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Research Article

Evaluating Habitat Suitability and Ecotourism Potential of Mangrove Ecosystems Along Progo River, Yogyakarta

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ARTICLE HIGLIGHTS

- Assessment of Habitat Suitability for Ecotourism: The article introduces an evaluation of mangrove habitat suitability for ecotourism in the Progo River area, which has not been extensively studied in this region.
- Combination of Sampling Methods: It employs nested and gridline sampling methods to measure habitat quality more comprehensively, leading to more accurate data on mangrove conditions.
- Monitoring Environmental Variables: The study examines the impact of physical and chemical factors such as temperature, salinity, and dissolved oxygen on mangrove growth and biodiversity.
- Identification of Ecotourism Potential Based on the Tourism Suitability Index: It uses the Tourism Suitability Index to identify locations suitable for nature tourism activities around the Progo River.
- Importance of Sustainable Management: The article stresses the need for improved management of mangrove ecotourism areas to preserve ecosystem sustainability and support the local economy.

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ABSTRACT

Mangrove forests are a transitional ecosystem located between land and sea. Habitat factors greatly influence the growth of mangrove plants. Habitat suitability is reflected in the suitability of the species that can grow in the habitat. Increased growth will ultimately increase water productivity, which can be seen from the presence of various types of biota and environmental improvements. The local community planted mangrove species (*Sonneratia* sp.) along the Progo River in an area of 75 h. This study aimed to: 1) assess the quality/characteristics of the Progo River waters that will be used for a water tourism center and 2) assess the suitability (IKW) of the Progo River waters for water tourism in Bleberan Hamlet. Data collection was carried out using nested sampling. Data analysis included the diversity of biota types using the Shannon Diversity Index and vegetation analysis. The results showed that the highest temperature occurred at station 3 plot 10, the highest mud thickness was observed at station 5 plot 9, the highest salinity was detected at station 3 plot 10, the highest water clarity was observed at station 2 plot 7, the highest pH was seen at station 1 plot 6 and 7, while the highest DO was spotted at station 3 plot 8. Some of the biota obtained included crustaceans, gastropods and actinopterygii. The habitat types of vegetation obtained were trees, shrubs, and some herbs. Based on the Tourism Suitability Index (IKW) value, there were 3 stations suitable for camping/outbound, 2 stations suitable for relaxing, and 2 stations suitable for river tracks.

Keywords: ecotourism development, habitat suitability, mangrove ecosystems, Progo River, sustainable management.

INTRODUCTION

Mangrove forests are important ecosystems that contribute to coastal stability which protect the coastal areas from various marine-related hazards that harm life (Hadi, 2012). Many marine species rely heavily on mangrove environments, with healthy mangroves having fish populations and biodiversity that are 116 - 129% higher than degraded mangroves (Onziral *et al.* 2020).

Mangrove ecosystem degradation causes significant issues, such as: 1) rapid degradation of mangroves, which accelerates the loss of mangrove islands and coastal areas (Sahu *et al.* 2015); 2) a decrease in the diversity of flora and fauna that are specific to mangrove forests (Polidoro *et al.* 2010); 3) increased seawater intrusion, as the mangrove ecosystem, which serves as a buffer zone, becomes less effective due to destruction, which can lead to environmental problems, such as flooding, erosion, and salt intrusion (Hilmi *et al.* 2017; Field 2004); 4) coastal abrasion, particularly affecting communities along beaches facing straits and the sea (Whidayanti *et al.* 2021); and 5) increased flooding risks. Maintaining mangrove ecosystems can significantly reduce water flow velocity by 29 - 92% and modestly decrease wave height by 4 - 16.5 cm during cyclones, offering protection from flooding in coastal areas (Dasgupta *et al.* 2019).

The greatest threat to mangrove areas is the conversion of mangrove land into shrimp or fish ponds. Converting mangrove land to shrimp or fish farms impacts marine biota by increasing nutrient and carbon conversion, reducing microbial communities and metabolic diversity, and promoting nitrifying, denitrifying and sulfur-oxidizing bacteria (Erazo & Bowman 2021). This conversion also resulted in the loss of 70% of the carbon stored in the mangroves and increased pressure from the exploitation of timber, fish, crustaceans and shellfish for trade (Elwin *et al.* 2019; Alongi 2002).

Additionally, there are growing conflicts arising from competing interests between different agencies and administrative regions. Ideally, the utilization of mangrove areas should take into account community needs without damaging the mangroves themselves (Zulfa *et al.* 2023). Furthermore, it is essential to develop activities that benefit the community, while preserving the ecological functions of the mangroves (both physico-chemical and biological). Therefore, ecotourism is an ideal solution to be implemented for the preservation of mangrove ecosystems, the development of community economies, and conservation efforts (Aziz *et al.* 2018).

Banaran and Bleberan Villages are both located in Galur District, Kulon Progo Regency. The locations of these villages are potential for mangrove ecosystems because it is directly adjacent to the sea and river, but this has not been further developed (Diella *et al.* 2022). In addition, these two villages have a beach called Trisik Beach which is an annual stopover for rare slithers, namely green turtle (*Chelonia mydas*) when laying eggs. However, currently the existence and survival of green turtles (*Chelonia mydas*) face serious threats from the main predator, humans (Mayastuti *et al.* 2024). Therefore, research on habitat suitability evaluation and ecotourism is important so that the preservation of mangrove forest ecosystems and the improvement of the community's economy can be realized.

The first step to realize mangrove forest ecotourism requires a systematic assessment of the land area by conducting inventory activities to assess the suitability for ecotourism (Nugraha *et al.* 2015). This study aimed to identify: 1) the characteristics of aquatic ecosystem habitats including: types of aquatic biota, types and density of existing vegetation, and other environmental factors, such as salinity, temperature, pH and muddiness and 2) the suitability of habitat characteristics for ecotourism.

MATERIALS AND METHODS

This research was conducted in the mangrove area in Bleberan Hamlet, Banaran Village, Galur District, Kulonprogo Regency. Geographically, the Banaran Village is located between 110°11' - 110°14' E and 7°57' - 7°59' S. The observation and sampling sites were determined, as presented in Figures 1-7.

This study applied the combination methods, i.e., the path and gridline methods (Indriyanto 2019). The path was laid as a perpendicular along the coastline to find out the vegetation condition changes. The path method was implemented based on Poedjirahajoe *et al.* (2017) as follows.

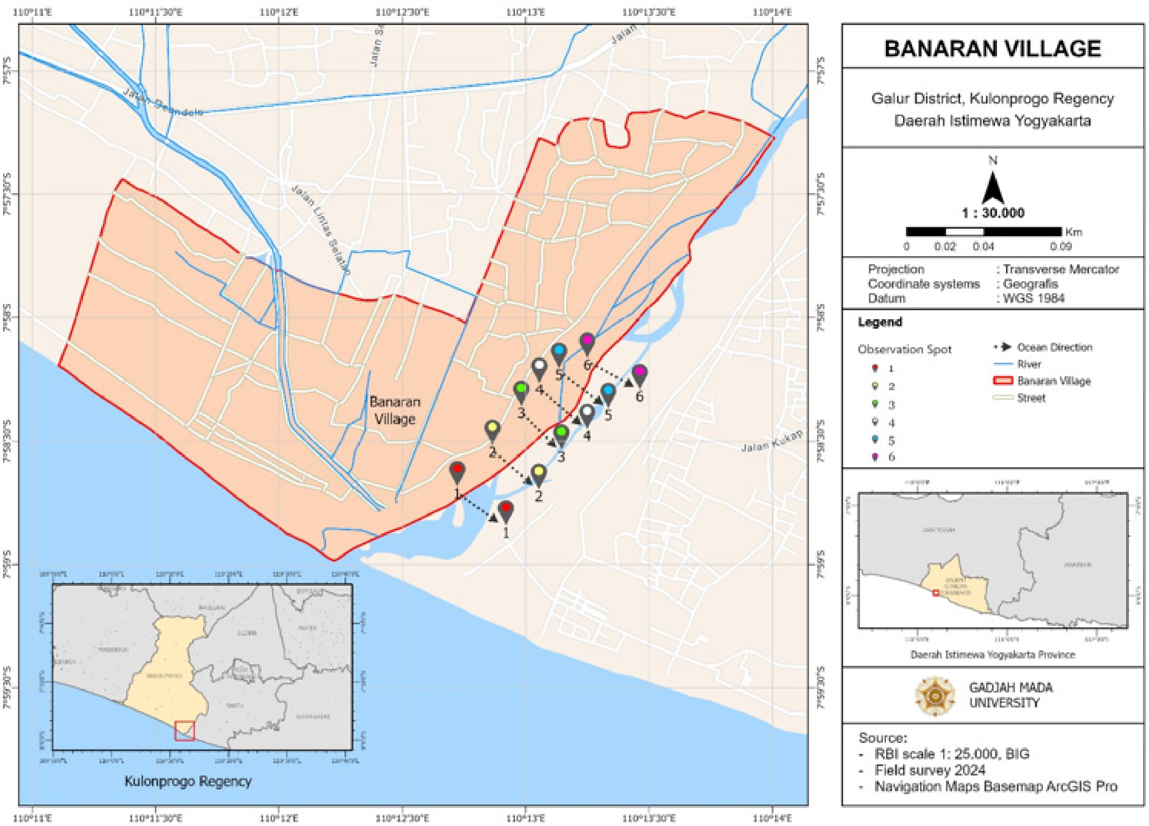

Figure 1 Study area in the Banaran Village of Progo River

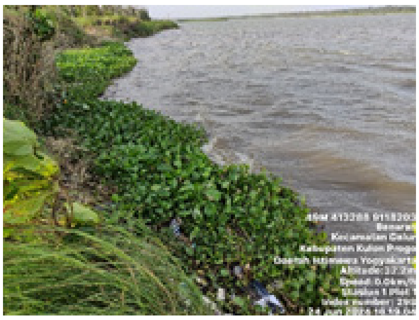

Figure 2 Bridge view
(Observation Spot 1)

Figure 3 River view
(Observation Spot 2)

Figure 4 Estuarine view
(Observation Spot 3)

Figure 5 Near village
(Observation Spot 4)

Figure 6 Fishing pool
(Observation Spot 5)

Figure 7 River island
(Observation Spot 6)

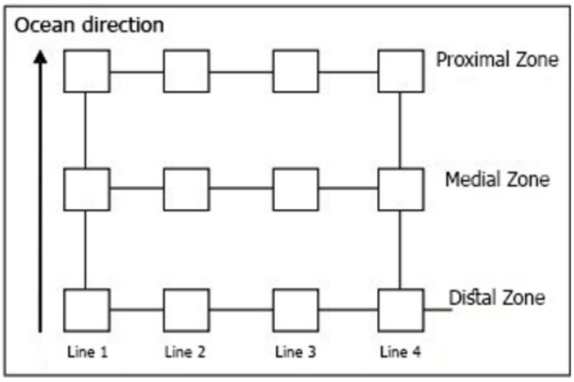

Figure 8 Path method design in coastal ecosystems
(Poedjirahajoe *et al.* 2017)

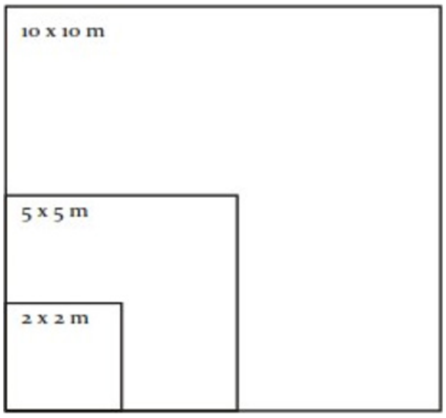

Figure 9 Nested sampling pattern

Observation spot (PU) were applied in each zone using nested plot sampling (Fig. 9) with a total of 12 nested plots at each observation spot. The vegetation measured is the vegetation located in the observation spot. The criteria for mangrove growth levels are based on the Decree of the Directorate General of Forestry No. 60/KPTS/DI/1978 concerning Guidelines for the Brackish Water Forest Silviculture System, namely:

a. Seedlings, plants less than 1.5 m high (plot size 2 x 2 m).

b. Saplings, plants more than 1.5 m high and less than 10 cm in diameter (plot size 5 x 5 m).

c. Trees, plants more than 10 cm in diameter (plot size 10 x 10 m).

Measurement of the physical and chemical quality of the habitat was also carried out at each observation spot, including measurements of water clarity (cm), water temperature (°C), pH, salinity (%), dissolved oxygen content (mg/L), and mud thickness (cm). Water clarity was measured using a Secchi disk, water temperature was measured using a thermometer stick, pH measurement was conducted using a pH meter, salinity was determined using a digital salt test, dissolved oxygen measurements were carried out using an Oximeter, and mud thickness was determined using a graduated pole that was inserted at several points.

Calculation of physical, biological, and chemical quality is used to assess the location suitability for tourism activities. The focus of tourism suitability in this study was divided into three forms of utilization, namely camping, relaxing, and river tracks. The suitability was calculated using the Tourism Suitability Index formula (*Indeks Kesesuaian Wisata* = IKW) (Yulianda 2019).

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

where:

n = Number of fit parameters
Bi = Weight of the parameter
Si = Score of the parameter

The calculated Tourism Suitability Index was compared with the class criteria of the tourism suitability index presented in Table 1 based on Yulianda (2019).

Table 1 Tourism suitability index class

Description	IKW result
Very suitable	IKW ≥ 2.5
Suitable	2.0 ≤ IKW ≤ 2.5
Not suitable	1.0 ≤ IKW ≤ 2.0
Very unsuitable	IKW ≤ 1.0

The feasibility of ecotourism was determined using the assessment criteria by the Director General of PHKA in 2003, namely Analysis of Operational Areas for Natural Tourism Objects and Attractions (*Analisis Daerah Operasi Obyek dan Daya Tarik Wisata Alam* = ADO-ODTWA). The data were obtained from respondents by means of written interviews and calculation using tabulation. The eligibility is determined by the value of each ADO-ODTWA criterion (Table 2). The value of each criterion in ADO-IDTWA was calculated using the following equation:

$$S = N \times B$$

where:

S = Score of each criterion
N = Number of criteria elements
B = Weight of value

Table 2 presents the Modified ADO-ODTWA Assessment Criteria Table from the Directorate General of Forest Protection and Nature Conservation 2003.

Table 2 ADO-ODTWA assessment criteria

No.	Criteria	Max	Min	Interval	Eligibility Criteria	
1	Attractiveness	1440	360	360	1080 - 1440 719 - 1079 < 719	Very potential Potential Not potential
2	Accessibility	1300	305	331	969 - 1300 637 - 968 < 637	Very potential Potential Not potential
3	Accommodation	180	60	40	140 - 180 139 - 99 < 99	Very potential Potential Not potential
4	Supporting facilities and infrastructure	180	45	45	135 - 180 134 - 89 < 89	Very potential Potential Not potential
5	Conditions around the area	1200	450	250	950 - 1200 699 - 449 < 449	Very potential Potential Not potential
6	Availability of clean water	720	240	160	560 – 720 559 - 399 < 399	Very potential Potential Not potential
7	Marketing	120	20	33	87 - 120 86 - 53 < 53	Very potential Potential Not potential

RESULTS AND DISCUSSION

The study was conducted at 6 observation spots measuring 6 parameters consisting of water temperature, mud thickness, salinity, water clarity, pH, and dissolved oxygen.

Water Temperature

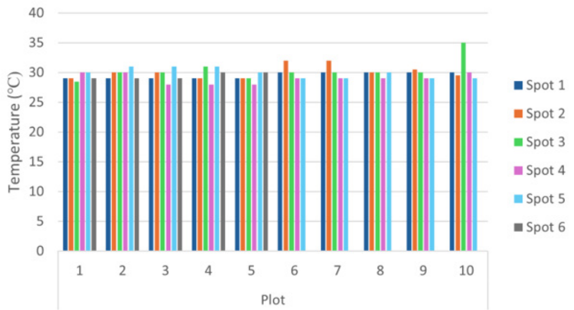

Figure 10 Temperature

The average water temperature at each station ranged from 28 - 35 °C, which was sufficient for mangrove growth. Zheng and Takeuchi (2022) stated that stomatal conductance and assimilation rate in mangrove leaves are optimal at temperatures below 35 °C. Affressia *et al.* (2017) stated that the temperature suitable for mangrove habitat ranges from 20 - 35 °C. Mangroves are highly adapted to extreme conditions including high temperatures (Kathiresan & Bingham 2001). However, when the temperature exceeds the peak photosynthetic temperature, photosynthetic productivity decreases and when the leaf temperature exceeds 38 - 40 °C, photosynthesis stops (Cloughet *et al.* 1982). Furthermore, high temperatures increase evaporation, resulting in increased salinity; the synergistic effects of salinity and drought can affect species diversity, size, and productivity of mangrove forests (Smith & Duke 1987; Ball & Sobrado 2002). This can affect the plant's ability to absorb water and nutrients, which in the long run can negatively affect the health of the mangrove.

Mud Thickness

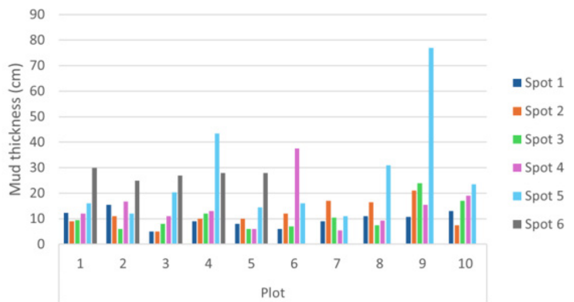

Figure 11 Mud thickness

The result showed that the mud thickness from 10 existing plots ranged from 4 to 78 cm (Fig. 11). Some plots exhibited significant differences; for instance, plot 9 showed the lowest mud thickness at 10 cm, while the deepest mud thickness was recorded at 78 cm. Thicker mud thickness provided support for better mangrove growth as it provided a stable, nutrient-rich substrate (Purwanto *et al.* 2022). However, there was no consistent pattern of mud thickness across all sites, suggesting that other factors also influenced mangrove growth. In addition, this difference may be due to the presence of several large rivers that flowed throughout the year. This observation aligns with the findings of Poedjirahajoe and Matatula (2019), who noted that areas with fewer large rivers flowing throughout the season can affect the thickness and characteristics of the mud substrate. The thickness of mud in deep water or mangrove environments can indicate sedimentation processes (Boulesteix *et al.* 2019). This is consistent with the statement by Noor *et al.* (1999) that mud thickness significantly impacted the ability of mangrove vegetation to capture sediment transported by water during tidal events. The thickness of the mud affects the ability of tree roots to bind and stabilize its position.

Salinity

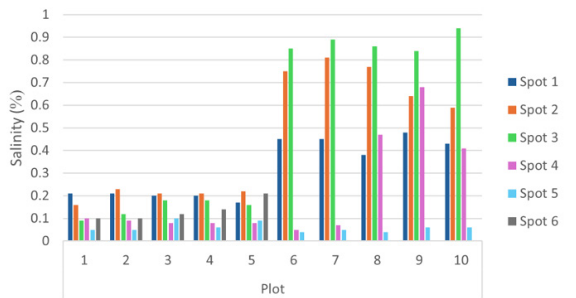

Figure 12 Salinity

Salinity from 10 existing plots ranged between 0.03 - 0.94% (Fig. 12). Septiarusli (2006) stated that mangroves can grow well in brackish water salinity between 2 - 22 ppt or salt water with salinity reaching 38 ppt. This condition indicated a reasonable salinity condition at the river mouth. Stable and suitable salinity allows mangroves to grow optimally. Mangroves effectively regulate water balance under saline conditions by adjusting their structure to exclude salt, maintain hydraulic conductance, avoid cavitation, and limit water loss (Reef & Lovelock 2015). Research conducted in the Sundarbans of Bangladesh showed that trees growing under low salinity conditions had higher growth rates (Rahman *et al.* 2020). However, significant changes in salinity, either increases or decreases, can disrupt communities in estuarine systems, affecting the biomass, abundance, and diversity of benthic macrofauna (Breaux *et al.* 2019; Diggelen & Montagna 2016).

Water Clarity

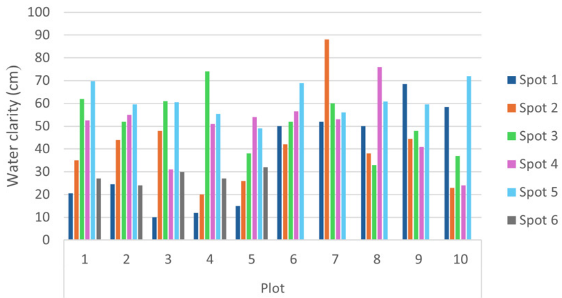

Figure 13 Water clarity

Water clarity of the 10 plots from 6 stations ranged from 10 to 89 cm (Fig. 13). There were both increases and decreases in the level of water clarity at the Progo River estuary. This indicated a difference in the amount of sedimentation that accumulated on the riverbed. The lower the water clarity level, the thicker the sedimentation will be, which can potentially reduce productivity and alter community structure (Ryan 1991). Turbidity and excessive sediment loads can harm surface water bodies due to urban development, construction activities, and agricultural practices (Neupane *et al.* 2015). During the wet season, the water around estuaries tends to be more turbid as the river flow carries more sediment from the land. In contrast, during the dry season, water clarity may increase (Asp *et al.* 2016). These changes in clarity may indicate natural seasonal dynamics, while unusual changes may suggest external disturbances.

pH

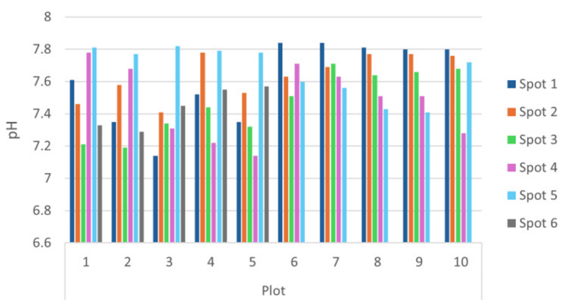

Figure 14 pH

pH range from the 10 existing plots was 7.1 - 7.8 (Fig. 14), which indicated that overall the Progo River water is a productive waters. Kaswadji (2001) stated that waters with pH 6.5 - 8.5 are waters with high productivity. The pH range observed in this study also indicated that the Progo River area is very suitable for mangrove growth. Widyastuti (1999) suggested that water pH range between 6 - 8.5 is very suitable for mangrove growth. This pH range which is almost neutral to slightly alkaline water condition can affect the quality of a water habitat, especially in the mangrove ecosystem. In maintaining the function of mangrove ecosystems, it is important to maintain soil pH within a reasonable range (Muhsoni 2020). These pH values indicate relatively balanced and ideal conditions for aquatic life, so most aquatic organisms can grow well within this pH range, including fish, plankton, and microorganisms that support mangrove ecosystems. This is supported by the Ambient Water Quality Criterion (AWQC) in the United States in 2003 which considers that the pH range of 6.5 to 9 is able to protect freshwater life.

Dissolved Oxygen

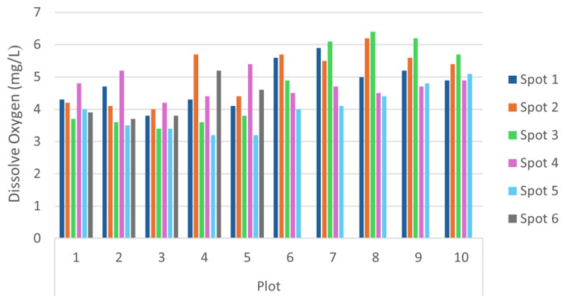

Figure 15 Dissolved oxygen

Muttaqin *et al.* (2024) mentioned that the ideal dissolved oxygen range for mangroves is 3 - 7 mg/L, which supports the ecosystem's health and biodiversity. The 6 stations had ideal mean DO values ranging from 3.1 - 6.3 mg/L. Factors such as tidal height, sunlight, and distance from the edge of the mangrove significantly affect DO dynamics. During high tides, DO levels are generally higher, but can decrease rapidly at low tide, especially in areas further inside the forest. Water quality with this DO value is considered moderate, which could be due to moderate levels of organic pollution. Organic waste will be consumed by bacteria, which in the process also consume oxygen, thus lowering DO. Increasing dissolved oxygen concentration also indicates the presence of bacteria and microorganisms as organic matter decomposers (Liu *et al.* 2021).

Several types of biota were found in the research area, such as crustaceans, gastropods, and actinopterygii. Crustaceans found included fiddler crabs (*Uca* spp.) and ketam crab (Gecarcinucoidea). Gastropods found included Langkitang (*Melanoides tuberculata*), and hermit crabs (Paguroidea). Actinopterygii found included mudskippers (Oxudercinae) and mullet (*Mugil cephalus*). Several vegetations were also found in the research area in the form of trees, shrubs, and herbs (Table 3).

Table 3 Types of vegetation found around the observation points

No	Type of vegetation					
	Herb		Shrub		Tree	
	Species	**n**	**Species**	**n**	**Species**	**n**
1	*Alternanthera sessilis*	19	*Carica papaya*	1	*Avicennia* sp.	3
2	*Brachiaria mutica*	26	*Chromolaena odorata*	1	*Calophyllum inophyllum*	5
3	*Chloris barbata*	21	*Cocos nucifera*	1	*Calotropis gigantea*	4
4	*Cyperus alternifolius*	8	*Euphorbia hyssopifolia l*	1	*Carica papaya*	2
5	*Eichhornia crassipes*	9	*Hibiscus tiliaceus*	1	*Cassuarina equisetifolia*	20
6	*Gomphrena globosa*	18	*Ipomoea carnea* Jacq.	36	*Cocos nucifera*	2
7	*Imperata cylindrica*	20	*Ludwigia decurrens* Walter	10	*Erythrina fusca*	6
8	*Ipomoea aquatica*	6	*Ludwigia peruviana*	18	*Gliricidia sepium*	1
9	*Tridax procumbens*	6	*Manihot esculenta*	49	*Hibiscus tiliaceus*	9
10	*Typha angustifolia*	6	*Mimosa pudica*	114	*Inocarpus fagiferus*	11
11	*Wedelia trilobata*	14	*Musa paradisiaca*	9	*Leucaena leucocephala*	33
12			*Senna alata*	1	*Mimosa pudica*	3
13			*Sida* sp.	51	*Morinda citrifolia*	1
14					*Muntingia calabura*	7
15					*Rhiziphora* sp.	13
16					*Rhizopora* sp.	6
17					*Sonneratia alba*	97
18					*Terminalia catappa*	14
	N	**153**	**N**	**293**	**N**	**237**
	Diversity (H')	**2.271**	**Diversity (H')**	**1.738**	**Diversity (H')**	**2.120**

Tourism Suitability Index (IKW) Assessment

Table 4 Results of the IKW assessment

Observation Spot	Camping/Outbound	Sit Back and Relax	River Track
1	2.4 (Suitable)	1.825 (Not suitable)	1.6 (Not suitable)
2	2.4 (Suitable)	2.075 (Suitable)	2.1 (Suitable)
3	1.95 (Not suitable)	1.375 (Not suitable)	1.45 (Not suitable)
4	1.575 (Not suitable)	1.275 (Not suitable)	1.6 (Not suitable)
5	1.8 (Not suitable)	1.475 (Not suitable)	1.9 (Not suitable)
6	2.4 (Suitable)	2.225 (Suitable)	2.55 (Suitable)

The Tourism Suitability Index obtained in this study indicated that there were several spots at the Progo River area which were suitable for camping/outbound, relaxing, and river tracks, while there were some spots not suitable for tourism activity (Tables 4 & 5). The stations that were suitable for camping, sitting, and river track were spot 2 (River view) and spot 6 (River island), while spot 1 (Bridge view) was only suitable for camping activities. The unsuitable spots need to be improved and better managed with expectations that in the future those spots can all be suitable for tourism activities.

ADO-ODTWA Assessment

Results of the ADO-ODTWA assessment indicated that the environmental conditions around the Progo River estuary in Bleberan Hamlet were generally suitable for being developed as a tourist destination, particularly in terms of accessibility, accommodation, and availability of clean water. However, only one attraction that was deemed unsuitable. Additionally, there is a need for improvements in the surrounding environment, as it tends to be quite hot. Providing shade is necessary to ensure a comfortable temperature for visitors. It is hoped that with these enhancements, the area can be transformed into a prime tourist location in the future.

Table 5 Results of the ADO-ODTWA assessment

Observation Spot	Attraction	Accessibility	Conditions Surrounding the Area	Accommodation	Availability of Clean Water
1	Not eligible	Eligible	Not eligible	Eligible	Eligible
2	Eligible	Eligible	Not eligible	Eligible	Eligible
3	Eligible	Eligible	Not eligible	Eligible	Eligible
4	Eligible	Eligible	Not eligible	Eligible	Eligible
5	Eligible	Eligible	Not eligible	Eligible	Eligible
6	Eligible	Eligible	Not eligible	Eligible	Eligible

CONCLUSION

The measured primary environmental parameters were as follows: the average temperature was 29.7 °C, average mud thickness was 15.9 cm, salinity range was 0.3 - 0.94%, average water clarity was recorded at 46 cm, the average of pH level was 7.5 (indicating slight alkalinity), and the average of dissolved oxygen concentration was 4.6 mg/L. All of these parameters indicated that the environmental characteristics of the area were suitable for marine life and has the potential to become mangrove ecotourism. Aquatic biota found in Progo River Estuary were crustaceans, gastropods, and actinopterygii.

Overall, the Progo River area is quite suitable for ecotourism development. Attention should be focused to the attractions and conditions in the surrounding area. Some suggestions include improving the environment at the less suitable spots, adding local attractions (such as fishing and kayaking), and encouraging scientific research to ensure sustainable ecotourism in the future.

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