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Marine Tourism Suitability Index and Ecological Carrying Capacity on the West and East Coasts of Pangandaran, Indonesia

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ABSTRACT

Indonesia is widely recognized for its diverse and attractive beach tourism destinations. With one of the longest coastlines in the world, the country holds substantial potential for coastal tourism development. Pangandaran, located in the southern part of West Java Province, is among the most popular beach destinations. However, assessments of tourism suitability and ecological carrying capacity in this area remain limited.

This study analyzes the tourism suitability index (TSI) and ecological carrying capacity (ECC) of the West and East coasts of Pangandaran for three types of beach tourism activities: recreation, swimming, and camping. The TSI results indicate that both coasts are categorized as *very suitable* for beach recreation. For camping, West Pangandaran Beach falls into the *very suitable* category, while East Pangandaran Beach is classified as *suitable*, reflecting its relatively rockier conditions. For swimming, suitability values varied across observation stations due to differences in wave height. The ECC results differed between the two coasts. West Pangandaran Beach demonstrated higher carrying capacity than East Pangandaran Beach, largely due to its greater length and area. Specifically, the ECC of East Pangandaran Beach was estimated at 253 tourists/day for recreation, 189 tourists/day for swimming, and 710 tourists/day for camping. In comparison, the ECC of West Pangandaran Beach was 340 tourists/day for recreation, 255 tourists/day for swimming, and 1,592 tourists/day for camping. Overall, these findings provide a scientific basis for supporting sustainable ecotourism management in Pangandaran, Indonesia, by integrating tourism suitability and ecological carrying capacity into coastal tourism planning.

INTRODUCTION

Indonesia has tremendous potential for coastal tourism development due to its strategic location and geographic characteristics as an archipelagic nation **(Supriyanto, 2022; Mawar *et al.*, 2023)**. With more than 17,000 islands and a coastline exceeding

99,000km, Indonesia possesses the world's second-longest coastline after Canada **(Indrawati *et al.*, 2023; Yolanda *et al.*, 2025)**. This vast coastal wealth supports thousands of diverse destinations, from white sandy beaches to coral reef shores, characterized by scenic beauty and high marine biodiversity **(Northrop *et al.*, 2020; Tomascik *et al.*, 2023)**.

Coastal tourism is a strategic sector for Indonesia's sustainable development, particularly in strengthening local economies and supporting environmental conservation **(Tegar & Gurning, 2017; Fadli *et al.*, 2022)**. Seaside tourism is one of the fastest-growing segments, largely due to its natural attractions—picturesque coastal landscapes, rich marine ecosystems, and the cultural uniqueness of coastal communities **(Widiyastuti & Ladampa, 2018; Setiyanto *et al.*, 2023)**. However, increased tourist visits have also created serious challenges, including environmental degradation, congestion, and declining visitor satisfaction **(Szromek *et al.*, 2019; Baloch *et al.*, 2022; García-Buades *et al.*, 2022)**. In this context, studies applying the tourism suitability index (TSI) and ecological carrying capacity (ECC) are highly relevant.

Pangandaran Beach, located in Pangandaran Regency, West Java, is one of Indonesia's premier coastal destinations, offering recreational activities such as swimming, camping, and beach exploration. Yet, rapid increases in visitor numbers pose significant risks to coastal ecosystems and resource quality **(Hasibuan *et al.*, 2019; Prawira *et al.*, 2024)**. During holiday seasons, visitor surges are particularly acute. For instance, the Pangandaran Regency Tourism Office (2025) recorded extreme crowding during the Eid al-Fitr holiday, with daily arrivals ranging from 40,341 to 51,720 visitors.

This phenomenon of overtourism not only threatens environmental sustainability but also diminishes the quality of visitor experiences. Overcrowding has been linked to ecosystem degradation, reduced opportunities for relaxation, negative emotional responses, and increased risks to safety **(Dodds & Butler, 2019; Turker *et al.*, 2024; Diah, 2025)**.

To mitigate these challenges, responsible tourism practices emphasizing environmental protection, cultural preservation, education, and sustainability are essential. Such principles are embodied in ecotourism, which has already begun to be promoted at Pangandaran Beach, though implementation remains limited **(Nugroho & Suryono, 2013; Nurhayati *et al.*, 2019)**. One key strategy is to evaluate site suitability for specific tourist activities and to establish visitor quotas based on ecological carrying capacity **(Yulianda, 2019)**.

The tourism suitability index (TSI) provides a framework for assessing how well a location supports different forms of tourism, considering parameters such as water depth, beach width and slope, substrate type, current velocity, water clarity, land cover, the presence of hazardous biota, and freshwater availability. Meanwhile, ecological carrying capacity (ECC) refers to the maximum number of visitors an area can sustain without

causing significant ecological harm **(Simanjuntak *et al.*, 2018; Widodo *et al.*, 2023; Putri *et al.*, 2024)**.

Therefore, this study aimed to analyze the coastal tourism suitability index and ecological carrying capacity of Pangandaran's West and East coasts. The findings are expected to provide valuable insights for planning and managing sustainable coastal tourism in the region.

BASIC CONCEPT

Ecotourism and it's principles

Ecotourism is a form of sustainable tourism that emphasizes environmental conservation, community empowerment, and ecological education **(Fennell, 2008; Samal & Dash, 2023; Satrya *et al.*, 2023)**. According to the International Ecotourism Society **(TIES, 2015)**, ecotourism involves travel activities in natural areas that aim to preserve the environment, improve the welfare of local communities, and incorporate educational values.

The implementation of ecotourism in coastal areas is particularly important due to the high vulnerability of these environments to degradation from uncontrolled tourism activities **(Sunaryo, 2013; Smith *et al.*, 2023; Sikotariya *et al.*, 2024)**. Effective coastal management must therefore be based on the concept of ecological carrying capacity to maintain ecosystem functions and to ensure a high-quality tourism experience **(Tang *et al.*, 2022; Fatina *et al.*, 2023)**.

Tourism suitability index (TSI)

The Tourism Suitability Index (TSI) is a quantitative method used to evaluate the suitability of an area for natural resource-based tourism, considering both biophysical factors and accessibility **(Pin *et al.*, 2021; Elisecarmel *et al.*, 2025)**. According to **Yulianda (2007)**, the TSI helps identify the potential and limitations of an area in supporting specific tourism activities. Commonly assessed criteria include water depth, water transparency, substrate type, current speed, and beach slope.

The final TSI assessment is expressed as a percentage of suitability, derived from scoring each criterion based on its relative weight, which reflects its importance to the tourism activity being evaluated. This framework allows for spatial comparisons across different coastal regions **(Yulianda & Mazaya, 2021; Fikri *et al.*, 2024; Withanage *et al.*, 2024)**.

Ecological carrying capacity (ECC)

Ecological carrying capacity refers to the maximum number of visitors or activities an environment can sustain without significant ecological degradation **(Wang, 2010)**. In tourism contexts, ECC defines the threshold of visitor numbers an ecosystem can tolerate while maintaining ecological stability. Calculations typically incorporate spatial and temporal factors such as effective area, visitation time, waste absorption capacity, and natural regeneration rates **(Long *et al.*, 2022; Skiniti *et al.*, 2024; Xu & Li, 2025)**.

The results of ECC analysis provide a scientific reference for determining visitor quotas at tourist sites, ensuring long-term sustainability of ecological areas **(Haribudiman *et al.*, 2023; Rasidi *et al.*, 2023; Diniz *et al.*, 2024; Christianty *et al.*, 2025)**.

Initial review of Pangandaran coastal area

The Pangandaran coastal area has been the subject of numerous studies addressing sustainable tourism. **Komalasari and Herwangi (2023)** highlight its potential for marine tourism development, while **Kurniasih *et al.* (2020)** examined socio-economic opportunities linked to Pangandaran Beach. Similarly, **Dhalyana and Adiwibowo (2015)** explored the influence of a coastal nature tourism park on community livelihoods. In a related study, **Millah and Fadlina (2023)** analyzed carrying capacity at Batu Karas Beach, another site in Pangandaran Regency.

Research has also examined environmental challenges such as climate change and marine debris, much of which originates from tourism and their impacts on coastal ecosystem health **(Suwarto, 2011; Satriawan *et al.*, 2024)**. These findings reveal a paradox: while tourism provides socio-economic benefits, it also contributes to environmental decline through unsustainable development.

Sustainable tourism and regional management

Sustainable tourism emphasizes balancing economic growth, environmental conservation, and socio-cultural sustainability **(Gupta *et al.*, 2024; Kusherdyana & Muslim, 2024)**. One widely applied management strategy is to regulate tourism intensity based on ecological carrying capacity, thereby preventing excessive pressure on ecosystems **(Llausàs *et al.*, 2019)**. Within this framework, the tourism suitability index and ecological carrying capacity serve as essential tools in planning and managing sustainable coastal tourism.

MATERIALS AND METHODS

Research location

This research was conducted on the West and East coasts of Pangandaran, Indonesia. Observations were performed on both coasts from April to June 2025. Five observation locations were systematically determined (with equal distance between stations) along the West and East coasts of Pangandaran. The five observation stations were chosen in each region to obtain a comprehensive representation of the physical parameters of the area being observed. A map of the study locations is presented in Fig. (1).

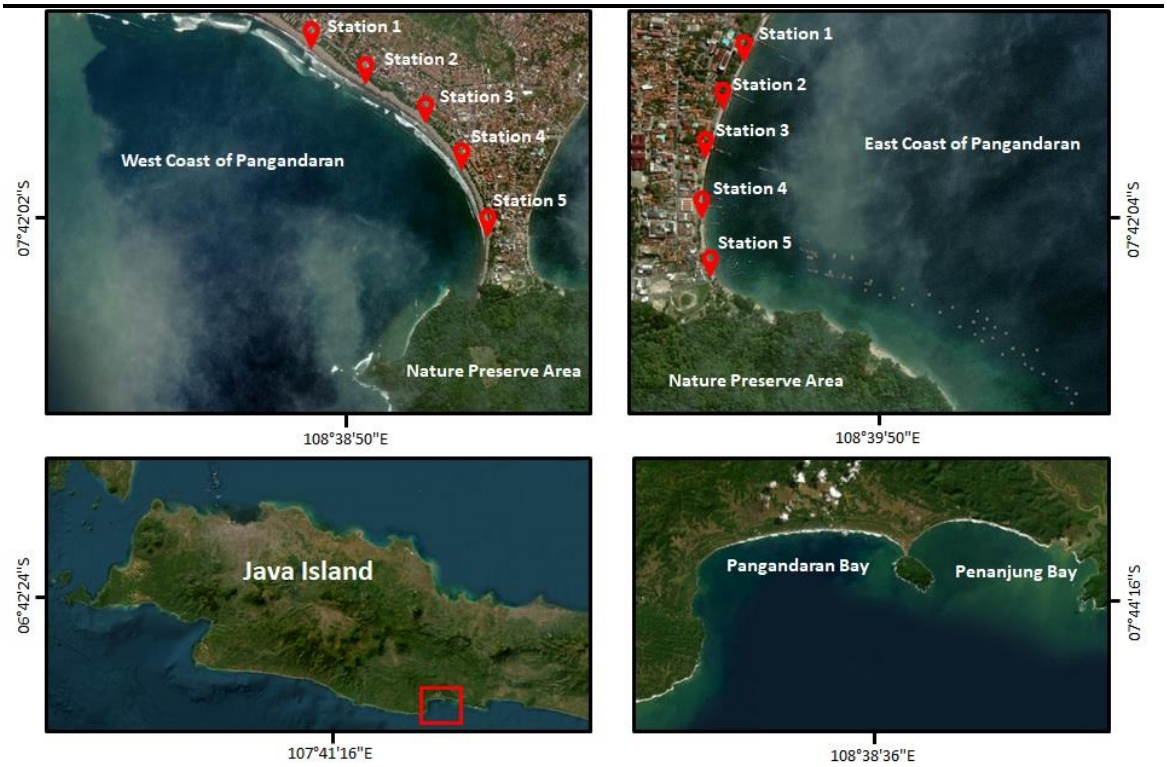

Fig. 1. Map of the research location. The comparative scale on the map of the West Coast of Pangandaran has 1:0.6, with a beach length of 3.2km. On the East Coast of Pangandaran, the scale has 1:0.4, with a beach length of 2.3km

Data analysis

The analysis of the tourism suitability index focuses on three types of activities typically carried out along the coast: beach recreation, swimming, and camping. These beach recreation activities include playing in the sand, engaging in beach sports such as beach volleyball, sunbathing, and taking in the beauty of sunset or sunrise at the beach. Each of these activities is evaluated using specific criteria and assigned individual weightings, following the framework outlined by **Yulianda (2019)**. For beach recreation, the index incorporates 10 assessment parameters, each with designated weights and classification levels, as shown in Table (1).

Table 1. The matrix used to assess the tourism suitability index for the beach recreation category

No.	Criteria	Criteria weight	Score distribution class			
			3	2	1	0
1	Type of Beach	0.200	White sand	White sand mixed with coral fragments	Black sand is a bit steep	Mud, rocky, steep
2	Width of the beach (m)	0.200	>15	10-15	3 - <10	<3
3	Substrate materials	0.170	Sand	Sandy coral /	Muddy sand	Mud or sandy

No.	Criteria	Criteria weight	Score distribution class			
			3	2	1	0
				Rocky sand		mud
4	Water depth (m)	0.125	0-3	>3-6	>6-10	>10
5	Water transparency (%)	0.125	>80	>50-80	20-50	<20
6	Current velocity (cm/s)	0.080	0-17	>17-34	>34-51	>51
7	Coastal slope angle (°)	0.080	<10	10-25	>25-45	>45
8	Beach closures	0.010	Coconut tree, open area	Low shrubs, savanna	Tall bushes	Mangrove forests, settlements, ports
9	The presence of dangerous biota	0.005	There are no dangerous biota	Sea urchins	Sea Urchins and Stingrays	Sea urchins, stingrays, lionfish, sharks
10	Distance to fresh water source (km)	0.005	<0.5	>0.5-1	>1-2	>2

Beach tourism activities under the swimming category are evaluated using nine assessment criteria, each with specific weights and classification levels. According to **Yulianda (2019)**, these nine criteria are detailed in Table (2), which outlines the suitability parameters for beach tourism focused on swimming activities. This assessment does not consider the beach slope. Although coastal slope affects aesthetics and other beach tourism activities, such as playing in the sand or sunbathing, in the context of swimming, factors related to water conditions and safety are prioritized more directly, including water depth, current speed, wave height, and water clarity.

Table 2. Assessment matrix of the suitability index for beach tourism in the swimming activity category

No.	Criteria	Criteria weight	Score distribution class			
			3	2	1	0
1	Water depth (m)	0.143	0-3	>3-6	>6-10	>10
2	Substrate materials	0.143	Sand	Sandy coral / Rocky sand	Muddy sand	Mud or sandy mud
3	Current velocity (cm/s)	0.143	0-17	>17-34	>34-51	>51
4	Wave height (m)	0.143	0-0.5	0.5-1	1-1.5	>1.5
5	Type of Beach	0.086	White sand	White sand mixed with coral fragments	Black sand is a bit steep	Mud, rocky, steep
6	Width of the beach (m)	0.086	>15	10-15	3-<10	<3
7	Water transparency (%)	0.086	>80	>50-80	20-50	<20

No.	Criteria	Criteria weight	Score distribution class			
			3	2	1	0
8	The presence of dangerous biota	0.086	There are no dangerous biota	Jellyfish	Sea urchins, jellyfish	Water snakes, sea urchins, jellyfish
9	Distance to fresh water source (km)	0.086	<0.5	>0.5-1	>1-2	>2

The camping category of beach tourism suitability is evaluated using just five criteria. These criteria, along with their respective weights and classification levels, are outlined in Table (3), as described by **Yulianda (2019)**. When camping, the distance from a tourist location to a freshwater source is generally excluded. This is because tourists typically prepare all supplies before embarking on a trip, including drinking water. Personal hygiene activities, such as bathing with freshwater, are also rarely undertaken. This is because camping aims to connect with nature for a limited period, typically a maximum of one night, using simple equipment such as a tent and a folding mattress. Camping differs from more modern overnight stays, which require resorts equipped with freshwater facilities **(Yulianda, 2007, 2019)**.

Table 3. Assessment matrix of the suitability index for coastal tourism in the camping activity category

No.	Criteria	Criteria weight	Score distribution class			
			3	2	1	0
1	Types of plains	0.375	Grass or sand	Grassy land	Mud or rocky	Rock or unstable soil
2	Width of the beach (m)	0.225	x >10	$7 < x \leq 10$	$5 < x \leq 7$	≤ 5
3	Coastal vegetation	0.150	Coconut, Pine, and Acacia trees	A tree system and a little undergrowth	Tall bushes	Tall bushes and swamps or non-vegetation
4	Coastal slope angle (°)	0.150	x <5	$5 < x \leq 15$	$15 < x \leq 30$	> 30
5	Object view	0.100	Beach, forest, mountains, rivers	Beach and 2 of 3 views	1 of 4 views	There is no beautiful view

To determine the value of each assessment criterion within the coastal tourism suitability matrix, direct field observations were carried out. Specific indicators, including beach type, substrate composition, coastal vegetation, scenic value, and proximity to freshwater sources, were recorded through direct observation. Meanwhile, other criteria required the use of specific measurement tools and techniques. For instance, flow velocity was measured using a flowmeter, depth and beach slope were gauged with a scale board and theodolite, wave height and clarity were assessed using a Secchi disk, and beach width was measured using a measuring tape and spatial mapping.

The analysis of the tourism suitability index was carried out by aligning the observed data with the corresponding value classes and assigned weights in the assessment matrix. The calculation method for the tourism suitability index follows the approach outlined by **Yulianda (2007)**, as described below:

$$TSI = \sum \left[\frac{N_i}{N_{max}}\right] x\ 100\%$$

Where, TSI: Tourism Suitability Index (%), N_i: criterion value (weight x score), and N_{max}: maximum value that can be obtained for each i-th criterion.

The resulting tourism suitability index values are categorized into four distinct class intervals to indicate the degree of suitability. These four classification levels are outlined in Table (4), as described by **Yusuf (2007)**.

Table 4. Classification of tourism suitability based on tourism suitability index value

No.	Classification	Value of TSI
1	Very suitable	81 - 100%
2	Quite appropriate	63 - <81%
3	Conditionally appropriate	44 - <63%
4	Not feasible	<44%

In addition, the ecological carrying capacity for coastal tourism is calculated separately for each tourism activity category. The calculation method for determining the ecological carrying capacity of tourists is based on the framework provided by **Yulianda (2019)**.

$$ECC = K\ x\ \left(\frac{L_p}{L_t}\right)\ x\ \left(\frac{W_p}{W_t}\right)$$

Where, ECC: ecological carrying capacity of the area (number of visitors); K: ecological potential of tourists per unit area (people); L_p: available area length or size for tourism activities (m^2 or m); L_t: unit area per activity category (m^2 or m); W_p: available time for tourism activities per day (hours); and W_t: average time spent by tourists on each activity (hours).

The ecological potential value (K) per unit area (L_t) is determined according to guidelines proposed by **Yulianda (2019)**, taking into account the principles of coastal ecotourism. This assessment is based on the maximum number of visitors that a coastal ecosystem can sustain without impairing its ecological functions. The ecological capacity varies by tourism category: for beach recreation and swimming, one visitor is allocated per 25 meters of coastline, while for camping, the limit is four visitors per 400 square meters of coastal area. The coastline length and the available coastal area (L_p) for each

site are derived from GPS-based mapping data, which is further analyzed using a Geographic Information System (GIS).

The available time for each type of tourism activity (W_p) varies by category: beach recreation and swimming are allocated eight operational hours per day, while camping activities are allotted a full 24 hours. Additionally, the average duration a visitor spends on each activity differs, approximately 3 hours for beach recreation, 4 hours for swimming, and 24 hours for camping, as outlined by **Yulianda (2019)**.

RESULTS AND DISCUSSION

Marine tourism suitability index

The results of observations on the conditions of the area at both beaches show general similarity in characteristics covering 11 of the 12 parameters observed. The distinguishing characteristic is the substrate material (Table 5). West Coastal Pangandaran has a substrate material type in the form of sand, while East Coastal Pangandaran has a rocky sand substrate (Fig. 2). Another parameter that tends to vary between sampling stations in each region is wave height.

Table 5. Characteristics of the West and East Coast areas of Pangandaran

No.	Criteria	Beach Location									
		West Coast of Pangandaran					East Coast of Pangandaran				
		St.1	St.2	St.3	St.4	St.5	St.1	St.2	St.3	St.4	St.5
1	Type of Beach	White sand					White sand				
2	Substrate materials	Sand					Rocky sand				
3	Width of the beach (m)	38	44	39	48	52	33	30	28	23	22
4	Water depth (m)	2.6	2.5	1.3	1.1	0.8	0.7	0.8	2.2	2.4	2.4
5	Water transparency (%)	85	82	82	83	85	88	85	82	82	82
6	Current velocity (cm/s)	28	27	24	23	21	19	20	24	25	25
7	Wave height (m)	1.3	1.2	1.1	0.9	0.8	0.8	0.8	1.3	1.3	1.4
8	Coastal slope angle (°)	3	3	2	1	1	1	2	3	4	4
9	Beach closures	Low shrubs, trees, open area, ports					Low shrubs, trees, open area, ports				
10	The presence of dangerous biota	There are no dangerous biota					There are no dangerous biota				
11	Distance to fresh water source (km)	<0.5					<0.5				
12	Object view	Beach, forest, mountains					Beach, forest, mountains				

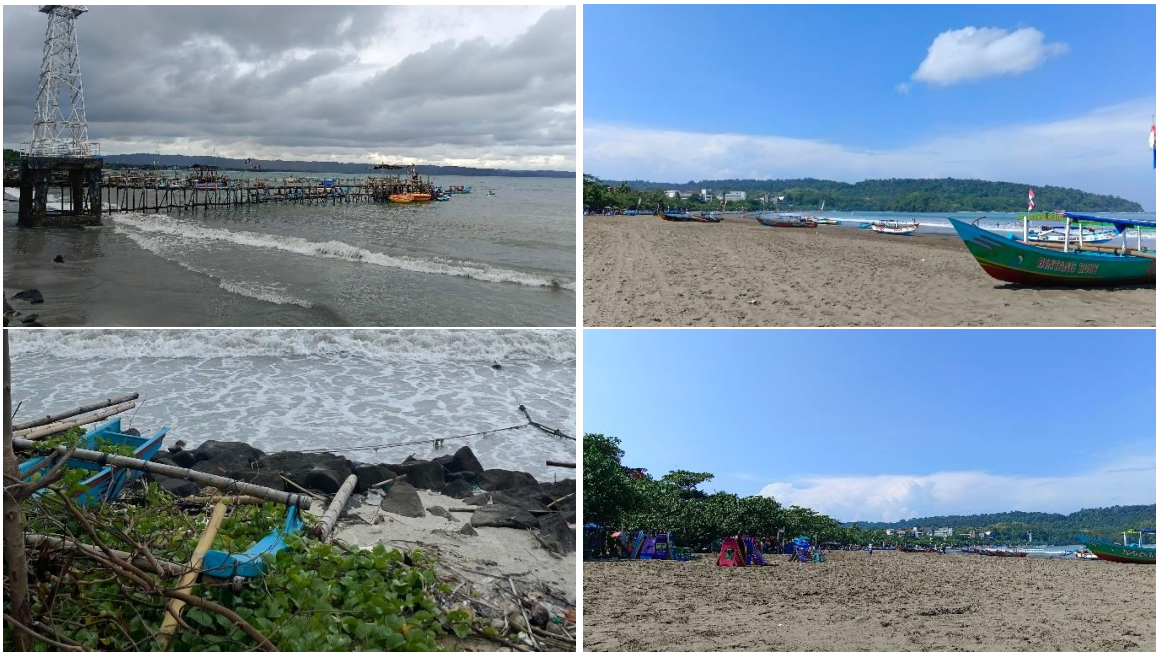

Fig. 2. Documentation of the characteristics of the West Coast (left) and East Coast (right) of Pangandaran

The tourism suitability index score for each beach is based on three forms of beach recreation. The scores indicate that Pangandaran's West and East coasts offer a very suitable category for beach recreation. For the camping category, Pangandaran's West Coast is considered very suitable, while the East Coast is categorized as quite appropriate. For the swimming category, the tourism suitability index value varies among each observation station on each coast. The swimming tourism suitability index value on Pangandaran's West Coast is at its highest at stations 4 and 5, with all observation stations falling into a very suitable category. The tourism suitability index value on Pangandaran's East Coast is the highest at stations 1 and 2, categorized as very suitable, but is deemed quite appropriate at stations 3, 4, and 5 (Table 6).

Table 6. Tourism suitability index for West and East Coast Pangandaran

No.	Tourism Activities	Tourism Suitability Index (%)									
		West Coast of Pangandaran					East Coast of Pangandaran				
		St.1	St.2	St.3	St.4	St.5	St.1	St.2	St.3	St.4	St.5
1	**Beach Recreation**	96.7	96.7	96.7	96.7	96.7	91.0	91.0	91.0	91.0	91.0
2	**Swimming**	81.2	81.2	81.2	90.7	90.7	85.9	85.9	76.4	76.4	76.4
3	**Camping**	96.7	96.7	96.7	96.7	96.7	66.7	66.7	66.7	66.7	66.7

Very suitable
Quite appropriate

The difference in tourism suitability index values between the two beaches is likely due to variations in the characteristics of the existing substrate types. The fine sandy

substrate type on Pangandaran West Beach causes a higher tourism suitability index value for the three tourism activities. The rocky sand substrate type on East Beach tends to yield a lower assessment score. Fine sandy beaches can provide comfort for tourists while they engage in beach tourism activities. While rocky sand beaches can reduce the comfort of tourists in carrying out tourism activities **(Orams, 2003; Yulianda, 2007)**.

Fine sand feels soft when stepped on and is more comfortable to use for activities such as walking, sunbathing, or playing in the sand. Fine sand beaches also provide better safety for beach tourism activities because there is minimal risk of slipping or being injured by sharp rocks. Furthermore, beaches with fine sand are usually more accessible to all groups, including children and older people. Meanwhile, beaches with rocky sand can reduce the comfort of tourism because they can hurt the feet, are less comfortable to sit or lie down on, and can cause minor injuries. In addition, rocky sand beaches offer accessibility that is more challenging for some groups, such as children and older people. Therefore, rocky sand beaches can reduce the appeal of beach tourism **(Yulianda, 2007; 2019)**.

Pangandaran West Beach tends to be wider than Pangandaran East Beach. However, both have characteristics of beaches that are wide enough for the three observed beach tourism activities (>15 meters). Beach width has a direct and significant relationship with the tourism suitability index, as it affects space, safety, and the overall quality of the tourism experience. A large beach width increases the value of the tourism suitability index by providing a vast, safe, and flexible space for various tourism activities while supporting the aesthetic aspects and physical carrying capacity of the area **(Elisecarmel *et al.*, 2025; Sucahyo *et al.*, 2025)**.

The West and East coasts of Pangandaran feature open areas with white sand, low bushes, and trees, as well as various traditional fishing vessels anchored nearby. The condition of the white sand beach, low bushes, and trees is quite suitable for beach tourism activities. However, the presence of numerous fishing vessels anchored around the beach reduces the tourism suitability index score. The presence of fishing vessels anchored around the beach can reduce the tourism suitability value because it disrupts the aesthetics of the natural scenery of the beach, has the potential to cause water pollution from ship waste such as engine oil, and reduces the adequate space on the beach that can be used for tourism activities **(Amffa *et al.*, 2023; Pauhesti *et al.*, 2024)**. However, with integrated development and good harmonization, the presence of fishing vessels anchored around the beach can also increase tourism appeal. Local culture-based tourism management, such as educational tourism centered on fishing communities, has excellent potential for development, which can create its unique appeal **(Mufidah & Sutopo, 2024; Wahyudi *et al.*, 2024)**.

The slope of the coast in both areas, West and East Pangandaran coasts, is in the range of a relatively gentle <5°. This condition provides a very suitable tourism suitability index value, especially for beach recreation and camping activities. A gentle

beach is more appropriate for tourism because it is safer, more comfortable, and easier to access, allowing for safer and more enjoyable recreational activities such as playing in the sand, beach volleyball, and sunbathing **(Staines & Ozanne-Smith, 2002; Wabang *et al.*, 2018)**. In assessing the tourism suitability index, especially for the development of family-based tourism and general recreation, the characteristics of the beach slope are among the main factors considered **(Simanjuntak *et al.*, 2018; Elisecarmel *et al.*, 2025)**.

The water conditions of the West and East coasts of Pangandaran are categorized as shallow waters (<3 meters) with clear water clarity (>80%). Shallow and clear waters are highly suitable for marine beach tourism, as they support aspects of safety, comfort, visual appeal, and diversity of tourism activities **(Kusumawati *et al.*, 2023; Hamzah *et al.*, 2025)**. Meanwhile, the speed of the waters in both coastal areas falls within the moderate current category (17- 34cm/ s), specifically 21- 28cm/ s on the West Coast of Pangandaran and 19- 25cm/ s on the East Coast of Pangandaran. This value falls within the fairly good category for beach tourism activities, particularly in the categories of beach recreation and swimming. The speed of coastal currents is closely related to the value of the coastal tourism suitability index, as it affects aspects of safety, comfort, and the feasibility of water tourism activities, such as swimming, snorkeling, and playing in the water. Slow currents are preferred and get a higher suitability value for general beach tourism. Conversely, strong currents lower the score because they increase the risk of tourist accidents **(Yulianda, 2007; Yulianda & Mazaya, 2021)**.

Wave heights on the West and East coasts of Pangandaran are classified as moderate to relatively high, ranging from 0.8 to 1.4 meters. Wave heights vary at each observation station in each coastal area. The highest wave heights are at stations 3-5 on the East Coast of Pangandaran. This explains the differences between these three stations and the other observation stations in their respective categories. As one of the beaches in the southern part of Java Island, Pangandaran Beach has relatively high wave heights **(Maudhi *et al.*, 2023)**. This is undoubtedly a primary consideration in ensuring the safety of tourists in various tourism categories. However, on the other hand, wave height can be a potential opportunity for several water sports, such as surfing **(Legowo *et al.*, 2019; Ciurana *et al.*, 2022; Nursyafii *et al.*, 2024)**.

On both beaches, there are also no dangerous biota that could potentially harm tourists. This condition enhances the sense of security and safety for tourists when engaging in tourism activities. The tourist locations on both beaches are also strategically placed, with proximity to freshwater sources (<0.5 km), and three of the five views that can be enjoyed are available: beaches, forests, and mountains. A strategic location that is close to freshwater sources and enchanting natural scenery can increase the appeal and suitability of beach tourism **(Yulianda, 2007, 2019)**.

Ecological carrying capacity

The results of the calculation of the ecological carrying capacity of the West and East coasts of Pangandaran are determined based on the area of the recreation area and the optimal time for each recreation activity. The West Coast of Pangandaran has a longer and wider beach and recreation area compared to the East Coast of Pangandaran. Therefore, the ecological carrying capacity of the West Coast of Pangandaran is greater than that of the East Coast of Pangandaran for each tourism activity. The West Coast of Pangandaran has a total ecological carrying capacity for tourism of 340 tourists per day for beach recreation activities, 255 tourists per day for swimming activities, and 1,592 tourists per day for camping activities. Meanwhile, the East Coast of Pangandaran has an ecological carrying capacity value for tourism of 253 tourists per day for beach recreation activities, 189 tourists per day for swimming activities, and 710 tourists per day for camping activities (Table 7).

Table 7. Ecological carrying capacity of tourism on the West and East coasts of Pangandaran

Tourism site	Length of coastline (m)	Suitable area (m^2)	Carrying capacity (Tourists/Day)		
			Beach recreation	Swimming	Camping
West Coast of Pangandaran	3,184	159,200	340	255	1,592
East Coast of Pangandaran	2,368	71,040	253	189	710

The ecological carrying capacity of coastal tourism is the maximum number of tourists who can visit and carry out a particular tourism activity in a coastal area without causing environmental damage or decreasing the quality of the coastal ecosystem, either physically, biologically, or ecologically **(Rahimah *et al.*, 2020; Arnold, 2021; Naranjo-Arriola, 2021)**. More specifically, the calculated value of the ecological carrying capacity of tourism serves as a scientific reference for managing and limiting the number of tourists to ensure the sustainability of coastal tourism activities **(Diniz *et al.*, 2024; Sabila & Azaria, 2024)**.

Overtourism can increase the potential for physical environmental damage, one of which is through increased domestic waste production **(Bhuiyan *et al.*, 2024)**. Furthermore, this potential will have a domino effect, environmental degradation, resource depletion, and social conflicts due to the influx of visitors that exceed the carrying capacity of destinations **(Omar *et al.*, 2024)**. In some cases, overtourism leads to the destruction of ecological landscapes, which also disrupts the lives of living organisms in those environments **(Baloch *et al.*, 2022; Omar *et al.*, 2024)**. Furthermore, overtourism can also lead to decreased tourist satisfaction and enjoyment with their experiences **(Yu & Egger, 2021; Baloch *et al.*, 2022)**.

Every tourist destination often experiences overcapacity or excessive tourist density, particularly during peak holiday periods. The Pangandaran Regency Tourism and

Culture Office recorded the number of tourists visiting the East and West coasts as 40,341-51,720 tourists/day at the beginning of April, 2025. This value is certainly much higher than the total ecological carrying capacity value on both beaches. The influx of tourists exceeding the ecological carrying capacity can lead to a decline in ecological health and environmental degradation. Ultimately, tourist congestion can lead to a decrease in the quality of tourism in the future **(Peeters *et al.*, 2018; García-Buades *et al.*, 2022)**.

Tourist restriction is one of the essential strategies that can be implemented in sustainable tourism management to maintain a balance between tourism activities and environmental capacity. This step is taken to ensure that the number of tourists visiting does not exceed the ecological, social, or physical carrying capacity of a destination **(Rasidi *et al.*, 2023; Lestari & Dewi, 2024)**. Several forms of restrictions that can be applied to the West and East coasts of Pangandaran are (1) Determination of daily visitor quotas, based on the results of a carrying capacity study; (2) Online reservation system for arranging the time and number of tourists; (3) Zoning of tourist areas, with limited areas for intensive activities and conservation areas; (4) Implementation of differential rates, for example higher prices during peak season; and (5) Restriction of visiting hours, such as certain operating hours specifically for beach environmental cleaning activities; (6) Apart from restrictions, tourism utilization zoning can also be carried out based on the feasibility and safety of tourist activities. In the recommendations for consideration in the last point, we recommend, especially for swimming activities, to avoid coastal areas with quite large wave heights, such as at stations 3-5 on the east coast of Pangandaran.

CONCLUSION

The tourism suitability index indicates that Pangandaran's West and East coasts are categorized as highly suitable for beach recreation activities. For camping, Pangandaran's West Coast is considered highly suitable, while the East Coast is also quite appropriate. This difference in category occurs because the East Coast's substrate is slightly rockier than that of the West Coast, which is composed of fine sand. For swimming, the tourism suitability index values vary across observation stations on each beach due to variations in wave height values. On Pangandaran's West Coast, the highest suitability index values are found at stations 4 and 5, with all observation stations falling into the highly suitable category. Meanwhile, on Pangandaran's East Coast, the highest suitability index values are found at stations 1 and 2, which are categorized as highly suitable; however, stations 3, 4, and 5 are considered quite appropriate.

The ecological carrying capacity value underlines the large number of visitors that the two coastal areas can accommodate without disrupting the sustainability of the environment for each tourism category. In general, the West Coast of Pangandaran has a greater ecological carrying capacity value because the beach conditions are longer and broader compared to the East Coast of Pangandaran. The West Coast of Pangandaran has

an environmental carrying capacity of 340 tourists per day for beach recreation, 255 tourists per day for swimming, and 1,592 tourists per day for camping. Meanwhile, the East Coast of Pangandaran has an ecological carrying capacity of 253 tourists per day for beach recreation, 189 tourists per day for swimming, and 710 tourists per day for camping.

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