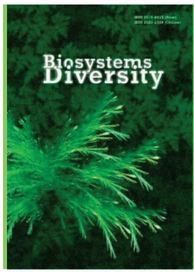

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Diversity, distribution and conservation status of mangrove species in Pulias Bay, Indonesia

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As an ecosystem, the mangrove ecosystem serves various purposes. The objectives of this study are to (1) identify the community structure of the important value index; and (2) evaluate the importance of the mangrove species diversity index in Pulias Bay in Ogodeide District, Tolitoli Regency. The study was conducted in 2021 using a quantitative descriptive methodology and survey method. The number of discovered species will be used to establish the species composition. The structure of the mangrove communities is being evaluated by calculating the relative density (RD) and frequency (FR). The data is tabulated to calculate the Important Value Index (IVI) value according to the Shannon-Wiener formula. There were 18 different species of mangroves discovered, including *Rhizophora apiculata*, *Rh. mucronata*, *Rh. stylosa*, *Bruguiera parviflora*, *B. gymnorrhiza*, *Ceriops tagal*, *C. decandra*, *Sonneratia alba*, *S. caseolaris*, *S. ovata*, *Avicennia lanata*, *Xylocarpus moluccensis*, *Acrostichum aureum*, *Nypa fruticans*, and *Pemphis acidula*. The Rhizophoraceae family predominated at each observation station, according to the findings of the vegetation analysis. Meanwhile the most rarely found species of mangrove were *Acrostichum aureum*, *Sonneratia casiolaris*, and *Xylocarpus moluccensis*, each with two specimens. The community structure reveals that *X. moluccensis* has the lowest IVI value of 12.7%, while *Rhizophora mucronata* has an IVI value of 101.3%. The mangrove Diversity Index (H') has a value of 2.48 and meets the standards for moderate diversity. Physical and chemical parameter measurements often indicate that the four stations or sites where the data was collected have similar conditions. Interestingly, we also found *Avicennia lanata*, a mangrove species that falls under the Vulnerable category. The collected information can be used to manage the mangrove forest in Pulias Bay in the Ogodeide Sub-District of the Tolitoli Regency and serve as a database for efforts to conserve mangroves and mitigate the effects of global warming.

Keywords: Celebes; diversity; mangroves of Teluk Pulias; Shannon-Wiener diversity index; Rhizophoraceae.

Introduction

Biodiversity is a term used to describe various life forms, including single and multicellular organisms. The three components of biodiversity are habitat, species, and genetic diversity (Siboro, 2019). The biodiversity of coastal natural resources is quite high. It includes mangrove forests, coral reefs, seagrass beds, seaweed, fishery products, and a wealth of minerals (Shannon & Wiener, 1963). According to Osland et al. (2017) mangroves are highly productive tidal wetland ecosystems and are found along tropical and sub-tropical coasts. In addition, mangroves have high adaptability when combined with an anaerobic environment and conditions (Oddson, 2020). They commonly form a dense intertidal forest that dominates muddy intertidal shores, with patches or bands that are almost entirely monospecific (Hogarth, 2015). In terms of ecosystem services for maintaining the environmental balance, coastal areas, as already stated, play a significant role and are of the highest value. According to Suryanti et al. (2019), coastal areas support human needs for public infrastructure, community livelihood, commerce, ports, ponds, and agricultural land.

Mangrove forests have been dominated by mangrove trees, which are subject to tides and are typically found along the coast or in river estuaries. The highest tides occur in this ecosystem, a transitional area influenced by land and sea-based factors. Mangrove forests are a distinctive and delicate ecosystem found along the coast. The existence of the mangrove ecosystem is crucial because it provides a variety of ecosystem services along the coastline (Alongi et al., 2016; Harefa et al., 2022). This ecosystem has ecological and economic functions, including shoreline protection, preventing seawater intrusion, providing plant habitat, feeding grounds, nursery grounds, spawning grounds for various aquatic biota, as well as micro-climate control, and can absorb CO_2 and produce O_2 at a relatively high rate compared to other forest types. Protection of mangrove forests is an important matter to be acted upon considering that mangroves have ecological and economic functions which are of great benefit to the coastal environment. Mangrove ecosystems have a very significant role in terms of maintaining the sustainability and balance of coastal ecosystems (Marchand, 2017; Nguyen et al., 2017; Baderan, 2019).

Mangrove forests are under pressure due to rising needs and increased community activities in coastal areas, which may endanger their existence. The majority of coastal people interfere with the mangrove ecosystem by converting mangrove-covered land into ponds, settlements, developing industries, and engaging in illegal logging for a variety of purposes in order to suit their demands. Mangrove ecosystems have vegetation that provides benefits and functions, namely reducing the risk of abrasion (Hilmi et al., 2019), the ability to dampen tidal waves and the damage caused by tsunamis (Kathiresan & Rajendran, 2005; Mynt et al., 2008; Dewiyanti et al., 2021) providing a habitat for different microorganisms (Ellison, 2008; Calabon et al., 2019) and acting as a food source (Baderan et al., 2015; Rahim & Baderan, 2019).

One of the regencies in Central Sulawesi Province is Tolitoli, with the city center of the regency located in Baolan District, 443 kilometres from Palu City, the province's capital. The total area of Tolitoli Regency is 4,079.77 km^2 of land and 300,859.22 ha of sea area, with a coastline length of 453.98 km^2. Mangrove forest ecosystems require targeted management actions that involve all parties with a stake in the region if they are to continue functioning. Mangrove forest zoning management is one of the options available in the Pulias Bay area for preserving and safeguarding the mangrove forest ecosystem. To support its management efforts, data on mangrove plant species and other ecological data on the diversity of mangrove plant species in the Pulias Bay area are required.

Material and methods

Research site. The Pulias Bay region, Ogodeide District, Tolitoli Regency, and Central Sulawesi Province served as the site of this study. The research was done in 2021. The four hamlets of Abaling, Pante, Pulias Island, and Malempa make up Pulias village, situated in the Ogodeide District of Tolitoli Regency. This research was located at the coordinate point of Hamlet of Abaling (00°57'31.0" N 120°42'52.3" E), Hamlet of Pante (00°57'29.6" N 120°43'23.5" E), Hamlet of Pulias Pulau (00°57'55.7" N 120°44'17.3" E) and Hamlet of Malempa (00°58'43.1" N 120°42'46.9":E, Fig. 1).

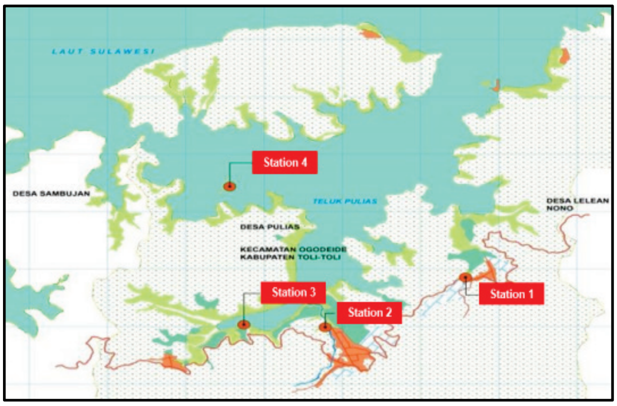

Fig. 1. Research sites in Pulias village consisted of Abaling, Pante, Pulias Island, and Malempa hamlets

Field sampling. The 150-meter-long transect line was made using a tape measure. Plots were made along the transect line with the size of each plot/quadrant, namely 20×20 m (trees), 10×10 m (saplings), and 5×5 m (seedlings). The number of mangrove species, the number of individuals, and the diameter of the stem at breast height (1.3 m above the surface) of each individual were recorded. The morphological characteristics of each mangrove plant also were observed (roots, stems, and leaves). The characteristics of each mangrove species listed in the identification guide (Reddy, 2008; Lebata-Ramos, 2013) were compared to the observational data (morphological characteristics of stems, roots, and leaves of mangrove plants). Mangrove plant species were identified using the identification key (Giesen et al., 2007; Pratiwi & Ernawati, 2016). The physicochemical factors such as soil pH, ambient temperature, and water salinity were measured using a soil tester, a thermometer, and a salinometer.

Data analysis. The mangrove species comparison among was visualized through InteractiVenn following Heberle et al. (2015). Relative Density (RD), Relative Frequency (RF), and Relative Dominance (RDI) calculations are used in the Community Structure Analysis and were tabulated to obtain an important value index (IVI), where:

IVI (Seedling and Sapling) = RD + RF;
VI (Tree) = RD + RF + RDI.

$$Density\ D = \frac{No.of\ individual\ of\ the\ species\ in\ all\ the\ sample\ plots}{Total\ no.of\ samples\ plots\ studied} x,$$

$$\text{Relative Density } RD = \frac{No.of\ individual\ of\ the\ species}{No.of\ individual\ of\ all\ species} X\ 100\%,$$

$$\text{Frequency } F = \frac{No.of\ sample\ plots\ in\ which\ the\ species\ occurs}{Total\ no.of\ plots\ sampled},$$

$$\text{Relative Frequency } RF = \frac{No.of\ occurences\ of\ the\ species}{No.of\ occurences\ of\ all\ species} X\ 100\%,$$

$$\text{Dominance } D = \frac{Total\ basal\ area}{Total\ of\ all\ the\ basal\ area},$$

$$Relative\ \text{Dominance RDI} = \frac{Total\ basal\ area\ of\ the\ species}{Total\ basal\ area\ of\ all\ the\ species} X\ 100\%.$$

The collected data were quantitatively and descriptively analysed using the Shannon-Wiener Diversity Index (H) community structure formula Shannon & Wiener (1963).

$$H' = -\sum_{i=1}^{S} pi\ ln\ pi$$

where: $pi = \frac{ni}{N}$. Description: H' (Shannon-Wienner diversity index), *S* (number of species), n_i (number of individuals in one species), *ln* (natural logarithm), N (total number of individual species found). The value of H' determines the level of species diversity in an area, where the definition of the value of species diversity according to Shannon-Wienner is: H'> 3: high species diversity, 1 ≤ H' ≤ 3: medium species diversity, H' < 1: Low species diversity. The evenness index of species refers to the *Pielow evenness indices* formula (Ludwig & Reynolds 1988), namely:

E = H'/ln S,

where E (Evenness Index), and H' (Shannon-Wienner diversity index). The species richness index uses the Margalef formula (Magurran, 1988), namely,

$$R_1 = \frac{(S-1)}{(\ln(N))},$$

where R_1 (Wealth Index), S (Number of species found), and N (total number of individuals). Past version 4.03 was used to perform Bray-Curtis cluster analysis with the Sorensen similarity index based on species presence to group mangrove diversity according to location (Djamaludin, 2008). The result of ecological data analysis was subjected to the interpretation following Table 1. Each research site measured physiological parameters consisting of soil pH, dissolved oxygen (DO), humidity, salinity, ambient temperature, and water temperature.

Table 1
Description of the analysis of diversity index (H'), richness (R), evenness (E), and species dominance (C)

Index	Descriptive Explanation
Species diversity (H')	H' < 1 – low diversity; 1 < H' < 3.22 – medium diversity; H' > 3.22 – high diversity.
Species Richness (R)	R < 3.5 – richness low; R = 3.5 – 5.0 – richness medium; R > 5.0 – richness high.
Species Evenness (E)	0 < E ≤ 0.4 – low uniformity, which means the individual richness owned by each species is quite different, and environmental conditions are unstable due to pressure; 0.4 < E ≤ 0.6 – medium uniformity, which indicates that the environmental conditions are not very stable; 0.6 < E ≤ 1.0 – high uniformity, which means the number of individual species from one species to another is not very different, and environmental conditions are stable.
Species Dominance (C)	0 < C ≤ 0.5 – dominance low; 0.5 < C ≤ 0.75 – dominance medium; 0.75 < C ≤ 1.0 – dominance high.

Results

The community structure is determined by measuring several variables and using an index of significant values. Eighteen species of mangrove plants were discovered at the tree, sapling, and seedling levels in the Pulias village area of the Ogodeide District. *Rhizophora mucronata* and *Rh. apiculata* were present in all sites where data were collected (Fig. 2). Interestingly, we also found *Avicennia lanata*, a mangrove species that falls under the Vulnerable category.

Malempa hamlet differs from the other hamlets in having a more varied species composition of the mangroves, showing seven exclusive species observed only in the area. There are three sub-habitats according to the cluster analysis of the mangrove habitat grouping in Pulias village. Pante and Abaling hamlets are mangrove habitats with a shared species composition, whereas Malempa and Pulias Pulau have a similarity below 75% (Fig. 3). The result shows that the species composition of the mangrove vegetation varies depending on the location.

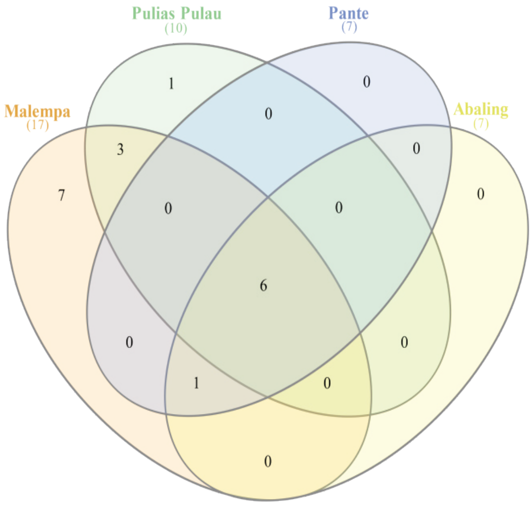

Fig. 2. The comparison of mangrove species composition observed in Abaling, Pante, Pulias Island, and Malempa hamlets showing some exclusive and shared species observed in the area

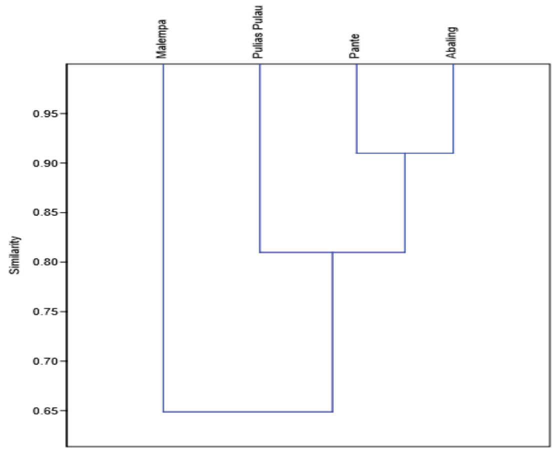

Fig. 3. Mangrove sub-habitat clusters based on the composition and presence of species at the data collection location

There are considerably more individuals in the sapling and seedling stages than there are in the tree stage. This is because the stage of a plant's life when it is a twig or seedling is very important. *Rhizophora mucronata* was the most widespread species of mangrove being present in four hamlets. *Pemphis acidula*, on the other hand, was only found in Pulias Pulau hamlet as a sapling stage. The IVI in each hamlet of Pulias village has a different value, as shown in Table 2. Malempa Hamlet had 17 species of mangroves, making it the hamlet with the greatest diversity. The Rhizophoraceae family predominated at each observation station, with the *Rhizophora mucronata* having the highest IVI of 101.3% and *Xylocarpus moluccensis* having the lowest IVI of 12.7%.

Table 2
Important value index (%) for trees, saplings, and seedlings in Pulias Village

Species	Family	IVI, %											
		Malempa Hamlet			Pulias Pulau Hamlet			Pante Hamlet			Abaling Hamlet		
		T	Sa	Se	T	Sa	Se	T	Sa	Se	T	Sa	Se
Rhizophora apiculata	Rhizophoraceae	75.77	63.24	64.45	53.95	54.12	67.52	68.59	78.26	58.06	54.47	82.25	74.90
Rh. mucronata	–“–	101.31	78.89	69.71	63.21	78.83	81.91	60.71	98.01	75.14	63.85	90.89	84.12
Rh. stylosa	–“–	50.24	–	–	–	30.68	–	–	–	–	–	–	–
Bruguiera parviflora	–“–	28.70	44	–	–	–	–	–	–	–	–	–	–
B. gymnorrhiza	–“–	43.99	–	–	47.22	41.18	52.67	45.80	45.11	–	54.05	49.99	–
Ceriops tagal	–“–	44.12	35.99	38.94	33.63	36.08	50.41	44.77	–	49.56	51.91	–	–
C. decandra	–“–	32.08	–	–	–	–	–	–	–	–	–	–	–
Sonneratia alba	Lythraceae	59.58	29.88	40.83	30.35	–	47.49	52.95	–	37.79	65.21	–	51.37
S. ovata	–“–	31.90	–	–	–	–	–	–	–	–	–	–	–
Avicennia alba	Verbenaceae	34.05	28.28	45.48	22.18	–	–	27.18	43.24	45.77	38.85	38.11	37.99
A. marina	–“–	26.45	–	–	26.26	–	–	–	–	–	–	–	–
A. lanata	–“–	16.74	–	–	–	–	–	–	–	–	–	–	–
Xylocarpus granatum	Meliaceae	23.07	–	–	23.19	–	–	–	–	–	–	–	–
X. moluccensis	–“–	12.69	–	–	–	–	–	–	–	–	–	–	–
Acrostichum aureum	Pteridaceae	15.49	–	–	–	–	–	–	–	–	–	–	–
Sonneratia caseolaris	Lythraceae	13.38	–	–	–	–	–	–	–	–	–	–	–
Pemphis acidula	–“–	–	–	–	–	20.55	–	–	–	–	–	–	–
Nypa fruticans	Arecaceae	–	19.70	40.59	–	–	–	–	35.35	33.69	–	38.75	51.63

Note: T – tree, Sa – sapling, Se – seedling.

The dominant species of Rhizopharaceae in Pulias village were *Rhizophora mucronata*, *Rh. apiculata*, and *Bruguiera gymnorrhiza* with a total individual number of 35, 28, and 24 respectively. Meanwhile the most rarely found mangroves were *Acrostichum aureum*, *Sonneratia casiolaris*, and *Xylocarpus moluccensis*, with only two specimens each (Table 3).

The diversity index for the coastal mangrove species in Pulias village is moderate (H), showing the value of H was 2.48. The species richness index (R) and species dominance index (C) are in a poor category when compared to the species evenness index (E). Based on the analysis of the diversity index, the mangrove habitat in Pulias Village is generally in sufficient condition to support the sustainability of the mangrove ecosystem. The dominance index value showed that none of any species are dominant in mangrove area (E). Due to the dominance values, there are several different types and species of flora. Physical and chemical parameter measurements often indicate that the four stations or sites where the data was collected have similar conditions. Other than soil pH and ambient temperature, the measured environmental parameters differed significantly based on the F test (Table 5). The Pulias village's mangrove ecosystem had an acidic soil composition, as indicated by the average pH value, ranging from 6.72 to 6.73. The Pulias Island hamlet had the highest dissolved oxygen value of 12.28, which meant that the mangrove region of Pulias village had a relatively high dissolved oxygen level. The Malempa hamlet's highest salinity reading was 27.18. Meanwhile, ambient and water temperatures ranged from 30.17 to 30.67 and 29.20 to 30.60, respectively.

Discussion

In other places with similar climate and geography, the species of mangrove plants are also similar. In the Mahakam Delta (East Kalimantan, Indonesia), the mangrove forest was divided into several zones: *Sonneratia* to *Avicennia* zone, *Rhizophora* zone, transition zone (made up of *Bruguiera*, *Xylocarpus*, *Avicennia*, and *Nypa*), and *Nypa* zone (Zain et al., 2014). Kartika et al. (2018) found that 10 mangrove species from the family Rhizophoraceae occupied the area of Bulungan (North Kalimantan, Indonesia). Similar species of mangroves were also found in Kutai National Park. These included *Rhizophora*, *Bruguiera*, *Ceriops*, *Sonneratia*, *Avicennia*, *Xylocarpus*, *Nypa*, and *Pandanus*. Lillo et al. (2019) identified 10 of the six families in the mangrove woods in the southeast of the Philippines. *Rhizophora mucronata*, *Rh. stylosa*, *Rh. apiculata*, *Bruguiera gymnorrhiza*, and *B. sexangula* were all the reported similar species found in the Philippines.

Table 3
Diversity of plants in Pulias village

Species	Classification	Total number of sampled individuals
Rhizophora apiculata	True mangrove	28
Rh. mucronata	–"–	35
Rh. stylosa	–"–	6
Bruguiera parviflora	–"–	4
B. gymnorrhiza	–"–	24
Ceriops tagal	–"–	18
C. decandra	–"–	4
Sonneratia alba	–"–	17
S. caseolaris	–"–	2
S. ovata	–"–	13
Avicennia alba	–"–	7
A. marina	–"–	2
A. lanata	–"–	6
Xylocarpus granatum	–"–	2
X. moluccensis	–"–	2
Acrostichum aureum	Mangrove associate	2
Nypa fruticans	–"–	11
Pemphis acidula	–"–	3

Table 4
Results of analysis of index diversity (H'), richness (R), evenness (E), and species dominance (C)

Index	Index Value
Species diversity (H')	2.48
Species richness (R)	3.30
Species evenness (E)	0.90
Species dominance (C)	0.11

Table 5
Statistical analysis of physicochemical parameters in the research sites

Environmental parameters	Station				F_{value},
	Malempa Hamlet	Pulias Pulau Hamlet	Pante Hamlet	Abaling Hamlet	$F_{0.05}$ = 3.10
Soil pH	6.72	6.72	6.73	6.73	0.26
Dissolved oxygen, mg/L	12.10	12.28	11.60	11.17	89.46*
Humidity, %	72.67	71.00	72.00	72.00	5.00*
Salinity, ppt	27.18	26.38	26.17	27.10	163.10*
Ambient temperature, °C	30.67	30.67	30.17	30.33	1.10
Water temperature, °C	30.60	29.80	29.20	30.00	5.56*

Aronson et al. (2016) proclaim that the number of species shows the current state of biotic groups. Landi et al. (2018) mentioned that the complex and stable ecosystem is due to the high number of species and the high amount of interaction between species. Communities with a lot of species have a high amount of diversity (van der Plas, 2019). The index value of variety is not just based on the number of species, but also on how evenly the species are spread out (Majecova et al., 2016). Species richness (R) and species abundance (N) are the two variables that affect the diversity of mangrove vegetation. Communities with high levels of both have diverse populations (Magurrana, 1988). According to the findings of the research done in Pulias Village's Mangrove area, 18 different species of mangroves existed. Rhizophoraceae species are one of the numerous mangrove species found in the Indo-Pacific area (Triest et al., 2021). The observed species of mangrove were *Rhizophora apiculata*, *Rh. mucronata*, *Rh. stylosa*, *Rh. paviflora*, *Bruguiera gymnorrhiza*, *Ceriops tagal*, *C. decandra*, *Sonneratia alba*, *S. caseolaris*, *S. ovata*, *Avicennia alba*, *A. marina*, *A. lanata*, *Xylocarpus granatum*, *X. moluccensis*, *Acrostichum aureum*, *Nypa fruticans*, and *Pemphis acidula*. Each observation station had a dominant member of the Rhizophoraceae family, according to the findings of the vegetation analysis.

Based on IUCN List of Threatened Species (2023), one species was identified as vulnerable, two species were identified as near threatened and moreover, 15 species were identified as Least Concern (Table 1). The threat category in IUCN Red List has totally different categories for a selected species and this can be because of their variations in scope or level of assessment.

Table 6
Threat category in IUCN Red List of plants in Pulias village

Species	Family	Threat category in IUCN Red List
Rhizophora apiculata	Rhizophoraceae	Least concern
Rh. mucronata	–"–	–"–
Rh. stylosa	–"–	–"–
Bruguiera parviflora	–"–	–"–
B. gymnorrhiza	–"–	–"–
Ceriops tagal	–"–	–"–
C. decandra	–"–	Near Threatened
Sonneratia alba	Lythraceae	Least concern
S. caseolaris	–"–	–"–
S. ovata	–"–	Near Threatened
Nypa fruticans	–"–	Least concern
Avicennia alba	Verbenaceae	–"–
A. marina	–"–	–"–
A. lanata	–"–	Vulnerable
Xylocarpus granatum	Meliaceae	Least concern
X. moluccensis	–"–	–"–
Acrostichum aureum	Pteridaceae	–"–
Pemphis acidula	Arecaceae	–"–

Based on Table 1, it was found that the Rhizophoraceae family was represented by 7 species, the Lythraceae family, 4 species and the Meliaceae family by 3 species. The Rhizophoraceae, Lythraceae, Meliaceae families can grow well in places where tides always pass, with muddy soil, can tolerate high water salinity and waves, besides which the Rhizophoraceae family also has very high speed of growth and very good adaptability. Moreover, this type has viviparous properties (seeds have germinated on fruits that are still attached to twigs). This was confirmed by Khairunnisa et al. (2020), who stated that this viviparous nature caused many seedlings to grow because every seed that fell to the ground was ready to germinate. Muddy soil in mangrove forests is a soil factor that strongly supports the growth of the seedlings of these species. The Pteridacea and Arecaceae families were represented by one species each. This is because these families cannot live well in places that experience frequent ups and downs so that it inhibits the growth process.

During the sapling stage, there is also the highest rate of mortality. Most of the time,the mangrove species grew from replanting or from nature (Idrus et al., 2019; Fickert, 2020). But it was shown that Pulias village is a good place for *Rh. mucronata* to grow in large numbers because this species grows better in silt (Hastuti et al., 2016). According to Faqih et al. (2020), the *Rhizophora* mangroves predominate in this area because of the muddy substrate in this mangrove area, which helps *Rhizophora* adapt well because it has supported roots and many sideways roots at the end of each root, allowing them to be firmly embedded in the mud. This statement is consistent with Djamaludin's (2018) assertion that *Rhizophora*-type mangroves can typically flourish in regions with soft deep (muddy soil). These results are also pertinent to research done by Baderan et al. (2015) in the Tabulo mangrove area, North Gorontalo, which showed that the species *Rh. mucronata* and *Rh. apiculata* tend to have the ability to adapt well in mangrove communities. The findings indicated that *Rh. mucronata* and *Rh. apiculata* had a broad tolerance range in this mangrove forest area because the species were dispersed at each station. On the other hand, *Pemphis acidula*, was represented by the lowest number of mangroves found in Pulias village, having a wood which was thought to be magical and was a favourite of bonsai lovers (Utami & Anggoro, 2017; Yunoh & Atan, 2019). This tree is hunted so much that the number keeps falling, and if nothing is done to save it, it could become endangered. Bray-Curtis cluster analysis using the Sorensen index showed that the species compositions of the four hamlets were very similar, especially for Pante and Abaling. This means that the sites in Pante and Abaling were very alike in the kinds of species they had. In the evaluation, a low forest diversity status can show that the mangrove forests have been damaged, probably because of various human activities (Hoppe-Speer et al., 2015). Based on the study's findings, it was determined that the number H' = 2.48 represented the degree of diversity of coastal mangroves in Pulias village. *Rhizophora apiculata* and *Rh. mucronata* dominate the coastal region of Pulias village, according to their distribution. *Bruguiera gymnorrhiza*, which still belongs to the Rhizophoraceae family, is the next most common plant in the region. In Pulias village, the diversity index of coastal mangrove plants falls into the moderate level of diversity, and it can be inferred. The number of species and variations in the composition of plant vegetation influence the value of diversity in an ecosystem (Ahmed et al., 2022).

The distribution of mangrove species is not always the same as that of other species, whose individuals are found in small or large numbers. According to the description above, mangrove species can grow in environments with low to high salinity, and each species has a different ability to adapt to environmental factors. The composition and structure of the mangrove forest ecosystem can be used to judge its quality. The diversity of the flora and fauna community, which is impacted by environmental factors like salinity, light intensity, sediment or substrate, and climate, is described by the composition of the mangrove. Species variation, population abundance, and interactions between populations or communities in mangrove ecosystems are all covered in this composition (Priosambodo et al., 2021).

Naturally, compared to tropical forests, the diversity of species in mangrove forests is lower. Despite the tidal zone's harsh conditions, this forest has features that can support life (Duken et al., 1998). According to Walters et al. (2008), mangrove ecosystems also have high primary productivity but are easily disturbed, particularly by anthropogenic disturbances. The fact that the gregarious, aggressive, and invasive *Nypa fructicans* occupied the middle place for abundance of mangrove species in the area showed that the mangrove ecosystem was badly disturbed and at risk of losing most of its plant species in the near future. It is assumed that human actions in the area, especially around the Cross River, make it easier for *Nypa* to move in (Asuk et al., 2018). *Nypa* then outcompetes other species and pushes the mangroves out of the area. The area had been destroyed by the aggressiveness of this invasive species, which has shallow, fibrous roots that are not strong enough to hold the land together or provide the wide range of natural services that native mangroves do. Population growth, clearing land for firewood and crops, and the unsustainable use of NTFPs for food, local crafts, and commercial fishing were some of the things that were blamed (Olowokudejo & Oyebanji, 2016; Asuk et al., 2018).

The coastal region of Pulias village is generally in sufficiently decent physical condition to allow the growth of mangrove species, according to environmental factors. An optimal soil pH for mangrove growth is 6.8, which is the average soil pH in the Pulias village mangrove area. The pH range between 6.6 and 7.5 is ideal. Because plants can efficiently absorb nutrients under these conditions, mangrove species benefit from growth and development (Dewiyanti et al., 2021). Dissolved oxygen, usually referred to as DO or the amount of oxygen dissolved in water, is a gauge of the environment, particularly for monitoring water quality. General parameters or indicators in the mangrove area are DO values > 5 mg/L (Faridah et al., 2019). The range of 11.1 to 12.3 in the mangrove area of Pulias village suggests that the water quality is sufficient to support the growth of the native mangrove plant species.

The air and water temperatures along the coast have a substantial impact on the sustainability of the mangrove ecosystem. Temperature measurements of the air and water in the mangrove region of the town of Pulias revealed a variety of factors that encourage the proliferation and longevity of the mangrove environment. A rise in temperature has the potential to accelerate metabolism, potentially reducing plants' capacity to absorb oxygen from water (Basyuni et al., 2018). Numerous variables, including the amount of sunlight, gas interaction between water and surrounding air, site altitude, and tree canopy cover, influence air temperature (Weber et al., 2017).

In addition to pH, temperature, and the condition of the substrate soil, salinity is a key environmental component for the mangrove ecosystem. Typically, mangrove regions have salinities between 0% to 34% (Basyuni et al., 2018). Water temperatures should be between 28 and 32 °C to promote mangrove development (Rizal & Anna, 2020). Salinity measurements revealed how much salt is present in the water or how many sodium and chloride ions are present, both of which are crucial for the development of mangrove species (Lu et al., 2013; Pratiwi & Ernawati, 2016). The ideal amount of air and water temperatures promote mangrove growth.

A significant or abrupt increase in salinity can inhibit plant growth and the growth of mangrove species, which can influence soil carbon (content organic carbon and roots), tree height, basal area, dominant tree height, Leaf Area Index, and the availability of macronutrients in the soil e.g. NH_4^+, P, and K (Ahmed et al., 2022). Several mangrove species have anatomically modified their xylem, or transport tissue, to salinity environments (Jiang et al., 2021).

Logging and conversion to other uses, such as ponds, rice fields, gardens and allotments, pose a significant threat to mangrove forest ecosystems. Mangrove forests in Indonesia commonly encounter devastation from natural disasters and human activity, which appears in different ways in different places. The degradation caused by nature often occurs as part of a natural cycle that will eventually result in succession and restore the mangrove forest to its previous condition. However, the mangrove forest ecosystem is threatened by human activity, which has the potential to devastate the ecosystem. One action that can be taken in order to protect the existence of mangrove forests is to designate a mangrove area to become a forest conservation area, and a form of green belt along the coast and riverbanks. This form of protection of mangrove forests is quite effective and brings results.

Conclusion

There were 18 different kinds of mangroves, with *Rh. apiculata* and *Rh. mucronata*, predominating at each observation station, followed by the type of *B. gymnorrhiza*. The lowest IVI value was 12.7% for the *X. moluccensis* species, while *Rh. mucronata* had an IVI value of 101.3%. The village of Pulias' coastal mangrove plants meets the requirements for medium diversity with a diversity level of H' = 2.48. The information gathered can be used to manage the mangrove forest in Pulias Bay in the Ogodeide sub-district of Tolitoli Regency and as a database for mangrove conservation efforts to lessen the effects of global warming.

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