0$). This outcome is primarily attributed to a mangrove density score of 1 on a 3-point scale. Mangrove density carries the highest weight (0.38) in the suitability matrix and exerts the greatest influence on the total score. A comparable trend was observed in a study of mangrove ecotourism suitability in Baros, Bantul, where stations with low mangrove density scores consistently fell into the “unsuitable” category, regardless of variations in other parameters (Anandita et al., 2024).

Pangkal Babu achieved a total IKW score of 2.76, classifying it as “Highly Suitable” ($IKW > 2.5$). Mangrove density contributed most significantly, with a value of 669 m and the highest possible score. This result supports the conclusion that mangrove density is the primary determinant of mangrove tourism suitability (Anandita et al., 2024). Additionally, the area’s high mangrove density and species diversity both received maximum scores, indicating a strong association with minimal anthropogenic disturbance in coastal environments (Aprianto et al., 2021). The only parameter not achieving a maximum score in Pangkal Babu was tidal patterns, a limitation also noted in the Bintan Mangrove area, where natural tidal fluctuations are inherently difficult to manage. Nevertheless, strong vegetation and biota parameters can compensate for this limitation, maintaining the area’s viability as an ecotourism destination (Jocom et al., 2024).

The 1.01-point difference in IKW scores between the two areas is attributable primarily (approximately 75%) to disparities in mangrove density scores. This finding underscores mangrove density as the most decisive factor in determining the final suitability category for mangrove tourism areas. Similar conclusions have been reported in studies of mangrove ecotourism suitability at Kutang Beach, Lamongan (Aprianto et al., 2021) and Telok Bediri, Kubu Raya (Falih et al., 2025). These results indicate that Pangkal Babu is ready for direct implementation of ecotourism development strategies. Conversely, Kelapa Beach requires mangrove rehabilitation and planting interventions to improve both mangrove density and species diversity before further development as an ecotourism destination.

Table 4
Results of the Tourism Suitability Index (IKW) Analysis for the Kelapa Beach and Pangkal Babu Mangrove Ecotourism Areas

Parameters	Weight	Kelapa Beach		Pangkal Babu	
		Results	Score	Results	Score
Mangrove thickness (m)	0.38	121	1	669	3
Mangrove density (ind/100 m²)	0.25	114	3	338	3
Types of mangroves	0.15	4	2	10	3
Tide (m)	0.12	4	1	4	1
Biota objects	0.10	Fish, mollusks, birds, mammals	2	Fish, mollusks, birds, mammals, reptiles	3
Total IKW		**1.75**		**2.76**	
Conformity category		**Inappropriate**		**Perfectly Suitable**	

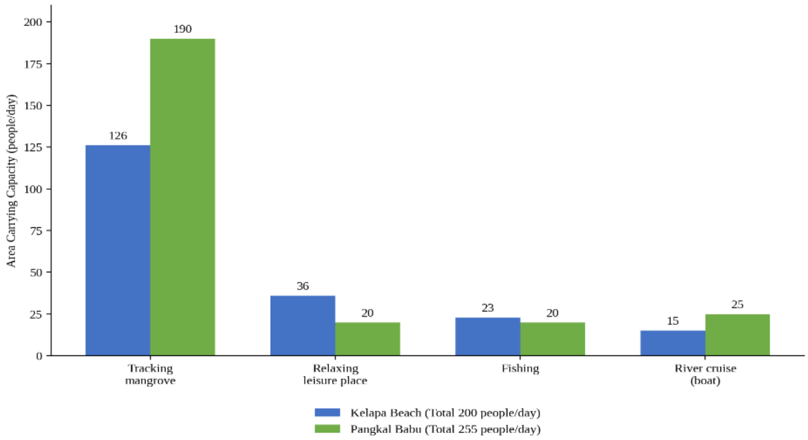

Figure 4. Comparison of Scores for the Five Parameters of the Tourism Suitability Index (IKW) for the Kelapa Beach and Pangkal Babu Mangrove Ecotourism Areas

Figure 4 presents the differences in suitability categories between the two areas. Pangkal Babu achieved the maximum score of 3 on four out of five parameters, whereas Kelapa Beach attained the maximum score only for mangrove density. Both areas received the lowest score of 1 for the tidal range parameter, suggesting that the tidal characteristics of the coastal waters in West Tanjung Jabung are relatively uniform and do not differentiate between the suitability of these geographically adjacent locations. Significant disparities in scores for mangrove thickness, mangrove species, and biota resulted in Kelapa Beach being classified as “Not Suitable,” despite its favorable stand density. The IKW parameters primarily describe ecological suitability and do not directly represent environmental sanitation or pollution conditions. Therefore, tourism suitability should also be interpreted together with potential pressures generated by visitors. Solid waste, food packaging, plastic debris, domestic wastewater from visitor facilities, and waste generated during boating or fishing activities may accumulate if collection and sanitation systems are inadequate. This issue is particularly relevant at sites with concentrated visitor activities because waste accumulation can reduce visual quality, disturb mangrove fauna, and deteriorate the environmental health of tourism areas. Accordingly, routine monitoring of waste generation, availability of waste bins, waste collection frequency, toilet sanitation, drainage, and cleanliness of tracking routes should complement the IKW assessment

4. Land Carrying Capacity Analysis (DDK)

Table 5 presents the Daya Dukung Kunjungan (DDK) calculations for four types of tourism activities in both areas. Kelapa Beach has a total DDK of 200 people per day, whereas Pangkal Babu has 255, a difference of 55 (approximately 27.5%). At both sites, mangrove tracking accounts for the largest share of visitors: 126 people per day (63%) at Kelapa Beach and 190 people per day (74.5%) at Pangkal Babu. This disparity is attributable to the larger tracking trail area (Lp) at Pangkal Babu (1,000.45 m²) compared to Kelapa Beach (640.92 m²). The predominance of mangrove trail activities in determining total carrying capacity is consistent with findings from a study on the mangrove ecotourism carrying capacity of Berakit Village, Bintan. That study found that trails with wooden bridges generally contribute more to visitor carrying capacity than other mangrove tourism activities (Yuliana et al., 2022).

The variation in DDK values between the two locations corresponds with the results of the IKW analysis. Kelapa Beach, classified as “Not Suitable” due to its lower mangrove density, exhibits a more restricted carrying capacity. In contrast, Pangkal Babu, classified as “Highly Suitable,” possesses a larger effective area for all tourism activities. This alignment indicates that the biophysical characteristics of mangroves, particularly their density and area, determine both the ecological suitability of a site for ecotourism and the spatial limitations for tourism activities, thereby affecting visitor carrying capacity (Nasution et al., 2023; Roiska et al., 2026). The calculated DDK values are also consistent with recent policy recommendations for the development of ecotourism in Pangkal Babu. These recommendations highlight the importance of daily visitor limits, institutional strengthening of the Pokdarwis, enhancement of attraction infrastructure, and implementation of sustainable financing schemes, such as blue finance, to ensure that tourism development does not compromise the area's conservation functions (Mirza et al., 2022; Alimudi et al., 2025).

Table 5

Results of the Carrying Capacity Analysis (CCA) for the Kelapa Beach and Pangkal Babu Mangrove Ecotourism Areas (people/day)

Type of Activity	K (Σ visitors)	DDK Kelapa Beach	DDK Pangkal Babu
Tracking mangrove	1	126	190
Relaxing leisure place	1	36	20
Fishing	1	23	20
River cruise (boat)	6	15	25
DDK Total		**200**	**255**

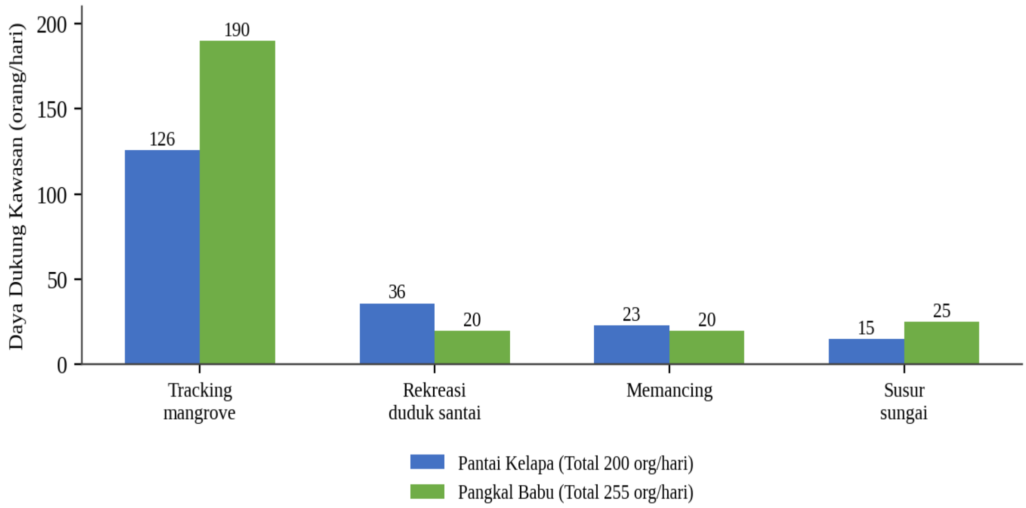

Figure 5. Comparison of Area Carrying Capacity (ACC) by Type of Tourism Activity in the Kelapa Beach and Pangkal Babu Mangrove Ecotourism Areas

Figure 5 demonstrates that the contribution of tourism activities to total DDK remains relatively consistent across regions for mangrove tracking, while the pattern differs for the other three activities. For relaxing (36 versus 20 people/day) and fishing (23 versus 20 people/day), Kelapa Beach exhibits a higher DDK than Pangkal Babu. This finding suggests that the gazebo areas and fishing spots at Kelapa Beach are designed with relatively generous per-unit capacity, despite the smaller total area. In contrast, river tours record the highest DDK at Pangkal Babu (25 people/day), which aligns with the presence of a longer river channel within the 121-hectare area. These differences indicate that managers should not implement uniform visitor restrictions across all activity types. Instead, specific daily quotas for each activity should be established based on its DDK value, as illustrated in Figure 4. Visitor carrying capacity is also relevant to environmental health because increasing visitor numbers can increase waste production, sanitation demand, and the probability of direct disturbance to coastal habitats. The DDK values should therefore be interpreted as maximum ecological visitation limits rather than targets that must always be reached. Actual visitor management should also consider the capacity of waste collection, sanitation facilities, clean water availability, and the ability of managers to maintain hygienic conditions. In this context, environmental health indicators such as cleanliness of tourism facilities, wastewater management, absence of accumulated waste, and safe access to visitor facilities are important supporting criteria for sustainable mangrove ecotourism

5. Management Implications

The IKW and DDK results are mutually reinforcing and suggest distinct management strategies for the two areas. In the Pangkal Babu area, which is classified as “Highly Suitable” with a carrying capacity of 255 people per day, more intensive ecotourism development and targeted promotional strategies are recommended. However, it is essential to restrict daily visitor numbers to remain within the established carrying capacity. In contrast, the Kelapa Beach area, categorized as “Not Suitable” with a carrying capacity of 200 people per day, should prioritize rehabilitation of the mangrove ecosystem, including planting additional mangrove species to enhance stand density and species diversity. These rehabilitation efforts should precede any increase in carrying capacity or tourism promotion. This tiered management approach is consistent with recommendations from previous studies on mangrove ecotourism suitability and carrying capacity in Indonesia, which emphasize that tourism development decisions should be informed by the specific biophysical conditions of each area rather than a uniform policy (Mirza et al., 2022; Alimudi et al., 2025). In addition to regulating visitor numbers and rehabilitating mangroves, management should incorporate routine environmental quality and sanitation monitoring. Practical measures include recording the volume and type of tourism waste, providing adequate segregated waste bins, ensuring regular waste removal, maintaining toilets and wastewater facilities, and periodically monitoring basic coastal water-quality parameters. These measures are important because healthy mangrove ecosystems and clean tourism environments are closely linked to the health and comfort of visitors and coastal communities that depend on fisheries, coastal water, and other ecosystem services. For Kelapa Beach, where tourism activities are concentrated within a smaller area, waste and sanitation control should accompany ecosystem rehabilitation. At Pangkal Babu, preventive monitoring is required so that increasing tourism intensity does not reduce the ecological quality that currently supports its “Highly Suitable” status.

6. Comparison with Similar Studies in Other Regions

The IKW value for Pangkal Babu (2.76) is comparable to those of mangrove areas classified as “Highly Suitable” in previous studies. For example, the Telok Bediri Mangroves in Kubu Raya demonstrate high suitability due to substantial mangrove thickness and density (Falih et al., 2025), while the Bintan Mangrove’s suitability is primarily determined by species diversity and associated biota (Jocom et al., 2024). In contrast, the IKW value for Kelapa Beach (1.75) corresponds with mangrove areas experiencing significant anthropogenic pressure and limited land area. This pattern is evident in several segments of the Teluk Ambon mangrove ecotourism study, where low-density scores were identified as the main factor in categorizing certain stations as “unsuitable” (Alimudi et al., 2025).

The total DDK for both areas in Tungkal 1 Village (200–255 people per day) is within the typical range for medium-scale mangrove ecotourism sites in Indonesia. This finding aligns with research on the carrying capacity of fishery resources and the economic conditions of the Pangkal Babu mangrove area, highlighting the necessity of regulating utilization to sustain both ecological integrity and economic benefits for the Tungkal 1 Village community (Nasution et al., 2023). The consistency of these results across multiple studies supports the validity of the research and demonstrates that the framework proposed is applicable to mangrove ecosystems along the eastern coast of Sumatra (Yuliana et al., 2022).

Conclusion

The Kelapa Beach mangrove ecotourism area received an IKW score of 1.75, classified as "Not Suitable," and has a carrying capacity of 200 people per day. In comparison, the Pangkal Babu mangrove ecotourism area achieved an IKW score of 2.76, placing it in the "Very Suitable" category and indicating a carrying capacity of 255 people per day. These results are supported by the low mangrove density at Kelapa Beach, measured at 121 meters, whereas Pangkal Babu exhibits a mangrove thickness of 669 meters, a density of 338 individuals per 100 m², and contains 10 mangrove species. In both locations, mangrove tracking activities contributed most significantly to the total carrying capacity, accounting for 63% at Kelapa Beach and 74.5% at Pangkal Babu. Overall, the findings suggest that Pangkal Babu is appropriate for immediate ecotourism development, provided that daily visits do not exceed the established carrying capacity. Conversely, Kelapa Beach requires rehabilitation of its mangrove ecosystem prior to further development as a sustainable ecotourism destination.

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