

# Mangrove community structure in Blongko, Kapitu, and Sondaken Villages, South Minahasa Regency, Indonesia

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**Abstract.** The structure of the mangrove community in South Minahasa, Indonesia, has been investigated. This research was conducted at Blongko village as station 1, Kapitu village as station 2, and Sondaken village as station 3. The research applied the continuous quadrant method by using a quadrat measuring 10 x 10 m<sup>2</sup> to obtain mangrove data. In this research, seven mangrove species were identified at three stations, consisting of *Sonneratia alba*, *Avicennia marina*, *Avicennia officinalis*, *Bruguiera gymnorrhiza*, *Ceriops tagal*, *Rhizophora apiculata*, dan *Rhizophora stylosa*. *S. alba* had the highest density at station 1 with 517 ind ha<sup>-1</sup>, *A. officinalis* at station 2 with 720 ind ha<sup>-1</sup>, and *R. apiculata* at station 3 with 1.583 ind ha<sup>-1</sup>. Diversity index (H') at station 2 was found to be the highest, namely 1.17, while the was at station 3, namely 0.37. Richness index (R) was observed to be the highest at station 2, as much as 0.97, and the lowest was at station 1, which was 0.38. The evenness index (E) was found to be the highest at station 1 with a value of 0.70, and the lowest was at station 3 with a value of 0.27. The highest dominance index (D) was found at station 3 with an index value of 0.85, and the lowest was at station 2 with an index value of 0.33. Correspondence analysis (CA) at each station showed relatively different characteristics of mangrove species. Station 1 was characterized by *A. marina*, station 2 by *R. stylosa*, *C. tagal*, and *A. officinalis*, and station 3 by *B. gymnorrhiza* and *R. apiculata*. *S. alba* spread almost evenly at the three observation stations.

**Key Words:** density, diversity, richness, evenness, dominance.

**Introduction.** Mangrove ecosystems are one of the most productive coastal habitats and are ecologically important in tropical and subtropical regions. Mangroves provide a variety of ecosystem services, including protection of shoreline from erosion and extreme weather, sediment stabilization, carbon absorption, nutrient cycle, and function as nursery and breeding grounds for a variety of fish, crustaceans, and molluscs (Alongi 2008; Tan & Siregar 2021). In archipelagic countries such as Indonesia, which has about 23% of the world's mangrove forests, mangroves support the livelihoods of millions of people living along the coastal areas through fisheries, ecotourism, timber, and non-timber products (Giri et al 2011). Indonesian mangroves comprise a diverse range of species forming dynamic plant communities. In mangrove ecology, the term community structure refers to the composition, abundance, spatial distribution, and size class structure (seedlings, saplings, and mature trees) of different mangrove species in a certain area. Understanding the mangrove structure is essential in assessing the health and sustainability of mangrove forests and in providing policies for conservation, restoration, and management strategies (Alongi 2012).

Indonesia has a mangrove area of 3.24 million hectares based on image data from 2006-2009 (Saputro 2009). The deforestation rate of mangroves in Indonesia is 0.05 million hectares per year (Ministry of Forestry of the Republic of Indonesia 2014). The causes of the decline of mangrove forests in Indonesia are: land conversion for other

purposes, namely agriculture, settlements, plantations, agriculture, exploitation of mangrove wood for fuel, building materials, etc. (Djamaluddin 2018). The decrease of mangroves in Indonesia continues, resulting in a deforested, fragmented, and degraded ecosystem. In the Wallacean biogeographic region that has very high biodiversity, the presence of mangroves has been threatened (Myers et al 2000; Struebig et al 2022). Sulawesi mangroves have undergone the second-highest rate of deforestation in Indonesia (39% loss) since the 1980s due to unsustainable shrimp farming, where the brackishwater ponds are typically left unused for 13 years because of shrimp diseases and pollutant accumulation (Ilman et al 2016; Aslan et al 2021). Even though there were efforts by the government and community initiatives to restore these intertidal forests, comprehensive and long-term assessments of restoration results are still lacking (Holmes et al 2025).

Various research has been conducted in Indonesia to document the structure of mangrove communities. For example, Ndede et al (2017) reported seven mangrove species on the coast of Sapa, North Sulawesi, with *Sonneratia alba* as the dominant species at various growth stages. In Blongko Village, South Minahasa, Schaduw (2015) identified the presence of species such as *Xylocarpus granatum*, *Avicennia lanata*, *A. marina*, *A. officinalis*, *Bruguiera gymnorhiza*, *Rhizophora apiculata*, and *Sonneratia alba*, indicating relatively high species richness in the area. In North Sulawesi, various studies have been conducted, including in Mantehage Island (Opa et al 2019; Wagey et al 2020) and the Minahasa Peninsula (Lintong et al 2023). Studies on mangrove ecotourism and potential mangrove carbon mitigation had been conducted in Mantehage Island (Opa et al 2021; Sondak & Kaligis 2022).

The mangrove status in Blongko is as a community-based Marine Protected Area (MPA), in Kapitu as an educational conservation area, and in Sondaken as part of the Southern Bunaken National Park. A study regarding the structure of the mangrove community status at these locations to evaluate the health conditions of the mangroves has never been conducted before.

## Material and Method

**Research locations.** The research was conducted from May - June 2024 in South Minahasa Regency, North Sulawesi Province. Mangrove data were gathered at three different stations. Station 1 was located at Blongko village, station 2 at Kapitu village and station 3 at Sondaken village (Figure 1). Station 1 is a coastal village located in Sinonsayang District. This location has a long history of community-based marine resource management. Blongko has been established as one of the community-based MPAs by the MPA management group, initially facilitated by the Coastal Project (USAID). There are mangrove, seagrass, and coral reef ecosystems at the Blongko coast. Station 2 is located not far from Blongko, but with a different history and a different management approach. Kapitu has experienced mangrove destruction in the past, partly due to land clearing activities, but currently, rehabilitation efforts have been carried out through a planting program of about 2,000 *Rhizophora* sp. by local non-governmental organizations, the ecosystem, and village youth groups. Thus, the mangrove ecosystem in Kapitu resulted from mangrove restoration by the local community. Station 3 is a coastal station located also in Sinonsayang District. Unlike Blongko and Kapitu, the Sondaken village has been developed as a mangrove-based ecotourism destination managed mutually by the local community and the Bunaken National Park Office.

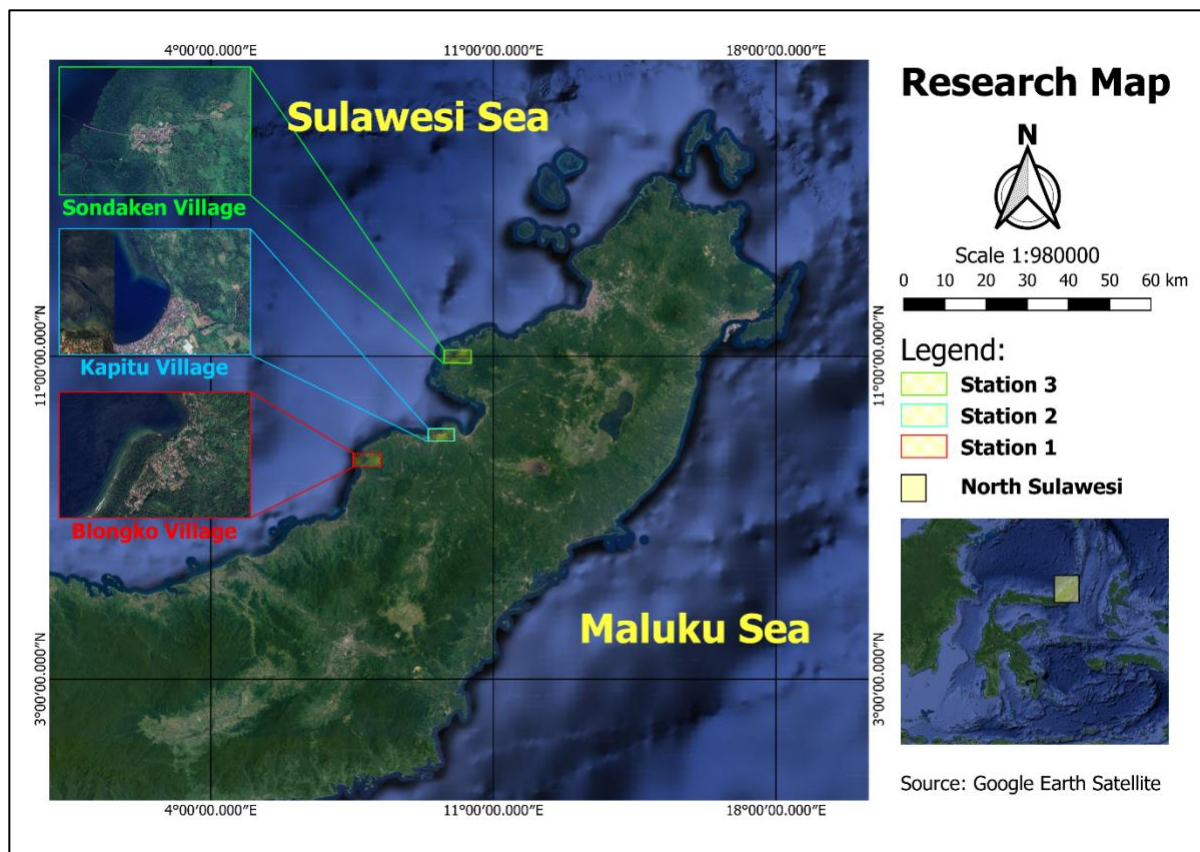


Figure 1. Map of research location.

**Sampling techniques.** Mangrove data were collected using the continuous quadrant method (Djamaludin 2018; Opa et al 2019). Data collection used a square measuring 10 x 10 m<sup>2</sup> as the main observation unit (Figure 2). A line transect was then drawn according to the mangrove area (McKenzie et al 2003). In Blongko village, the mangrove area was divided into three transects: the first transect with 4 quadrats, the second transect with 9 quadrats, and the third transect with 10 quadrats. In Kapitu village, the mangrove area was divided into five line transects, each transect had 5 quadrates, while in Sondaken village, the mangrove area was divided into 4 line transects, each with 10 quadrates.

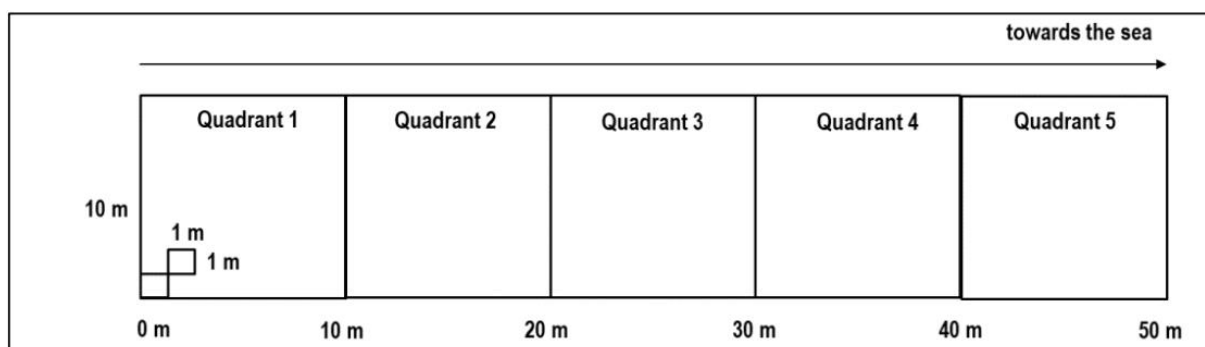


Figure 2. Continuous quadrant method

**Sample identification.** Mangrove species were identified by observing the leaves' shape, stems, roots, and fruit following the method of Djamaludin (2018) and Govaerts (2022).

**Species density, richness index (R), diversity index (H'), evenness index (E), and dominance index (D).** Species density was calculated by dividing the total number of individuals by the total sampling area, following the method described by Krebs (1999). Species richness, diversity, evenness, and dominance indices were computed using

standard ecological formulas based on the framework of Ludwig and Reynolds (1988). Shannon's diversity index ( $H'$ ) and evenness index ( $E$ ) were derived using natural logarithmic transformations, where  $H'_{max}$  represents the maximum diversity based on the number of species ( $S$ ). The dominance index ( $D$ ) was calculated using the formula provided by Odum (1971).

**Correspondence analysis (CA).** The density data collected were first tabulated into a two-way contingency table (cross table) consisting of seven rows (species) and three columns (stations). The data input into the cross table was then transformed into  $\log(x+1)$  form to stabilize the variance and make the zero value meaningful (Thouzeau 1989; Bakus 2007). Subsequently, the dataset was subjected to multivariate analysis techniques through correspondence analysis (CA) to generate a visual geometric representation of the studied variables. This analytical approach spatially mapped ecological parameters as points along orthogonal axes, enabling simultaneous optimization of relationships between station clusters (columns) and species assemblages (rows).

The CA framework aimed to establish statistically robust associations between the two examined variables - species distribution and sampling stations - through dimensional reduction. As outlined by Lebart et al (1982), the interpretation of CA-derived axes relies on two distinct coefficient categories: absolute contributions (reflecting variable dominance in axis formation) and relative contributions (quantifying factor-variable correlations), which collectively inform the ecological patterns revealed by the ordination model. The absolute contribution describes the part taken by a particular element in the variance explained by a factor. It allows us to find out the variables responsible for forming one factor. Relative contribution explains how much effect one factor has in explaining the distribution of one element. It makes it possible to know which variables are the exclusive characteristics of that factor. Data modeling in a two-way contingency table through CA was carried out using the STATGRAPHICS Centurion packaging program by selecting the CA menu.

## Results and Discussion

**Composition of mangrove species.** Seven mangrove species consisting of *S. alba*, *A. marina*, *A. officinalis*, *B. gymnorhiza*, *C. tagal*, *R. apiculata*, and *R. stylosa* (Table 1) were identified morphologically in Blongko village (Station 1), Kapitu village (Station 2), and Sondaken village (Station 3). These species belong to three different families, which are Lythraceae, Acanthaceae, and Rhizophoraceae.

Table 1  
Composition of mangrove species

<i>Class</i>	<i>Order</i>	<i>Family</i>	<i>Species</i>
Magnoliopsida	Myrtales	Lythraceae	<i>Sonneratia alba</i>
		Acanthaceae	<i>Avicennia marina</i> <i>Avicennia officinalis</i>
	Malpighiales	Rhizophoraceae	<i>Bruguiera gymnorhiza</i>
			<i>Ceriops tagal</i>
			<i>Rhizophora apiculata</i> <i>Rhizophora stylosa</i>

**Species density.** Station 1 exhibited three mangrove species: *S. alba*, *A. marina*, and *R. apiculata*. Among these, *S. alba* dominated with a density of 517 individuals per hectare ( $\text{ind ha}^{-1}$ ), followed by *A. marina* ( $322 \text{ ind ha}^{-1}$ ) and *R. apiculata* ( $22 \text{ ind ha}^{-1}$ ), yielding a mean density of  $286 \text{ ind ha}^{-1}$  for the station (Figure 3). *S. alba* became the dominant species, indicating this station has open water characteristics and fine muddy substrates as a preferable habitat of *S. alba* (Kathiresan & Bingham 2001). This dominance also indicates the potential of good natural recovery in this area, especially if there is not much anthropogenic pressure.

At Station 2, seven distinct mangrove species were documented, displaying substantial variation in density (400-720 ind ha<sup>-1</sup>). *A. officinalis* accounted for the highest density (720 ind ha<sup>-1</sup>), whereas *C. tagal* and *R. stylosa* showed minimal densities of 4 ind ha<sup>-1</sup> each, resulting in an average station density of 271 ind ha<sup>-1</sup> (Figure 4). Individuals' distribution is relatively even, although there are severe fluctuations. This denotes the presence of the influence of microhabitat conditions or selective rehabilitation activities on certain types.

Station 3 hosted four mangrove species with densities spanning 30-1.583 ind ha<sup>-1</sup>. *R. apiculata* markedly surpassed other species at this site, registering 1.583 ind ha<sup>-1</sup>, while *A. officinalis* had the lowest density (30 ind ha<sup>-1</sup>). The mean mangrove density at station 3 was 430 ind ha<sup>-1</sup> (Figure 5). These data suggest that this area is probably a rehabilitation or reforestation site that focuses on *Rhizophora* species, as is often implemented in mangrove restoration programs.

From the three stations, it can be concluded that the differences in number and density levels of species are influenced by local ecological conditions and the history of area management. Station 2 has the highest *S*, which is most likely due to a natural or semi-natural habitat with low pressure, while Station 3, mostly dominated by *R. apiculata*, is probably a monospecific rehabilitated site. In contrast, Station 1 represents a natural mangrove ecosystem dominated by *S. alba*, as characteristic of intertidal areas near the river mouths.

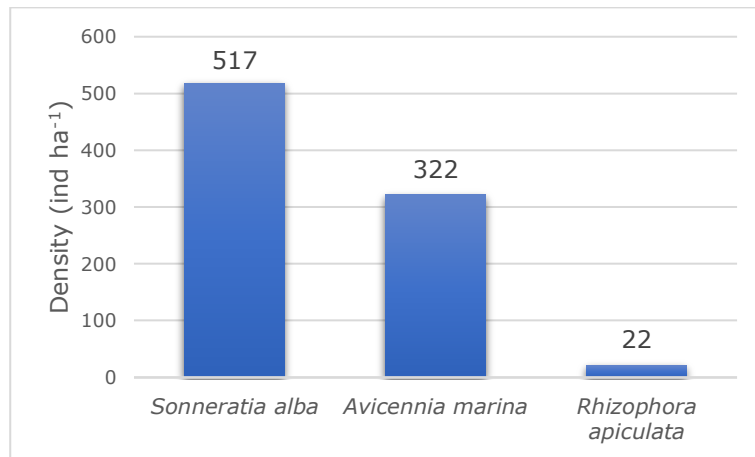


Figure 3. Mangrove density at station 1 (Blongko).

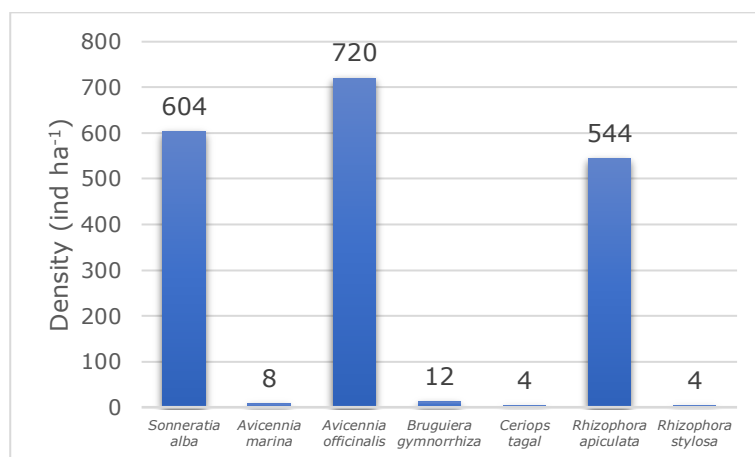


Figure 4. Mangrove density at station 2 (Kapitu).

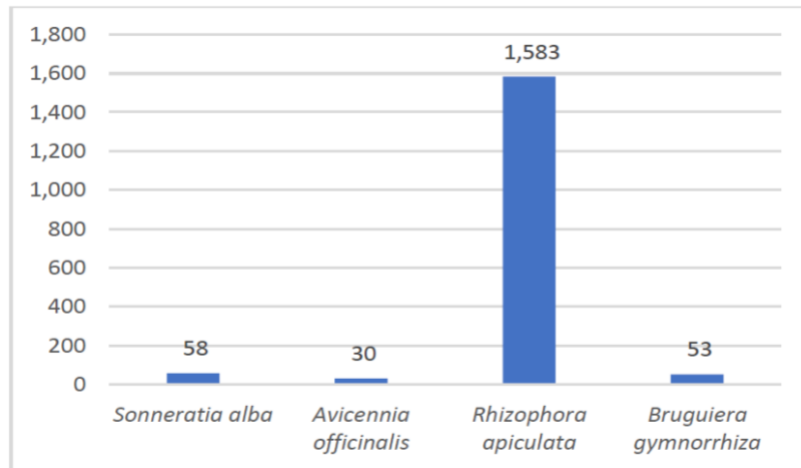


Figure 5. Mangrove density at station 3 (Sondaken).

**The number of species, diversity index, richness index, evenness index, and dominance index.** The  $H'$ , R, E, and D obtained from the computation of various ecological indices for mangroves at each station are presented in Table 2.

Table 2

Indices of the mangrove community

Index	Station		
	Blongko	Kapitu	Sondaken
Diversity index ( $H'$ )	0.77	1.17	0.37
Richness index (R)	0.38	0.97	0.46
Evenness index (E)	0.7	0.6	0.27
Dominance index (D)	0.5	0.33	0.85

Biodiversity encompasses three hierarchical tiers: genetic variation, species composition, and ecosystem complexity, as defined by Ludwig and Reynolds (1988). This multidimensional framework governs a population's adaptive capacity to engage in ecological interactions. Operationally, diversity can be deconstructed into two core elements: (1) taxonomic count (species richness) and (2) equitability (species evenness). Species richness refers to the total taxonomic units within a defined habitat, while evenness quantifies the proportional distribution of individuals or biomass among these taxa. The latter serves as a metric to assess ecological balance, quantified via parameters such as population size, biomass allocation, or analogous proxies. Vannucci (2000) stated that high genetic diversity in mangrove ecosystems is caused by the presence of aquatic and terrestrial species and their ability to adapt to various severe environmental conditions. This is indicated by the presence of high salinity, high temperatures, muddy anaerobic soils, extreme tides, and strong winds, which fluctuate wildly and frequently. Naeem et al (2016) described that biodiversity is a diverse way of describing the variety of life forms on our planet, from one level of organization to the biosphere. Generally, it confesses the diversity of life that exists based on taxonomy, function, phylogeny, tropics, or genes. Edwin et al (2021) added that the diversity of species in Indonesia is 157 species, consisting of 52 species of trees, 21 species of shrubs, 13 species of lianas, 7 species of palms, 14 species of grasses, 8 species of herbs, 3 species of parasites, 36 species of epiphytes, and 3 species of ferns.

**The number of species.** Mangrove species richness in coastal ecosystems is ecologically significant, underpinning biodiversity conservation and coastal resilience. Across the three surveyed stations, seven mangrove taxa were identified. Comparative analyses indicate regional variations in mangrove species composition across Indonesian coastal ecosystems. For instance, in Mantehage and Paniki islands, there are 8 mangrove species (Opa et al 2019). Lintong et al (2023) documented 10 mangrove species (*S. alba*, *Avicennia* spp., *Rhizophora* spp., *B. gymnorhiza*, *Xylocarpus granatum*, and *Nypa fruticans*) in the Minahasa Peninsula. In contrast, Schaduw (2018) reported only two species (*R. apiculata* and *A. marina*) in Nain Island, while Tidore et al (2021) identified three taxa (*R. apiculata*, *S. alba*, and *B. gymnorhiza*) in Budo Village. These disparities highlight site-specific environmental conditions influencing mangrove community structure. Holmes et al (2025) reported that based on contemporary ecological surveys, there were found 20 mangrove species were found in Mantehage, and 21 mangrove species were found in Likupang.

**Diversity index.** The analysis revealed notable variations in the Shannon-Wiener  $H'$  across the study sites. Station 2 exhibited the highest  $H'$  value (1.17), followed by Station 1 (0.77), and Station 3, which recorded the lowest index (0.37). All stations demonstrated low to moderate diversity levels ( $H'$  range: 0.37-1.17), consistent with Odum's (1971) classification, where values below 3 signify limited ecological complexity. Notably, Station 3's exceptionally low  $H'$  (0.37) suggested diminished species diversity and markedly reduced productivity. This metric further implied the presence of pronounced ecological stressors, potentially destabilizing the mangrove ecosystem's equilibrium. Mangrove diversity occurs naturally and is planted by the community. In Sondaken village, the *Rhizophora* species grows naturally, and the community plants a small portion. In Blongko village, *S. alba* resulted from mangrove planting through the DPL program. The number of *Rhizophora* sp. is still few because the mangrove restoration efforts have just been started by the community in Blongko village in 1999 (Kusen et al 1999). In Kapitu village, mangrove species are dominated by *S. alba* and *A. officinails*.

Differences in  $H'$  values between stations can also describe the management history of each location. Station 2, with the highest level of diversity, is a semi-natural area with minimal anthropogenic intervention, while Station 3 is a rehabilitation location with a monospecific planting pattern, which generally only involves one type of mangrove, namely *Rhizophora* sp. Single-species restoration is commonly applied because of the ease of *Rhizophora* growth, but it has ecological consequences in the form of low community complexity (Primavera & Esteban 2008). Meanwhile, Station 1 only has 3 mangrove species, apparently due to the narrowness of the mangrove area, even though the area is an MPA.

**Richness index.** The highest  $R$  was found at station 2 (0.97), while the lowest was at station 1 (0.38).  $R$  at station 3 was 0.46. Different areas and habitat conditions resulted in differences in these richness indices. This finding proved that all the observed stations had an  $R$  of less than 3.5, which was considered low. Species dominance indicates internal competition in utilizing resources and unbalanced or stressed aquatic environmental conditions. A higher  $H'$  means a lower evenness index. This condition is in line with the ecological principle described by Barange & Campos (1991), that high species dominance tends to reduce the diversity and evenness, which in turn will suppress the species richness. This indicates there are internal competitions between individuals of dominant species in utilizing resources, and indicates environmental imbalance or ecological stress that can inhibit the regeneration and growth of other species.

**Evenness index.** The evenness analysis revealed spatial heterogeneity across stations. Station 1 exhibited the highest equitability (index = 0.70), followed by Station 2 (0.60), while Station 3 displayed the lowest value (0.27). Collectively, these metrics suggest moderately to highly equitable species distribution patterns at all sites. The evenness index, a measure of abundance uniformity among taxa within a community, reflects ecological balance by quantifying how evenly individuals are distributed across species. As posited by Magurran (1988), this index serves as a critical tool for assessing community

structure, where values approaching unity denote near-uniform abundance. In contrast, values tending toward zero signal pronounced disparity. A perfectly equitable community (index = 1) implies no single species dominates, while deviations from this ideal highlight ecological dominance hierarchies. Observed variations in evenness across stations further suggest the existence of taxa with disproportionately high abundance or ecological preference, which may drive skewed abundance patterns. Such disparities in equitability are often interpreted as proxies for species dominance dynamics within ecosystems.

**Dominance index.** Station 3 had the highest D value of 0.85, while station 2 had the lowest value of 0.33. The D at station 1 was 0.50. If the D is closer to one, the community has the dominant organism; otherwise, there is no dominance hierarchy. These findings confirmed a dominant species at station 3, that is *R. apiculata*. This species grows naturally at station 3.

Analysis of the D showed significant variation in mangrove community structure in the three research locations. Station 3 recorded the highest dominance value (D = 0.85), indicating the presence of a very strong dominant species, namely *R. apiculata*. This dominance reveals an unbalanced community structure and is likely to be at low risk in terms of ecological diversity. On the other hand, Station 2, with the lowest dominance value (D = 0.33), showed a more even distribution of species and a more complex and ecologically stable community. Station 1 has a moderate level (D = 0.50), indicating specific but not extreme dominance. These results confirm that high dominance values are correlated negatively with species diversity and richness, and can be an indicator of the presence of environmental pressure or the result of monospecific rehabilitation activities.

**Correspondence analysis.** In this study, CA was applied to species density data that had been subjected to a logarithmic transformation using the formula  $\log(x+1)$  to normalize the distribution and reduce the influence of extreme values. The dataset was structured into a two-way contingency table comprising seven rows, each representing a different species, and three columns corresponding to the sampling stations. Station 1 was characterized by a slightly sandy substrate and was located in proximity to a river and nearby human settlements, which may influence ecological conditions. In contrast, Stations 2 and 3 were predominantly composed of muddy substrates. The type of substrate is a critical environmental factor that can significantly affect species distribution and growth patterns. The CA produced a total inertia value of 0.4809, reflecting the overall variance explained by the ordination. This total inertia was distributed across two primary axes: the first axis accounted for 0.3410 (70.91%) of the total variation, while the second axis contributed 0.1399 (29.09%). Combined, these two axes explained 100% of the variation captured by the model, as detailed in Table 3.

Table 3

Inertia and chi-square decomposition

Dimension	Singular value	Inertia	Chi-Square	Percentage	Cumulative percentage	Histogram
1	0.5840	0.3410	9.5483	70.91	70.9089	***** *****
2	0.3740	0.1399	3.9173	29.09	100.0000	*****
TOTAL		0.4809	13.465			

Figure 6 illustrates a dendrogram that categorizes the three sampling stations into two distinct groups based on the relative abundance patterns of the seven recorded species. The resulting classification revealed two primary clusters: Group I, which consisted solely of Blongko Station, and Group II, comprising Kapitu and Sondaken Stations. This grouping pattern appears to be associated with environmental characteristics, particularly the type of sediment and the diversity of mangrove species present at each site. Blongko village is characterized by a predominantly sandy substrate, which may influence species composition and ecological dynamics. In contrast, Kapitu and Sondaken villages share

similar environmental features, including muddy substrates, which tend to support different species assemblages compared to sandy environments.

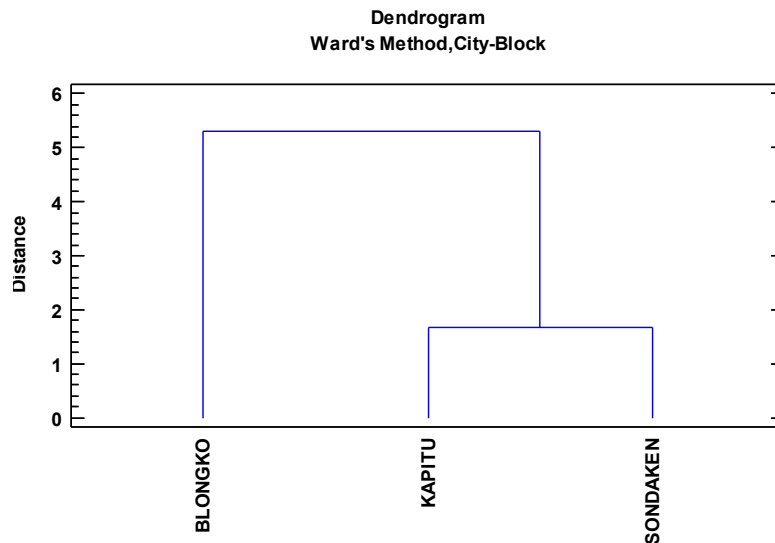


Figure 6. Cluster analysis dendrogram (stations).

In general, the classification of mangrove areas was influenced by factors such as sediment type and anthropogenic activities within the coastal communities, including the level of village accessibility and the development of ecotourism initiatives, as illustrated in Figure 7. Station 1 was formerly designated as an MPA; however, it is currently under community-based management aimed at safeguarding the site from the adverse impacts of extreme weather events. In contrast, Stations 2 and 3 have undergone a functional transformation and are now being utilized as eco-tourism destinations, reflecting the growing emphasis on the sustainable use of mangrove ecosystems for conservation and local economic development.

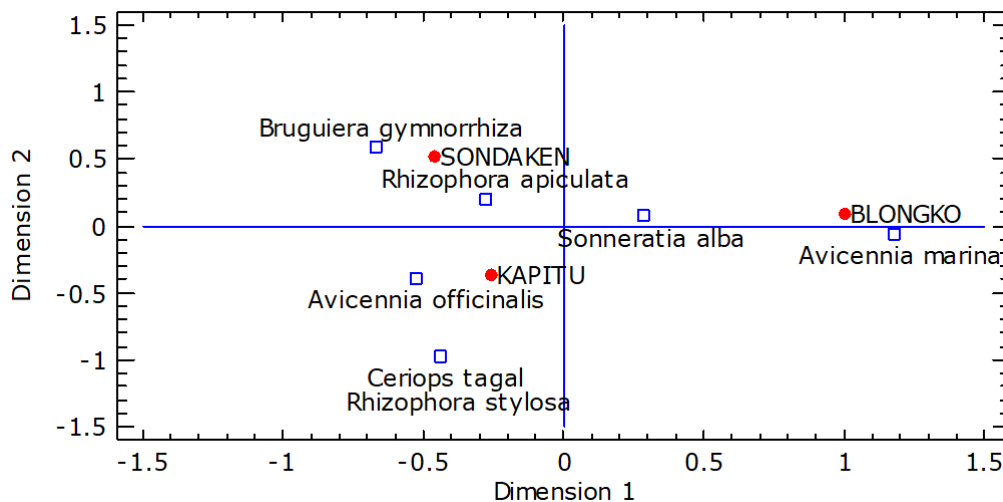


Figure 7. Map of correspondence analysis of sampling stations and mangrove species.

Figure 7 presents the results of a CA conducted on log-transformed species density data, which were organized into a two-way contingency table consisting of seven rows (representing species) and three columns (representing sampling stations). The analysis yielded a total inertia value of 0.4809, accounting for 100% of the explained variation within the data. This total was partitioned across two principal dimensions, with Dimension 1 contributing 0.3410 (equivalent to 70.91%) and Dimension 2 contributing 0.1399 (29.09%) to the overall inertia. Among the station variables analyzed, Blongko Station emerged as the most influential in shaping the structure of Dimension 1, contributing an

absolute value of 73.4%, thereby indicating its dominant role in explaining the variation along this axis. The total inertia of Kapitu was 44.6% and Sondaken was 53.8%. Having a total absolute contribution of 98.4%, these stations were most responsible for the formation of dimension 2. The species variable responsible for the formation of dimension 1 was *A. marina* with an absolute contribution of 57.9%; for dimension 2 was *B. gymnorrhiza* (26.5%), *C. tagal* (24.5%), and *R. stylosa* (24.5%) with a total absolute contribution of 75.5%. The station variable as an exclusive characteristic was Blongko (relative contribution of 99.1%) for dimension 1 and Kapitu (67.2%) and Sondaken (55.6%) for dimension 2. Species variable as an exclusive characteristic of dimension 1 was *A. marina* (99.8%) and *S. alba* (94.2%); dimension 2 was *C. tagal* and *R. stylosa* with a relative contribution of 83.3% each. The CA map (Figure 7) showed that each station had relatively different characteristics of mangrove species. Blongko station was characterized by *A. marina*, Sondaken station by *B. gymnorrhiza* and *R. apiculata*, and Kapitu station by *R. stylosa*, *C. tagal*, and *A. officinalis*. *S. alba* spread almost evenly at the three stations. The proximity of Sondaken station and Kapitu station was due to the similar distribution of *R. apiculata* and *A. officinalis*.

**Conclusions.** Seven mangrove species were identified in the three research locations, consisting of *S. alba*, *A. marina*, *A. officinalis*, *B. gymnorrhiza*, *C. tagal*, *R. apiculata*, and *R. stylosa*. The highest diversity and richness indices were found at station 2, the highest evenness index at station 1, and the highest dominance index at station 3. Correspondence analysis revealed that the *S. alba* spreads almost evenly at the three research stations.

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

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