Ecological review of mangroves in coastal ecotourism areas: A case study of mangroves in Lubuk Kertang, Langkat Regency, Indonesia

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Abstract. This study was conducted to obtain data related to the condition of mangrove ecosystems in the Lubuk Kertang ecotourism site on the coast of Langkat Regency, Indonesia. Data were collected directly using the quadrat transect method from July to September 2023. There were 2 observation locations in this study. Transects were made measuring 10x10 m^2 with a distance of 20 m between each transect. There were 9 identified species (*Rhizophora stylosa*, *Rhizophora apiculata*, *Nypa fruticans*, *Avicennia* sp., *Sonneratia caseolaris*, *Xylocarpus granatum*, *Ceriops tagal*, *Bruguiera sexangula*, and *Excoecaria agallocha*), belonging to 6 families (Rhizophoraceae, Lythraceae, Meliaceae, Euphorbiaceae, Arecaceae, and Acanthaceae). The diversity index value between 3.58-3.86 is classified as moderate. The highest density and relative density was observed for *R. stylosa*, with 1070 ind ha^{-1} (33.67%). The highest frequency value of mangrove species was 1 for *R. stylosa, R. apiculata* and *N. fruticans*, while the highest relative frequency value was 20.83%. Dominance value is close to 0, and the highest Important Value Index was found for *R. stylosa*, with a value of 76.47, followed by *R. apiculata* with a value of 50.26, and *N. fruticans*, with 43.32. The results of measuring water parameters show that the water quality at the research site is good for marine life and suitable for ecotourism activities. It can be concluded that the condition of the mangrove ecosystem in the Lubuk Kertang ecotourism site on the coast of Langkat Regency is good with a moderate level of diversity.

Key Words: importance value index, species richness, species density.

Introduction. Mangrove forests are among the most biologically productive and complex ecosystems in the world, with higher standing biomass than any other forest type (Alongi 2008). Ecologically, mangrove ecosystems can ensure the maintenance of the physical environment, such as retaining waves, wind and are the habitat of various wildlife such as monkeys, snakes, monitor lizards, birds, fish, mangrove crabs, *Uca* sp. crabs, and shellfish (Bunting et al 2018). In addition, the mangrove ecosystem has multiple functions, namely as nursery grounds, spawning, and foraging areas, and also act as tourist spots. Like other forest ecosystems, mangroves also function as CO_2 sinks and absorbers of emission substances (Alongi 2008; Spalding et al 2010).

According to Spalding et al (2010), the total area of the world's mangrove forests is approximately 137800 km² or 13780000 ha. Meanwhile, the area of mangrove forests in Indonesia reaches about 3490000 ha, making it one of the countries with the largest mangrove forests in the world (Hamzah et al 2023). North Sumatra is one of the provinces in Indonesia that has mangrove forests with an area of 65000 ha (Ndruru & Delita 2021). Giri et al (2011) revealed that about 3.6 million ha of mangrove forests have been lost over the past two decades. Alongi (2014) further explained that about 35% of global mangrove forests have been lost since the 1980’s with deforestation rates increasing especially in Southeast Asia and South America. Factors such as expansion of the fishing industry, infrastructure development, and urbanization are the main causes. Alongi (2008) explains that this destruction will have a significant impact on the stability of coastal ecosystems, the livelihoods and economies of local communities. Therefore, efforts are needed to preserve it. One form of mangrove forest preservation is to settle the area as an ecotourism location.

According to Sukardjo & Alongi (2012), mangrove ecotourism can be one of the solutions to protect and preserve mangrove forests, as well as improve the welfare of local communities. However, a recent study showed that the uncontrolled growth of mangrove ecotourism can result in environmental damage such as trampling of mangrove vegetation and increased waste (Smith et al 2020). One of the mangrove ecotourism locations in North Sumatra is in Lubuk Kertang village. The results of Hafni (2016) show that the mangrove forests in Lubuk Kertang Village, West Brandan District, have an area of 740 ha (61.67%) of mangrove forest damaged from the total of 1200 ha. The Covid-19 pandemic also had a damaging impact on mangrove forests in North Sumatra. This is due to the rampant illegal logging that occurred during the Covid-19 pandemic in Indonesia. However, in 2021, through the mangrove rehabilitation program by the government of the Republic of Indonesia, mangrove forest rehabilitation has been carried out in various regions in North Sumatra. Therefore, it is necessary to know the condition of mangrove forests in the Lubuk Kertang ecotourism area after the rehabilitation program is carried out.

Material and Method. The method used in this study was the quadrat transect method. Mangrove data were collected by counting the number and species of mangroves in each sample plot measuring 10x10 m^2 with a distance of 20 m between transects (Figure 1). Data were collected in July 2023 in the Lubuk Kertang mangrove agro eco-tourism area, Langkat Regency, North Sumatra Province (Figure 2). After installing the transect/plot, the leaves, fruits, and roots of mangroves were collected for each mangrove species to obtain mangrove species composition. Mangrove species were identified using the mangrove recognition guidebook (Noor et al 2006).

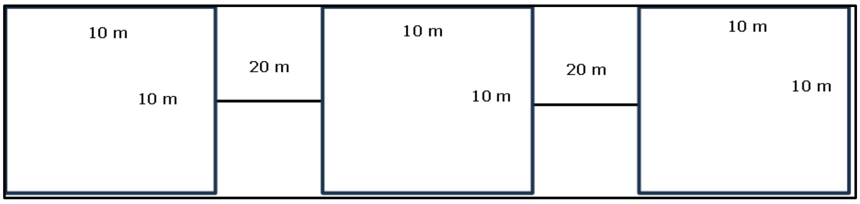

Figure 1. Illustration of the mangrove observation plot.

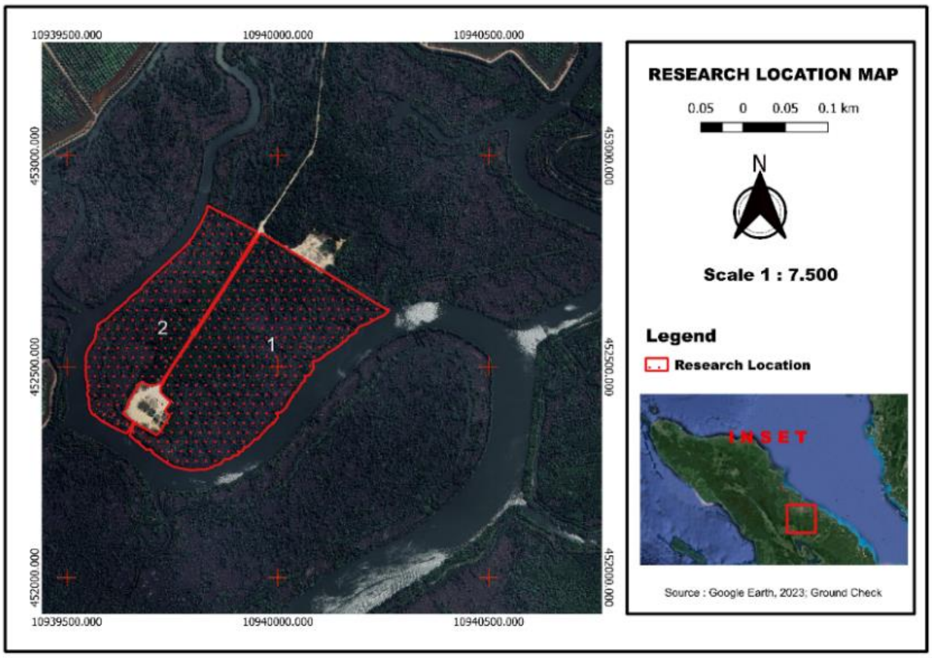

Figure 2. Research location.

Water quality in the mangrove areas was determined by collecting water samples. Several environmental parameters were measured at the research site, including salinity using a refractometer, pH with a pH meter, temperature using a thermometer, dissolved oxygen (DO) with a DO meter, light penetration with a Secchi disk. Some chemical parameters were also determined in the laboratory: biological oxygen demand (BOD), chemical oxygen demand (COD), nitrate, nitrite, ammonia, iron and mercury. The results of the measurements were compared with the quality standards of seawater based on the Decree of the Minister of Environment of the Republic of Indonesia Number 51 of 2004 (KepMen LH No. 51 2004).

The diversity index was determined using the Shannon-Wiener formula (Odum 1993):

$$H' = (\Sigma \frac{ni}{N} \text{ Ln } \frac{ni}{N})$$

Where: H' - species diversity index; ni - number of individuals of each species; N - total number of individuals of all species; Ln - natural logarithm.

The Shannon-Wiener diversity index is used to determine the level of biodiversity in a given area. The value of the index ranges from 0 to infinity, with higher values indicating greater biodiversity. The criteria for interpreting the value of the index are as follows: $H'<1$ - low diversity; $1<H'<3$ - moderate diversity; $H'>3$ - high diversity (Barbour et al 1987).

Mangrove condition data was analyzed based on the design of observation plots in the field. The density, frequency, and dominance were calculated and the Important Value Index and Diversity Index were determined (Table 1) (Odum 1993; English et al 1994). Frequency is a parameter used to express the proportion between the number of samples contained in a particular species to the total number of samples. Relative frequency is the percentage ratio between the frequency of a vegetation type and the frequency of all vegetation types in the area (Kahir et al 2022).

Table 1

Determined indices (English et al 1994)

Data analysis	*Formula*
Species density (D_i)	N_i/A
Relative density (RD_i)	$N_i/\Sigma n*100\%$
Species frequency (F_i)	$P_i/\Sigma p$
Relative frequency (RF_i)	$F_i/\Sigma f*100\%$
Species cover (C_i)	$\Sigma BA/A$
Relative cover (RC_i)	$C_i/\Sigma C*100\%$
Importance Value Index (IVI)	$RD_i+RF_i+RC_i$

Note: D_i - density of the i-th species; N_i - total number of individuals of the i-th species; A - total sampling area; RD_i - relative density; Σn - total number of individuals; F_i - frequency of the i-th species; P_i - number of sampling plots created; Σp - total number of sampling plots created; RF_i - relative frequency; Σf - total frequency of all species; C_i - area of cover of the i-th species; BA - basal area of a species; RC_i - relative species cover; ΣC - total area of cover of all species; IVI - importance value index.

Results and Discussion

Mangrove diversity. The mangrove community at the Lubuk Kertang mangrove agro-tourism site consists of 6 families and 9 species (Table 2). Mangrove species identified include *Rhizophora stylosa*, *Rhizophora apiculata*, *Nypa fruticans*, *Avicennia* sp., *Sonneratia caseolaris*, *Xylocarpus granatum*, *Ceriops tagal*, *Bruguiera sexangula*, *Excoecaria agallocha*.

The diversity index was 3.86 in the first location and 3.58 in the second location, placing them in a moderate category. This is thought to be due to the sporadic cutting of mangroves by the community to be used as fuel, so that some species of mangroves can no longer be found at the Lubuk Kertang ecotourism site. The level of diversity can be an indication of the stability of an environment (Kartika et al 2018). A community is classified as having a low level of species diversity, if the community consists of few species, with one species dominating (Pratama & Sari 2022). Low diversity indicates that the ecosystem is under pressure and its condition is degrading (Lukman et al 2023).

Table 2

Families and species of mangroves in the Lubuk Kertang Agroekowisata area

	Name	*Location 1*	*Location 2*
Rhizophoraceae			
	Rhizophora stylosa	+	+
	Rhizophora apiculata	+	+
	Ceriops tagal	+	+
	Bruguiera sexangula	+	+
Lythraceae			
	Sonneratia caseolaris	+	-
Meliaceae			
	Xylocarpus granatum	-	+
Euphorbiaceae			
	Excoecaria agallocha	+	+
Arecaceae			
	Nypa fruticans	+	-
Acanthaceae			
	Avicennia sp.	+	+

Note: (+) - found; (-) - not found.

Species density and relative density. *R. stylosa* had the highest density, with 798 ind ha^{-1}. *R. apiculata* had 431 ind ha^{-1}, *N. fruticans* had 319 ind ha^{-1}, *Avicennia* sp. had 290 ind ha^{-1}, *S. caseolaris* had 250 ind ha^{-1}, *X. granatum* had 170 ind ha^{-1}, *C. tagal* had 130 ind ha^{-1}, *E. agallocha* had 130 ind ha^{-1}, and *B. sexangula* had 110 ind ha^{-1}. According to Akbar et al (2016), the high density value indicates that the regeneration level of mangrove species is good and they can survive in these environmental conditions. The high density of *R. stylosa* occurs because it has a wide distribution and can live in various habitat conditions. According to Tomlinson (1986), *R. stylosa* grows in diverse habitats in tidal areas, such as mud, sand, and rock, but is also a pioneer species in coastal environments or inland parts of mangroves. *Rhizophora* is known to prefer muddy and soft substrates and has a very wide distribution (Hariphin et al 2016; Malahayati et al 2023). Furthermore, Gazali et al (2019) explained that the high density of *Rhizophora* species is also because this species produces flowers and fruits throughout the year. The ability to produce flowers and fruit is very closely related to the condition of sunlight intensity. The highest relative density was observed for the species *R. stylosa* (33.67%) and *R. apiculata* (16.68%) (Figure 3). *Rhizophora* sp. has diverse areas in which it can live and develop, as long as it has a good supply of salt water (Parmadi et al 2016), unlike *S. caseolaris*, which requires a sheltered area to grow and develop well (Sahami 2018).

Frequency and relative frequency. The highest frequency value was observed for *R. stylosa, R. apiculata,* and *N. fruticans*, with a value of 1 for each, while the highest relative frequency value was 20.83% for *R. stylosa*, *R. apiculata*, and *N. fruticans* (Figure 4). The high value of frequency and relative frequency in *Rhizophora* species is due to its good reproductive ability. Bengen (2002) explains that the life cycle of *Rhizophora* sp. has a peculiarity with seeds that can germinate while still in the parent plant. This greatly supports the process of wide distribution in the mangrove ecosystem area. Furthermore, Warpur (2018) explains that relative frequency is influenced by the level of presence of a species in one research location.

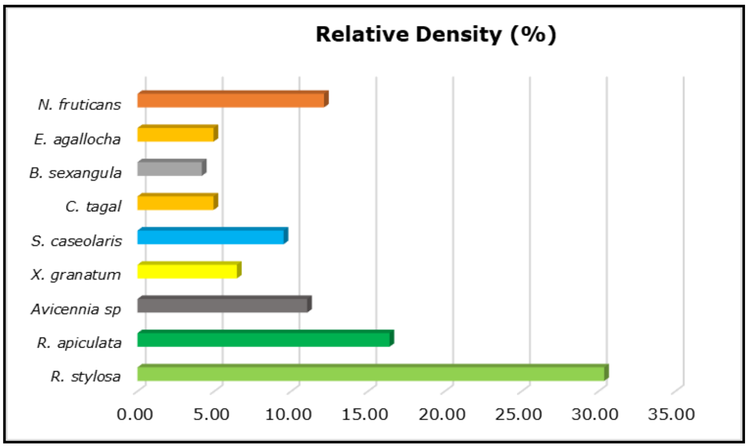

Figure 3. Mangrove relative density in Lubuk Kertang Argoecotourism area.

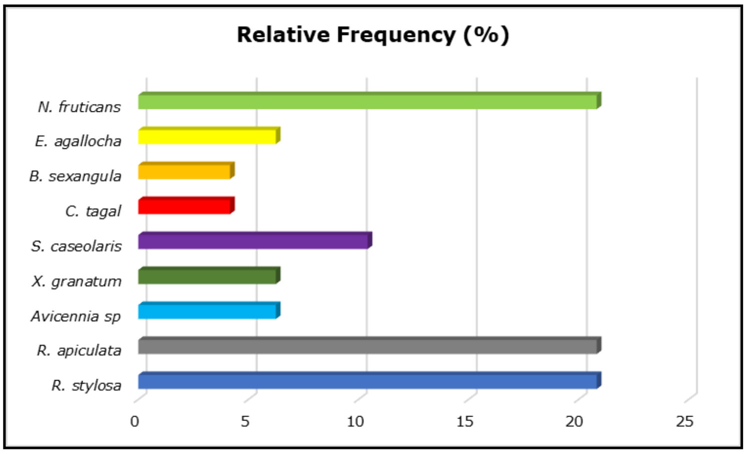

Figure 4. Mangrove relative frequency curve in Lubuk Kertang Argoecotourism area.

Dominance and relative dominance. The dominance value during the study ranged from 0.0000023-0.0000121. The highest dominance index value was found in *C. tagal*, with 0.0000121, and the lowest was found for *E. agallocha*, 0.0000023 (Figure 5). The dominance index value close to 0 indicates that there are no dominant species (Destiana et al 2022). In general, the dominance value of all observations was low, meaning that there are no dominant mangrove species. Species in mangrove communities tend to be uniform when ecological conditions are stable (Sipahelut et al 2020).

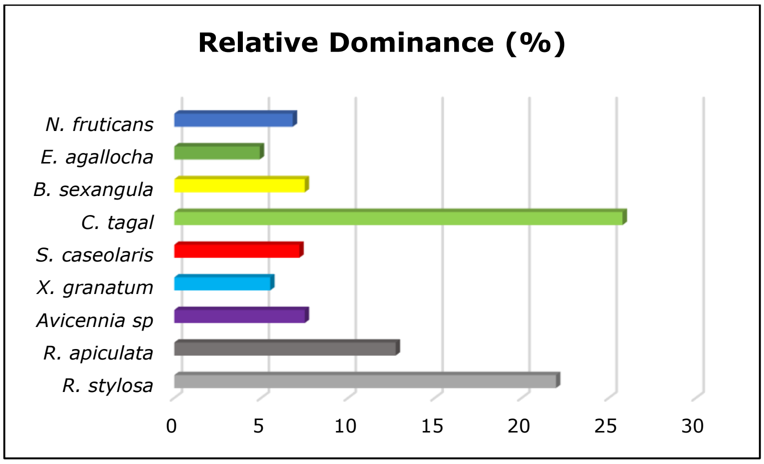

Figure 5. Relative dominance curve of mangroves in Lubuk Kertang Argoecotourism area.

Importance value index (IVI). The highest IVI was found for *R. stylosa*, with a value of 76.47, followed by *R. apiculata*, with a value of 50.26, and *N. fruticans*, with 43.32 (Table 3). The high IVI of *Rhizophora* in this research is inseparable from the carrying capacity of the environment at the research site, where the type of substrate is sandy and muddy.

Table 3

Importance Value Index in the mangrove Agro-ecotourism Lubuk Kertang area

Species	*D_i*	*RD_i (%)*	*F_i*	*RF_i (%)*	*C_i*	*RC_i (%)*	*IVI*
R. stylosa	798	30.37	1	20.83	0.0000103	21.97	73.17
R. apiculata	431	16.40	1	20.83	0.0000060	12.75	49.99
Avicennia sp	290	11.04	0.3	6.25	0.0000035	7.51	24.80
X. granatum	170	6.47	0.3	6.25	0.0000026	5.52	18.24
S. caseolaris	250	9.51	0.5	10.42	0.0000034	7.20	27.13
C. tagal	130	4.95	0.2	4.17	0.0000121	25.79	34.90
B. sexangula	110	4.19	0.2	4.17	0.0000035	7.51	15.87
E. agallocha	130	4.95	0.3	6.25	0.0000023	4.92	16.12
N. fruticans	319	12.14	1	20.83	0.0000032	6.82	39.79
	2628	100.00		100.00	0.0000467	100.00	300.00

Note: D_i - density of the i-th species; RD_i - relative density; F_i - frequency of the i-th species; RF_i - relative frequency; C_i - area of cover of the i-th species; RC_i - relative cover; IVI - importance value index.

Water quality in the mangrove area. The measurement results of water quality parameters can be seen in Table 4.

Table 4

Value of water quality parameters in the mangrove area

Parameter	*Unit*	*Standard*		*Result*	*Category*
		*	**		
pH	-	7 s/d 8.5	7 s/d 8.5	7.2	Suitable
Temperature	^oC	Natural	28-32	30	Suitable
Salinity	ppt	Natural	s/d 34	25	Suitable
Dissolved oxygen (DO)	mg L^{-1}	>5	>5	5.9	Suitable
Light penetration	cm	<600	-	15	Suitable
Biological oxygen demand (BOD)	mg L^{-1}	10	20	2.5	Suitable
Chemical oxygen demand (COD)	mg L^{-1}	-	-	8.2	Suitable
Ammonia	mg L^{-1}	-	0.03	<0.013	Suitable
Nitrate	mg L^{-1}	0.008	0.008	<0.4	Suitable
Nitrite	mg L^{-1}	-	-	0.83	Suitable
Iron (Fe)	mg L^{-1}	-	-	0.000642	Suitable
Mercury (Hg)	mg L^{-1}	0.002	0.001	0.000035	Suitable

Note: * - seawater quality standard for marine tourism based on KepmenLH No 51 of 2004; ** - seawater quality standard for aquatic biota based on KepmenLH No 51 of 2004.

The water quality in the Lubuk Kertang mangrove ecotourism area is suitable for ecotourism activities and marine biota. In the mangrove forest site of the King's Royally Initiated Laem Phak Bia Environmental Research and Development Project in Thailand, it was found that the water quality met the effluent standards for coastal aquaculture, with the mangrove forest improving water quality by increasing dissolved oxygen and reducing phosphate, ammonia, and nitrate levels (Jitthaisong et al 2012). In Prafi River in Manokwari, West Papua, the water quality was categorized as excellent to acceptable based on Prati's index, and the macro-zoobenthos diversity index indicated that the water was not polluted (Sinuraya et al 2018). Additionally, a study in Pante Deere Village, Alor

Regency, East Nusa Tenggara, found that the majority of respondents strongly agreed on the benefits of mangrove tourism and the need for improvement in the quality of mangrove tourism assets (Singgalen & Manongga 2022). These studies highlight the importance of monitoring and maintaining water quality in mangrove ecotourism areas to ensure their sustainability and the well-being of the surrounding ecosystems.

Conclusions. The condition of the mangrove ecosystem in the Lubuk Kertang Mangrove ecotourism area, Langkat Regency, Indonesia is very good, with a dominance value close to 0 and H'>3, as well as IVI values that exceed 40% for *R. stylosa, R. apiculata*, and *N. fruticans*. Water quality conditions in this area are suitable for marine life and marine tourism activities.

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

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