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The mangrove ecosystems on the north coast of Bangkalan, Indonesia, and its potential for mangrove ecotourism

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Abstract. *Nugraha WA, Ambariyanto A, Insafitri. 2024. The mangrove ecosystems on the north coast of Bangkalan, Indonesia, and its potential for mangrove ecotourism. Biodiversitas 25: 859-868.* Mangrove ecosystems have the potential to be used as objects of marine ecotourism, in addition to many ecological functions and one of the main producers in marine fisheries. Bangkalan has a mangrove area of 1500 hectares which has the potential to be used as ecotourism. However, there is no research that analyzes and identifies the suitability index of mangrove tourism along the north coast of Bangkalan, Madura. The purpose of this study was to determine mangrove species, mangrove density, and mangrove tourism suitability index on the north coast of Bangkalan in order to identify the potential of mangrove for eco-tourism. The research was done at 14 stations on the north coast of Bangkalan. Data calculation and analysis were carried out by calculating the thickness of mangroves forest, mangrove species, mangrove density, biota that can be found, tides, accessibility, and infrastucture that were used to calculate mangrove tourism suitability index. The results showed that mangrove thickness in the north coast of Bangkalan were 138 m-864 m. 17 mangrove species were found, with the highest number of species was found in site 13 (Labuhan Education Park) with 14 species. Mangrove density was between 400-3500 trees/ha, with 10 sites in dense category, 2 in average category, and 2 in low category. The results showed that all research sites were included in the sufficient criteria for mangrove tourism. Mangroves in Bangkalan have great potential to develop mangrove tourism since all research sites were included in the sufficient criteria for mangrove tourism.

Keywords: Mangrove density, mangrove ecosystem, mangrove species, mangrove thickness, marine tourism, north coast of Bangkalan

INTRODUCTION

Mangrove ecosystems serve a variety of biological roles and are major producers in marine fisheries. Mangroves are biologically a link in the food chain in seas that may handle many kinds of fish, mollusks, and shrimps (Kristiningrum et al. 2019). Mulyadi et al. (2021) said that the mangrove of Bandar Bakau Dumai has been inhabited by 13 species of birds, 7 species of reptiles, and 16 species of mollusks. Mangroves not only provide food for aquatic biota but mangroves can also create a conducive atmosphere for the biota. Mangrove forest areas have diverse biodiversity and biota such as gastropods (Laraswati et al. 2020; Goulding and Dayrat 2023), fish (Fierro-Arcos et al. 2021), crustaceans (Putri et al. 2018; Wanjiru et al. 2023), oysters (McClenachan et al. 2021), and other biotas. Mangrove ecosystem has the potential to be developed as a marine ecotourism area (Thompson 2022).

According to Ellison et al. (1999), all mangrove taxa originate in the Indo-Pacific, therefore it is not surprising that Indonesia possesses the world's largest mangrove forest, accounting for around 25% of total mangrove area (Murdiyarso et al. 2015). Indonesia contains some of the world's largest mangrove forests. Mangrove forests in Indonesia are estimated to cover approximately 3.3 million hectares, with 2.2 million ha within forest regions and 1.3 million ha outside forest areas (Giri et al. 2011). Mangrove forests have unique biological components and ecosystems (Lovelock et al. 2022). Mangrove is one of the world's carbon sinks (Macreadie et al. 2021; Hidayah et al. 2022). This area absorbs over 1.463,22 tonnes of carbon per hectare, which is three times the capacity of non-mangrove forests (Richards et al. 2020; Yaqin et al. 2022). Humans have taken use of the availability of food and other resources in mangrove ecosystems, ranging from timber and branches to biochemical and pharmacological applications (Dahibhate et al. 2020; Das et al. 2022). The mangrove ecosystem in Bangkalan Regency covers an area of 1,500 Ha (Muhsoni 2014). The number of poor people in Bangkalan has increased from 2018-2020, from 191.23 thousand people to 200.4 thousand people (Central Bureau of Statistics for Bangkalan Regency 2023), so efforts are needed to increase the welfare of the people. One of the existing potentials is optimizing mangrove resources for ecotourism. Eagles and Nilsen (2001) said that Ecotourism is a travel to natural areas natural order to save the environment and improve the economy of local communities. Ecotourism can also play a role to conserve natural resources (Insafitri et al. 2020). With a large mangrove area, Bangkalan Regency has the potential for

mangrove ecotourism that can be developed (Turisno et al. 2021). However, 66% of mangrove forests in Bangkalan Regency are in poor condition (Wardhani et al. 2022), which is caused both overexploitation and conversion of land into settlements, ponds, and stalls (Turisno et al 2021; Ramadhani et al. 2022).

The tourism suitability index is one of the indices that can be used to determine if a place is suitable for usage as a tourist attraction (De Luna 2021). The tourism appropriateness index study itself includes variables such as estimating mangrove thickness, mangrove species, biota that can or are discovered, tides, and mangrove density (Ali et al. 2021). The north shore of Bangkalan contains a mangrove habitat and is thought to be suitable for marine tourism (Hakim et al. 2017). Several mangrove tours on the north coast of Bangkalan were created and developed utilizing Tourism Suitability Index (TSI) tools. In addition, research on mangroves on the north coast of Bangkalan so far has only discussed the density of mangroves and rarely identify their potential as coastal tourism objects so this research needs to be carried out.

The purpose of this study is to identify potential mangrove tourism objects and evaluate mangrove tourism areas on the north coast of Bangkalan using the approach of mangrove tourism suitability index and area carrying capacity, furthermore, this study aims to analyze mangrove thickness, identify mangrove species, mangrove density, and Mangrove tourism suitability index.

MATERIALS AND METHODS

Study area

This research was conducted in August-November 2022 along the north coast of Bangkalan District, East Java Province, Indonesia. Surveys were done at 14 sites with 3 transects at each site (transect 10 m x 10 m) (See Table 1; Figure 1). The 14 sites were chosen with consideration because they have adequate road access to the sites. Adequate road access is important in the development of mangrove ecotourism. Mangrove forest ecosystems with sufficient access were surveyed and analyzed for tourism suitability. Mangrove ecosystems where tourism activities are already operating (sites 1, 6, 9, 10, 11, 12, 13, 14) were also evaluated for their tourism suitability.

Procedures

Research station selection

The selection of the research stations was carried out using the google earth application. Image from google earth was carefully examined. The location along the north coast of Bangkalan was surveyed for the thickness of mangroves and their accessibility. Mangroves with sufficient thickness and accessibility in the form of adequate roads were then selected as prospective research stations.

Table 1. Latitude and longitude of the research site

Site	Location	Latitude	Longitude
1	Tajungan	-7.156362427	112.6954429
2	Socah	-7.1024058	112.7084925
3	Junganyar 1	-7.096351444	112.692312
4	Junganyar 2	-7.086816839	112.6847907
5	Pernajuh	-7.066944	112.675278
6	Langgundi	-7.038846	112.708612
7	Pesarean Buju' Sara	-7.039664858	112.7178002
8	Pangeranan	-7.020078581	112.74002
9	Bancaran	-7.0105073	112.7567407
10	Pandela Beach	-6.9750657	112.7946112
11	Tengket	-6.943313	112.826026
12	Jung Koneng	-6.885777778	112.9822194
13	Labuhan Education Park	-6.886519444	112.992775
14	Lembung Paseser	-6.888944444	113.0109972

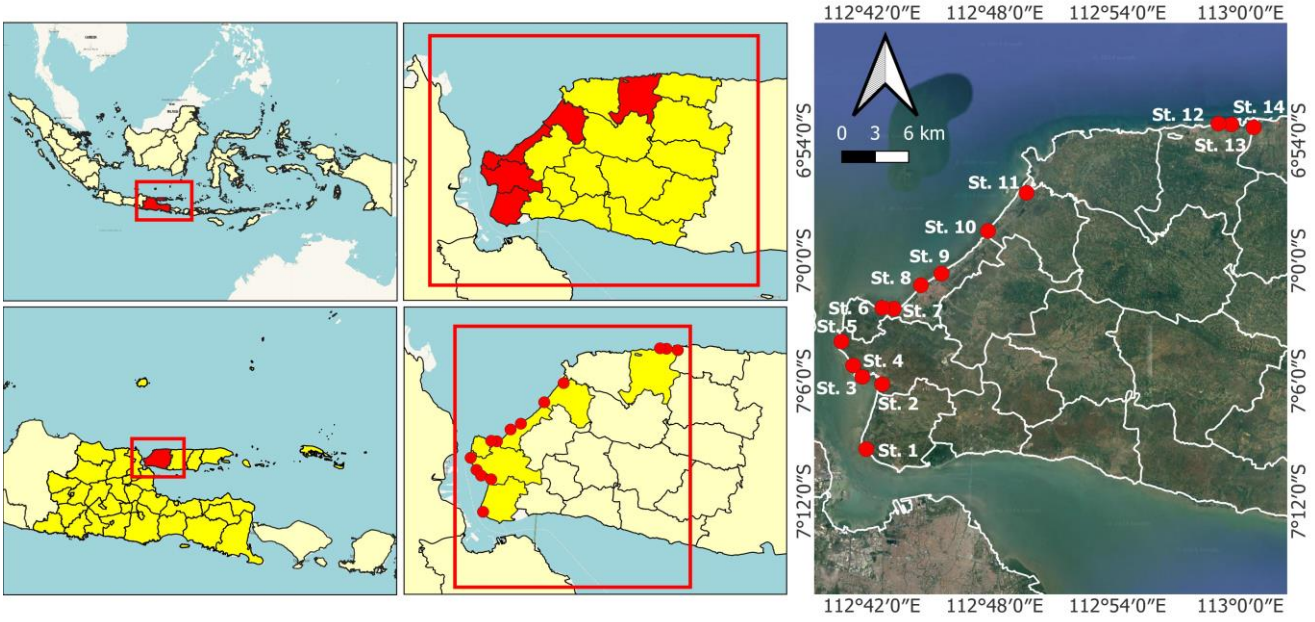

Figure 1. Research station map on the north coast of Bangkalan District, East Java Province, Indonesia

Preliminary survey

Based on the prospective research stations that were chosen, a preliminary survey was carried out by conducting a ground check directly at the site to ensure that the thickness of the mangroves and accessibility were adequate. At this stage, a rapid survey of mangrove density estimation was also carried out. Based on the survey of mangrove thickness, mangrove density and site accessibility, then research stations were determined. Especially for locations that already have mangrove tourism objects, it is immediately designated as one of the research sites.

Data collection

At each site, there were 3 transects used. Mangrove survey was established using fiber tape transects measuring 10 m x 10 m for each transect. The data taken using this transect includes the thickness of mangroves, mangrove species, biota objects, and the density of mangrove species. In addition, at each site there is a record of tides, accessibility of locations and available infrastructure.

Mangrove thickness

The thickness of mangroves was measured based on the length of the mangrove ecosystem at each station perpendicularly from the land boundary to the sea boundary. The thickness of the mangroves was measured from the outermost line towards the sea perpendicular to the land to the last mangrove vegetation (Askar et al. 2021).

Mangrove species

Mangroves were identified by collecting a section of the twigs, complete with blooms and leaves, and using Noor et al.'s (1999) identification book. Mangrove identification is based on appearance, leaves, flowers, fruit or propagules, and roots, with the use of mangrove plant identification keys (Giesen et al. 2007). Several photographs were taken of the various types of mangroves present at the sites (Askar et al. 2021).

Biota objects

Biota objects are observed directly in the field. Those biotas include fish, shrimp, crab, mollusk, reptile, and bird (Vipriyanti et al. 2022). This observation only counts the number of types of biota that have the potential for tourist attractions at the phylum level and does not display the taxonomic classification according to Ali et al. (2021).

Mangrove density

Transects of 10 x 10 m were established to assess the density of mangroves. The collected mangrove ecosystem vegetation data was used to assess the environment ecologically, which is limited to determining the value of mangrove density only, which is one aspect in determining the suitability of a mangrove ecotourism area. To calculate mangrove density, only tree category mangroves were recorded. Tree category mangroves are mangroves with a trunk diameter of more than 10 cm at a trunk height of 1.3 m (Setyadi et al. 2021). Density of mangrove was done by using the formula (English et al. 1994):

$$Di = \frac{Ni}{A}$$

Where:
Di : Density of type to-i (ind m^{-2})
Ni : Total number of individuals of the type to-i (ind)
A : Total area of sampling (m^2)

Tidal

Determining a representative location for the installation of tidal poles and recording their position is important in mangrove ecotourism planning, especially with regard to the plan to make a walking track. Tidal is obtained through the procedure of installing tidal signs placed in locations where at the highest tide and lowest tide, the sign is still submerged in water. Tidal measurements were carried out for 24 hours with a time interval of 1 hour (English et al. 1994). The tidal data is then compared with the average tidal data from the Geospatial Information Agency (BIG). In this study, data from BIG is only used as a reference because the BIG measuring station is only found in Tanjung Perak Surabaya so the values of all observation stations will be considered the same if only using data from BIG.

Accessibility and infrastructure

Accessibility is defined as the ease of accessing or enjoying a tourist attraction, including aspects such as the availability of transportation, roads, and guides. Meanwhile, infrastructure is defined as facilities found in tourist areas to support the comfort of visitors. Accessibility and infrastructure at the study site were viewed then recorded.

Tourism Suitability Index (TSI)

The data obtained were analyzed using the mangrove tourism suitability index and the carrying capacity of mangrove ecotourism areas (Table 2). At this stage, the expected output is the availability of TSI which will be used to conclude the potential of mangrove ecotourism. TSI was calculated by using the formula (Yulianda 2019) as follows:

$$TSI = \sum \left(\frac{Ni}{Nmax} \right) \times 100\%$$

Where:
TSI : Tourism Suitability Index
Ni : i-th Parameter Value
Nmax : The maximum value of a category of conservation areas

Grouping of tourist suitability index values for each mangrove ecotourism activity based on the following provisions: (i) S1: Appropriate/very appropriate, with a value of 83%-100%. (ii) S2: Conditionally compliant, with a value of 50%-83%. (iii) S3: Non-matching, with a value of <50%.

Tabel 2. Mangrove ecotourism suitability category matrix

Parameter	Weight	Category	Score
Mangrove thickness (m)	5	>500	3
		>200-500	2
		50>200	1
		<50	0
Mangrove density (ind/100 m^2)	4	>15-20	3
		>10-15;>20	2
		5-10	1
		<5	0
Mangrove Species	4	>5	3
		3-5	2
		1-2	1
		0	0
Tides (m)	3	0-1	3
		>1-2	2
		>2-5	1
		>5	0
Biota objects	3	Fish, shrimp, crab, mollusk, reptile, bird	3
		Fish, shrimp, crab, mollusk	2
		Fish, mollusk	1
		One of aquatic biota	0
Accessibility	5	It is easy to get to the ecotourism location (near the main road, adequate roads, and adequate transportation)	3
		Easy to get to the ecotourism location (There are 2 criteria)	2
		There is 1 criterion	1
		Difficult to get to ecotourism locations	0
Infrastructure	3	Complete Infrastructure (there are trash cans, road conditions are good, there are piers, there are parking lots, there are food/beverage kiosks)	3
		Incomplete infrastructure (there are 3 criteria)	2
		There is 1 criterion	1
		Infrastructure unavailable	0

Note: Maximum value: 81. Modification of Ali et al. (2021)

RESULTS AND DISCUSSION

Mangrove thickness

The mangrove thickness on the north coast of Bangkalan ranges from 138 m-864 m (Table 3). Locations in Tajungan, Socah, Bancaran, Pandela Beach, Tengket, Jung Koneng, Labuhan Education Park, and Lembung Pasesser have mangrove thickness more than 500 m which makes it get the maximum value to be developed as a mangrove tourism park. All study locations that are currently mangrove tourism objects, such as Tajungan, Jung Koneng, and Labuhan Education Park, have the ideal mangrove thickness (width) for mangrove tourism objects. The thickness of the mangroves on the north coast of Bangkalan is greater than the thickness of mangroves on the south coast of Bangkalan, which ranges from 10-280 m (Wardhani et al. 2022). It is also generally greater than the mangrove ecosystem at the Idaman Mangrove Ecotourism which mangroves thickness ranged from 127 to 209 m (Askar et al. 2021), and in Nusa Penida Island, Bali which ranged from 200 to 500 m (Vipriyanti et al. 2022).

Mangrove species composition

The number of species on the north coast of Bangkalan are 7 species namely *Aegiceras corniculatum, Avicennia alba, Avicennia marina, Bruguiera cylindrica, Bruguiera gymnorrhiza, Bruguiera parviflora, Ceriops decandra, Ceriops tagal, Exocoecaria agallocha, Lumnitzera racemosa, Nypa fruticans, Pemphis acidula, Rhizophora apiculata, Rhizophora mucronata, Rhizophora stylosa, Sonneratia alba, Xylocarpus moluccensis* (Table 4). Station 1 has the least number of species (5 species) while Station 13 has the highest number of species (14 species). Species *Avicennia marina, Sonneratia alba, and Rhizophora mucronata* were found at all stations. This is in accordance with Tomlinson (2016) dan (Giesen et al. 2007) who stated that the genera of *Rhizophora*, *Sonneratia* and *Avicennia* are genera found in the Indo-Pacific, Atlantic, Caribbean regions. The genus Rhizopora and Avecennia and Sonneratia are the most commonly found genera in all mangrove locations in Indonesia such as in Buleleng, Bali (Ginantra et al. 2018), Jakarta and Segara Anakan, Cilacap (Sari et al. 2019; Hilmi et al. 2021), Pasuruan, East Java (Isroni et al. 2019), Belitung Island (Irawan et al. 2021), Papua Island (Setyadi et al. 2021), North Sumatra (Harefa et al. 2022), and other locations in Indonesia (Rahman et al. 2019). The number of species found on the north coast of Bangkalan is more than in Rawa Timur mangrove forest that there are 14 species of mangrove derived from 10 genera of 8 families, on six PP's (1.50 ha) that have been established (Hidayat et al. 2017); Mentawir Village, Penajam Paser District, East Kalimantan Province which found 12 species, with the *R. apiculata* was the dominant species (Kristiningrum et al. 2019) namely *R. apiculate*, *R. mucronata*, and *Avicennia* sp.; Jor Bay, East Lombok which is found seven mangrove species, namely *A. marina, C. tagal, R. apiculata, R. stylosa, S. alba, S. caseolaris*, and *Lumnitzera racemosa* (Zulhalifah et al. 2021) and more than in the south coast of Bangkalan which is 7 species of *A. marina, A. alba, B. gymnorhiza, R. apiculata, R. mucronata, R. stylosa, S. alba,* and *Nypa fruticans* (Wardhani et al. 2022). However, the number of mangrove species on the north coast of Bangkalan is still lower compared with the number of mangrove species found in the Mimika Region, Papua where 66 mangrove species consisting of 20 major, 10 minor, and 36 associate mangrove species were found (Setyadi et al. 2021); and lower compared with Karimunjawa Island, Central Java with 24 species of mangrove (Rahmandhana et al. 2022). The difference in the composition of mangroves at different stations is thought to be due to differences in environmental parameters, Tihurua et al. (2020) stated that leaf anatomy is influenced by differences in environmental parameters, one of which is salinity affects the thickness of the watershed, and the density of the stomata. Different mangrove diversity may be caused by the difference in land elevation, which will cause different tides and salinity, which eventually can control mangrove diversity (Setyadi et al. 2021). Differences in salinity and tides will in turn affect mangrove species

that are able to live in a location according to the type of roots and the ability of Pneumatophores (Setyadi et al. 2021). Further, increased water salinity would be advantageous to the abundance of salt-tolerant species such as *A. marina* and less favorable for the abundance of salt-sensitive mangroves such as *R. mucronata* (Chowdhury et al. 2016).

Mangrove density

The mangrove density on the north coast of Bangkalan is between 400-3500 trees ha^{-1} (Table 5). The highest mangrove density was found at Station 2 (Socah) of 2500 trees ha^{-1}. Meanwhile, the lowest density value was found at station 12 (Jung Koneng) of 400 trees ha^{-1}. Based on the Decree of the Minister of Environment number 201 of 2004, 10 observation locations were in the dense category (density >1500 trees ha^{-1}), 2 locations were in the moderate category (density 1000-1500 trees ha^{-1}) and 2 locations were in the rare category (density <1000 trees ha^{-1}). The density of mangroves on the north coast of Bangkalan is generally higher compared to Pasuruan, East Java (Isroni et al. 2019). The density of mangroves on the north coast of Bangkalan is a bit higher than mangrove density of Mimika District ranging from 577-1345 trees ha^{-1} (Setyadi et al. 2021); comparable to Aceh Besar ranging from 1200-3200 trees ha^{-1} (Permatasari et al. 2018); but lower compared to mangrove density of Segara Anakan, Central Java with 8000 trees ha^{-1} (Hinrichs et al. 2009).

The thickness of mangroves in this study is the distance between the first time they were discovered in the water area and the last time they were discovered on land. The density of mangroves is determined by the number of trees per study area (Ali et al. 2021). There is no relationship between mangrove thickness and mangrove density, this is reinforced by research by Pin et al. (2021) which states that at the research location in Cimalaya Wetan Beach Karawang the research area which has a thick thickness of mangroves had a low density and some had a high density, and the thickness of mangroves is due to the adaptation pattern of mangrove species on land, logging, and reforestation.

Associated biota

Because the mangrove environment on Bangkalan's north coast is home to a variety of biotas, including fish, prawns, crabs, mollusks, birds, and reptiles, all observation sites in the area can be promoted as mangrove tourism destinations (Table 6). According to Bengen (2000), the distinctive qualities of the plants that make up mangrove ecosystems indicate that mangrove areas have a great potential for the development of tourism. The main attraction of mangrove ecosystems is the potential diversity of wildlife, especially waterbirds, migratory birds, reptiles, mammals, primates and fish.

Table 3. Mangrove thickness at the north coast of Bangkalan District, East Java Province, Indonesia

Site	Location	Thickness (m)	Score
1	Tajungan	716	3
2	Socah	864	3
3	Junganyar 1	225	2
4	Junganyar 2	289	2
5	Pernajuh	138	1
6	Langgundi	289	2
7	Pesarean Buju' Sara	334	2
8	Pangeranan	346	2
9	Bancaran	609	3
10	Pandela Beach	508	3
11	Tengket	528	3
12	Jung Koneng	539	3
13	Labuhan Education Park	518	3
14	Lembung Paseser	819	3

Table 4. Composition of mangrove species and their distribution or occurrence in the different research sites at the north coast of Bangkalan District, East Java Province, Indonesia

Species	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14
Aegiceras corniculatum (L.) Blanco		√				√	√		√		√		√	√
Avicennia alba Blume		√								√		√		
Avicennia marina (Forssk.) Vierh.	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Bruguiera cylindrica (L.) Blume								√					√	
Bruguiera gymnorrhiza (L.) Lam.											√	√	√	√
Bruguiera parviflora (Roxb.) Wight & Arn. ex Griff.				√										
Ceriops decandra (Griff.) Ding Hou									√		√	√	√	
Ceriops tagal (Perr.) C.B.Rob.		√		√		√			√	√		√	√	√
Exocoecaria agallocha L.							√		√		√		√	
Lumnitzera racemosa Willd.	√	√	√		√	√	√	√	√		√		√	
Nypa fruticans Wurmb								√			√			
Pemphis acidula J.R.Forst. & G.Forst.							√				√		√	
Rhizophora apiculata Blume	√	√	√	√	√		√		√	√	√	√	√	√
Rhizophora mucronata Lam.	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Rhizophora stylosa Griffith								√	√			√	√	√
Sonneratia alba Sm.	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Xylocarpus moluccensis (Lam.) M.Roem.		√	√	√	√	√			√		√	√	√	
Total species	5	9	6	7	6	7	8	7	11	6	12	10	14	8

Note: S: Site

According to Bengen (2004), mangrove forest fauna communities form a mixture between two groups, namely: (i) Terrestrial/terrestrial fauna groups that generally occupy the upper parts of mangrove trees, consisting of insects, snakes, primates and birds; (ii) The group of aquatic fauna consists of two types, namely fauna that live in the water column such as fish and shrimp, fauna that occupy the root substrate and trunks of mangrove and mud trees such as crabs, shellfish and various other types of invertebrates. Biota that often visit mangrove forests are from vertebrates, such as birds, amphibians, reptiles, and mammals. Mangrove forests are visited by several species of migratory birds. Tuwo (2011) found 53 species of birds in the mangrove forests of Arakan Wawontulap and Mantehage Island in North Sulawesi. Mollusks are invertebrates that are often found in mangrove forests, namely from the gastropoda and Bivalve classes (Ginantra et al. 2020).

Tide

The tide height at all observation stations on Bangkalan's north coast ranges from 0 to 1 m (Table 7), which is reasonably low and won't impede with any future development of mangrove tourism activities. Mangroves are plants that are found in tidal areas (Nybakken 1997). However, in order to be a good mangrove tourism area, it is important to consider the comfort of visitors. According to Ali et al. (2021), low tides (0-1 m) are ideal because they are a height that is comfortable for visitors.

Accessibility

Mangrove locations on the north coast of Bangkalan, only 5 of 14 locations have adequate accessibility (Table 8), such as being close to the main road, there are sufficient roads, and there is adequate transportation to the location so that it is very supportive for the development of mangrove tourism. Meanwhile, 7 locations only have adequate roads, but are far from main roads and there is no transportation. In the absence of accessibility, the development of mangrove tourism will require a very large amount of money, especially to increase accessibility to locations. Karlina (2015) said that beautiful and natural mangrove areas will be easy and comfortable to visit if they have good accessibility infrastructure. According to Ali et al. (2021) said the infrastructure needed by mangrove ecotourism is near the main road, adequate roads, and adequate transportation.

Infrastructure

Mangrove tours are one type of tourism that is possible in the mangrove region. This activity involves travellers exploring the areas surrounding mangroves, where they may take in the local flora and fauna as well as sample prepared fish and other marine foods. The provision of suitable amenities and infrastructure is crucial in promoting the allure of ecotourism, since it provides tourists with a comfortable and satisfying experience. According to Ali et al. (2021), these facilities and infrastructure include: availability of good roads, the availability of docks, the availability of parking lots, the availability of food and beverage stalls, and the adequacy of trash cans are supporters for the convenience of visitors who come. 6 sites have the entire necessary infrastructure, while 2 locations in Socah and Lembung Paseser only have good roads, and the rest have sufficient infrastructure (Table 9).

Mangrove tourism potential

The mangrove tourism suitability index at all research stations, it is included in the appropriate criteria for mangrove tourism (Table 10). In more detail, the results showed that Stations 1, 2, 4, 6, 7, 9, 10,11 have a mangrove tourism suitability index that is included in the very sufficient criteria, while stations 3, 5,8,12, 13, 14 are included in the conditionally sufficient criteria. Stations 1, 6, 9, 10, 11, 12, 13, 14 are already operated as mangrove tourism area however at stations 12,13, 14 are included in the conditionally sufficient criteria which means there must be an evaluation so that tourist activities can take place sustainably.

Research on the suitability index of mangrove tourism has been carried out in other areas such as Pin et al. (2021) in the Cimalaya Wetan Beach area of Karawang area but biota objects that live in mangroves, accessibility, infrastructure, and tides are not taken into account unlike in this study. Sukuryadi et al. (2020) also examined the suitability index of mangrove tourism in the Lombok-sheet area also does not consider accessibility and infrastructure.

Table 5. Mangrove density at the north coast of Bangkalan, Indonesia

Location	Mangrove density		Score
	(Trees/100m^2)	Trees ha^{-1}	
Tajungan	23	2300	2
Socah	35	3500	2
Junganyar 1	20	2000	3
Junganyar 2	32	3200	2
Pernajuh	12	1200	2
Langgundi	29	2900	2
Pesarean Buju' Sara	32	3200	2
Pangeranan	28	2800	2
Bancaran	19	1900	3
Pandela Beach	20	2000	3
Tengket	25	2500	2
Jung Koneng	4	400	0
Labuhan Education Park	9	900	1
Lembung Paseser	14	1400	2

Table 6. Associated biota found in the mangrove ecosystem at the north coast of Bangkalan District, Indonesia

Location	Associated biota	Score
Tajungan	Fish, shrimp, crab, mollusk, bird, reptile	3
Socah	Fish, shrimp, crab, mollusk, bird, reptile	3
Junganyar 1	Fish, shrimp, crab, mollusk, bird, reptile	3
Junganyar 2	Fish, shrimp, crab, mollusk, bird, reptile	3
Pernajuh	Fish, shrimp, crab, mollusk, bird, reptile	3
Langgundi	Fish, shrimp, crab, mollusk, bird, reptile	3
Pesarean Buju' Sara	Fish, shrimp, crab, mollusk, bird, reptile	3
Pangeranan	Fish, shrimp, crab, mollusk, bird, reptile	3
Bancaran	Fish, shrimp, crab, mollusk, bird, reptile	3
Pandela Beach	Fish, shrimp, crab, mollusk, bird, reptile	3
Tengket	Fish, shrimp, crab, mollusk, bird, reptile	3
Jung Koneng	Fish, shrimp, crab, mollusk, bird, reptile	3
Labuhan Education Park	Fish, shrimp, crab, mollusk, bird, reptile	3
Lembung Paseser	Fish, shrimp, crab, mollusk, bird, reptile	3

Table 7. Tide at the mangrove ecosystem at the north coast of Bangkalan District, Indonesia

Location	Tide (m)	Score
Tajungan	0-1	3
Socah	0-1	3
Junganyar 1	0-1	3
Junganyar 2	0-1	3
Pernajuh	0-1	3
Langgundi	0-1	3
Pesarean Buju' Sara	0-1	3
Pangeranan	0-1	3
Bancaran	0-1	3
Pandela Beach	0-1	3
Tengket	0-1	3
Jung Koneng	0-1	3
Labuhan Education Park	0-1	3
Lembung Paseser	0-1	3

From the research data, what needs to be improved is the accessibility with the availability of transportation and the addition of infrastructure such as the procurement of trash cans, docks, food stalls, and adequate roads. Although all sites are accessible using car, however, the road is in the bad condition, so improvement of road quality is mandatory for the development of mangrove as tourist area. Accessibility is one of the supporting factors in developing an area to connect outside and location-related areas. Existing facilities and infrastructure can be more easily accessed from and to tourist areas on the north coast of Bangkalan. Accessibility is divided into four requirements by Bahar (2004), including: 1. An asphalt road is a suitable route to a minimal place, 2. Several alternative roads lead to that location, 3. Numerous shuttles to the address, 4. supporting structures like docks. The dock was a part of the infrastructure in this study.

Increasing community involvement and law enforcement is another action that can be used to preserve mangrove habitats. Increasing the calibre of human resources and getting support from relevant stakeholders is another action that can be taken (Joandani et al. 2019).

Increasing the capacity of Human Resources can be done by counseling and socialization activities is one method that can be used to convey something new, namely about mangrove management from the introduction of mangrove types, the benefits of mangroves, the types of biotas that live in mangrove ecosystems to mangrove conservation efforts and the development of conservation education potential. Understanding and awareness of the role of local communities can be introduced, trained, and practiced in a linear program such as socialization of ecotourism understanding, tour guide training or beginner ecotourism interpreters equipped with material about mangroves and their ecosystems.

Mangrove tourism is an activity that utilizes the nature around mangroves so that species that grow in tourist areas play an important role. For the lowest mangrove thickness parameter is found at station 5 which means that mangrove planting can be done so that the thickness of the mangrove can be better. Station 12 and station 13 has the lowest score for the mangrove density parameter so mangrove planting efforts are also needed at this station. Planting additional mangrove plant and species would increase the mangrove density and mangrove thickness, in which would increase the suitability score of mangrove suitability index in station 5, 12 and 13. The parameters of the number of species, biota objects, and tides at all stations scored well. Stations 2, 4, 6 are very suitable for opening new mangrove tourism in the Bangkalan area. Mangrove tourism can also be added to tours by boat and visiting resorts to add to the attractiveness of existing tour packages (Rahmila and Halim 2018). The number of mangroves species in the mangrove ecosystem is one of the things that attract tourists. This is an important value for tourism activities in the research area. Susi et al. (2018) said that the diversity of mangrove species in mangroves is an important value in mangrove tourism activities and increases visitor attraction. Furthermore, according to Sadik et al. (2017), the number of mangrove species also affects the diversity of other biota living in mangroves.

Table 8. Accessibility to mangrove ecosystem at the north coast of Bangkalan District, Indonesia

Site	Location	Accessibility	Score
1		Adequate roads, and adequate transportation	2
2	Socah	Near the main road, adequate roads, and adequate transportation	3
3	Junganyar 1	Adequate roads	1
4	Junganyar 2	Near the main road, adequate roads, and adequate transportation	3
5	Pernajuh	Near the main road, adequate roads, and adequate transportation	3
6	Langgundi	Near the main road, adequate roads, and adequate transportation	3
7	Pesarean Buju' Sara	Near the main road, adequate roads, and adequate transportation	3
8	Pangeranan	Adequate roads	1
9	Bancaran	Adequate roads	1
10	Pandela Beach	Near the main road, adequate roads	2
11	Tengket	Adequate roads	1
12	Jung Koneng	Adequate roads	1
13	Labuhan Education Park	Adequate roads	1
14	Lembung Paseser	Adequate roads	1

Table 9. Infrastructure around mangrove ecosystem at the north coast of Bangkalan District, Indonesia

Location	Infrastructure	Score
Tajungan	There are trash cans, there are parking lots, there are food/beverage kiosks	2
Socah	Good road condition	1
Junganyar 1	Road conditions are good, there are piers, there are parking lots	2
Junganyar 2	Road conditions are good, there are piers, there are parking lots	2
Pernajuh	There are trash cans, road conditions are good, there are piers, there are parking lots, there are food/ beverage kiosks	3
Langgundi	There are trash cans, road conditions are good, there are piers, there are parking lots, there are food/ beverage kiosks	3
Pesarean Buju' Sara	There are trash cans, road conditions are good, there are piers, there are parking lots, there are food/ beverage kiosks	3
Pangeranan	Road conditions are good, there are piers, there are parking lots	2
Bancaran	There are trash cans, road conditions are good, there are piers, there are parking lots, there are food/ beverage kiosks	3
Pandela Beach	There are piers, there are parking lots, there are food/beverage kiosks	2
Tengket	There are trash cans, road conditions are good, there are piers	2
Jung Koneng	There are trash cans, road conditions are good, there are piers, there are parking lots, there are food/ beverage kiosks	3
Labuhan Education Park	There are trash cans, road conditions are good, there are piers, there are parking lots, there are food/ beverage kiosks	3
Lembung Paseser	Road conditions are good	1

Table 10. Resume of mangrove tourism suitability index on the north coast of Bangkalan District, Indonesia

Parameter	Site													
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14
Thickness (m)	3	3	2	2	1	2	2	2	3	3	3	3	3	3
Density (inv/100 m^2)	2	2	3	2	2	2	2	2	3	3	2	0	1	2
Number of species	2	3	3	3	3	3	3	3	3	3	3	3	3	3
Tidal (m)	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Biota object	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Accessibility	2	3	1	3	3	3	3	1	1	2	1	1	1	1
Infrastructure	2	1	2	2	3	3	3	2	3	2	2	3	3	1
TSI (%)	80.25	87.65	77.78	85.15	82.72	88.89	88.89	72.84	87.65	90.12	79.02	72.84	77.78	75.31
Criteria	CS	VS	CS	VS	CS	VS	VS	CS	VS	VS	CS	CS	CS	CS

Note: S: Site, VS: very suitable, CS: conditional suitable

In conclusion, mangrove ecosystem on the north coast of Bangkalan has high diversity and has great potential to develop as mangrove tourism. All research stations based on their tourist suitability index fall into the appropriate category, although some are in the criteria for conditional suitability due to the need for additional accessibility and infrastructure.

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