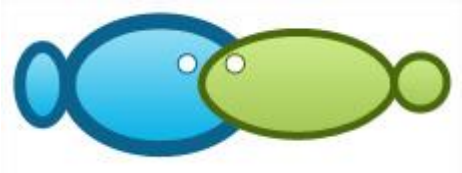

Suitability index and carrying capacity of mangrove tourism on Jeflio Island, Indonesia

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Abstract. Mangroves are very abundant on Jeflio Island, West Papua. Thus, it has the potential to be developed into a mangrove ecotourism area. This study aims to determine the suitability index and carrying capacity of the Jeflio mangrove ecotourism area. This study uses the Line Transect Plot Method. Sampling of mangrove ecosystem with a plot sampling approach was done in a line drawn across the ecosystem areas**.** Data includes species density, mangrove thickness, tides, and associated biota collected from four stations. Our results found that the mangrove densities of all stations (stations 1 to 4) have a score of 3. The mangrove thickness of stations 1, 2 and 4 has a score of 1, while station 3 has a score of 2. The suitability of mangrove tourism for the category of mangrove species is at a score of 2, as 3 to 5 mangrove species were found. The Mean Sea Level (MSL) is 3.9 m, the Highest High Water Level (HHWL) is 5.3 m, and the Lowest Low Water Level (LLWL) is 2.7 m. The tidal category has a score of 2, which is 3.9 m. The associated biota objects found include mollusks, fish, crustaceans, birds, and mammals. The suitability indexes of mangrove tourism were 64 % for Station 1, 62 % for Station 2, 74% for Station 3, and 62 % for Station 4. Therefore, the suitability indexes of all stations were categorized 'Appropriate' for mangrove tourism and the carrying capacity of the mangrove tourism area was found to be 52 visitors/day. Based on this data, Jeflio mangrove tourism can accommodate 52 visitors/day with an operational time of 8 working hours/day.

Key Words: Mangrove density, thickness, tides, associated biota, visitors

Introduction. Mangrove forest vegetation in Indonesia has a high species diversity, with a recorded number of 202 species, consisting of 89 tree species, five palm species, 14 liana species, 44 epiphytic species, and 1 cycad. However, there are only approximately 47 species of mangrove forest-specific plants. One dominant major plant group belongs to four families: *Rhizophoraceae (Rhizophora, Bruguiera, Ceriops), Sonneratiaceae (Sonneratia), Avicenniaceae (Avicenia)* and *Meliaceae (Xylocarpus)* (Pieter et al., 2015). Mangroves can grow well in coastal areas with large river mouths and deltas, where the water flow contains a lot of mud. It is difficult for mangroves to grow and develop in steep coastal areas and with big waves with strong tidal currents. This is because it is difficult to form silt in this environment, which is a needed substrate for mangrove growth (Puspitaningsih, 2012).

Mangroves have significant roles in coastal areas. The physical role of mangrove vegetation is as a wave absorber and to prevent abrasion. With a stem diameter of more than 15 cm, a thickness of more than 200 meters, and a density of 30 trees per 100 meters, mangroves can reduce the energy of tsunami waves (Henri & Ardiawati, 2020). Mangroves, bioecologically, have unique aspects compared to other tropical ecosystems, so they are an attraction factor for tourists. Mangrove ecotourism can be developed as a form of educational tourism that focuses on human behavior in protecting the environment in a sustainable manner (Henri & Ardiawati, 2020).

The concept of ecotourism considers the carrying capacity of tourist areas (Yulianda & Agus, 2019). Ecotourism utilizes and preserves the conditions of natural resources and community culture (Yulianda, 2007). Ecotourism is a form of tourism that

relies more on the character of natural resources than other resources. The resources for ecotourism consist of natural resources and human resources that can be integrated for tourism utilization. Aquatic ecotourism development requires appropriate resources and a coastal environment that follows the required criteria. The suitability of coastal and marine resources is aimed at meeting the required characteristics of tourism resources. Each tourism activity has its own specific resources and environmental requirements according to the tourism object to be developed (Yulianda, 2019).

The utilization of natural resources and marine services located in the Jeflio island area is managed directly by the local traditional community. Currently, Jeflio Island is designated as one of the destinations for marine tourism in Sorong Regency. The current tourist attraction developed is mangrove tracking tourism. This area can be visited by land by using two-wheeled or four-wheeled vehicles . The distance of the tourism area is about 10 km from the regency's capital. In a previous study, Marasabessy (2021) analyzed the suitability and model of ecotourism activities that were likely to be applied to Jeflio Island, using satellite image maps Landsat 8, SRTM map, and altimetry satellite NASATOPEX/Poseidon, Jason 1/Envisat, with the purpose to observe if the conformity index mangrove ecotourism at Jeflio Island was in the appropriate category. The model of mangrove ecotourism activities on Jeflio Island was adjusted with the geographical location and distribution of natural resources, namely tracking mangroves and boating. The mangrove ecosystem at Jeflio Island has the potential to be developed as a mangrove ecotourism area. Still, few studies were conducted to determine whether the island had tourism potential. The present study aimed to fill in this gap and determine the suitability and carrying capacity of the Jeflio mangrove tourism area to support ecotourism development.

Material and Method

Research Site. This study was conducted in Jeflio Island, Sorong Regency, West Papua Province from March to May 2021 (Figure 1).

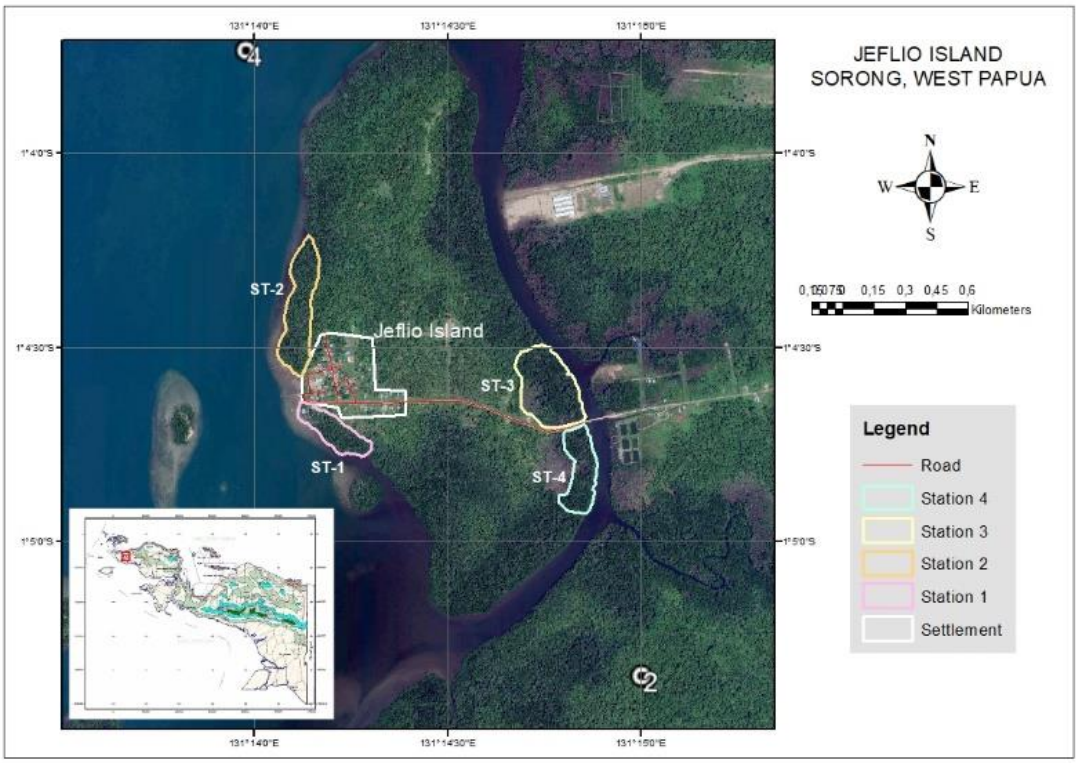

Figure 1. Research Site (Jeflio Island)
(Source: Based on Google Earth Image)

This study uses the Line Transect Plot Method. Sampling of mangrove ecosystem used plot sampling approach (Decree of Indonesian Ministry of Environment No. 201 of 2004). The measurement of parameters included the following steps. 1) The research location was chosen based on the distribution of mangroves on Jeflio Island. The observation points are called stations; 2) Station 1 (ST-1) is for existing mangrove tourism (the total area is 4.04 m^2), station 2 (ST-2) is for mangrove areas near residential areas (the total area is 7.45 m^2), stations 3 (ST-3) is on the right of the main road to Jeflio Island (the total area is 8.99 m^2) and station 4 (ST-4) is on the left of the main road to Jeflio Island (the total area is 4.96 m^2); 3) at each observation station, a line transect was determined from the sea to the land (perpendicular to the coastline) along with the mangrove forest zones; 4) along the line transect, 3 plots were placed randomly in the form of squares with a size of 10 x 10 meters; 5) in each specified sample plot, each type of mangrove plant was identified, and then the number of each type and the size of the trunk circle of each mangrove tree at breast height (more than 4-cm tree diameter with a height of more than 1 m).

Mangrove Density. Population Density is the number of individuals in the station. The following formula is used to determine population density (Legendre & Legendre 2012):

$$\text{Population density (ind ha-1)} = \frac{\text{Number of individuals}}{\text{Total sampled areas}}$$

Mangrove Thickness. Mangrove thickness was measured based on the length of each station from the coastal toward the sea line (Sadik et al., 2017).

Sea Tides. For tides calculation, the *Admiralty* method developed by Doodson was applied. Observations have produced the main tidal constants, namely M2, S2, N2, K2, K1, P1, O1, M4, and MS4, using 15 or 29 days of data. The tidal constants were used to calculate the position of the average water level and the position of the lowest water level. The type of tide is determined by the frequency of high and low tides every day. Quantitatively, the tidal type of waters can be determined by comparing the amplitudes of the main single tidal elements and the main double tidal elements by using the Formzahl number, which has the same equation (Suhaemi et al., 2018).

$$\text{Formzahl Index (F)} = \frac{A(O1) + A(K1)}{A(M2) + A(S2)}$$

Where :
F = Formzhal number
A = Amplitude
(K1), (O1)= single major daily tidal constant
(M2), (S2)= double main daily tidal constant

The following are the tidal classification:

F< 0.25	= Semi Diurnal
0.25<F<1.5	= Semi-Diurnal Sloping Mix
1.5<F<3.0	= Diurnal Slope Mix
F<F 3.0	= Diurnal

Biota Objects. Biota objects are observed directly on Jelfio Island by taking pictures/photos of biotas samples which were then identified. Mangrove-related animals were collected and identified using the Carpenter and Niem's (1998, 2001) FAO Species Identification Guide For Fishery Purposes.

Data Analysis. The parameters used to determine resource suitability include five parameters: density, thickness, species, tides, and biota that live in the mangrove ecosystem. Each parameter is assessed separately against the four categories given. The determination of the suitability of mangrove tourism is based on the multiplication between the score and the weight of each parameter. The Tourism Suitability Index (IKW) is calculated from the suitability value based on the total of all parameters (Table 1).

Determination of the Tourism Suitability Index was done by using the following formula (Yulianda, 2007):

$$IKW = \sum \frac{Ni}{Nmax} \times 100\%$$

IKW = Tourism Suitability Index
Ni = Parameter Value to i (Weight x Score)
Nmax = Maximum value of a tourism category.

Table 1

Parameters of Suitability for Mangrove Ecotourism

No.	*Parameters*	*Weight*	*Category*	*Score*
1.	Mangrove Thickness (m)	5	>500	3
			>200-500	2
			50-200	1
			<50	0
2.	Mangrove density (100 m^2)	3	>15-25	3
			>10-15:>25	2
			10-15	1
			<5	0
3.	Mangrove Species	3	>5	3
			3-5	2
			1-2	1
			0	0
4.	Tides (m)	1	0-1	3
			>1-2	2
			>2-5	1
			>5	0
5.	Biota Objects	1	Fish, shrimp, crabs, mollusks, reptiles, birds and unique wildlife / endemic / endangered animal	3
			Fish, shrimp, crab, mollusk	2
			Fish, mollusk	1
			One of the organisms	0

Source: adapted after Yulianda (2007)
Maximum value (Nmax) = 39
S1 (Very Suitable), if the Tourism Suitability Index (IKW) is 83 – 100%
S2 (Appropriate), if the Tourism Suitability Index (IKW) is 50 - < 83%
N (Not suitable), if the Tourism Suitability Index (IKW) is < 50%.

Regional Carrying Capacity. The area's carrying capacity was calculated to determine the maximum number of visitors who can physically be accommodated in the available area at a certain time without causing disturbance to nature and humans. The formula used in this analysis is shown below and is based on (Yulianda, 2014):

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

Where:

DDK : Regional Carrying Capacity (Person)
K : The ecological potential of visitors per unit area (person)
Lp : Total area (m) that can be utilized
Lt : Unit area for a certain category of mangrove tourism (m^2 or m)
Wt : Time allotted for activities in one day (hours)
Wp : Time spent by visitors for each activity (hours)

The ecological potential of visitors is determined by the conditions of the resources and types of activities developed. The area used by visitors must pay attention to the ability of nature to tolerate visitor activity so that authenticity is maintained (Table 2).

Table 2

Visitor Ecological potential (K), area of activity (Lt), time spent by visitors (Wp) and time allotted for activities in one day (Wt)

No	*Type of Activity*	*K (∑Visitors)*	*Unit Area (Lt)*	*Description*	*Time spent by visitors (Wp)*	*Time allotted for activities in one day (Wt)*
1.	Dive	2	2000 m^2	Every 2 people in 200 m x 10 m	2	8
2.	Snorkeling	1	500 m^2	Every 1 person in 100 m x 5 m	3	6
3.	Seagrass Tourism	1	250 m^2	Every 1 person in 50 m x 50 m	2	4
4.	Mangrove Tourism	1	50 m	Track length, every 1 person along 50 m	2	8
5.	Recreational Beach	1	50 m	1 person per 50 m long beach	3	6
6.	Sports Tour	1	50 m	1 person per 50 m long beach	2	4

Source : Yulianda (2007)

Results and Discussion

Mangrove Density. The total mangrove density value at station 1 was 1,600 ind ha^{-1} (16 ind 100 m^{-2}), at station 2 was 1,966 ind ha^{-1} (19.66 ind 100m^{-2}), at station 3 was 2,000 ind ha^{-1} (20 ind 100 m^{-2}) and at station 4 was 1,966 ind ha^{-1} (19.66 ind 100 m^{-2}). The density of mangrove vegetation on Jeflio Island at station 1, station 2, station 3 and station 4 were in the dense criteria, namely ≥ 1,500 ind ha-1 (Yanti et al., 2021). According to the tourism suitability parameters in Table 1, the suitability of areas for mangrove tourism for the category of mangrove density at Station 1, Station 2, Station 3 and Station 4 has a score of 3. Score 3 means that the mangrove density is between 15-25 ind 100 m^{-2} (Table 3). To find out the area's suitability for mangrove ecotourism, the value of each category is entered in the table of parameter analysis of the suitability of mangrove tourism (Table 8).

Table 3

Mangrove Density

Station	*Species*	*Density (ind/100 m²)*	*Criteria**
1	*Avicennia alba*	1.00	
	Rhizophora mucronate	6.34	
	Bruguiera gymnorrhiza	3.33	
	Xylocarpus granatum	5.33	
Total		**16.00**	Score 3
2	*Avicennia alba*	1.66	
	Rhizophora mucronate	6.33	
	Bruguiera gymnorrhiza	5.67	
	Xylocarpus granatum	6.00	
Total		**19.66**	Score 3
3	*Avicennia alba*	0	
	Rhizophora mucronate	9.00	
	Bruguiera gymnorrhiza	9.67	
	Xylocarpus granatum	1.33	
Total		**20.00**	Score 3
4	*Avicennia alba*	0.00	
	Rhizophora mucronate	9.00	
	Bruguiera gymnorrhiza	10.00	
	Xylocarpus granatum	0.66	
Total		**19.66**	Score 3

* Criteria according Yulianda (2007) (Table 1)

Mangrove thickness. Mangrove thickness was measured based on the length of the roll meter stretch at each station perpendicularly from the land boundary to the sea boundary (Table 4). Based on the results of the study, the highest mangrove thickness was at Station 3 with a thickness of 274.5 m and the lowest mangrove thickness was at Station 4, which was 131.8 m. Mangrove density correlates with mangrove thickness, when mangrove density is "rare" then the mangrove thickness is small. Conversely, if the mangrove density is "very dense" then the mangrove thickness will be large (Marasabessy, 2021). According to the tourism suitability parameters in Table 1, the suitability of mangrove tourism for the mangrove thickness category for Station 1 has a score of 1, Station 2 has a score of 1, Station 3 has a score of 2 and Station 4 has a score of 1. A score of 2 means that the thickness of the mangrove is more than 200 m, while a score of 1 means that the thickness of the mangrove is in the range of 50-200 m. To find out the suitability of the area for mangrove ecotourism, the value of each category is entered into the table of parameter analysis of the suitability of mangrove tourism (Table 8).

Table 4

Mangrove Thickness

No.	*Location*	*Thickness (m)*	*Criteria**
1.	Station 1	119.4	Score 1
2.	Station 2	128.3	Score 1
3.	Station 3	274.5	Score 2
4.	Station 4	131.8	Score 1

* Criteria according Yulianda (2007)(Table 1)

Mangrove type. The species of mangroves were *Avicenia alba, Rhizopora mucronata, Bruguiera gymnorrhiza, and Xylocarpus granatum* (Table 5). Four species were found at Station 1 and Station 2, and three were found at Station 3 and Station 4. Previous research found four types of mangroves, namely *Rhizophora apiculata, Rhizophora*

stylosa, Avicennia alba, and *Avicennia lanata* (Marasabessy et al., 2021). The discrepancy in species found were due to differences in area of observation stations and the number of transects and plots used. According to the tourism suitability parameters in Table 1, the suitability index of mangrove tourism for the category of mangrove species has the score of 2, as 3-5 mangrove species were found (Yulianda, 2007). To determine the suitability of mangrove ecotourism, the value of each category is entered in the table of parameter analysis of the suitability of mangrove tourism (Table 8).

Table 5

Types of Mangroves

Station	*Species*	*Criteria**
1	*Avicennia alba* *Rhizophora mucronate a* *Bruguiera gymnorrhiza* *Xylocarpus granatum*	
Total no of mangrove types	4	Score 2
2	*Avicennia alba* *Rhizophora mucronate a* *Bruguiera gymnorrhiza* *Xylocarpus granatum*	
Total no of mangrove types	4	Score 2
3	*Rhizophora mucronate* *Bruguiera gymnorrhiza* *Xylocarpus granatum*	
Total no of mangrove types	3	Score 2
4	*Rhizophora mucronate* *Bruguiera gymnorrhiza* *Xylocarpus granatum*	
Total no of mangrove types	3	Score 2

* Criteria according Yulianda (2007)(Table 1)

Sea tides. Tidal data was taken based on secondary data from the Hydrographic and Oceanographic Center, Indonesian Navy for March 2021. Based on the calculation of the Formzahl number for March 2021, which was 0.89. Tidal Harmonic Analysis was conducted using the Admiralty method. The value of the amplitude and phase of the main tidal components were M2, S2, K1, 01, MS4, M4, K2, and P1 from the measurement results for 29 days of observation, as shown in Table 6.

Table 6

Value the amplitude and phase of the main tidal components M2, S2, K1, 01, MS4, M4, K2 and P1 from the measurement results for 29 days of observation

	So	*M2*	*S2*	*N2*	*K2*	*K1*	*O1*	*P1*	*M4*	*MS4*
A cm	396.6	17.0	33.7	8.4	7.8	21.4	23.6	7.0	7.0	3.9
G		304.4	185.4	34.9	185.4	202.2	208.7	202.2	276.3	173.3

Legend:
A: Amplitude; g (0): Deceleration phase; So: Average sea level (Mean Sea levels); M2: Harmonic constant by month; S2: Harmonic constant by sun; N2: Harmonic constant by Moon Distance change; K2: Harmonic constant by Sun Distance change; O1: Harmonic constant by Moon declination; P1: Harmonic constant by declination of the sun; K1: Harmonic constant by declination of the Moon and Sun; MS4: Constants of interaction harmonics between M2 and S2; M4: Double harmonic constant M2.

Therefore, it can be seen that the tidal type in Sorong waters is a mix tide prevailing semidiurnal. Mixed type double slope is a tide that occurs twice a day and two low tides and the shape of the first tidal wave is not the same as the second tide (asymmetrical) with a semi-diurnal inclined shape (Fadilah, 2014). The mix tide prevailing semidiurnal is found on the southern coast of Java and eastern Indonesia (Wyrtki, 1961). Forecast tidal charts can be seen in Figure 2. The Mean Sea Level (MSL) 3.9 m, the Highest High Water Level (HHWL) 5.3 m, and the Lowest Low Water Level (LLWL) 2.7 m (Figure 2). According to the tourism suitability parameters in Table 1, the suitability of mangrove tourism for the tidal category has a score of 2, which is more than 2 m. To find out the suitability of mangrove ecotourism, the value of each category is entered in the table of parameter analysis of the suitability of mangrove tourism (Table 8).

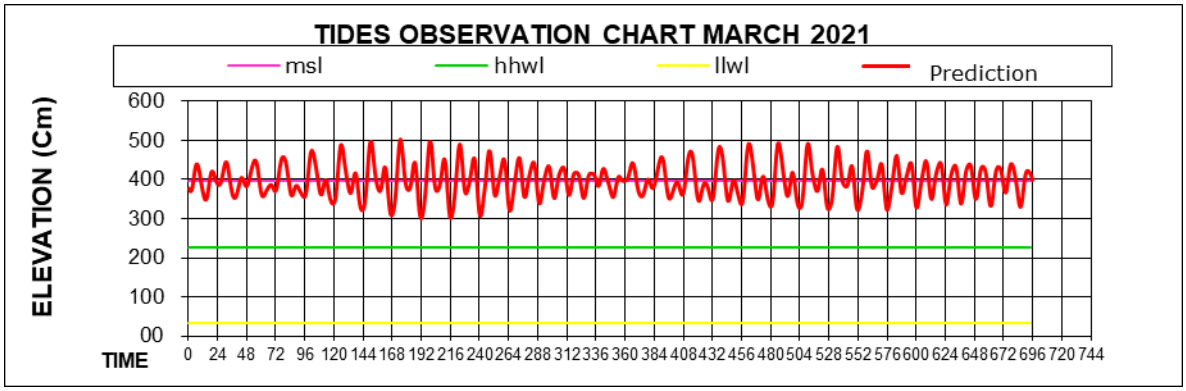

Figure 2. Tides Observation Chart
(Source : authors' elaboration)

Biota object. Table 7 shows biota objects found at the stations. Mollusks, Fish, Crustaceans, birds, and mammals were found. The mollusks found included *Ellobium aurimisdae*, *Neritina violacea, Telescopium telescopium, Cymatium pileare, Terebralia sulcate, and Polymesoda expansa.* The fish found included chopstick fish (*Toxotes sp.)* and glodok fish (*Peroipthalmus sp).* The crustaceans found were mangrove crabs (*Scylla* sp.) and rebon shrimp (*Acetes* sp.*).* Bats (*Macroglossus minimus)*, were also found, along with lizards and birds.

Table 7

Associated Biota

No.	*Mangrove Biota*	*Family*	*Species*	*Discovery of each Station*			
				Station 1	*Station 2*	*Station 3*	*Station 4*
1.	Mollusk	Ellobidae	*Ellobium aurimisdae*	V	V	-	V
2.		Neritidae	*Neritina violacea*	V	V	-	-
3.		Potamididae	*Telescopium telescopium*	V	V	V	V
4.		Rannelidae	*Cymatium pileare*	V	V	-	-
5.		Potamididae	*Terebralia sulcate*	V	-	-	-
6.		Cyrenidae	*Polymesoda expansion*	V	-	V	V
7.	Fish	Toxotidae	*Toxotes sp.*	V	V	-	-
8.		Gobiidae	*Peroipthalmus sp*	V	-	-	-
8.	Crustaceans	Arthropods	*Scylla sp.*	V	V	-	-
			Acetes sp.	V	V	-	-
10 .	Mammals (Bats)	Pteropodidae	*Macroglossus minimus*	V	-	-	-
11 .	Bird	Passeridae	*Passer montanus*	V	V	V	V
1 2 .	Reptile	Scincidae	Emoia atrocostata	V	V	V	V
Score				**3**	**2**	**2**	**2**

The picture of the associated biota in the mangrove ecosystem can be seen in Figure 3. The object of mangrove ecosystem biota can be observed directly and can satisfy visitors and add value for the mangrove ecotourism area (Nelly et al., 2020). To determine the suitability of mangrove ecotourism, the value of each category is entered in the table of parameter analysis of the suitability of mangrove tourism (Table 8).

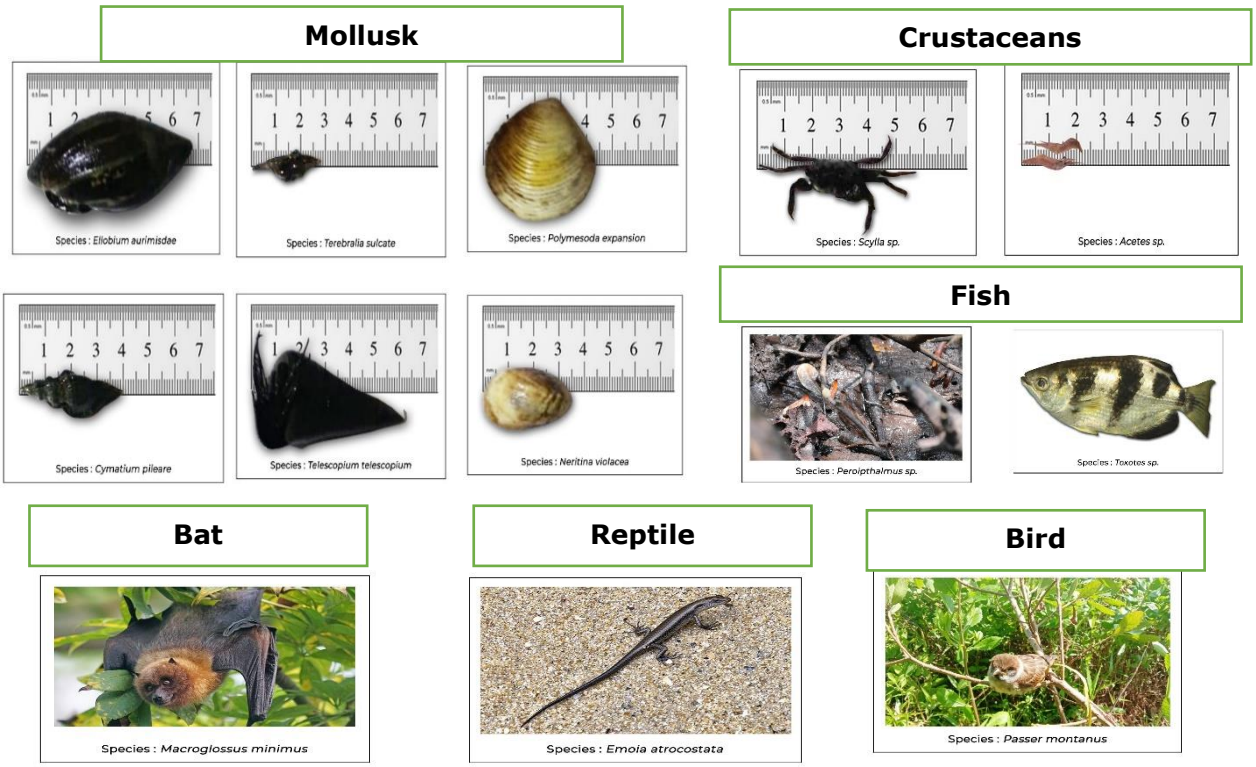

Figure 3. The associated biota in the mangrove ecosystem
(Source: Mollusk, Crustacean, Glodok Fish, Bird based on personal documentation), bat based on Pixel-mixer/Pixabay, reptile based on https://www.ecologyasia.com/verts/lizards/mangrove_skink.htm, Toxotes Sp based on https://en.wiktionary.org/wiki/Toxotes)

Analysis of the suitability of mangrove tourism. Values for all parameters of each station are then entered in the table for analysis of the area for the suitability of mangrove tourism (Table 8). This study revealed that the suitability index of mangrove tourism on Jelfio Island are as follows: 64 % at Station 1, 62 % at station 2, 74% at station 3 and 62 % at station 4. All of the stations are categorized as "Appropriate" for mangrove tourism. Determination of the area for a tourist attraction should be based on an assessment of certain parameters to ensure that the area is worthy of becoming a sustainable tourist attraction (Mas'ud, 2020).

Table 8

Analysis of Parameters Mangrove Tourism Suitability

No.	*Parameter*	*Weight*	*Category (Station 1)*	*Score*	*Category (Station 2)*	*Score*	*Category (Staion 3)*	*Score*	*Category (Station 4)*	*Score*
1.	Mangrove Thickness (m)	5	50-200	1	50-200	1	>200-500	2	50-200	1
2.	Mangrove Density (100 m2)	3	> 10-15	3	> 10-15	3	> 10-15	3	> 10-15	3
3.	Mangrove type	3	3 - 5	2	3 – 5	2	3 – 5	2	3 - 5	2
4.	Tides (m)	1	> 1-2	2	> 1-2	2	> 1-2	2	> 1-2	2
5.	Biota object	1	fish, shrimp, crab, mollusk, birds, bat	3	fish, mollusks, shrimps, reptile, birds	2	fish, mollusks, reptile, bird	2	fish, mollusks, reptile, birds	2
Total Score				25		24		29		24
Tourism Suitability Index (IKW) of Mangrove Tourism				64 %		62 %		74 %		62 %

Carrying capacity. The carrying capacity of a tourist area is an analysis used to determine the number of visitors that can be accommodated in a tourist area. The Jeflio mangrove tourism area has a tracking length in the ecotourism area of 648.5 m based on calculations using the polyline Arcgi. The DDK mangrove tour is 52 visitors / day (Table 9). Based on this data, it was calculated that the Jeflio mangrove tourism could accommodate 52 visitors/day with an operational time of 8 working hours per day. This amount is used as a reference in limiting the number of visitors. This is done to reduce the negative impact of ecotourism areas (Sukuryadi et al., 2020).

Table 9

Carrying Capacity of the Jeflio Mangrove Tourism Area

Regional Carrying Capacity Parameters	*Data obtained*	*Carrying Capacity*
Ecological potential of visitors per unit area (person)	1	52 people/day
The area (m) that can be tracking mangrove (Tracking mangrove is the path is in the form of a wooden platform located in the middle of a mangrove forest)	648.5 m	
Area unit for a certain category (m^2 or m)	50 m	
Time allotted for activities in one day (hours)	8 hours	
Time spent by visitors on each activity (hours)	2 hours	

Conclusion. Analysis of the suitability of the area for mangrove tourism at station 1 was 64 %, station 2 was 62 %, station 3 was 74% and station 4 was 62 %, which showed that all stations were within the appropriate criteria. Based on the research, stations 1, 2, 3, and 4 are within the "Appropriate" criteria for mangrove tourism. The carrying capacity of the Mangrove Tourism Area is also 52 visitors/day. Based on this data, Jeflio mangrove tourism can accommodate 52 visitors/day with an operational time of 8 working hours/day.

Conflict of Interest. The authors declare that there is no conflict of interest.

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