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ECOLOGICAL MARINE ECOTOURISM SUITABILITY ANALYSIS OF KELONG PANCING MADU TIGA IN SENGGARANG BESAR WATERS, BINTAN REGENCY, INDONESIA

***Irwan Effendi*[1], *Ismandianto Ismandianto*[2], *Fiffy Hanisdah Saikim*[3], *Indra Purnama*[4], *Arrafiqur Rahman*[5], *Nurhayati Nurhayati*[6], *Falmi Yandri*[7], *Ahmad Kurnain*[8], *Rechinta Lovya Junakea*[9]**

[1]ORCID: 0000-0002-4536-8402
[2]ORCID: 0000-0003-2251-8321
[3]ORCID: 0000-0001-5608-5531
[4]ORCID: 0000-0002-9911-3923
[5]ORCID: 0009-0004-2409-9997
[6]ORCID: 0009-0006-5259-9846
[7]ORCID: 0009-0001-6006-0000
[8]ORCID: 0009-0000-6907-716X
[9]ORCID: 0009-0009-5589-6872
[1,9]Department of Marine Sciences
[2]Department of Communication Sciences
University of Riau, Pekanbaru, Indonesia
[3]Institute for Tropical Biology and Conservation
University Malaysia Sabah, Kota Kinabalu, Malaysia
[4]Department of Agrotechnology
University of Lancang Kuning, Pekanbaru, Indonesia
[5]Department of Management
[6]Department of Accountancy
University of Pasir Pengaraian, Pasir Pengaraian, Indonesia
[7]Marine Sciences Department
Raja Ali Haji Maritime University, Tanjungpinang, Indonesia
[8]Civil Engineering Department
Abdurrab University, Pekanbaru, Indonesia

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A b s t r a c t

This study evaluates the ecological suitability of the Kelong Pancing Madu Tiga (KPMT) area in Senggarang Besar Waters, Bintan Regency, Indonesia, for the development of marine ecotourism. Field surveys conducted between August 2024 and January 2025 assessed environmental and ecological parameters across three stations, including wave height,

Address: Irwan Effendi, University Malaysia Sabah, 88450 Kota Kinabalu, Malaysia, e-mail: helpingirwan@gmail.com

sediment type, current speed, seawater depth and clarity, temperature, pH, freshwater availability, the presence of dangerous biota, and fish abundance. Suitability was quantified using the Ecotourism Suitability Index (ESI), supported by statistical comparison of physical-chemical variables. Results showed that ecological conditions in the KPMT area ranged from suitable to very suitable for a variety of marine ecotourism activities. Activities such as offshore stays, fishing with fishermen, bedroom-front fishing, shuttle boating, canoeing, and seafood-based tourism consistently achieved ESI values between 83.33 % and 100 %, indicating strong ecological potential. Key drivers of suitability included calm wave conditions, high fish abundance, safe biotic environments, and favorable water quality parameters. Although some spatial variation was observed – particularly in current speed, clarity, and temperature – these remained within acceptable thresholds for sustainable ecotourism. Overall, the findings confirm that KPMT possesses high ecological feasibility for continued ecotourism development, while also highlighting the need for careful environmental management and strategic promotion to ensure long-term sustainability.

Introduction

Ecotourism is a form of sustainable tourism that emphasizes responsible travel to natural areas, aiming to educate travelers while promoting environmental conservation and the well-being of local communities. Marine ecotourism involves activities related to marine activities carried out under or above the sea surface. This approach not only seeks to minimize the negative impacts of tourism but also strives to balance ecological preservation with economic benefits for local populations (STARCZEWSKI et al. 2018, SEERVI 2023, BAYDENIZ et al. 2024). Ecotourism focuses on protecting natural ecosystems and biodiversity, involves local communities in tourism planning and benefits, ensuring their needs are met, aims to maintain and respect local traditions, provides employment opportunities for residents, and contributes to long-term economic growth without compromising environmental integrity (RAKHMONOV 2024, HOJCSKA et al. 2025).

Ecotourism is a form of responsible travel to natural areas that aims to conserve environmental resources, enhance the well-being and empowerment of local communities, and promote environmental education. It is underpinned by principles that seek to minimize negative ecological impacts, generate direct socio-economic benefits for host communities, foster respect for local communities, and contribute to the long-term conservation of natural heritage. A destination may be formally classified as ecotourism only when it fulfills five core criteria: it is nature-based, ecologically sustainable, incorporates environmental education, provides tangible benefits to local communities, and ensures a high-quality visitor experience consistent with conservation objectives (RAMÍREZ and SANTANA 2019, DE GROSBOIS and FENNNEL 2021).

Ecotourism suitability index (ESI) analysis involves evaluating various environmental and ecological parameters to determine the potential of coastal and marine areas for tourism activities. This analysis is crucial

for sustainable tourism development, ensuring that tourism activities do not damage the environment while providing economic benefits. A suitability analysis using a tourism suitability matrix was used by SAHRI et al. (2022) in Tanjung Kelapa. This method involves mathematical calculations and field data to assess suitability for beach recreation, snorkeling, and diving. The analysis results showed varying suitability at various stations, with some areas considered unsuitable for diving. The tourism suitability index (TSI), more specifically for ecotourism areas using the terminology of the ecotourism suitability index (ESI), was also applied at Tamiang Beach Bay, Pulau Laut Tanjung Selayar, Kotabaru, South Kalimantan. This study considered ten parameters, including seawater depth and clarity, to evaluate suitability. The analysis revealed high suitability scores at all stations, indicating a favorable environment for marine tourism. Tamiang Bay area was found to be very suitable for snorkeling and beach activities, with a significant tourist capacity, supporting sustainable tourism development (HUSEIN et al. 2024).

Kelong refers to a set of traditional fishing gear consisting of a wooden house built above sea level and equipped with a fish-trapping net under the house. The building is erected on poles embedded in the seabed. Kelong houses can function as permanent residences or as residential areas for fishermen (LIM 2017). Kelongs, originally used only as traditional fishing gear, is now utilized by the community as a marine tourism destination. The use of kelongs for marine ecotourism is in line with the shift in tourist interest from old tourism to new tourism, namely managing and seeking specific, natural, and biodiverse ecotourism destinations. Types of natural ecotourism in the kelong area include: fishing and harvesting fish catches with fishermen in the kelong, enjoying the natural beauty at dusk and morning, fishing, overnight stays at sea, swimming, canoeing, and others.

Kelong Pancing Madu Tiga (KPMT) is a tourist destination in Tanjungpinang City, built in 2021 and beginning operations in December 2023. This 3.1-hectare area features a restaurant offering a variety of seafood dishes, a fishing area, water sports, accommodation, and various other facilities. The location of KPMT is very strategic and easily accessible to residents and tourists. It is located approximately 600 meters from the shoreline of Senggarang Besar. To reach Kelong Pancing, visitors can use boats provided by KPMT management. Ecotourism suitability analysis is crucial for the development of sustainable tourism. It is essential to ensure that tourism activities are economically viable, while not damaging the environment and providing economic benefits to the surrounding community. This analysis is essential for the KPMT. This research aimed to assess the environmental suitability of the Senggarang Besar waters for marine ecotourism activities based on water quality parameters and ecological indicators.

Materials and Methods

Time and place

This research was conducted from August 2024 to January 2025 in the Kelong Pancing Madu Tiga (KPMT) area, Senggarang Besar Waters, Tanjungpinang City, Riau Islands Province, Indonesia (Figure 1). Sampling was conducted in the second week of August (sampling 1) 2024, the second week of September 2024 (sampling 2), and the second week of January 2025 (sampling 3). Data were collected from three stations. The KPMT layout is L-shaped. Station *A* is located at the base of the L, at the eastern end of the landing pier. Station *B* is located 150 m to the western end of the KPMT, parallel to the landing pier. Station *C* is located at the apex of the L, 150 m from the arrival pier. These station locations are chosen to represent the station's water conditions and the needs of marine ecotourism activities.

Suitability parameter measurements

Suitability parameters measured included wave height, sediment profile, current speeds, seawater depth, seawater clarity, distance to freshwater stock, presence of dangerous biota, fish population abundance, seawater temperature, and seawater pH. Wave height was measured by measuring the height of the waves above the normal sea surface. Sediment profiles were determined by taking seabed sediments and visually identifying their type, whether sand, sand mixed with coral, muddy sand, or all mud. Current speeds were measured using a current meter. Seawater depth was measured by extending a Secchi disk to the seabed. Seawater clarity was measured using a Secchi disk, and the results were converted to present values. Distance to freshwater stock was measured by pulling a meter line, and freshwater stock was determined by checking the size of the freshwater tank. The presence of dangerous biota was determined by observing water conditions and interviewing fishermen around the location, tourist workers, or ordinary people (YULIANDA et al. 2019, INS 2008, RICE and BRIDGEWATER 2012, MER, 2014).

Fish abundance was calculated using the underwater visual census (UVC) method, referring to SAMOIYS and CARLOS (2000). Using an underwater camera, the entire coral reef was photographed. These images were arranged using UVC software to cover the entire reef area at that location. Then, using the same software, the number of species and fish individuals was counted. Coral community coverage, the number of life form types at the coral, the coral reef depth position, and the flat expanse of the coral reef were

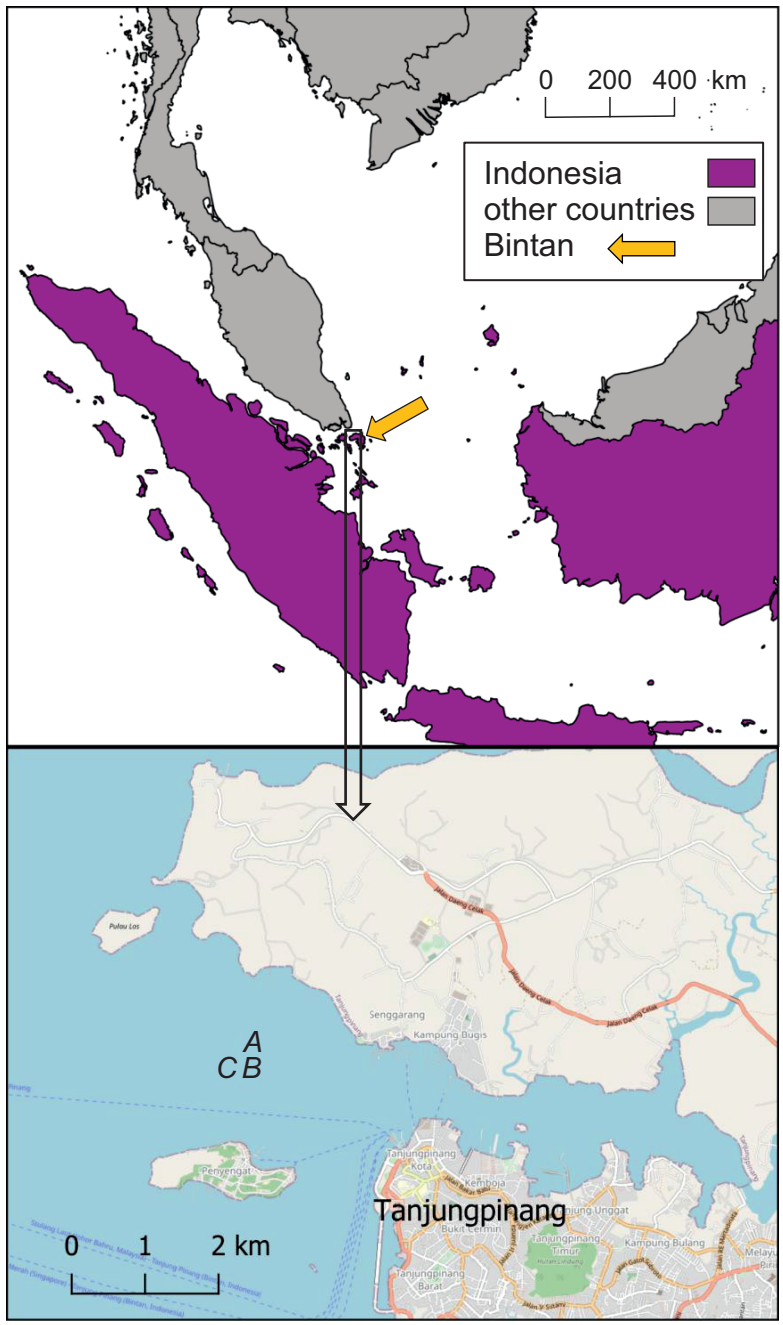


Fig. 1. Study area, Senggarang Besar Waters, Bintan Regency, Indonesia. *A*, *B*, and *C* represent the location of sampling

measured using the underwater photo transect (UPT) method, referring to SHAO et al. (2024). The photographs taken using an underwater camera were then analyzed using the Coral Point Count with Excel extension (CPCe) program, referring to KOHLER and GILL (2006). Meanwhile, seawater temperature and seawater pH were measured using a water checker kit (Reed Instruments R3525 pH Meter, 0.00 to 14.00 pH, -1999 to 2000 Mv, Auto Temp Compensation, 32 to 122 Deg F).

Ecological analysis of ecotourism suitability index

Analysis of the ecotourism suitability index (ESI) used a suitability matrix compiled based on the importance of each parameter to support the ecotourism activities of the area. Each parameter is given a weight and value with reference to YULIANDA et al. (2019), WITHANAGE et al (2024), and TAMBUNAN et al. (2013). Based on field conditions, the ecotourism suitability analysis parameters around the KPMT are wave height, sediment profile, current speeds, seawater depth, seawater clarity, distance to freshwater stock, presence of dangerous biota, fish abundance, seawater temperature, and seawater pH (Table 1). The ecotourism suitability index was determined using a formula adapted from the Marine Tourism Suitability Index assessment method:

$$\mathrm{ESI} = \sum [N_i/N_{max}] \cdot 100\ \%$$

where:

ESI – ecotourism suitability index [%]
N_i – value of the i-th parameter (value x score)
$N_{\max}$ – the maximum value of a type/category of ecotourism activity

Note: very suitable (100 %); suitable (75–100 %); conditionally suitable (50–75 %); not suitable (<50 %). Value (V) is a suitability weighting constant that refers to YULIANDA et al. (2019), WITHANAGE et al (2024), and TAMBUNAN et al. (2013).

Table 1

Ecotourism suitability index (ESI) parameters, ranges, scores, and categories around KPMT

Parameters	Range	Value (V)	Category
1	2	3	4
Wave height [cm]	< 25	3	very suitable
	25–50	2	suitable
	50–75	1	condit. suitable
	> 75	0	not suitable

cont. Table 1

1	2	3	4
Sediment profile	sand	3	very suitable
	sandy coral	2	suitable
	muddy sand	1	condit. suitable
	mud	0	not suitable
Current speeds [m/sec.]	0–0.15	3	very suitable
	0.15– 0.30	2	suitable
	0.30–0.50	1	condit. suitable
	> 0.50	0	not suitable
Seawater depth [m]	< 5	3	very suitable
	5–15	2	suitable
	15–20	1	condit. suitable
	> 25	0	not suitable
Seawater clarity [%]	> 80	3	very suitable
	50–80	2	suitable
	20–50	1	condit. suitable
	< 20 0	0	not suitable
Distance to freshwater stock [km]	< 0.5	3	very suitable
	> 0.5–1	2	Suitable
	> 1–2	1	condit. suitable
	> 2	0	not suitable
Freshwater stock [ton]	> 15	3	very suitable
	10–15	2	suitable
	5–10	1	condit. suitable
	< 5	0	not suitable
Presence of dangerous biota	None	3	very suitable
	pufferfish	2	suitable
	sting ray	1	condit. suitable
	shark, crocodile	0	not suitable
Fish abundance [per 100 m^2]	very much (> 100)	3	very suitable
	many (50–100)	2	suitable
	little (20–50)	1	condit. suitable
	very little (< 20)	0	not suitable
Seawater temperature [^oC]	> 30	3	very suitable
	20–30	2	suitable
	10–20	1	condit. suitable
	< 10	0	not suitable
Seawater pH	8	3	very suitable
	7	2	suitable
	6	1	condit. suitable
	5	0	not suitable

Source: own elaboration based on: YULIANDA et al. (2019), WITHANAGE et al (2024), and TAMBUNAN et al. (2013)

Data analysis

The data obtained were tabulated, analyzed using Welch's independent samples *t*-test (*p*-values), ESI, and discussed descriptively with reference to theories and previous research results related to the results of this study. Due to the presence of both quantitative and qualitative variables, statistical analysis was conducted exclusively on measurable physical-chemical parameters, while descriptive analysis was applied to categorical attributes. Pairwise comparisons among stations were performed using Welch's independent samples *t*-test to account for small sample sizes and potential heterogeneity of variances, with a significance level set at $p < 0.05$.

The suitability of ecotourism for staying in the middle of the ocean was analyzed by measuring and weighting some parameters: wave height, current speeds, seawater clarity, seawater temperature, seawater depth, presence of dangerous biota, distance to freshwater stocks, and quantity of freshwater stocks. The KPMT is also equipped with a fishing net under its hull. The fishing gear is operated by professional personnel from the KPMT. This activity can involve a limited number of visitors, including preparing the gear, lowering it into the water, waiting, lifting it, harvesting, cleaning the catch, cooking, and consuming it. The selection of these parameters is based on technical considerations of suitability (attractiveness, economics, safety, and conservation) for fishing with the fishermen. The suitability of ecotourism for this activity was analyzed by measuring wave height, current speeds, seawater depth, and fish population abundance. Fishing in front of the bedroom was analysed by measuring and weighting some parameters: wave height, sediment profile, current speeds, seawater depth, presence of dangerous biota, fish population abundance, fish biodiversity index, distance to freshwater stocks, and quantity of freshwater stocks.

Water tours around the waters of Senggaran Besar are quite popular with tourists. They use a shuttle boat with a capacity of 50 people, lasting 1–2 hours per trip. Four parameters have been selected based on technical considerations of the suitability of shuttle boating around Senggarang Besar waters. The parameters analysed were wave height, current speeds, seawater depth, and the presence of dangerous biota. For canoeing around KPMT, measurements and weighting some parameters, such as wave height, sediment profile, current speeds, seawater depth, seawater clarity, seawater temperature, seawater pH, presence of dangerous biota, distance to freshwater stocks, and quantity of freshwater stocks. An ecological analysis of the suitability of seafood culinary tourism was carried out by measuring wave height, current speeds, and the presence of dangerous biota.

Results

General conditions of the research location

Senggarang Besar is a coastal area on Bintan Island, part of Senggarang Village, Bintan Regency, Riau Archipelago Province, Indonesia. Most residents of Senggarang Besar work as fishermen, with settlements located along the coast and along the harbor. KPMT is a marine ecotourism area that covers 3.31 hectares in these waters. This ecotourism resort employs more than 25 workers, both permanent and contract, ensuring smooth operations. Its organizational structure consists of a resort manager, operational leaders and members, housekeeping leaders and members, chefs, cooks, cook helpers, stewards, receptionists, baristas, waiters, security, engineering, boat captains and crew, administrators, and maintenance operators.

All tourism activities (Figure 2) consistently emphasize the importance of human love for nature. This tourist area is smoke-free, clean, and healthy living is encouraged, and tourists are strictly prohibited from throwing trash into the sea. They are also constantly reminded to conserve fresh water and minimize electricity use. This tourism business activity also involves the surrounding community, for example, by involving them as permanent workers, and utilizing agricultural commodities, fisheries, livestock, and other products from the local community. This tourism business also respects the culture and religion of the surrounding community. In other words, KPMT's marine ecotourism business contributes to the development of the local economy.

Accommodation facilities

KPMT offers three types of bedrooms, each equipped with different amenities: Sea Standard Room, Sea Deluxe Room, and Sea Villa Room. The type, number, size, and amenities of each room type are listed in Table 2.

Table 2

Number, size, and amenities of each room type at KPMT, Senggarang Besar, Bintan Regency, Indonesia

Room type	Number (units)	Area [m^2]	Facilities
Sea standard room	10	17	bed, air conditioning, bathroom, television, and wi-fi
Sea deluxe room	10	20	bed, air conditioning, bathroom, television, and wi-fi
Sea villa room	10	41	bed, air conditioning, bathroom, television, and wi-fi

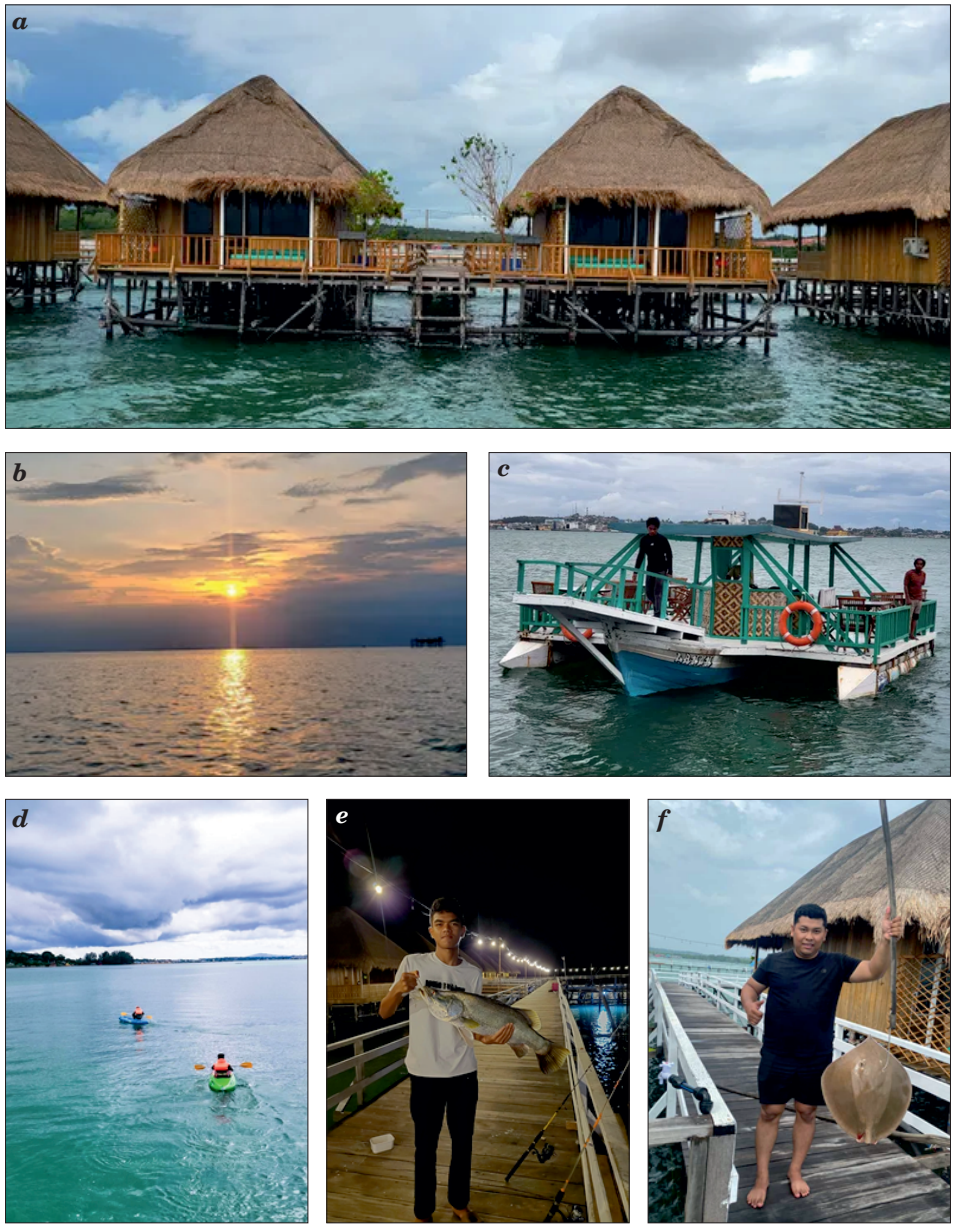


Fig. 2. Some ecotourism activities in KPMT, Senggarang Besar, Bintan Regency, Indonesia:
a – sea villa room view; *b* – sunset view; *c* – shuttle boat;
d – canoeing activity; *e, f* – fishing activities

Marine ecotourism activities in KPMT

KPMT is a popular marine tourism destination and a tourist icon for Tanjung Pinang City. Inaugurated as a tourist attraction on December 23, 2023, KPMT features fishing facilities with an abundance of various fish populations, offering stunning natural beauty with expansive ocean views, clear, and calm waters. The area also features comfortable accommodations, a restaurant serving fresh seafood, and various other amenities. Some of these activities are: experience staying in the middle of the ocean, experience watching the sunset, experience fishing with the fishermen, cook and eat the catch, fishing in front of the bedroom, or any position in KPMT, shuttle boating around Senggarang Besar waters, canoeing around the KPMT, and seafood culinary tourism.

Suitability analysis of ecotourism

Detailed results for each parameter are presented in Table 3. Quantitative ecotourism suitability parameters were statistically compared among the three research stations (*A*, *B*, and *C*) in the KPMT area of Senggarang Besar waters, Bintan Regency.

Significant differences in wave height were observed between Stations *A* and *C* ($p < 0.05$), with Station C exhibiting higher values, whereas no significant differences were detected between Stations *A* and *B* or *B* and *C*. Current speed varied significantly across all station comparisons ($p < 0.05$), with the highest velocities consistently recorded at Station *C*. In contrast, seawater depth did not differ significantly among stations ($p > 0.05$), indicating relatively uniform bathymetric conditions throughout the study area.

Seawater clarity showed significant spatial variation, with clarity values increasing from Station *A* to Station *C*. All pairwise comparisons revealed statistically significant differences ($p < 0.05$), suggesting heterogeneous light penetration conditions among stations. Seawater temperature differed significantly between Station *A* and Stations *B* and *C* ($p < 0.05$), with Station *A* displaying lower mean temperatures, while no significant difference was observed between Stations *B* and *C*. Similarly, seawater pH values were generally stable across stations; however, a significant difference was detected between Stations *A* and *C* ($p < 0.05$), with Station *C* presenting slightly higher pH values.

Qualitative parameters, including sediment type, presence of dangerous biota, freshwater availability, and fish population abundance, were uniform across all stations. Sediments were dominated by sand, no dangerous biota

Table 3

Ecotourism suitability parameters in KPMT, Senggarang Besar waters, Bintan Regency, Indonesia

Parameters	Research stations		
	A	*B*	*C*
Wave height [cm]	18	20	23
	22	24	24
	24	23	24
Sediment profile	sand	sand	sand
	sand	sand	sand
	sand	sand	sand
Current speeds [m/second]	0.09	0.13	0.28
	0.08	0.12	0.19
	0.06	0.14	0.18
Seawater depth [m]	4.6	4.5	4.5
	4.1	4.5	4.6
	4.4	4.5	4.8
Seawater clarity [%]	60	70	80
	50	70	85
	55	60	82
Distance to freshwater stock [km]	0.5	0.5	0.5
	0.7	0.8	0.9
	0.7	0.8	0.9
Freshwater stock [ton]	10	10	10
	10	10	10
	10	10	10
Presence of dangerous biota	none	none	none
	none	none	none
	none	none	none
Fish abundance	very much	very much	very much
	very much	very much	very much
	very much	very much	very much
Seawater temperature [ºC]	29.7	30.8	31.2
	29.2	31.1	30.1
	29.3	31.4	30.4
Seawater pH	8.1	8.2	8.4
	8.1	8.1	8.3
	8.1	8.1	8.2

were recorded, freshwater availability was adequate, and fish populations were consistently described as very abundant, indicating favorable ecological conditions for marine ecotourism activities.

Overall, the statistical analysis demonstrates that while several key environmental parameters vary significantly among stations – particularly current speed and water clarity – these variations remain within acceptable ecological thresholds for ecotourism development. The combination of statistically favorable physical conditions and consistently positive biological indicators suggests that the KPMT area possesses strong potential for sustainable marine ecotourism.

The Ecotourism Suitability Index (ESI) is associated with activities around the kelong, such as staying in the middle of the ocean, and fishing in front bedroom. The analysis was conducted by considering some ecotourism suitability index parameters. This analysis is necessary to determine whether the KPMT tourist area meets the standards for marine tourism.

Experience staying in the middle of the ocean

The suitability of ecotourism for staying in the middle of the ocean was analyzed by measuring and weighting some parameters. The selection of these parameters is based on technical considerations of suitability of attractiveness, economics, safety and conservation. The values of each of these parameters were then analyzed using a suitability index (Table 4). This analysis is also used to assess the feasibility of the experience of enjoying the melancholy atmosphere at sunset.

The Ecotourism Suitability Index (ESI) for staying in the middle of the ocean in the KPMT area ranged from 85.71 % to 90.48 %, indicating that all research stations were classified as *suitable* for staying in the middle of the ocean. Station *C* recorded the highest ESI value (90.48 %), followed by Station *B* (88.10 %) and Station *A* (85.71 %). High suitability across stations was primarily driven by favorable wave height, current speed, seawater temperature, and the absence of dangerous biota, all of which consistently achieved high scores. Variations in ESI values among stations were mainly attributed to differences in seawater clarity, fish abundance, and seawater depth, with Station *C* showing more optimal ecological conditions. Overall, the results indicate that the KPMT offshore area possesses strong potential for sustainable marine ecotourism development.

Table 4

Analysis of ecotourism suitability index (ESI) for staying in the middle of the ocean in KPMT, Senggarang Besar waters, Bintan Regency, Indonesia

Parameter	Score (N) per station			Value (V)	Total score ($N \cdot V$) per station		
	A	*B*	*C*		*A*	*B*	*C*
Wave height [cm]	3	3	3	3	9	9	9
Current speeds [m/sec.]	3	3	3	3	9	9	9
Seawater clarity [m]	2	2	3	2	4	4	6
Seawater temperature [°C]	3	3	3	1	3	3	3
Fish abundance around the coral reef [individuals per 100 m^2]	1	2	2	1	1	2	2
Seawater depth [m]	3	3	2	1	3	3	2
Presence of dangerous biota	3	3	3	1	3	3	3
Distance to freshwater stock [km]	2	2	2	1	2	2	2
Freshwater stock [ton]	2	2	2	1	2	2	2
Value of the i-th parameter (N_i) for staying in the middle of the ocean in KPMT					36	37	38
The maximum value (N_{max}) for staying in the middle of the ocean in KPMT					42	42	42
Ecotourism suitability index (N_i / N_{max} · 100 %)					**85.714**	**88.095**	**90.476**

Explanations: very suitable (100 %); suitable (75–100 %); conditionally suitable (50–75 %); not suitable (<50 %).

Experience fishing with the fishermen

The KPMT is also equipped with a fishing net under its hull. The fishing gear is operated by professional personnel from the KPMT. This activity can involve a limited number of visitors, including preparing the gear, lowering it into the water, waiting, lifting it, harvesting, cleaning the catch, cooking, and consuming it. Some parameters have been measured, and an ecological analysis of the suitability of this tourism activity was carried out, as shown in Table 5.

The ESI for fishing activities with local fishermen in the KPMT area showed high suitability across all research stations. Stations A and B achieved the maximum ESI value of 100 %, classifying them as *very suitable*, while Station *C* recorded an ESI of 88.89 % and was categorized as *suitable*. High suitability at Stations *A* and *B* was driven by optimal wave height, current speed, seawater depth, and high fish population abundance. The slightly lower ESI at Station *C* was mainly influenced by reduced current speed, although overall conditions remained favorable for fishing-based ecotourism (Table 5).

Table 5

Analysis of ecotourism suitability index (ESI; %) for fishing with the fishermen in KPMT, Senggarang Besar waters, Bintan Regency, Indonesia

Parameter	Score (N) per station			Value (V)	Total score ($N \cdot V$) per station		
	A	*B*	*C*		*A*	*B*	*C*
Wave height [cm]	3	3	3	3	9	9	9
Current speeds [m/sec.]	3	3	2	3	9	9	6
Seawater depth [m]	3	3	3	1	3	3	3
Fish population abundance	3	3	3	2	6	6	6
Value of the i-th parameter (N_i) for fishing with the fishermen in KPMT					27	27	24
The maximum value (N_{max}) for fishing with the fishermen in KPMT					27	27	27
Ecotourism suitability index (N_i / N_{max} · 100 %)					**100**	**100**	**88.889**

Fishing in front of the bedroom or from any position in KPMT

The suitability of ecotourism for fishing in front of the bedroom was analysed by measuring and weighting some parameters. The selection of these parameters is based on technical considerations of the suitability of this activity. The values of each of these parameters were then analysed using a suitability index (Table 6).

Table 6

Analysis of ecotourism suitability index (ESI) for fishing in front bedroom or other place in KPMT, Senggarang Besar waters, Bintan Regency, Indonesia

Parameter	Score (N) per station			Value (V)	Total Score ($N \cdot V$) per station		
	A	*B*	*C*		*A*	*B*	*C*
Wave height [cm]	3	3	3	3	9	9	9
Sediment profile	3	3	3	2	6	6	6
Current speeds [m/sec.]	3	3	2	3	9	9	6
Seawater depth [m]	3	3	3	1	3	3	3
Presence of dangerous biota	3	3	3	1	3	3	3
Fish abundance	3	3	3	2	6	6	6
Value of the i-th parameter (N_i) for fishing in front of the bedroom in KPMT					36	36	33
The maximum value (N_{max}) for fishing in front of the bedroom in KPMT					36	36	36
Ecotourism suitability index (N_i / N_{max} · 100 %)					**100**	**100**	**91.667**

The Ecotourism Suitability Index for fishing in front of the bedroom or nearby areas in the KPMT waters indicated very high suitability across all research stations. Stations *A* and *B* achieved maximum ESI values of 100 % and were classified as *very suitable*, while Station *C* recorded an ESI

of 91.67 % and was categorized *as suitable*. High suitability at Stations *A* and *B* was driven by optimal wave height, favorable sediment conditions, appropriate seawater depth, absence of dangerous biota, and high fish abundance. The slightly lower ESI at Station *C* was mainly due to reduced current speed, although overall conditions remained favorable for nearshore fishing ecotourism (Table 6).

Shuttle boating around Senggarang Besar waters

Water tours around the waters of Senggaran Besar are quite popular with tourists. They use a shuttle boat with a capacity of 50 people, lasting 1–2 hours per trip. Four parameters have been selected based on technical considerations of the suitability of shuttle boating around Senggarang Besar waters. An ecological analysis of the suitability of this ecotourism is presented in Table 7.

Table 7

Analysis of ecotourism suitability index (ESI) for shuttle boating around Senggarang Besar waters, Bintan Regency, Indonesia

Parameter	Score (N) per station			Value (V)	Total score ($N \cdot V$) per station		
	A	*B*	*C*		*A*	*B*	*C*
Wave height [cm]	3	3	3	3	9	9	9
Current speeds [m/sec.]	3	3	2	3	9	9	6
Seawater depth [m]	3	3	3	1	3	3	3
Presence of dangerous biota	3	3	3	1	3	3	3
Value of the i-th parameter (N_i) for shuttle boating around Senggarang Besar waters					24	24	23
The maximum value (N_{max}) for shuttle boating around Senggarang Besar waters					24	24	24
Ecotourism suitability index (N_i / N_{max} · 100 %)					100	100	95.833

The ESI for shuttle boating around Senggarang Besar waters showed very high suitability across all research stations. Stations *A* and *B* achieved maximum ESI values of 100 % and were classified as *very suitable*, while Station *C* recorded an ESI of 95.83% and was categorized as *Suitable*. High suitability was supported by favorable wave height, adequate seawater depth, and the absence of dangerous biota. The slightly lower ESI at Station *C* was mainly influenced by reduced current speed, although overall conditions remained suitable for shuttle boating operations (Table 7).

Canoeing around the KPMT

The suitability of ecotourism for canoeing around KPMT was analysed by measuring and weighting some parameters. The values of each of these parameters were then analysed using a suitability index (Table 8).

Table 8

Analysis of ecotourism suitability index (ESI) for canoeing around KPMT, Senggarang Besar waters, Bintan Regency, Indonesia

Parameter	Score (N) per station			Value (V)	Total score ($N \cdot V$) per station		
	A	*B*	*C*		*A*	*B*	*C*
Wave height [cm]	3	3	3	3	9	9	9
Sediment profile	1	1	1	1	1	1	1
Current speeds [m/sec.]	3	3	2	3	9	9	6
Seawater depth [m]	3	3	3	1	3	3	3
Seawater clarity [m]	2	2	3	1	2	2	3
Seawater temperature [°C]	3	3	3	1	3	3	3
Seawater pH	3	3	3	1	3	3	3
Fish population abundance	1	1	1	1	1	1	1
Presence of dangerous biota	3	3	3	2	6	6	6
Distance to freshwater stock [km]	3	3	3	1	3	3	3
Freshwater stock [ton]	2	2	2	1	2	2	2
Value of the i-th parameter (N_i) for canoeing around KPMT					42	42	40
The maximum value (N_{max}) for canoeing around KPMT					48	48	48
Ecotourism suitability index (N_i / N_{max} · 100 %)					**87.500**	**87.500**	**83.333**

Canoeing around the KPMT waters classified all research stations as *suitable*. Stations *A* and *B* recorded identical ESI values of 87.50 %, while Station *C* showed a slightly lower value of 83.33 %. High suitability was supported by favorable wave height, appropriate seawater depth, suitable temperature and pH, and the absence of dangerous biota. The lower ESI at Station *C* was mainly influenced by reduced current speed and lower seawater clarity, although overall conditions remained acceptable for canoeing activities (Table 8).

Seafood culinary tourism

KPMT has a restaurant serving a variety of fresh seafood. This restaurant has an area of 150 m^2 and can accommodate up to 100 guests. An ecological analysis of the suitability based on technical considerations of this ecotourism is presented in Table 9.

Table 9
Analysis of ecotourism suitability index (ESI) for seafood culinary tourism in KPMT, Bintan Regency, Indonesia

Parameter	Score (N) per station			Value (V)	Total score ($N \cdot V$) per station		
	A	*B*	*C*		*A*	*B*	*C*
Wave height [cm]	3	3	3	3	9	9	9
Current speeds [m/sec.]	3	3	2	3	9	9	6
Presence of dangerous biota	3	3	3	1	3	3	3
Value of the i-th parameter (N_i) for seafood culinary tourism in KPMT					21	21	18
The maximum value (N_{max}) for seafood culinary tourism in KPMT					21	21	21
Ecotourism suitability index (N_i / N_{max} · 100%)					**100**	**100**	**87.500**

The ESI for seafood culinary tourism in KPMT indicated very high suitability across all stations. Stations *A* and *B* achieved maximum ESI values of 100 % (*very suitable*), while Station *C* recorded 87.50 % (suitable). High suitability was driven by optimal wave height, favorable current speeds, and the absence of dangerous biota. The slightly lower ESI at Station *C* was mainly due to reduced current speed, although overall conditions remained favorable for seafood culinary tourism.

Discussion

This study revealed that ecological suitability index (ESI) levels ranged from suitable (83.333 %) to very suitable (100 %). This is comparable with PUTRA et al. (2018), who assessed the tourism suitability of recreational beaches in Padang City. Their results indicated that 18 beach locations were classified as 'very suitable', with an average suitability index of 82.28 %, while eight locations were categorized as 'moderately suitable', with an average score of approximately 70 %. Only one site, located in front of Bung Hatta University, fell into the 'conditionally suitable' category, with a suitability value of 27 %. For mangrove ecotourism, six locations were identified as 'very suitable', with an average suitability index of 92 %, and nine locations were classified as 'moderately suitable', averaging 73 %. In addition, three locations were considered 'conditionally suitable', with an average score of 49%. In contrast, the Carolina (Pasa Laban) Beach area was categorized as 'not suitable' for mangrove ecotourism, with a suitability value of 33 %.

Similar findings were reported by ANNIDA and BAIHAQI (2025), who studied the marine tourism suitability index and ecological carrying capacity on the west and east coasts of Pangandaran, Indonesia. TSI for marine tourism activities was generally of high suitability on both the West

and East Coasts, with clear spatial differences. Beach recreation exhibits consistently very high suitability, with uniform values of 96.7 % across all stations on the West Coast and slightly lower but still very suitable values of 91.0 % on the East Coast, reflecting optimal coastal conditions for this activity. Swimming suitability on the West Coast ranges from 81.2 % to 90.7 %, classifying the area as quite appropriate to very suitable, whereas the East Coast shows greater variability and lower values (76.4–85.9 %). Camping activities demonstrate the most pronounced contrast between coasts, with the West Coast showing uniformly very suitable conditions (96.7 %) at all stations, while the East Coast records lower and consistent values of 66.7 %. LELLOLTERY et al. (2018) revealed a high marine resource potential in Marsegu Island Nature Tourism Park, Maluku, Indonesia. TSI indicated that the area is suitable for ecotourism, with a snorkeling suitability value of 74.79 %, while diving showed a suitability value of 67.32 %. JOHAN et al. (2017) also reported that Enggano Island had three categories for marine ecotourism suitability of diving categories, namely suitable, quite suitable, and not suitable, while the marine ecotourism of snorkeling had only two categories: suitable and quite suitable.

Ecotourism is responsible travel to natural areas that conserves the environment, supports the well-being of local communities, and promotes environmental education and cultural appreciation. Its key pillars include minimizing negative impacts on ecosystems, providing direct financial benefits and empowerment to local communities, fostering understanding and respect for local cultures, and contributing to the conservation of natural and cultural heritage (DE GROSBOIS and FENNELL 2021, FURGAŁA-SELEZNIOW and JANKUN-WOŹNICKA 2021, BALOCH et al. 2023). There are five fundamental core principles that an area must meet to be considered an ecotourism area: nature-based, ecologically sustainable, environmental education, local benefits, and visitor satisfaction (BUCKLEY 2012, RAMÍREZ and SANTANA 2019). Comparable findings were reported by LEOTAUD et al. (2024), who examined tourism diversification strategies in the Caribbean and highlighted the growing role of ecotourism and community-based tourism within marine and coastal environments as mechanisms for promoting sustainable development. The ecotourism nuance is clearly visible in the KPMT area. Educational aspects regarding the importance of environmental conservation for tourists and the community involved in this activity are prominent. Every visitor is always advised on the importance of environmental sustainability, such as not damaging the ecosystem, using everything sparingly, using water sparingly, disposing of waste properly, and so on. The presence of KPMT also has an impact on the economic development of the surrounding community, from their direct involvement as KPMT employees to the utilization of agricultural products and fish caught in this ecotourism area.

An ecotourism suitability index is a tool used to assess whether a location is suitable for ecotourism development by considering its physical, ecological, and environmental factors. In general, it appears that all ecotourism activities in the KPMT area are feasible to be conducted. The Ecotourism Suitability Index (ESI) for each activity has the following range of numbers: staying in the middle of the ocean for (85.714–90.476 %), fishing in front of the bedroom or elsewhere within the KPMT (93.333–100 %), and canoeing around the KPMT for (87.500–91.667 %).

Safety is a fundamental component of ecotourism development. Even when supporting aspects such as tourist attractions, facilities, and accessibility are well established, they become insignificant if a destination cannot guarantee visitor safety. Ecotourism activities are typically conducted in open and often remote natural environments, where levels of risk and vulnerability are inherently higher. Under these conditions, safety plays a crucial role in safeguarding visitor well-being and ensuring the long-term sustainability of the destination. The primary safety challenges in ecotourism originate from natural environmental factors, including wave height, ocean current velocity, and interactions with potentially dangerous wildlife. As a result, visitors' perceptions of safety strongly influence their trust in the destination, which subsequently affects satisfaction and revisit intention (NEVES 2013, YU et al. 2023, JAWORSKA 2024). In the context of Kelong Pancing Madu Tiga (KPMT), this study demonstrates that safety is consistently prioritized by site managers. All ecotourism activities are carefully planned and implemented by considering environmental conditions, particularly the presence or absence of dangerous animals, wave dynamics, and current speeds. Around KPMT, these aspects include wave height, current speeds, the presence of dangerous biota, and seawater temperature. Waves that are too high can cause canoes to capsize, boats to toss passengers, scatter furniture, and cause passengers to become intoxicated and suffer injuries or illnesses (ZOLJOODI 2017, TRUNG et al. 2020, KIM et al. 2024). Likewise, current speed, where currents that are too strong (> 0.50 m/second) can endanger boat passengers, canoeists, and anglers (PEREIRA et al. 2014, AUGUSTINE et al. 2022, WULANDARI et al. 2024). The presence of dangerous biota such as pufferfish, sharks, sea crocodiles, jellyfish, stingrays, and other dangerous animals is absolutely intolerable (ARIEFIANDA et al. 2019, KELANA et al. 2022). Fortunately, in the KPMT ecotourism area, so far, these dangerous animals have never been found. Best practice combines prevention, capacity building, community participation, and legal safeguards; some studies recommend structured safety systems, regulated standards, and continuous monitoring (GSTAETTNER et al. 2017, FYALL et al. 2022, HILD and JÓHANNESSON 2023). The provision of more comprehensive facilities, together with enhanced safety and security

support, has the potential to improve the suitability of several marine tourism activities, particularly canoeing, by increasing operational safety and visitor confidence.

The comfort aspect of ecotourism is also important (SYUKUR et al. 2021, ASKAR 2023). In the KPMT area, this aspect includes wave height, current speeds, seawater depth, the absence of dangerous biota, and seawater temperature. The comfortable feeling is created by various natural factors in this area. Wave heights are neither too high nor too calm, creating a feeling like riding a swing. Current speeds are also very friendly. Although slow, the movement of the water mass is visible, as if trying to cleanse and replace the existing water with fresh seawater. Furthermore, the seawater depth is very suitable, so visitors don't have to worry about the depth. The seawater temperature is tropical, close to human body temperature. This provides a refreshing feeling for visitors who swim, snorkel, and dive. The absence of dangerous animals certainly adds to the feeling of comfort (AN and SHIN 2019, ARIANI et al. 2020).

The attractiveness of an ecotourism program constitutes a critical determinant of visitor preference and satisfaction, as tourists may be willing to overlook other destination attributes to obtain high-quality experiential outcomes (CAPARRÓS-MARTÍNEZ et al. 2022, ABIDIN et al. 2023, SULISTIOWATI et al. 2023). In the context of ecotourism activities in the KPMT area, this attractiveness is closely associated with biophysical and environmental quality indicators, including sediment profile, seawater depth and clarity, fish population abundance, coral community cover, diversity of coral life forms, reef depth positioning, reef flat extent, seawater temperature, and pH. Comparable evidence was reported by AGIUS et al. (2019), who analysed Mediterranean island destinations and demonstrated that marine ecotourism – particularly within coastal and marine protected areas – has considerable potential to meet the expectations of specialist ecotourist markets. Their findings further emphasize that the quality of ecotourism settings is a key driver of ecotourist satisfaction. Moreover, in island environments subject to substantial anthropogenic pressure, optimal ecotourism sites tend to be located in peripheral coastal and marine zones, with marine ecotourism emerging as the most appropriate ecotourism product for balancing tourism development and environmental conservation.

The availability of ecotourism facilities and infrastructure is certainly no less important (EFFENDI et al. 2022, TJILEN et al. 2022). In the KPMT ecotourism area, this factor includes the availability of freshwater for tourists, namely the distance to freshwater stocks and the quantity available. During the study, the distance (0.5–0.9 km) and amount of fresh water supplies (10 tons) were considered sufficient for the needs of tourists (YULIANDA et al. 2019). Furthermore, the availability of canoes (ten units), speedboats

(two units), and other facilities is also crucial. The equipment and supplies for this activity were considered more than adequate. This equipment can also be rented from other parties nearby if more is needed. Nevertheless, the long-term development of marine ecotourism requires carefully planned and systematically implemented facilities and infrastructure to ensure environmental sustainability and the economic viability of the ecotourism sector.

These ESI figures are still significantly suitable, suggesting that ecotourism activities can still be developed through appropriate marketing strategies. For example, strengthening environmental awareness through ecotourism. Marketing through collaborations with tourism operators from other countries, social media promotions, and holding environmental awareness events such as mangrove planting, turtle hatchling releases, and so on (MAUGERI et al. 2017, EFFENDI et al. 2025). An important consideration is the influence of seasonal variability. During the northern monsoon period (December–February), the study area is characterized by stronger wind regimes, increased rainfall, elevated wave heights, and reduced water clarity. These conditions may temporarily limit the suitability and safety of certain marine ecotourism activities, indicating the need for seasonal management and adaptive planning.

Conclusion

The KPMT area has been developed through an integrated approach that emphasizes environmental conservation, educational functions, and the empowerment of surrounding local communities. The analysis of the ecotourism suitability index (ESI) at each research station for each ecotourism activity ecologically shows a suitability level ranging from suitable to very suitable. This figure shows that ecotourism activities in the area can still be developed through appropriate planning. Marketing through collaborations with tourism operators from other countries, social media promotions, and holding environmental awareness events is recommended. Further research is necessary to strengthen the sustainable management and development of the ecotourism area. Future studies should focus on identifying the dominant ecotourism attractions that contribute most significantly to visitor interest, as well as examining how individual ecotourism activities are perceived and experienced by tourists. In addition, systematic evaluation of promotional strategies is needed to determine their effectiveness in increasing visitor awareness, satisfaction, and visitation rates.

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