



## Tourism Carrying Capacity of Coastal Ecosystems on Ketawai Island, Central Bangka, Indonesia

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### ABSTRACT

Ecotourism development, especially in Central Bangka Island of Ketawai more rapidly. The rapid tourist activities on the Island of Ketawai can cause loss of quality attractions for damage to the ecosystem. This is because the pressure on the environment caused by the increased number of tourists. This study aims to determine the maximum capacity rating with ratings of three aspects: (1) the carrying capacity of the region (DDK), (2) the carrying capacity of the environment (the carrying capacity of the physical / PCC and the carrying capacity of the real / RCC), and (3) ecological carrying capacity (AR). This study uses primary data by direct observation in the field and secondary data from relevant agencies. An assessment of the carrying capacity of the region (DDK), an assessment of the carrying capacity of the environment using methods the Physical Carrying Capacity (PCC), the carrying capacity of the Real (RCC), and an assessment of the ecological carrying capacity (AR). The results obtained, there are two tourist activity on the island of Ketawai are picnic and camping. The result of the carrying capacity of the region (DDK) for picnic activities is 240 people / day and camping activities is 900 people/day. The results of the physical carrying capacity (PCC) for picnic activities is 249 people / day and for camping is 100 people / day. Assessment of the real carrying capacity (RCC) for picnic activities is 239 people / day and camping 96/day. Ecological carrying capacity assessment. (AR) obtained the results of 81 people / day for a picnic and activity type 43 / day for camping activities. The value of these calculations are still well above the actual number of tourists who currently account for 9 person / day. Attraction Development Ketawai Island can still be optimized however, by taking into account the balance and sustainability of the local environment.

**Keyword:** Carrying Capacity, Central Bangka, Coastal Ecosystems, Ecotourism, Ketawai Island

### 1. Introduction

Indonesia, as an archipelagic country, has considerable potential for ecotourism development, particularly in coastal areas, marine environments, and small islands [1], [2]. In Bangka Belitung Province, tourism development has increasingly focused on the utilization of coastal and island ecosystems due to their natural attractiveness and strategic economic value [3]. Among the small islands in this region, Ketawai Island represents a coastal island with strong potential to be developed as an ecotourism destination based on its natural and ecological characteristics.

Ecotourism emphasizes a balance between resource utilization and environmental sustainability rather than prioritizing economic growth alone [4]. Coastal areas play a central role in beach-based ecotourism and marine recreation because they provide ecological functions as well as aesthetic value for visitors [5]. The ecotourism potential of Ketawai Island is derived from its natural resources, including white sandy beaches, coral reef ecosystems, clear seawater, and relatively undisturbed environmental conditions. These characteristics make the island attractive to both domestic and international tourists [6]. Effective ecotourism

management should therefore emphasize the conservation of natural resources, social values, and local community welfare, while maintaining ecological integrity [7].

The development of tourism destinations inevitably generates both positive and negative impacts. Increased tourist visitation can place substantial pressure on coastal ecosystems, leading to habitat degradation, resource depletion, and reduced environmental quality if not properly managed [8]. Consequently, regulating tourist numbers based on the carrying capacity of an area becomes essential to ensure sustainable tourism development [9]. However, visitor limitation policies may also pose socio-economic challenges, as tourism demand is often difficult to control and restrictions may affect local economic growth [10].

One of the fundamental principles of ecotourism development is regulating visitor numbers according to environmental carrying capacity. Exceeding carrying capacity thresholds has been shown to accelerate ecosystem degradation, particularly in sensitive environments such as coral reefs [11]. Previous studies have demonstrated that increased tourism intensity, including diving and snorkeling activities, can significantly increase physical damage to coral reef ecosystems [12]. Therefore, marine ecotourism should be managed using a conservation-oriented approach that integrates ecological, environmental, and management considerations [4], [13].

Despite the growing body of research on tourism carrying capacity, integrated quantitative assessments that simultaneously consider regional, environmental, and ecological carrying capacity for small-island ecotourism in Bangka Belitung Province remain limited [9], [14]. This study was conducted on Ketawai Island, Central Bangka Regency, to address this gap by evaluating tourism carrying capacity using an integrated approach. Tourism activities on the island are predominantly marine-based, supported by coral reef ecosystems suitable for snorkeling and diving. Nevertheless, these ecosystems have a finite capacity to absorb pressures generated by tourism activities. Therefore, this study aims to assess tourism carrying capacity using three complementary approaches: (1) regional carrying capacity, (2) environmental carrying capacity, and (3) ecological carrying capacity, as a scientific basis for sustainable ecotourism management on small islands.

## 2. Methods

### 2.1. Study Area

The study was conducted on Ketawai Island, located in Kurau District, Central Bangka Regency, Bangka Belitung Province, Indonesia. Geographically, Ketawai Island is situated at approximately 2°19'–2°21' South Latitude and 106°25'–106°27' East Longitude. Ketawai Island has a total land area of approximately 29.2 ha, of which about 0.9 ha (9,000 m<sup>2</sup>) is actively utilized for tourism activities. The island is characterized by white sandy beaches, coastal vegetation dominated by coconut trees (*Cocos nucifera*), gentle topography, and coastal–marine ecosystems that support nature-based tourism activities, particularly picnic and camping. These physical and ecological characteristics make Ketawai Island suitable for carrying capacity assessment in the context of small-island ecotourism development [1], [2].

### 2.2. Field Observation and Data Collection

This study employed a descriptive quantitative approach to assess tourism carrying capacity, following established methods for coastal and ecotourism evaluation [3], [4]. Field observations were conducted during both peak and non-peak visitation periods to capture temporal variation in tourism activities and environmental conditions. Primary data were collected through direct field observations and in situ measurements within the designated tourism utilization area.

Sampling locations were determined using purposive sampling, focusing on zones intensively used for tourism activities, namely picnic and camping areas. Observation units included: (1) tourism utilization area (m<sup>2</sup>), (2) coastal vegetation plots, (3) slope and soil observation points, and (4) landscape assessment points. Observation points were distributed proportionally across the 9,000 m<sup>2</sup> tourism utilization area to represent dominant environmental conditions and land-use characteristics [5].

Environmental variables measured in the field included vegetation height and trunk diameter of coconut trees (*Cocos nucifera*), slope gradient measured using a clinometer, and soil sensitivity to erosion assessed based on field observations of soil texture and structure. Rainfall intensity data were obtained from the nearest meteorological station and used as a biophysical correction factor in the real carrying capacity (RCC)

calculation [6]. Landscape potential was evaluated through visual assessment of scenic quality, accessibility, and environmental integrity, following standardized ecotourism suitability criteria [3], [7].

Secondary data comprised tourism visitation statistics and supporting environmental information obtained from relevant government agencies, which were used to support the analysis of regional and ecological carrying capacity [4], [8].

### 2.3. Data Analysis

#### 2.3.1. Regional carrying capacity (*Daya Dukung Kawasan/DDK*)

Regional carrying capacity (DDK) was calculated to estimate the maximum number of visitors that can be accommodated in the tourism area based on spatial availability and time utilization. The calculation considers the ecological potential of tourists (K), the area available for tourism activities (Lp), the unit area requirement per visitor (Lt), and the ratio between the available time for tourism utilization (Wt) and the average time spent by visitors on tourism activities (Wp). This approach follows established carrying capacity assessment methods for coastal and ecotourism areas [1]-[3].

The DDK was calculated using the following formula:

$$DDK = K \times \frac{Lp}{Lt} \times \frac{Wt}{Wp} \quad (1)$$

Where:

- K : ecological potential of tourists
- Lp : area available for tourism activities
- Lt : unit area requirement per visitor
- Wt : time allocation for tourism utilization
- Wp : time allocation for visitor activities

#### 2.3.2. Environmental carrying capacity

Environmental carrying capacity was assessed through the calculation of Physical Carrying Capacity (PCC) and Real Carrying Capacity (RCC), which account for spatial limitations and biophysical constraints of the study area [1], [4].

- a. Physical Carrying Capacity (PCC) represents the maximum number of visitors that can be physically accommodated within the tourism area, based on available space and visitor rotation during a given time period. PCC was calculated using the following formula [1], [5]:

$$PCC = A \times 1/B \times Rf \quad (2)$$

Where:

- A : area used for tourism activities (m<sup>2</sup>)
- B : area required per visitor to obtain satisfactory experience (m<sup>2</sup>/person)
- Rf : rotation factor (number of visitor cycles per day)

- b. Real Carrying Capacity (RCC) was calculated by adjusting the PCC using correction factors (Cf) that represent biophysical and environmental limitations of the tourism area. This adjustment ensures that environmental constraints are incorporated into the carrying capacity estimation [1], [6].

The RCC was calculated using the following formula:

$$RCC = PCC \times (100-Cf1/100) \times (100-Cf2/100) \times \dots \times (100-Cfn/100) \quad (3)$$

Each correction factor (Cf) was calculated using the following equation:

$$Cf = Mi/Mt \times 100\% \quad (4)$$

Where:

- Mi : measured magnitude of the limiting variable
- Mt : maximum tolerable value of the variable based on environmental standards and relevant literature

The correction factor parameters included vegetation height (Cf1), vegetation diameter (Cf2), rainfall intensity (Cf3), slope gradient (Cf4), soil sensitivity to erosion (Cf5), and landscape potential (Cf6). These parameters were selected because they directly influence ecosystem stability, visitor safety, and environmental resilience in coastal tourism areas and are commonly applied in carrying capacity studies of small islands and coastal ecosystems [3], [6]–[8].

### 2.3.3. Ecological carrying capacity (AR)

Ecological carrying capacity (AR) was calculated to determine the maximum level of tourism activity that can be sustained without exceeding the ecosystem's natural recovery capacity. This approach incorporates the recovery factor (TF), area requirements for each tourism activity, and the number of effective utilization days per year, ensuring long-term ecosystem sustainability [2], [9].

Ecological carrying capacity was calculated using the following formula:

$$AR = \frac{D \times A}{Cd \times TF \times 43,560} \quad (5)$$

Where:

- AR : Ecological carrying capacity for a specific tourism activity
- D : Number of tourist visits per year
- A : Area requirement per activity (ft<sup>2</sup>)
- Cd : Number of effective utilization days per year
- TF : Recovery factor
- 43,560 : Conversion constant from acres to square feet

The recovery factor (TF) represents the ecosystem's ability to recover from disturbances caused by tourism activities. A TF value of 1.5 was applied for picnic activities due to higher trampling intensity and frequent use, while a TF value of 1.0 was applied for camping activities, reflecting lower spatial disturbance but longer duration of stay. These values were determined based on field conditions and supported by previous carrying capacity studies in coastal and ecotourism environments [1], [9], [10].

## 3. Results and Discussion

### 3.1. Regional Carrying Capacity (DDK)

Regional carrying capacity (DDK) was calculated to determine the maximum number of visitors that can be accommodated based on spatial availability and time utilization for each tourism activity. According to the criteria proposed by [9], the time allocated by management (Wt) for beach recreation activities is 8 hours per day, while the average time spent by visitors (Wp) is 6 hours. The unit area requirement (Lt) for beach recreation is 50 m<sup>2</sup> per visitor, and the total area available for tourism utilization (Lp) is 9,000 m<sup>2</sup>. Based on these parameters, the regional carrying capacity for beach recreation activities was calculated as 240 visitors per day.

For camping activities, both the time allocated by management and the time utilized by visitors were assumed to be 24 hours per day [9]. The ecological potential of tourists (K) was set at five visitors per unit, with a unit area requirement of 50 m<sup>2</sup>. Each tourist requires approximately 100 m<sup>2</sup> to maintain comfort during camping activities. Using these parameters, the regional carrying capacity for camping activities was calculated as 900 visitors per day as shown in Table 1.

**Table 1.** Regional Carrying Capacity (DDK)

Tourist Activity	K (∑ Tourists)	Utilization Area (Lp, m <sup>2</sup> )	Lt (M <sup>2</sup> )	Wt (Hour)	Wp (Hour)	DDK (visitors/day)
Beach Recreation	1	9.000	50	8	6	240
Camping Area	5	9.000	50	24	24	900

These values represent the maximum number of visitors that Ketawai Island can accommodate per day for each activity while maintaining visitor comfort and satisfaction.

### 3.2. Environmental Carrying Capacity

Environmental carrying capacity was assessed using two indicators, namely Physical Carrying Capacity (PCC) and Real Carrying Capacity (RCC). These indicators were selected because they represent the physical and biophysical limitations of the tourism area and reflect the potential environmental impacts caused by tourist activities on Ketawai Island. The limiting factors consisted of biotic parameters, including coconut (*Cocos nucifera*) vegetation height (Cf1) and vegetation diameter (Cf2), and abiotic parameters, including rainfall intensity (Cf3), slope gradient (Cf4), soil sensitivity to erosion (Cf5), and landscape potential (Cf6) [10].

#### 3.2.1. Physical carrying capacity (PCC)

Physical Carrying Capacity (PCC) represents the maximum number of visitors that can be physically accommodated within the tourism area based on available space and visitor rotation. The PCC values for picnic and camping activities are presented in Table 2.

**Table 2.** Physical Carrying Capacity (PCC)

Tourist Activity	Utilization Area (A) (m <sup>2</sup> )	Area per Visitor (B) (m <sup>2</sup> )	Rotation factor (Rf)	PCC Value (visitors/day)
Picnic	9.000	65	1,8	249
Camping	9.000	90	1	100

The results show that the PCC for picnic activities was 249 visitors per day, while the PCC for camping activities was 100 visitors per day. These values serve as baseline estimates and were subsequently adjusted using biophysical correction factors to calculate the real carrying capacity (RCC) [11].

#### 3.2.2. Real carrying capacity (RCC)

Real Carrying Capacity (RCC) represents the maximum number of visitors that can be accommodated after considering biophysical and environmental constraints. RCC values were calculated by applying correction factors (Cf) derived from site-specific environmental characteristics to the PCC values [12]. The correction factor values and RCC results for each tourism activity are presented in Table 3.

**Table 3.** Real Carrying Capacity Value (RCC)

Tourist Activity	Correction Factor Value (Cf)						PCC Value	RCC Value
	Cf <sub>1</sub>	Cf <sub>2</sub>	Cf <sub>3</sub>	Cf <sub>4</sub>	Cf <sub>5</sub>	Cf <sub>6</sub>		
Picnic							249	239
Camping	0,2846	0,3355	0,9583	0,8	0,8	0,7407	100	96

The RCC values indicate that Ketawai Island can accommodate a maximum of 239 visitors per day for picnic activities and 96 visitors per day for camping activities after accounting for environmental limitations. When both activities are considered together, the total RCC is 335 visitors per day, equivalent to approximately 10,050 visitors per month or 120,600 visitors per year. In contrast, actual visitation data over a three-year period recorded a total of 10,285 visitors, with an average of approximately 9 visitors per day. This indicates that current tourism intensity remains well below the environmental carrying capacity of the island.

### 3.3. Ecological Carrying Capacity (AR)

Ecological carrying capacity (AR) incorporates the recovery factor (TF) to account for the ecosystem's ability to recover from disturbances caused by tourism activities [13]. Different tourism activities require different spatial areas to ensure visitor comfort and minimize ecological stress. The results of the ecological carrying capacity calculation for Ketawai Island are presented in Table 4.

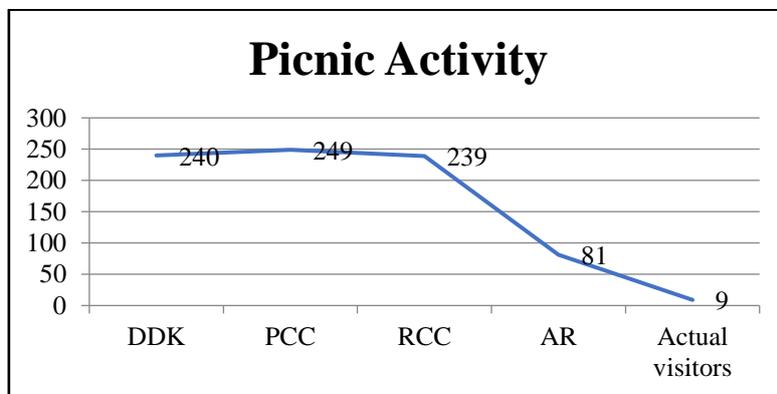
**Table 4.** Ecological Carrying Capacity Value (AR)

Activity	Annual Visitors (D)	Area Requirement (a) (feet)	Days Available/year (CD)	TF	Constant	AR value (visitors/day)
Picnic	3.428	726	365	1,5	43,560	81
Camping	3.428	907	365	1,0	43,560	43

The ecological carrying capacity values were 81 visitors per hectare for picnic activities and 43 visitors per hectare for camping activities. These values represent the most conservative thresholds and indicate the maximum number of visitors that can be accommodated while maintaining ecosystem stability and long-term sustainability on Ketawai Island.

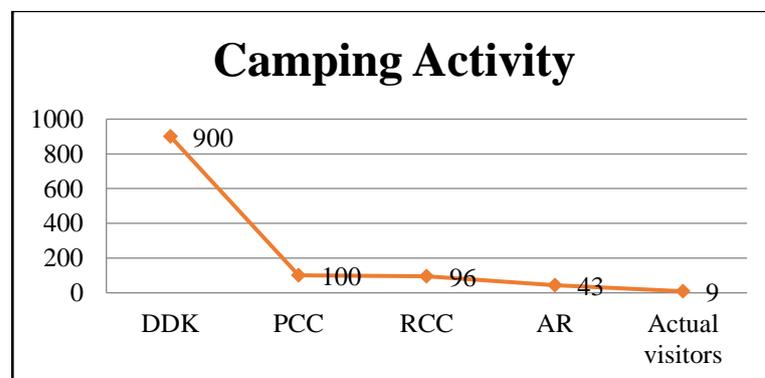
### 3.4. Comparison Between Tourism Carrying Capacity and Actual Visitor Numbers

A comparison between regional carrying capacity (DDK), environmental carrying capacity (PCC and RCC), ecological carrying capacity (AR), and actual visitor numbers demonstrates that current tourism intensity on Ketawai Island remains significantly below all calculated carrying capacity thresholds. This result indicates that the current level of tourism utilization has not yet exceeded the sustainable limits of the ecosystem and remains within acceptable environmental thresholds. Carrying capacity assessment is widely recognized as an essential tool for managing tourism sustainably and preventing environmental degradation, particularly in small island ecosystems that are highly sensitive to external pressures [15], [20], [23]. Furthermore, sustainable tourism development requires the integration of environmental considerations into tourism planning to ensure long-term ecological balance and resource conservation [16], [21]. Therefore, ecological carrying capacity should be used as the primary reference for tourism management because it provides the most precautionary and environmentally protective threshold.



**Figure 1.** Picnic activity

As shown in Figure 1, there is a progressive decrease in allowable visitor numbers from regional carrying capacity (DDK) to ecological carrying capacity (AR). This pattern reflects the increasing level of environmental and ecological constraints applied in each stage of carrying capacity assessment. Actual visitor numbers remain far below all calculated thresholds, particularly the ecological carrying capacity, indicating that picnic activities currently exert minimal environmental pressure on Ketawai Island. This condition suggests that the ecosystem remains in a stable condition and tourism activities are still within sustainable limits. Similar findings have been reported in other coastal tourism areas, where low visitor intensity contributes to maintaining ecosystem resilience and environmental sustainability [17], [22].



**Figure 2.** Camping activity

The results presented in Figure 2 show a substantial reduction in visitor limits when physical, biophysical, and ecological correction factors are applied. Ecological carrying capacity provides the most conservative threshold for camping activities due to the longer duration of stay and greater environmental interaction

associated with this activity. This reduction highlights the importance of incorporating environmental parameters into carrying capacity assessments to prevent environmental degradation and ensure sustainable tourism management. Previous studies have emphasized that ecological carrying capacity plays a critical role in visitor management and ecosystem protection, particularly in fragile coastal environments [18], [19], [23].

#### 4. Conclusion

This study assessed tourism carrying capacity on Ketawai Island using an integrated approach encompassing regional carrying capacity (DDK), environmental carrying capacity (PCC and RCC), and ecological carrying capacity (AR). The results indicate that the regional carrying capacity values were relatively high, reaching 240 visitors/day for picnic activities and 900 visitors/day for camping. However, when physical and biophysical limitations were considered, the real carrying capacity decreased to 239 visitors/day for picnic activities and 96 visitors/day for camping. The most conservative estimates were obtained from ecological carrying capacity analysis, with values of 81 visitors/ha for picnic activities and 43 visitors/ha for camping activities. Comparison with actual visitation data shows that current tourism intensity on Ketawai Island remains far below all carrying capacity thresholds, particularly the ecological carrying capacity. This finding indicates that ecological carrying capacity should be prioritized as the main reference for sustainable tourism management on small islands. The integrated carrying capacity assessment applied in this study provides a scientific basis for visitor regulation, zoning strategies, and ecotourism planning to ensure long-term ecosystem sustainability while maintaining visitor comfort.

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