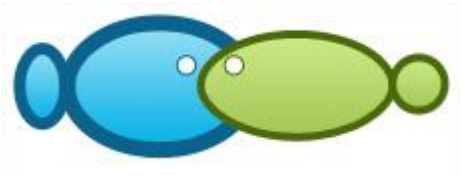

The ecological potential of mangroves in the development of coastal eco-tourism areas: A case study of mangroves in North Buton District, Indonesia

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Abstract. Mangrove provides ecological value as a habitat for a variety of marine and land animals. Therefore, this study aimed to analyze the ecological potential of mangroves in the development of coastal eco-tourism areas in North Buton Regency, Indonesia. Data used for ecological analysis included mangrove species, associated biota, and density. There were five species of mangrove identified: *Xylocarpus granatum, Rhizophora apiculata, Rhizophora mucronata, Sonneratia alba,* and *Bruguiera gymnorrhiza.* The associated biota included species of fish, crabs, shrimp, clams, snails, oysters, insects, birds, snakes, and bats. The density values obtained were high. Based on the results, the mangrove area of North Buton Regency is in a high-density category with a variety of associated biota and suitable for developing coastal eco-tourism.
Key Words: crab, density, estuary, mangrove species, rhyzophora.

Introduction. A mangrove forest has several essential physical, ecological, and socio-economic functions (Yusuf 2017). Ecologically, it provides a habitat to live, take shelter, find food, or to breed for marine and land animals. In addition, mangrove forests can function as shoreline stabilizers to prevent erosion caused by waves, they can add coastal land, and protection of coasts and land areas. Mangrove contributes to various environmental services, including trapping and recycling organic matter, providing shelter or surfaces for terrestrial and aquatic organisms, and contributing to the overall health of the coastal environment. It also prevents seawater intrusion into the land (Rangkuti et al 2017).

However, mangrove ecosystems across developing countries face various problems that can potentially lead to extinction (Bengen 2022; DasGupta & Shaw 2013; Akbar et al 2017). Sumar (2021) observed that disruption to activities in the mangrove area and a reduced population would cause natural disasters such as coastal erosion. This is because the loss of mangroves is the initial stage of decreasing biodiversity, both in quality and quantity, significantly affecting the coastal economy. This leads to a reduction in the vast ecological niches for foraging, breeding, and hatching of fish and other animals. The decline also impacts the coastal economy, considering many coastal residents depend on marine resources and fishing (Giesen et al 2006; Greasley 2008; Eddy et al 2015).

Mangrove has great potential for sustainable tourism development. One of the areas in Southeast Sulawesi Province, Indonesia, with a mangrove forest ecosystem, is North Buton Regency. This coastal natural resource has social, economic, and ecological

roles and functions primarily as a counterweight in the ecosystem. Moreover, it provides various needs for humans and other living beings. Studies on mangrove forests as a tourist area have been conducted by Muhaerin (2008), who examined resources for eco-tourism management in the Perancak Jembrana estuary, Bali. According to Riana et al (2020), the mangrove tourism of Janggalu West Gading Cempaka Circle in Bengkulu City is good and has the potential to boost the economy, specifically in the extended coastal areas. Furthermore, Rijal et al (2020) also examined the potential of a mangrove forest as a tourist attraction in South Sulawesi.

Globally, tourism is essential to enhance and support environmental preservation, including mangrove ecosystems in the tropics. The development of nature tourism is considered necessary (Rijal et al 2020) and relevant to the Indonesian government's development policies. North Buton Regency has abundant mangrove resources with a high density and various biota. Therefore, this study aims to analyze the ecological potential of mangroves in the development of coastal eco-tourism areas in North Buton Regency.

Material and Method. This study was conducted between February and April 2020 in three stations in Kulisusu District, North Buton Regency, Southeast Sulawesi, Indonesia (Figure 1). Ecological data collection was performed by several observation and measurement procedures in the field. The identification of the mangrove species at the study site using an identification book to monitor the structure of Indonesian mangrove communities (Dharmawan et al 2020). We also estimated mangrove density and counted the number of mangrove species for the category of woody trees with a diameter of ≥4 cm. This method was carried out on all trees at each observation point with an area of 10x10 m. This determination was carried out 3 times in each of the 3 stations. At each station, observations have been made, including identifying mangrove species, determining the size of the mangrove forest area, and the density of organisms associated with mangroves. To obtain sufficient data, visits were carried out 3 times per month. Station 1 was selected to be the area near the tourism location and close to the river mouth. Station 2 was in the coastal area, near the mangrove tracking. Station 3 was close to residential areas. The mangrove area was determined using GPS.

Species density represents the number of individual mangrove species in a unit area (Yulianda 2007; Onrizal 2008). Mangrove density was determined using the tree spacing of each species as a ratio of the number of individuals of a species in the 10x10 m observation points.

The water quality in the mangrove area at each station was determined by collecting water samples. Water samples were collected at all stations with the same sampling technique. Each station was sampled at 3 different points, in the middle and on the left and right sides, at a distance of 10 m. Several environmental parameters were measured at the research location, including salinity using a refractometer, pH with a pH meter, temperature using a thermometer, total dissolved solids (TDS) using a TDS meter, and dissolved oxygen (DO) with a DO meter. Pearson's correlation coefficient was determined to identify the correlation between mangrove species and the presence of organisms associated with mangroves.

Substrate sampling was carried out directly, especially in growing mangroves. In this area, 100 g of sediment was collected for analysis.

The density of mangrove species. Species density was determined in the studied sites. Species density is the number of species individuals in a unit area (Bengen 2022. The density of mangrove vegetation shows the ability of a species to grow and reproduce in a particular location. The tree trunk diameter was also determined. Woody plants with a diameter of more than 4 cm entered the tree category (Bahar 2015).

Diversity index. The Shannon-Wiener diversity index is used to determine species diversity at each growth level (Odum 1993). The uniformity index was also determined. The range values are as follows: $0.01<C\leq0.3$ - low dominance; $0.31<C\leq0.6$ - medium dominance; $0.61<C\leq1$ - high dominance.

Species diversity was determined using the Shannon-Wienner Diversity Index (Odum 1993), with the following formula:

$H' = -S\ Pi\ ln\ (Pi)$

Where: Pi = (ni/N); H' = Shannon-Wienner Diversity Index; Ni = number of individuals of species i; N = number of individuals of all species. The criteria for the value of the Shannon-Wiener Diversity Index (H') are as follows: H'<1, low diversity; 1<H'<3, medium diversity; H'>1, high diversity.

The uniformity index was also determined based on the Shannon-Wiener Diveristy Index, as follows:

$E = H'/Hmax = H'/lnS$

Where: E - Uniformity Index; H' - Diversity Index; S - number of species.

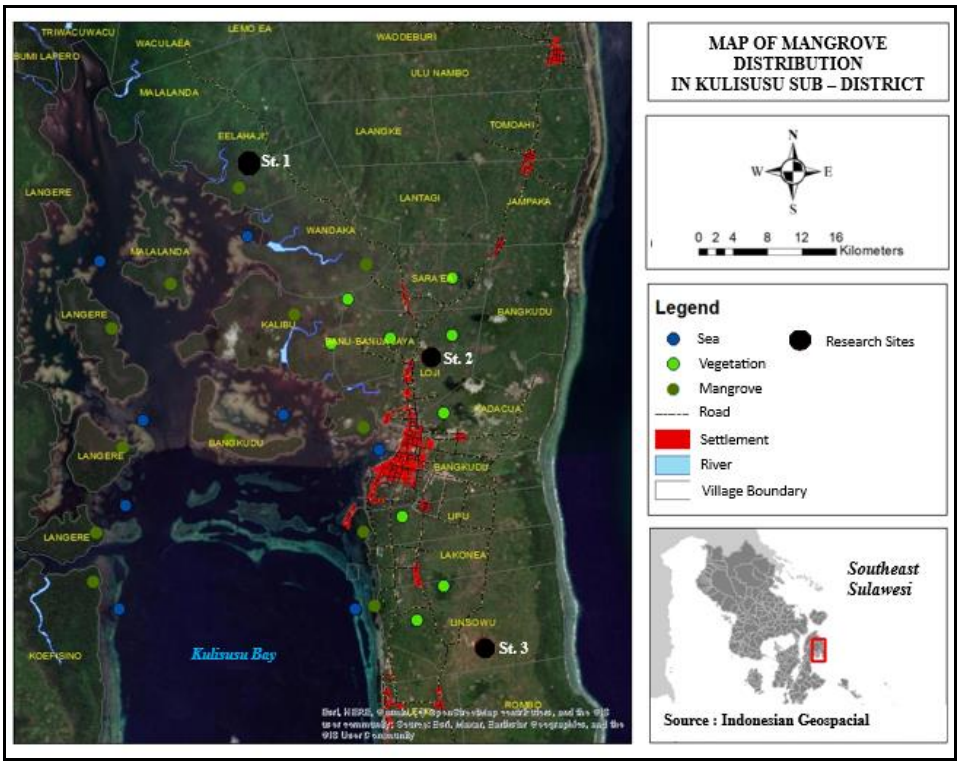

Figure 1. Study locations in Kulisusu Bay.

Statistical analysis. The values of determined parameters were analyzed with the Pearson correlation coefficient. The strength of the correlation is the following (Sarwono 2006): when the correlation coefficient is 0 there is no correlation; when it is under 0.25, there is a very weak correlation; when it is between 0.25 and 0.5, there is a medium correlation; when it is between 0.5 and 0.75, there is a strong correlation; between 0.75 and 0.99 there is a very strong correlation; the 1 value for the correlation coefficient shows a perfect correlation.

Results

Species of mangroves. The identified mangrove species in the three stations are presented in Table 1.

Mangrove area. The mangrove area obtained in the three stations is presented in Table 2.

Table 1

Species of mangroves in Kulisusu District, North Buton Regency, Indonesia

No	*Station*	*Mangrove species*	*Number of mangrove species*	*Percentage (%)*
1	I	*Xylocarpus granatum, Rhizophora apiculata, Rhizophora mucronata*	3	30
2	II	*Rhizophora apiculata, Xylocarpus granatum, Sonneratia alba*	3	30
3	III	*Rhizophora apiculata, Xylocarpus granatum, Sonneratia alba, Bruguiera gymnorrhiza*	4	40
	Total		10	100

Table 2

Mangrove area determined in the three stations from Kulisusu District, North Buton Regency, Indonesia

No	*Station*	*Area (ha)*	*Percentage (%)*
1	I	960.21	80.5
2	II	218.10	18.28
3	III	14.62	1.22
	Total	1192.93	100

Mangrove density. The mangroves at the research location are in relatively good condition with density according to Kepmen LH No. 201 of 2004. The density values obtained in the mangrove forest area are presented in Table 3.

Table 3

Density of mangrove in Kulisusu District, North Buton Regency, Indonesia

No	*Station*	*Density of mangrove (ind ha^{-1})*	*Category (Kepmen LH No. 201 of 2004)*
1	I	4533	Congested
2	II	2550	Congested
3	III	2533	Congested

Mangrove tree diversity and uniformity index. The number of mangrove individuals and diversity and uniformity indices are presented in Table 4. This also shows the obtained indices of diversity and uniformity at the level of mangrove species.

Table 4

Mangrove diversity and uniformity index

No	*Mangrove species*	*Number of individuals in the station*			*Mean±SD*
		I	*II*	*III*	
1	*Rhizophora apiculata*	50	47	17	
2	*Rhizophora mucronata*	7		3	
3	*Bruguiera gymnorizha*		12	4	
4	*Sonneratia alba*		14	20	
5	*Xylocarpus granatum*		25		
	Number of individuals	57	98	44	
	Number of species	3	3	4	
	Diversity index	0.372	1.294	1.127	0.699± 0.567
	Criteria	Medium	High	High	High
	Uniformity index	0.537	1.515	0.813	0.716± 0.581

Associations of organisms in the mangrove area. Associated biota in the mangrove forest area in Kulisusu District, North Buton Regency is presented in Table 5.

Table 5

Species of biota associated with mangroves in Kulisusu District, North Buton Regency, Indonesia

No	*Station*	*Fauna associated with mangroves*	*Number of associated species*
1	I	*Mugil cephalus*, *Lutjanus* sp., *Scylla serrata*, *Alpheus* sp., *Polymesoda erosa*, *Saccostrea cucullata*, *Cerithidea decollata*, *Telescopium telescopium*, and different species of insects and birds	11
2	II	*Mugil cephalus*, *Scylla serrata*, *Alpheus* sp., *Polymesoda erosa*, *Saccostrea cucullata, Cerithidea decollata*, species of insects, snakes and bats	11
3	III	*Lutjanus* sp., *Scylla serrata*, *Alpheus* sp., *Polymesoda erosa*, *Cerithidea decollate*, *Saccostrea cucullata*, *Cerithidea decollata*, *Telescopium telescopium*, species of insects and birds	9

Water quality in the mangrove area. The values of the water quality parameters are presented in Table 6.

Table 6

Results of water quality analyses at each research station

No	*Stations*	*Parameter*				
		Salinity (ppt)	*pH*	*Temperature (°C)*	*Total dissolved solids (TDS)*	*Dissolved oxygen*
1	I	15	7.2	26	17.048	5.39
2	II	33	8.0	24	44.818	7.26
3	III	31	8.4	25	33.972	7.26
	Mean±SD	26.33±9.86	7.86±0.61	25±1	31.94±13.99	6.63±1.53

Correlation of variables. Pearson's correlation coefficient between different variables in the mangrove ecosystem are presented in Table 6.

Table 6

Pearson's correlation coefficient values

Variable	*Pearson's correlation coefficient*	*P value*	*Information*
Area with a diversity of dominant mangrove species	0.838	0.000<0.05	Have a positive and significant relationship.
Area with a diverse number of species associated with mangrove	0.666	0.007<0.05	Have a positive and significant relationship.
Area with density	0.980	0.000<0.05	Have a positive and significant relationship.
Diversity of dominant mangrove species with diversity in the number of mangrove-associated species	0.965	0.000<0.05	Have a positive and significant relationship.
Diversity of dominant mangrove species with density	0.714	0.003<0.05	Have a positive and significant relationship.
Diversity of the number of species associated with mangrove density	0.506	0.054>0.05	Has a positive, but not significant relationship.

Discussion. The species found in this study belong to the true mangrove category based on the grouping of Tomlison (1994). The results of direct observations in the field showed that the first two stations contain a substrate in the form of mud, ranging from silty sand and silty rock. There are differences in the mangrove species at each station probably due to the different substrates.

Mangrove forests are located in tidal zones such as swamps, lagoons, river estuaries, and beaches in tropical and subtropical coastal areas, which are relatively protected, contain mud deposits and sediment slopes of no more than 0.25-0.5% and are composed of trees and shrubs (Fatoyinbo et al 2008; Strauch et al 2012). As for station 3, namely Linsowu Village, a sandy rocky substrate was found. The observation station's uniqueness is that the substrate's bottom is in the form of rocks, while the top comprises mud and sand. According to Noor et al (2006), *R. apiculata* grows on muddy, smooth, deep, and inundated soils during high tide. The dominance level of these species can reach 90% of the vegetation that grows in a specific location. Mangrove also adds beauty and comfort when visiting eco-tourism according to Bengen (2022).

The density of mangrove species in Kulisusu District is in the dense category. The average diameter of mangrove at all observation stations is 13.11 cm, with the average height reaching 10.45 m to 14.92. The higher density of mangroves is closer to the coastline, and people living nearby can develop eco-tourism, highlighting the importance of mangroves in human life and also for other organisms. The government recognized this by issuing the decision of the Minister of Environment Kepmen LH No. 201 of 2004, which identifies mangroves with values above 1000 ind ha^{-1} as part of the solid category. According to Raymond et al (2010), the effect of a population on communities and ecosystems depends not only on the species involved but also on the number or density. The mangrove forest is one of the ecosystems rich in nutrients, with various marine biota that interact with each other. At all three stations, the diversity criterion at the tree level was low, being 0.372 in station 1, while at stations 2 and 3, it was 1.2941 and 1.127, respectively. Station 1 has medium criteria, and stations II and III have high criteria. The diversity and uniformity values obtained show variations in composition and species in each station, differing from the moderate category values. These results are similar to those of Mukhlisi & Hartuti (2013) in Sidodadi Village, Padang Cermin District, Pesawaran Regency, Lampung Province. The diversity index of this study is lower than that reported by Akbar et al (2017) in Dodinga Bay West Halmahera Regency, North Maluku Province, where the diversity of mangrove species is included in the moderate category. Indriyanto (2006) stated that high species diversity is achieved when the community is composed of several different species. On the other hand, a community will have a low species diversity value when it is composed of few dominant species. As stated by Kusuma (1996) and Giesen et al (2006), in general, the species diversity in mangrove forests is relatively lower, and the number of species that can live in the ecosystem is limited.

All three stations have varieties of marine biotas that interact with each other. This condition can increase the income of the people around the stations and might be used as an object of investigation. Maulud et al (2017) stated that there are differences in the species composition found in each mangrove forest due to variations in the adaptability to the surface of stems, leaves, and roots. Each species' attachment strength is different, hence, only species with high adhesion can survive the currents or waves that hit the mangrove during high tides.

The results regarding the water quality conditions around the mangrove showed that the salinity, pH, temperature, TDS, and DO vary. There are differences in water quality in each station even though they are all in one sub-district. This is presumably due to the influence of some conditions, including substrate and sunlight exposure in places where mangroves grow. However, the overall water quality conditions in the sea around the mangrove area are good. According to Susiana (2015), the difference in water quality and a fraction of sediments strongly affect the structure and composition of mangroves, gastropods, bivalves, as well as other biota in a location. Differences in water quality are closely related to ecosystem stability, and the presence of the sea. According to Ghufran & Kordi (2012), water flows with silt, and sand provides the primary medium for mangrove growth. Meanwhile, Yulinda et al (2015) stated that the presence of

substrates affects the growth rate. During our research, there are three significant correlations. The first is the relationship between mangrove area and the diversity of dominant species, which has a positive value of 0.838. This means the mangrove area and dominant species have a strong and significant correlation. A greater mangrove area indicates a community with high complexity and the interaction of species. The second is the relationship between the mangrove area and species diversity, which has a positive with a value of 0.666, indicating a strong and significant correlation. Hence, a larger area will have a higher species diversity. The relationship between mangrove area and density has a positive Pearson correlation coefficient value of 0.98, which implies a strong correlation. The status category of mangrove eco-tourism in Kulisusu District has been classified as suitable for ecological sustainability. This categorization will serve as a reference point to assess the area's sustainability. It is essential to maintain this status while preserving environmental conditions and the carrying capacity to ensure it remains pristine (Sri 2017).

Conclusions. The mangrove area of North Buton Regency falls under the dense density category, providing sufficient space for various associated biota and making it suitable for the development of coastal eco-tourism.

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

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