Tourism Suitability and Carrying Capacity as a Basis for Sustainable Coastal Ecotourism Development at Karangsong Beach, Indonesia

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Abstract

Coastal ecotourism development requires an integrated understanding of environmental suitability, ecological carrying capacity, and management strategies to ensure long-term sustainability. This study evaluates the suitability of tourism, carrying capacity, and development strategies for sustainable coastal ecotourism at Karangsong Beach, Indramayu Regency, Indonesia. Tourism suitability and carrying capacity were assessed based on biophysical parameters, field observations, and stakeholder surveys. Tourism suitability was analyzed using the Tourism Suitability Index (TSI), while the Area Carrying Capacity (ACC) was calculated to determine the maximum number of visitors that can be accommodated without compromising environmental quality or visitor comfort. Strategic priorities for ecotourism development were identified using an integrated SWOT analysis and Quantitative Strategic Planning Matrix (QSPM). The results indicate spatial variation in tourism suitability across the study area, with several coastal segments classified as highly suitable for tourism activities, while others require management interventions. The carrying capacity analysis suggests that Karangsong Beach can sustainably accommodate an average of 184 visitors per day under current environmental conditions. Priority development strategies include improving and maintaining tourism facilities, enhancing accessibility, strengthening community participation in tourism management, and conserving mangrove ecosystems as key ecotourism attractions. This study demonstrates that integrating tourism suitability assessment and carrying capacity analysis provides a robust scientific framework for sustainable coastal ecotourism planning. The findings offer practical insights for balancing tourism development, coastal ecosystem conservation, and community-based economic benefits and contribute to sustainable marine ecotourism management in tropical coastal regions.

Keywords: Marine Ecotourism, Tourism Suitability Index, Coastal Management, Community-Based Ecotourism

INTRODUCTION

Coastal tourism development often prioritizes economic benefits at the expense of ecological limits, leading to environmental degradation in many coastal areas (Wong, 1998). In response to these challenges, sustainable marine ecotourism has emerged as an alternative approach that integrates environmental conservation, community participation, and long-term economic benefits (Rahman *et al.,* 2022). In this regard, assessing tourism suitability and ecological carrying capacity is crucial to ensure that tourism activities remain within the ecological boundaries of coastal ecosystems (Skiniti *et al*., 2024). Furthermore, sustainable coastal ecotourism emphasizes a balanced integration of conservation, social engagement, and economic viability (Casimiro *et al*., 2023). Uncontrolled coastal tourism development often exceeds ecological thresholds, resulting in habitat and resource degradation, water quality degradation, and ultimately reduced visitor satisfaction (Tsypko, 2024). Therefore, tourism suitability assessment and carrying capacity analysis are crucial for implementing sustainability principles and ensuring that coastal ecotourism planning and management remain within safe ecological boundaries.

Ecotourism has become an important economic activity because it not only provides visitors with opportunities to learn about the local environment and culture, but also raises awareness of the importance of biodiversity and cultural conservation (Supriadi, 2016). At the same time, ecotourism also has positive impacts on conservation efforts and the livelihoods of communities surrounding ecotourism sites (Ogutu, 2002). However, ecotourism activities in tropical regions such as Indonesia, which boast high diversity of endemic flora and fauna, are vulnerable to environmental change and mismanagement (Iswandi, 2015).

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Karangsong Beach is located in Karangsong Village, Indramayu District, Indramayu Regency. From 1969 to 1983, Karangsong Village Beach was covered with 45 hectares of mangrove forest (Oni *et al*., 2019). However, around 1985, the community began converting the mangrove land into fish ponds. The community argued that the mangrove area did not provide direct economic benefits. As a result of mangrove conversion from 1985 to 2001, the coastal area lacked coastal protection, leading to abrasion on Karangsong Beach (Oni *et al*., 2019). From 2008 to 2016, a local organization called Kelompok Pantai Lestari (KPL) carried out mangrove rehabilitation efforts on the Karangsong coast, so that the coastal area, which had previously been affected by abrasion, has now recovered into a good mangrove ecosystem area (Fatimatuzzahroh *et al*., 2021).

Subsequent studies have focused on evaluating tourists' perceptions of existing attractions to support tourism management and development planning (Gnanapala, 2015). Tourist assessments, commonly collected through questionnaires, provide essential inputs for estimating tourism carrying capacity and identifying management priorities (Skiniti *et al.,* 2024). Improved tourism planning based on visitor perceptions can enhance the potential of Karangsong Beach as a coastal tourism destination that supports local economic development while delivering positive experiences for visitors and tourism stakeholders. With appropriate infrastructure development and management, Karangsong Beach has the potential to become one of the preferred coastal destinations in Indramayu Regency (Haryati *et al*., 2022).

This study aims to assess the ecotourism potential of Karangsong Beach in Indramayu Regency, Indonesia, characterized by extensive mangrove ecosystems and a variety of marine tourism activities, including boat tours, beach recreation, and environmental education. Despite its considerable potential as a regional tourism destination, tourism utilization in the area must be carefully managed to prevent ecosystem degradation and declines in environmental quality. Therefore, this study analyzes tourism suitability using the Tourism Suitability Index (TSI), evaluates the Area's Carrying Capacity (ACC) to determine the maximum number of visitors that can be accommodated without compromising environmental quality or visitor comfort, and formulates strategic directions for sustainable coastal ecotourism development. The results are expected to provide a scientific basis for integrated and sustainable coastal tourism management planning.

MATERIALS AND METHODS

This research was conducted at Karangsong Beach, Indramayu Regency, West Java. Three stations were determined using purposive sampling. Purposive sampling is the deliberate selection of samples based on the assumption that the samples taken can represent the population of the research location (Sugiyono, 2017). These stations, spaced 20 meters apart, were expected to represent the research location and provide a detailed overview of it (Jihab *et al*., 2024). The selection of station locations aimed to describe the overall condition of the beach. The station points were chosen because the majority of visitors prefer activities that are not too far away and are still close to the coastline, as well as being close to the entrance to the coastal area. The spatial distribution of the sampling stations is shown in Figure 1.

Field data were collected using a purposive sampling approach, where sampling stations were intentionally selected based on their representation of primary tourist activity zones and their relevance to coastal recreational use. Coastal physical and environmental parameters measured included bottom substrate, water depth, brightness, beach type, beach width, current velocity, slope, land cover, presence of hazardous biota, freshwater availability, and tidal characteristics. Bottom substrate samples (~500 g) were collected using a shovel, labelled per station, and stored in sealed bags. Samples were sun-dried, then oven-dried to constant weight, followed by granulometric analysis via sieving and weighing to determine the grain-size distribution. Sediment types were classified using the Shepard triangular diagram and grouped into sand, muddy sand, mud, or rocky substrates. Sandy substrates were considered most suitable for beach tourism. Water depth measurements were conducted at three stations during high tide, 15 m from the shoreline, using a graduated measuring rod, with three repetitions per station. Water brightness was measured using a Secchi disk at the same distance and tidal condition. Brightness values were calculated as the average of disappearance and reappearance depths. Beach type was determined through direct visual observation in the intertidal zone and classified as sandy, muddy, rocky, or coral-dominated. Beach width was measured from the last vegetation line to the shoreline using a measuring tape. Current velocity was measured using a floating object method, in which flow speed is determined from drift distance and travel time. Beach slope was measured using a calibrated digital waterpass with three repetitions per station; slopes below 10° were categorized as gently sloping and more suitable for recreation. Land cover was assessed through direct field observation and photographic documentation, then classified into vegetation, open land, shrubland, built area, or wetland categories. Hazardous marine biota presence was recorded through snorkelling observations within and around station areas, including sea urchins, stingrays, sharks, fire corals, sea snakes, and jellyfish. Freshwater availability was measured as the distance from each station to the nearest freshwater source using a measuring tape. Tidal data were obtained from field observations, local officer information, and geospatial reference data sources. Tidal conditions were considered in interpreting beach area availability and recreational suitability.

The Tourism Suitability Index (TSI) is an index that determines whether an area is suitable or unsuitable for use as a tourist area by assessing existing parameters (Yulianda, 2019). The suitability of resource and environmental characteristics for tourism development is assessed from the perspectives of human resource utilization and ecology (Waemese *et al.,* 2025). Therefore, a tourism suitability index is needed as supporting data in the development of a sustainable tourism area. Tourism area development requires tourism suitability to estimate the environmental impacts of control and management restrictions, ensuring harmonious alignment with tourism objectives.

The tourism suitability parameters measured to determine suitability in a region are beach type, water depth, beach width, beach slope, water brightness, current speed, dangerous biota, land cover, and freshwater availability. Each indicator has a weight as a criterion for determining tourism suitability in a region. Each parameter has a score, which is then weighted to evaluate the results. According to Yulianda (2019), these are the resource suitability parameters for recreational beach tourism (Table 1).

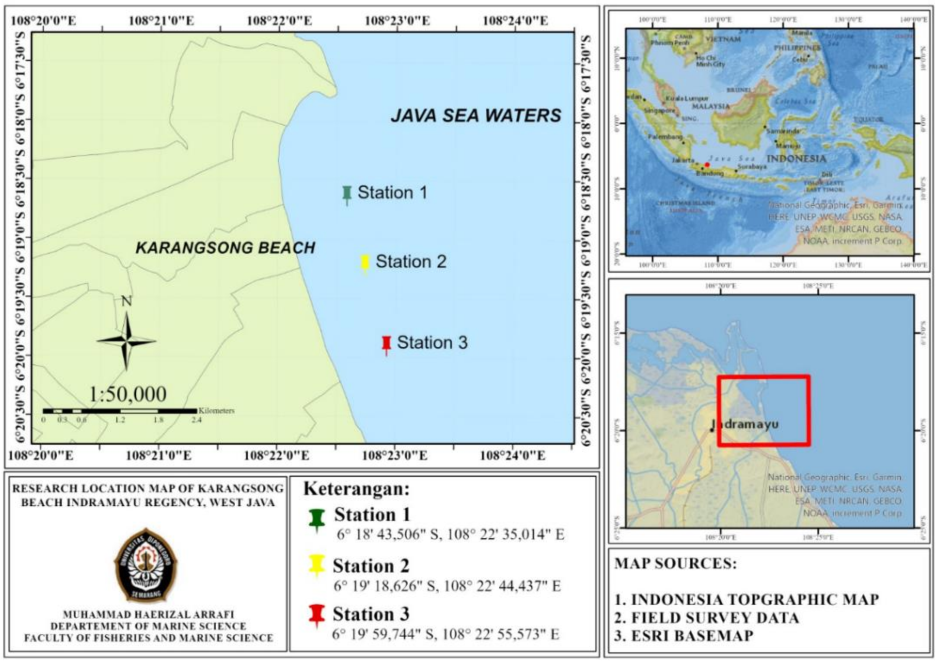

Figure 1. Research Locations at Karangsong Beach, Indramayu, Indonesia

Table 1. Assessment matrix of the suitability index for beach tourism

Parameter	Weight	Category	Score
Water depth (m)	0.125	0-3	3
		>3-6	2
		>6-10	1
		>10	0
Beach width (m)	0.200	>15	3
		10-15	2
		3-<10	1
		<3	0
Beach slope (°)	0.080	<10	3
		10-25	2
		>25-45	1
		>45	0
Beach type	0.200	White sand	3
		White sand mixed with coral fragments	2
		Black sand is a bit steep	1
		Mud, rock, step	0
Water clarity (m)	0.125	>80	3
		>50-80	2
		20-50	1
		<20	0
Current velocity (m/s)	0.080	0-17	3
		17-34	2
		34-51	1
		>51	0
Bottom material	0.170	Sand	3
		Sandy coral	2
		Muddy sand	1
		Mud or sandy	0
Land cover	0.010	Coconut tree, open land	3
		Bushses, low savannah	2
		High bushes	1
		Mangrove forest, settlement, ports	0
Hazardous biota	0.005	None	3
		Sea urchin	2
		Sea urchin, stingray	1
		Sea urchin, stingray, shark	0
Freshwater supply (km)	0.005	<0,5	3
		>0,5-1	2
		>1-2	1
		>2	0

The weights and scores in the tourism suitability index matrix above, as formulated by Yulianda (2019), are based on the importance of each parameter to a tourist area. The criteria for determining the weight values for the above analysis parameters were obtained from direct field measurements, which were then converted to obtain the tourism suitability index. According to Yulianda (2019), the Tourism Suitability Index (TSI) is calculated using the following formula:

$$TSI = \sum_{i=1}^{n} \times (\mathrm{Bi} \times \mathrm{Si})$$

Note: TSI = Tourism Suitability Index (%); n = Number of suitability parameters; Bi = i th Weight Parameter; Si = Score of the i th parameter

The concept of carrying capacity was initially introduced in the field of recreation studies during the early 1960s (Coccossis and Mexa, 2004). Tourism Carrying Capacity (TCC) has since been interpreted from ecological, economic, and social perspectives. From an ecological standpoint, TCC emphasizes the equilibrium between tourist numbers and the tolerance limits of the physical environment. It refers to the maximum number of visitors at a given area can accommodate without disrupting ecological functions or degrading natural conditions (Coccossis and Mexa, 2004), or leading to congestion of facilities and infrastructure (Roe *et al.,* 1997). The carrying capacity of coastal tourism was evaluated for each tourism activity category independently. The calculation of tourist carrying capacity was conducted using the framework introduced by Yulianda (2019).

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

Note: CC = Carrying capacity (person/day); K = Ecological potential of visitors per unit area (person); Lp = Area/legth of area that can be utilized (m or m^2); Lt = Unit area for a certain category (m or m^2); Wt = Time provided by the area for tourism activities in one day (hours); Wp = Time spent by the visitor for each particular activity

The scientific literature on SWOT analysis in ecotourism emphasizes the need to consider internal and external factors when formulating ecotourism strategies (Ali *et al.,* 2024). Henri *et al*. (2017) used SWOT analysis to reveal internal and external factors for formulating ecotourism development strategies in forest areas. Quantitative SWOT analysis of ecotourism planning is essential for establishing protected natural areas. Nejad *et al.* (2017) highlight the positive impact of the SWOT and QSPM models in formulating sustainable strategies to increase ecotourism activities along the Caspian Sea. Henri and Ardiawati (2020) emphasize the importance of community-based methods in ecotourism development, in line with a focus on internal variables and community participation in ecotourism initiatives.

The initial stage of data collection in SWOT analysis, by determining strengths, weaknesses, opportunities, and threats, aims to organize perspectives (Damarawati, 2025). According to David and David (2017), identifying internal and external factors, then assigning weights to these factors from 0.0 to 1.0, and then assigning values from 1 to 4, where 1 indicates a significant weakness, moderate weakness, strength, or significant strength. A value below 2.5 indicates that the strength is lower than the weakness, while a value above 2.5 indicates that the strength exceeds the weakness (Bohari *et al.,* 2013). This is followed by determining the average score for each variable by multiplying the weight and the score. This is followed by data reconciliation, which involves reconciling the IFAS and EFAS matrices and then entering the results into the SWOT matrix.

The Quantitative Strategy Planning Matrix is used to assess various strategic options, identify the most feasible alternatives, and prioritize them over other possibilities (Mahmoodi, 2014; Siswanto, 2022). This method aims to determine the optimal strategy objectively by combining information from various management strategies and performing simple calculations. The first step is to identify key strategic elements. Internal factor estimation and external factor estimation matrices are used to complete the SWOT analysis.

In the second step, a comprehensive analysis will be conducted to compare strategies and identify the most appropriate one in line with the research objectives. In the final step, QSPM will evaluate the relative attractiveness of various strategies by assessing how well important external and internal success variables can be improved or utilized. The magnitude of the difference between the total attractiveness scores for each alternative indicates how much more desirable one strategy is than another (Budiasa *et al*., 2024).

RESULTS AND DISCUSSION

Observations from the three stations show general similarities in the parameters measured. See Table 2. However, at station one, differences were found in the base material and beach slope. Tourism suitability index scores for beach recreation. The tourism suitability index values for Karangsong Beach at stations 2 and 3 fall into the highly suitable category, while at station 1 they fall into the unsuitable category. These differences in index values are due to differences in the substrate type, brightness, and slope.

According to Yulianda (2019), sandy substrates and clear waters are important factors in supporting the comfort of beach tourism activities. In addition, the beach's sloping terrain, rather than steep terrain, increases tourists' sense of safety when swimming and engaging in other activities. It suggests that Karangsong Beach has great potential to be developed into a safe and comfortable marine tourism area.

Based on the results of this study, it is evident that, although parts of the beach at station 1 are not suitable for tourism, Karangsong Beach still has great potential as a marine recreation area. Efforts to manage the area need to focus on improving water quality and reducing sedimentation from the mainland. The entire beach area can be optimally utilized as a sustainable tourist destination.

Karangsong Beach is dominated by black sand. This type of sand is generally less ideal than white sand because it has lower aesthetic and comfort values (Yulianda, 2019). However, black sand can still be used for recreation as long as it is supported by other conditions such as a wide beach and calm waves. Beach type is an important parameter because it is one of the main attractions in marine tourism.

Beach width is included in the parameters of the suitability index, which is very important. According to Habibi *et al.* (2017), beach width measurements are used to determine the extent of the coastal area suitable for tourism activities. Beach width affects visitor activity. The wider the beach,

Table 2. Observation results of ten variables at three stations on Karangsong beach

Variabel	Weight	Stasion		
		1	2	3
Water depth (m)	0.125	0.55	0.65	0.40
Beach width (m)	0.200	28	28	28
Beach slope (^{0})	0.080	10	2.4	5.13
Beach type	0.200	Black sand	Black sand	Black sand
Water clarity (%)	0.125	0	0	0
Current velocity (m/s)	0.080	0.035	0.053	0.054
Bottom material	0.170	Sandy silt	Sand	Sand
Land cover	0.010	Mangrove forest, port	Mangrove forest, port	Mangrove forest, port
Hazardous biota	0.005	None	None	None
Freshwater (km)	0.005	0.059	0.079	0.099
		1.645	2.55	2.55
		Not suitable	Highly suitable	Highly suitable

the better it is for visitors to carry out activities. The results in Table 2 show that all stations have a score of 3 because their beach widths are less than 15 meters. This is in accordance with the criteria stated by Yulianda (2019), which indicate that a wide beach allows tourists to engage in various activities. In addition, a large area also supports safety and comfort, especially when the beach is crowded with visitors.

The water at the research location varies in composition, namely sand, sandy mud, and sand mixed with fine sediments. Stations 2 and 3 with sandy substrates received higher suitability scores because they are more comfortable for tourist activities. Meanwhile, Station 1 has a sandy mud substrate. In fact, sandy coastal substrates are the most suitable for beach tourism, compared to rocky or coral beaches.

The depth of the beach at the three stations that have been measured is approximately 0.40–0.65 m. Beaches with this depth are still categorized as suitable for water recreation activities. The shallow depth provides greater safety for tourists, especially children, when swimming. According to Juliana *et al*. (2013), the suitability of tourism for depth ranges from less than 3 m to a category of very suitable for swimming tourism. Depth is an important factor in tourism because it affects tourists' comfort and safety.

The current speed at each station is low or slow and is categorized as suitable. Currents that are not too strong provide a high level of safety for tourists, especially when swimming and playing in the water at the beach. Station one has a current speed of 0.035 m/s, station two has a current speed of 0.053 m/s, and station three has a current speed of 0.054 m/s. The current speeds at all three stations fall within the appropriate category and do not pose a danger to tourists when engaging in beach activities (Subandi *et al*., 2018).

The slope of Karangsong Beach ranges from 2.4° to 10°, which falls into the gentle category. According to Bibin & Mecca (2020), measuring beach slope is useful for determining the steepness of a tourist area. This is because the beach slope can affect visitors' comfort and safety while vacationing; a steep beach area is also very risky. A beach slope of less than 10° is considered appropriate, while a slope of more than 45° is considered steep and poses a risk of slipping. The gentler the slope of a beach, the wider the intertidal zone, and conversely, the steeper the beach, the narrower the intertidal zone.

The water clarity at Karangsong Beach is very low, so it does not meet the criteria. The weather influences this condition, the time of measurement, and suspended density (Wabang *et al*., 2017). Low clarity reduces the attractiveness of tourism, especially for activities involving underwater observation.

The closure of land on Karangsong Beach indicates that mangrove forests and fishing boat harbors cover it, and thus, it falls into the unsuitable category. The ideal vegetation for tourism is usually coconut trees or low vegetation that provides aesthetic value and comfort.

The results of observations on hazardous biota are nil. All observation stations showed no hazardous biota activity, so this area can be considered safe for activities such as swimming and playing in the water. A tourist area without dangerous wildlife can provide a sense of safety and comfort. According to Katanyane *et al*. (2023), an area with dangerous biota must be able to minimize the presence of such biota. With the absence of dangerous biota, it is given a high score because it meets the standards for beach recreation safety.

Fresh water is generally needed for cleaning after tourist activities. The availability of fresh water plays an important role as the main infrastructure in recreational tourist areas. Karangsong Beach has a freshwater supply that is very suitable for tourism. The results of the observation show that all three stations meet the tourism suitability index standards, with a distance between the coastline and freshwater sources, such as bathrooms/toilets, of less than 500 meters. According to Soares *et al*. (2021), freshwater availability within 500 meters of the coast affects the suitability of the area for coastal ecotourism development.

Tides can affect physical conditions in the intertidal zone. Tides at the research site showed an average sea level of 2.04 m, with the highest tide at 0.86 m and the lowest at 0.07 m. Tidal data was taken from GBIG data for 2025. This tidal range is relatively small, resulting in a relatively narrow and stable intertidal zone. Based on this tidal range, the tidal amplitude at the study site is estimated to be -1.19 m, indicating relatively small sea level fluctuations. The difference in slope causes variations in the width (horizontal distance) of the intertidal zone, even though they have relatively the same tides. Station 1 has a beach slope of 10°, so it has the narrowest intertidal zone width of 11.6 m. Station 2 has a beach slope of 5.13°, with an intertidal zone width of 48.6 m, while station 3 has a beach slope of 2.4°, which means it has the widest intertidal zone width of 30 m. The data for the intertidal zone width calculation are presented in Appendix 12. A steep beach slope will result in a relatively narrow intertidal zone compared to a gentle beach slope (Basith, 2014). The Carrying Capacity analysis provides a quantitative threshold to prevent environmental degradation. Based on the effective area and duration of activities, the results are as shown in Table 3.

The results of the analysis of the carrying capacity of the Karangsong Indramayu coastal area, including the categories of recreation and swimming, are shown in Table 2. The calculation results indicate that the carrying capacity of the Karangsong coastal area for beach recreation activities is 214 people/day. Meanwhile, water activities have a higher carrying capacity of 1043 people/day. The carrying capacity of an area is the maximum number of tourists that can be accommodated without degrading the environment. This concept serves to limit the use of natural resources to keep them sustainable and to prevent damage to the ecosystem. Carrying capacity analysis is important in ecotourism management because it determines the safe daily visitation limit, thereby maintaining tourist comfort and environmental sustainability. To support the development of sustainable ecotourism, it is necessary to improve supporting facilities and waste management to maintain comfort and environmental carrying capacity.

The IFAS matrix analysis is an internal assessment of Karangsong Beach's strengths and weaknesses. The IFAS matrix for Karangsong Beach is shown in Table 4. The IFAS matrix results show that the main strengths are the beach's cleanliness and comfort, with a score of 0.39. In addition, Karangsong Beach also still has a natural coastal area with a score of 0.38. The weaknesses of Karangsong Beach are the lack of clean water, poor road access, and several provider networks that are not yet optimal, each with a score of 0.41.

The EFAS matrix analysis is based on an assessment of internal factors, including the impact of opportunities and threats. The EFAS matrix analysis for the development of Karangsong Beach is shown in Table 5. The matrix results show that the main opportunities are the potential for ecotourism development through education and business opportunities for communities around Karangsong Beach, with a score of 0.45. The biggest threats to Karangsong Beach in Indramayu include trash, visitors who can damage facilities and infrastructure, and boat building activities.

Table 3. Carrying capacity analysis results for Karangsong beach. K: Ecological potential of visitors per unit area (person); Lp: Area/legth of area that can be utilized (m or m²); Lt: Unit area for a certain category (m or m²); Wt: Time provided by the area for tourism activities in one day (hours); Wp: Time spent by visitor for each particular activity.

Types of Activities	K	Lp (m²)	Lt (m²)	Wp (h)	Wt (h)	Carrying capacity (people/day)
Beach Recreation	1	1.604	25	3	10	214
Playing in the water	2	4.174	20	2	10	1043

Table 4. Analysis results from Internal Factors Analysis Strategic (IFAS) for Karangsong beach

Strength	Weight	Rating	Score
The beauty of Karangsong Beach, Indramayu	0.11	3.26	0,36
Travel costs are relatively inexpensive	0.11	3.06	0.34
The natural condition of the coastal area	0.11	3.38	0.38
Adequate tourist facilities	0.11	3.26	0.36
Clean and comfortable environmental conditions	0.11	3.50	0.39
Total Strength	0.55		1.83
Weakness	Weight	Rating	Score
Lack of knowledge among local communities and tourists about coastal conservation	0.11	3.26	0.35
Communication network channels are only available from certain providers	0.11	3.12	0.38
Availability of fresh water	0.11	3.46	0.41
Road access to Karangsong Beach. Indramayu	0.11	3.72	0.41
Total Weakness	0.44		1.67
Total IFAS	1.00		0.27

Table 5. Analysis results from External Factors Analysis Strategic (EFAS) for Karangsong beach

Strength	Weight	Rating	Score
Tourist interest in beach tourism at Karangsong Beach. Indramayu	0.13	3.26	0.41
Participation of local governments	0.13	3.54	0.44
There is potential for ecotourism development through education.	0.13	3.58	0.45
Business opportunities for communities around Karangsong Beach	0.13	3.54	0.45
Total Opportunities	0.52		1.75
Threat	Weight	Rating	Score
Trash	0.13	3.62	0.42
Tourist activities that can damage beach tourism facilities and infrastructure	0.13	3.38	0.42
The existence of shipbuilding activities around the Karangsong Village area	0.13	3.20	0.40
Areas vulnerable to abrasion	0.13	3.38	0.42
Total Threat	0.52		1.66
Total EFAS	1.00		0.08

SWOT analysis is a process of examining a company's internal and external environment and then formulating strategies based on strengths, weaknesses, opportunities, and threats (Nugroho *et al.,* 2022). In addition, internal factors can be examined using SWOT analysis, namely strengths and weaknesses, while external factors are opportunities and threats. The results show that strengths outweigh weaknesses and opportunities outweigh threats. SWOT analysis has proven to be a useful tool in decision-making because it offers a qualitative approach.

After carefully assessing the highest-weighted scores for internal and external components and identifying their interconnections, four strategies were formulated using SWOT analysis. There is a strong correlation between strengths and opportunities (SO), indicating that the natural conditions of Karangsong Beach can be used for school education. Conversely, the significant relationship between weaknesses and threats (WT) is seen as an indication to use a defensive approach. The high correlation between strengths and threats (ST) allows for the implementation of various solutions. Finally, the interaction between weaknesses and opportunities (WO) can be examined as a possible avenue for review. Table 6.

Table 6. SWOT strategies based on strengths, weaknesses, opportunities, and threats

IFAS	STRENGTH	WEAKNESS
	1. The beauty of Karangsong Beach. Indramayu 2. Travel costs are relatively inexpensive 3. The natural condition of the coastal area 4. Adequate tourist facilities 5. Clean and comfortable environmental conditions	1. Lack of knowledge among local communities and tourists about coastal conservation 2. Communication network channels are only available from certain providers 3. Availability of fresh water 4. Road access to Karangsong Beach. Indramayu
OPPORTUINITIES 1. Tourist interest in beach tourism at Karangsong Beach. Indramayu 2. Participation of local governments 3. There is potential for ecotourism development through education. 4. Business opportunities for communities around Karangsong Beach. Indramayu	STRATEGY S-O 1. Create educational tours about Karangsong Beach to attract tourists and schools 2. Offer promotional ticket prices in collaboration with the government to increase the number of visitors 3. Develop community-based ecotourism so that tourists are directly involved in nature conservation 4. Provide additional facilities, such as comfortable rest areas, to enhance the tourist experience 5. 5. Organizing regular events or beach festivals to attract repeat tourists	STRATEGY W-O 1. Conducting coastal conservation education programs for the community and tourists with the support of the local government 2. Improving communication network infrastructure in collaboration with providers 3. Providing a water storage and freshwater system in tourist areas 4. Improving road access to the beach with the help of regional development funds 5. Using digital promotion to increase tourist awareness and knowledge
THREAT 1. Trash 2. Tourist activities that can damage beach tourism facilities and infrastructure 3. The existence of shipbuilding activities around the Karangsong Village area 4. Areas vulnerable to abrasion	STRATEGY S-T 1. Establish adequate facilities to provide trash bins at every strategic point. 2. Organize tourist routes to avoid damage to beach facilities and infrastructure. 3. Educate the public about development that could increase abrasion. 4. Preserve natural areas by limiting development in vulnerable zones.	STRATEGY W-T 1. Create signage prohibiting littering and increasing the number of trash bins. 2. Provide educational signage on environmental conservation 3. Provide a freshwater supply in anticipation of drought during the dry season 4. Conduct cleanliness patrols and raise awareness about trash with the local community

The SWOT matrix analysis (Ali *et al.,* 2024) indicates that the development potential of Karangsong Beach closely aligns with the core principles of sustainable marine ecotourism, which emphasize environmental conservation, community participation, and long-term economic viability. The integration of internal strengths—such as relatively natural coastal conditions, adequate tourism facilities, and a clean and comfortable environment—with external opportunities —including increased tourist interest, government involvement, and ecotourism-based educational potential — supports the formulation of sustainability-oriented strategies. In particular, S–O strategies highlight the importance of community-based ecotourism, environmental education, and nature-oriented tourism activities, which are widely recognized as effective approaches for reducing ecological pressure while enhancing local economic benefits. These strategies are especially relevant for coastal ecosystems such as mangroves, where conservation-oriented tourism can simultaneously function as a protection mechanism and a source of livelihood for surrounding communities.

Moreover, the W–O, S–T, and W–T strategies emphasize the need to manage tourism development within ecological limits to ensure long-term sustainability. Addressing internal weaknesses, such as limited environmental awareness and infrastructure constraints, through education, improved accessibility, and basic services can reduce external threats, including waste pollution, ecosystem degradation, and coastal abrasion. The incorporation of SWOT-based strategies alongside considerations of carrying capacity provides a comprehensive management framework that balances tourism use with ecosystem resilience. This integrated approach ensures that tourism activities remain within acceptable environmental thresholds, maintaining ecosystem functions and visitor satisfaction over time. Consequently, the SWOT analysis confirms its strategic value as a decision-support tool for guiding sustainable marine ecotourism development in coastal areas such as Karangsong Beach.

The Quantitative Strategic Planning Matrix (QSPM) analysis was applied to prioritize strategic alternatives derived from the SWOT framework by objectively evaluating their relative attractiveness (Siswanto, 2022). The results indicate that the strategy of developing community-based ecotourism with direct tourist involvement in nature conservation achieved the highest Total Attractiveness Score (TAS), demonstrating its strategic superiority over other alternatives. Table 7. This finding reflects the growing recognition that sustainable marine ecotourism is most effective when local communities play a central role in tourism management and conservation activities. Community-based approaches enhance environmental stewardship, increase local ownership of natural resources, and ensure that economic benefits are distributed equitably, which are key dimensions of sustainability in marine ecotourism development.

Other high-priority strategies, such as organizing regular educational and cultural events and developing environmentally oriented tourism programs, further reinforce the importance of sustainability-oriented planning. These strategies raise environmental awareness among visitors while maintaining tourism activities within ecological limits, as indicated by the carrying capacity analysis. This aligns with the criteria for sustainable marine ecotourism, including Environmental Conservation (protecting marine ecosystems and wildlife), Local Well-Being (empowering the economy and preserving the culture of coastal communities), and Tourism Management (limiting visitor numbers and operating in an environmentally friendly manner) (Arismiyanti, 2017). By prioritizing strategies that integrate conservation, education, and community empowerment, the QSPM results support a management approach that balances tourism growth with ecosystem resilience. Overall, the QSPM analysis provides a robust decision-making tool for selecting development strategies that are consistent with sustainable marine ecotourism principles, ensuring long-term environmental protection, visitor satisfaction, and socio-economic benefits for coastal communities at Karangsong Beach.

Table 7. Quantitative Strategic Planning Matrix (QSPM)

Strategies		TSK	Ranking
S – O 1	Creating educational tours about Karangsong Beach to attract tourists and schools	5.7639	II
S – O 2	Offering promotional ticket prices in collaboration with the government to increase the number of visits	4.7083	V
S – O 3	Developing community-based ecotourism so that tourists are directly involved in nature conservation	5.9861	I
S – O 4	Providing additional facilities, such as comfortable rest areas, to enhance the tourist experience	4.9028	IV
S – O 5	Hold regular events or beach festivals to attract repeat tourists	5.5556	III

CONCLUSION

This study demonstrates that integrating tourism suitability assessment, carrying capacity analysis, and strategic planning tools provides a robust scientific basis for sustainable marine ecotourism development at Karangsong Beach, Indonesia. The Tourism Suitability Index (TSI) results indicate that most coastal segments are highly suitable for recreational beach tourism. However, certain areas require targeted management interventions due to physical and environmental constraints. The carrying capacity analysis further defines clear quantitative thresholds for visitor numbers, emphasizing the importance of regulating tourism intensity to prevent ecosystem degradation and maintain visitor comfort. Together, these findings highlight that tourism development at Karangsong Beach must be managed within ecological limits to ensure long-term sustainability. The SWOT and QSPM analyses reinforce that sustainability-oriented strategies, particularly community-based ecotourism and environmental education, are the most effective pathways for the development of marine ecotourism in the study area. The prioritization of strategies that integrate conservation, local community participation, and educational tourism aligns closely with the core principles of sustainable marine ecotourism. By combining environmental protection with socio-economic benefits for coastal communities, the proposed strategies support ecosystem resilience, enhance environmental awareness, and promote inclusive local development. Overall, this integrated approach offers a practical and transferable framework for sustainable marine ecotourism planning in tropical coastal regions, contributing to balanced tourism growth, coastal ecosystem conservation, and long-term community well-being.

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