BIODIVERSITAS
Volume 26, Number 9, September 2025
Pages: 4775-4782

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d260946

Structure and ecological dominance of mangroves in Tanah Laut, South Kalimantan, Indonesia

P. M. LESTARINA[1,2,♥], D. G. BENGEN[3], T. PRARTONO[3], M. A. RIFA'I[1], N. P. ZAMANI[3]
[1]Faculty of Fisheries and Marine, Universitas Lambung Mangkurat. Jl. A. Yani Km. 36, Banjarbaru 70714, South Kalimantan, Indonesia. Tel.: +62-511-4777247, ♥email: putri.mudhlika@ulm.ac.id
[2]Doctoral Program of Marine Science and Technology, Faculty of Fisheries and Marine Science, Institut Pertanian Bogor. Jl. Agatis Kampus IPB Dramaga, Bogor 16680, West Java, Indonesia
[3]Department of Marine Science and Technology, Faculty of Fisheries and Marine Science, Institut Pertanian Bogor. Jl. Agatis Kampus, IPB Dramaga, Bogor 16680, West Java, Indonesia

Manuscript received: 4 July 2025. Revision accepted: 29 September 2025.

Abstract. *Lestarina PM, Bengen DG, Prartono T, Rifa'I MA, Zamani NP. 2025. Structure and ecological dominance of mangroves in Tanah Laut, South Kalimantan, Indonesia. Biodiversitas 26: 4775-4782.* The Tanah Laut Region is one of the districts in South Kalimantan, Indonesia, with significant mangrove potential. However, like many other coastal areas in Indonesia, the mangrove forests in Tanah Laut face serious threats. Strategic development of effective conservation and management requires a comprehensive understanding of the structure of mangrove communities and their ecological conditions. Research on relative density and the Importance Value Index (IVI) provides invaluable quantitative tools for assessing the status of mangrove communities. Relative density provides an overview of a species' abundance relative to others within a community. This study focuses on identifying and characterizing existing mangrove species and evaluating their community structure using quantitative methods. The study was conducted at four selected sampling points in the Tanah Laut coastal area of South Kalimantan: Muara Asam-Asam, Pagatan Besar, and Bawah Layung, *Avicennia marina* (152.44% to 300 %), and Muara Kintap, *Rhizophora mucronata* (104.27% to 202.86%) have high importance value indices at nearly all locations. The number of trees found of all types at the research site. The most abundant type of mangrove tree was *A. marina* with 208 trees, followed by *R. mucronata* with 155 trees. Bawah Layung site has the highest number of unique species (S = 7) and has a (H′) of 1.670 and a (D) of 0.764. Pagata Besar came second with an H′ index of 1.413 and a (D) of 0.688. Muara Kintap and Muara Asam-Asam have only two dominant species. Their H′ index values are below 1, and their Simpson's values are below 1. This study revealed that *A. marina* and *R. mucronata* species play an important role in maintaining the stability of mangrove ecosystems in the Tanah Laut coastal area. Therefore, to support long-term ecosystem resilience, conservation and rehabilitation efforts should focus on protecting these important species and increasing community heterogeneity.

Keywords: *Avicennia marina*, IVI, mangrove, *Rhizophora mucronata*, Tanah Laut

INTRODUCTION

As an essential tropical habitat, mangroves maintain coastal ecological balance. The importance of mangroves is illustrated by their rich biodiversity, support, and direct dependence of human populations on them. The primary function of mangroves is their ability to absorb carbon, absorbing five times more carbon than other ecosystems to reduce atmospheric emissions. In addition, this ecosystem protects coastlines, provides critical habitat for species, and provides economic support for coastal communities through fisheries, forest products, and ecotourism (Suhardi et al. 2024).

As the world's largest archipelago, Indonesia contains a significant portion of the world's mangrove forests, covering approximately 23% of the global total (Jia et al. 2023; Rahman et al. 2024). While this extensive coverage places Indonesia in a strategic position for global conservation efforts, the country also faces major challenges due to human-caused pressures (Md Noor et al. 2024; Abdillah et al. 2025). The biodiversity of Indonesian mangroves is high, with families such as *Rhizophora, Avicennia, Sonneratia*, and *Bruguiera* dominating the coastal landscape (Basyuni et al. 2022; Suhardi et al. 2024). This diversity reflects both the genetic richness and the complexity of ecological interactions within these ecosystems. Each species has distinctive morphological and physiological adaptations that enable survival in environments characterized by fluctuating salinity, low soil oxygen levels, and dynamic tidal conditions (Leeuwis and Gamperl 2022).

South Kalimantan Province in Indonesia, located on the biodiversity-rich island of Borneo, features a long coastline with diverse ecosystems, including mangrove forests (Nugroho et al. 2022a). The Tanah Laut Region, one of South Kalimantan's districts, has significant mangrove potential. These forests are important not only for the local ecology but also for communities that rely on coastal resources. However, like many other coastal areas in Indonesia, the mangrove forests in Tanah Laut face serious threats. Human activities such as land conversion for agriculture and aquaculture (e.g., ponds), infrastructure development, illegal logging, and pollution have contributed to the degradation and loss of mangrove areas.

Research on relative density and Importance Value Index (IVI) serves as a valuable quantitative tool for assessing the health of mangrove communities. Relative density reflects the importance of a species compared to other species in a community. IVI combines several parameters, such as relative density, relative dominance, and relative frequency, into a single value that indicates a species' ecological importance within an ecosystem. Species with high IVI values are generally dominant and influence the structure and function of mangrove communities. This analysis enables the identification of keystone and rare species, along with their distribution patterns, which serve as indicators of the overall health of the ecosystem (Pimple et al. 2022; Ferreira et al. 2024).

Although the importance of mangrove ecosystems in South Kalimantan has been recognized, comprehensive quantitative studies on the biodiversity and importance of mangrove species in Tanah Laut remain limited. This lack of knowledge hinders effective conservation and management efforts (Nugroho et al. 2022a). Without baseline data on species composition, population structure, and the ecological role of individual species, it becomes difficult to design effective restoration programs or implement suitable protection policies (Malhi et al. 2020; Nugroho et al. 2022b). Understanding the diversity and ecological importance of mangroves in Tanah Laut is crucial for identifying priority conservation areas, guiding effective restoration efforts, and developing sustainable management strategies. The quantitative data generated from this study will provide a solid foundation to ensure this vital ecosystem continues to provide ecological and social benefits for current and future generations while contributing to both regional and national goals. This study is expected to serve as an important reference for future mangrove studies in South Kalimantan and other coastal regions of Indonesia, particularly Tanah Laut.

MATERIALS AND METHODS

Study area

This study was conducted at four selected sampling sites along the coastal area of Tanah Laut, South Kalimantan, Indonesia (Figure 1, Table 1): Muara Kintap, Muara Asam-Asam, Pagatan Besar, and Bawah Layung, each sampling location covers an area of 1,500 m^2, with 3 stations and 9 sub-stations, for a total of 12 stations and 27 sub-stations. These locations represent characteristics of mangrove ecosystems. The study was conducted in July 2024, timed to coincide with optimal tidal conditions for site access and species identification.

Procedures

Mangrove vegetation data collection

Mangrove data were collected using the line transect method. At each station, a transect was laid perpendicular to the shoreline extending inland. Three transect lines were established per station, with three 10 m x 10 m plots placed along each transect at 50-meter intervals, with a tree diameter >4 cm or trunk circumference > 16 cm measured at chest height or approximately 1.3 meters. Data were recorded in an observation table, then described and analyzed. Mangrove vegetation data includes species type and the number of individuals obtained from observations and measurements at each station, with three replicates, developed by Bengen et al. (2023).

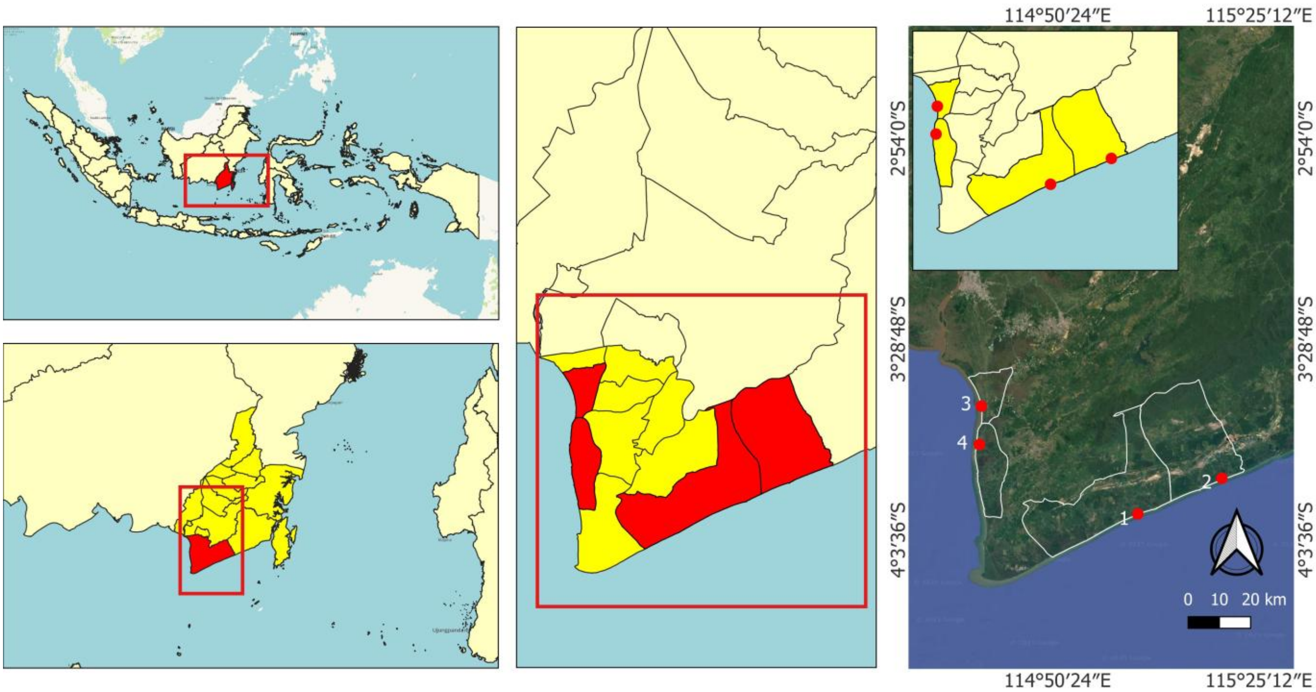

Figure 1. Location study sites along the coastal area of Tanah Laut, South Kalimantan, Indonesia. Coordinate points of sampling stations: 1. Muara Asam-Asam Village, Jorong Sub-district; 2. Muara Kintap Village, Kintap Sub-district; 3. Bawah Layung Village, Kurau Sub-district; 4. Pagatan Besar Village, Takisung Sub-district

Table 1. Geographical position of the sampling station

Station	Coordinate point	Description
Muara Asam-Asam Village, Jorong Sub-district	03°59'03.8" S, 115°04'17.21" E	It is located at the mouth of the river, where the mangroves are dominated by the species *Rhizophora apiculata,* and the substrate is muddy.
Muara Kintap Village, Kintap Sub-district	03°52'52" S, 115°18'49.29" E	It is located on the edge of the river and has a fishing port.
Bawah Layung Village, Kurau Sub-district	03°40'30" S, 114°37'30" E	It is located on the edge of the beach and river mouth. The dominant mangrove species are *Avicennia alba* and *A. marina*, and the substrate is mud.
Pagatan Besar Village, Takisung Sub-district	03°47'02" S, 114°36'54.87" E	It is located on a beach where the mangrove vegetation is directly affected by seawater. There are also crowded mangrove tours and a small pier where fishing boats anchor.

Data analysis

Importance Value Index (IVI)

IVI: RCi + RDi + RFi [1]

Description:

RCi: Measures how many individuals of a species compared to the total individuals of all species in the study area

RFi: Measures how often a species is found in sample plots compared to the total frequency of all species.

RDi: Measures how much basal area or canopy cover a species has compared to the total basal area/canopy cover of all species.

Density

K= ni / A [2]

Description:

K: Density

ni: Total number of individuals of the i-th species

A: Total area of the sample observation area

Shannon-Wiener

$$H' = -\sum_{i=1}^{s} \rho i \; In\,(\rho i) \quad [3]$$

Description:

H': Shannon-Wiener diversity index

S: Total number of species

ρi: Proportion of individuals of the i-th species

ni: Number of individuals of the i-th species

In: Natural logarithm

Simpson

$$D = \sum_{i=1}^{s} \rho^2{}_1 \quad [4]$$

Description:

D: Simpson's dominance index

S: Total number of species

ρi: Proportion of individuals of the i-th species

Species richness

This determines the number of species found at the research location.

RESULTS AND DISCUSSION

The analysis revealed variations in species dominance across stations at the Bawah Layung site (Table 2). At Station 1, *Avicennia marina* was the dominant species, with an Importance Value Index (IVI) of 177.34, reflecting its high density and canopy cover. These conditions favor the *Avicennia* genus and suggest that the zone may be a frontier area with greater tidal exposure or a dense substrate. In comparison, dominance at Station 3 shifted to *Avicennia alba* (IVI 152.73) and *Sonneratia caseolaris* (IVI 85.78), while *A. marina*'s IVI decreased significantly to 61.48. At several stations in Pagatan Besar, *A. marina* remained a prominent keystone species, although with a more balanced dominance pattern. At Station 1, *A. marina* recorded the highest IVI at 125.47, followed by *R. mucronata* at 98.72, indicating that environmental conditions are favorable for the growth of both genera. In contrast, IVI values at Station 2 were more evenly distributed among the five identified species. *Rhizophora mucronata* had the highest IVI at 81.02, only slightly above the other, indicating possible environmental heterogeneity or transitional areas that support the coexistence of multiple species. At Station 3, *A. marina* showed dominance, with an IVI of 152.44.

The Muara Kintap site exhibited a strong and consistent dominance pattern by *R. mucronata*, which recorded IVI values consistently above 190, reaching 202.86 at Station 2. This makes *R. mucronata* the most important and prominent species at the Muara Kintap site. *Avicennia marina* was also present, but with a significantly lower IVI, at approximately 100. In comparison, the Muara Asam-Asam site showed extreme dominance by the *A. marina*. At Station 1, it recorded an IVI of 233.72 and was most prominent at Station 3, achieving a perfect IVI of 300.00.

At the Bawah Layung site, *A. marina* exhibited the highest density, reaching 0.28 ind/m² (2800 ind/ha) (Table 3). *Avicennia alba* was also recorded at a significant density (0.17 ind/m² or 1700 ind/ha), indicating the dominance of the *Avicennia* genus in this area. The presence of *Sonneratia alba* and *S. caseolaris*, albeit at lower densities (0.06-0.07 ind/m²), may indicate zones with muddier, more stagnant substrates, favored by the *Sonneratia* genus. Meanwhile, the densities of *Rhizophora* species (*apiculata* and *mucronata*) were relatively low

(0.04 ind/m²). At the Pagatan Besar site, *A. marina* showed strong dominance, reaching a density of 0.32 ind/m² (3233 ind/ha), surpassing its value at Bawah Layung. This indicates highly favorable environmental conditions for the growth of *A. marina* in Pagatan Besar. *Rhizophora mucronata* was also recorded at a substantial density of 0.18 ind/m² (1,767 ind/ha), suggesting the presence of a mixed habitat that supports both genera. Other species, such as *A. alba* (0.06 indi/m²) and *S. alba* (0.04 ind/m²), were also identified, contributing to overall species diversity, albeit at lower density than the dominant species. The presence of *R. apiculata* and *Avicennia officinalis* further indicates a high species diversity in Pagatan Besar. At Muara Asam-Asam site, density patterns showed clear dominance of *A. marina*, with a density of 0.25 ind/m² (2467 individuals per ha). In comparison, *R. mucronata* was found at a much lower density of 0.03 ind/m² (333 ind/ha). Unlike Muara Asam-Asam, the Muara Kintap was significantly dominated by *R. mucronata*, recorded at 0.27 ind/m² (2667 ind/ha), while *A. marina* was present at a lower density (0.11 ind/m² or 1.133 ind/ha).

The number of mangroves found across the study sites determines the species composition of mangroves, as shown in Figure 2. The largest population size was *A. marina* with 288 individuals, followed by *R. mucronata* with 155 individuals, and *A. alba* with 70 individuals. Species with lower populations were *A. officinalis* with 32 individuals, *S. alba* with 30 individuals, *R. apiculata* with 21 individuals, and *S. caseolaris* with 20 individuals. The dominance of *A. marina* and *R. mucronata* species indicates that these two species are dominant.

Mangrove diversity in the four study sites showed quite striking differences between each area. Table 4 shows that the Bawah Layung site has the highest number of unique species (S = 7) and has a Shannon-Wiener diversity index (H′) of 1.670 and a Simpson index of 0.764. These values indicate that the community structure in the area is relatively balanced and diverse. With six different species, Pagata Besar came second with an H′ index of 1.413 and a Simpson's index of 0.688. In contrast, Muara Kintap and Muara Asam-Asam have only two dominant species, indicating low diversity. Their H′ index values are below 1, and their Simpson's values are below 1, indicating a community structure dominated by a few species. These differences suggest that environmental pressures vary and ecosystem conditions may be uneven in different places.

Table 2. Mangrove ecosystem importance index in the sampling stations

Location	Station	Species	RCi (100%)	RDi (100%)	RFi (100%)	IVI
Bawah layung	1	*Avicennia marina*	73.64	70.37	33.33	177.34
		Avicennia alba	7.13	7.41	33.33	47.87
		Sonneratia alba	19.23	22.22	33.33	74.78
	2	*Avicennnia officinais*	29.70	29.69	25.00	84.39
		Rhizophora apiculata	16.73	18.75	25.00	60.48
		Rhizophora mucronata	17.31	18.75	25.00	61.06
		Avicennia marina	36.26	32.81	25.00	94.07
	3	*Avicennia marina*	19.70	8.45	33.33	61.48
		Avicennia alba	56.02	63.38	33.33	152.73
		Sonneratia caseolaris	24.28	28.17	33.33	85.78
Pagatan Besar	1	*Avicennia marina*	50.47	50.00	25.00	125.47
		Avicennia alba	4.04	4.05	25.00	33.09
		Rhizophora mucronata	37.23	36.49	25.00	98.72
		Sonneratia alba	8.26	9.46	25.00	42.72
	2	*Avicennia marina*	23.61	24.62	20.00	68.23
		Avicennia alba	25.22	24.62	20.00	69.83
		Rhizophora mucronata	31.79	29.23	20.00	81.02
		Sonneratia alba	6.96	7.69	20.00	34.65
		Rhizophora apiculata	12.42	13.85	20.00	46.26
	3	*Avicennia marina*	54.03	65.08	33.33	152.44
		Avicennia officinalis	35.55	23.81	33.33	92.69
		Rhizophora mucronata	10.42	11.11	33.33	54.86
Muara Kintap	1	*Rhizophora mucronata*	81.25	68.75	50.00	200.00
		Avicennia marina	18.75	31.25	50.00	100.00
	2	*Rhizophora mucronata*	80.13	72.73	50.00	202.86
		Avicennia marina	19.87	27.27	50.00	97.14
	3	*Rhizophora mucronata*	73.59	69.39	50.00	192.98
		Avicennia marina	26.41	30.61	50.00	107.02
Muara Asam-Asam	1	*Rhizophora mucronata*	8.17	8.11	50.00	66.28
		Avicennia marina	91.83	91.89	50.00	233.72
	2	*Avicennia marina*	71.66	74.07	50.00	195.73
		Rhizophora mucronata	28.34	25.93	50.00	104.27
	3	*Avicennia marina*	100.00	100.00	100.00	300.00

Table 3. Mangrove tree density in each research location

Location	Species	Ind	Density (ind/m²)	Density (ind/ha)
Bawah Layung	*Avicennia marina*	84	0.28	2800
	Avicennia alba	51	0.17	1700
	Sonneratia alba	18	0.06	600
	Avicennia officinalis	19	0.06	633
	Rhizophora apiculata	12	0.04	400
	Rhizophora mucronata	12	0.04	400
	Sonneratia caseolaris	20	0.07	667
Pagatan Besar	*Avicennia marina*	97	0.32	3233
	Avicennia alba	19	0.06	633
	Rhizophora mucronata	53	0.18	1767
	Sonneratia alba	12	0.04	400
	Rhizophora apiculata	9	0.03	300
	Avicennia officinalis	14	0.05	467
Muara Asam-Asam	*Rhizophora mucronata*	10	0.03	333
	Avicennia marina	74	0.25	2467
Muara Kintap	*Rhizophora mucronata*	80	0.27	2667
	Avicennia marina	34	0.11	1133

Table 4. Species richness index and diversity index by location

Location	Species richness (S)	Shannon-Wiener (H')	Simpson (D)
Bawah Layung	7	1.670	0.764
Pagatan Besar	6	1.413	0.688
Muara Asam-Asam	2	0.365	0.210
Muara Kintap	2	0.609	0.419

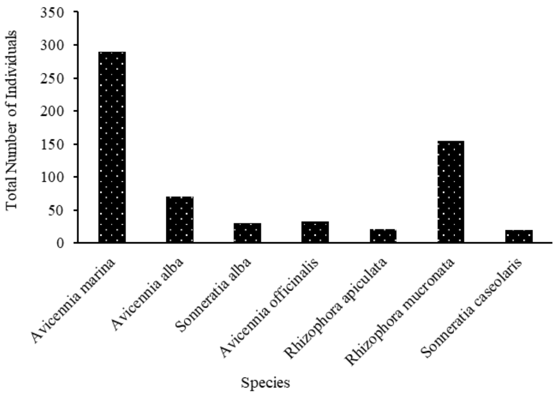

Figure 2. Mangrove species composition

Discussion

The spatial distribution and dominance of mangrove species across the four study sites (Bawah Layung, Pagatan Besar, Muara Kintap, and Muara Asam-Asam) revealed significant heterogeneity in community composition at each observation station. Importance Value Index (IVI) analysis identified *A. marina* and *R. mucronata* as the most ecologically dominant species across most of the study area (see Table 2). *Avicennia marina* reached absolute dominance with an IVI of 300.00 at Station 3 in Muara Asam-Asam. At the same time, *R. mucronata* showed strong dominance in Muara Kintap, with IVI ranging from 200.00 to 202.86. The high IVI values of these two species indicate superior ecological adaptation and strong competitive ability in utilizing local environmental resources. In contrast, *A. alba*, *S. alba*, and *R. apiculata* generally had lower IVI values, suggesting a less significant ecological role or more fragmented distribution within the studied mangrove ecosystems.

Variations in species dominance and distribution patterns can be attributed to abiotic environmental factors such as salinity, substrate characteristics, topographic elevation, tidal hydrological dynamics, and freshwater availability. These findings align with global and regional studies on mangrove distribution. In addition to environmental determinants, propagule dispersal capacity and physiological tolerance to climatic conditions are key factors influencing mangrove species distribution (Van der Stocken et al. 2019; Ferreira et al. 2024). Furthermore, studies on mangrove distribution mapping and modeling suggest that genera such as *Avicennia* and *Rhizophora* dominate more extreme or dynamic habitats, while other species are restricted to specific ecological niches (Hu et al. 2020; Martínez-Díaz and Reef 2023; Samal et al. 2023). A high IVI for one or two species at each site indicates a tendency toward monodominance, a phenomenon commonly observed in mangrove ecosystems worldwide. However, species diversity is crucial for maintaining ecosystem stability, supporting ecological function, and increasing resilience to environmental dynamics. Thus, a thorough understanding of mangrove species distribution and dominance is vital for effective conservation planning, rehabilitation programs, and sustainable coastal management.

A comprehensive tabular analysis revealed significant variability in mangrove species composition and dominance among sites and stations (Sreelekshmi et al. 2020). At the Bawah Layung site, *A. marina* was the dominant species, as indicated by the highest IVI value, followed by *A. alba* and *S. alba* (Ondiviela et al. 2014). At

Pagatan Besar, *A. marina* also dominated, although *R. mucronata* and *A. alba* were present at certain stations. In contrast, *R. mucronata* showed strong dominance at Muara Kintap, reflected in high IVI values. At Muara Asam-Asam, *A. marina* was the most dominant species, peaking at Station 3 with an IVI of 300.00. Species' dominance in a given area reflects strong ecological adaptation to local environmental conditions. *Avicennia marina*, for example, is known for its tolerance of salinity and muddy substrates; therefore, it often dominates the front zone of mangroves, which is located right next to marine waters. In contrast, *R. mucronata*, with its sturdy supporting root system, is more commonly found in the middle to back zones. These areas are more protected from waves and have relatively stable substrates (Ondiviela et al. 2014). The spatial distribution and dominance of mangrove species are strongly influenced by environmental factors, including salinity, tidal regime, substrate type, availability of freshwater, and microclimate characteristics. Global-scale studies have shown that air temperature and precipitation are the two main factors that limit the global distribution of mangroves. In some regions, minimum winter temperatures are important limiting factors, while in others, precipitation and freshwater supply play a more dominant role (Heino et al. 2009; Dodds et al. 2019).

In addition to regional climatic factors, local microhabitat characteristics such as topography, elevation relative to sea level, and substrate composition are key determinants of mangrove zonation and species composition. For instance, *A. marina* tends to dominate areas with greater tidal exposure, while *R. mucronata* is more prevalent in sheltered areas with deep mud substrates (Wong et al. 2021). These habitat preferences drive natural zonation patterns in mangrove ecosystems, where species dominate certain zones based on their ecological tolerance ranges. Beyond abiotic factors, the dispersal capacity of mangrove propagules, which are reproductive units that can float in the water column, plays a fundamental role in determining the species distribution. Global-scale studies show that ocean currents, wave intensity, and tidal rhythms significantly influence the distance and direction of mangrove propagule dispersal. Propagules of certain genera, such as *Avicennia* and *Rhizophora*, remain viable under prolonged exposure to seawater, enabling long-distance dispersal and the colonization of new habitats.

The mangrove density analysis across the four study sites (Bawah Layung, Pagatan Besar, Muara Asam-Asam, and Muara Kintap) revealed that *A. marina* and *R. mucronata* had the highest densities, as shown in Table 3. At Pagatan Besar, *A. marina* was recorded at 0.32 ind/m^2 (equivalent to 3,233 ind/ha), and *R. mucronata* at 0.18 ind/m^2 (equivalent to 1,767 ind/ha). This quantitative dominance aligns with the high Importance Value Index (IVI) values observed for these species in various mangrove ecological studies. Both species often exhibit IVI values exceeding 100%, indicating their significant ecological role in the mangrove community. The high densities of *A. marina* in Pagatan Besar and Bawah Layung, and *R. mucronata* in Muara Kintap, contributed significantly to their IVI values. These findings suggest that these species are likely the primary determinants of community structure at these sites.

According to the Shannon-Wiener index (H´ = 1.670) and Simpson index (1-D = 0.764) (Table 4), the mangrove community in Bawah Layung showed the highest diversity among the observed locations, which was not much different from Pagatan Besar, which had a Shannon-Wiener index value (H' = 1.413) and Simpson (1-D = 0.688) indices, which correlate with species richness (7 species) and (6 species) compared to the other two locations, Asam-Asam (2) and Kintap (2). At locations such as Asam-Asam and Kintap, where there are only two dominant species, this low species richness reinforces the view that the community structure is highly skewed and evenness is low. The high IVI values of *A. marina* and *R. mucronata* species found in almost all sites suggest that these two species play a dominant role in the community structure. Physiologically, these species play multiple roles in the environment, including stabilizing sediments, protecting the shoreline, and providing habitat for estuarine biota. The dominance of *A. marina* and *R. mucronata* indicates adaptation to the physical conditions of tropical waters and helps the ecosystem survive (Figure 2) (Pimple et al. 2022). Vegetation can recover after disturbances such as abrasion or human pressure because dominant species are strong and resistant to disturbance. Therefore, to ensure the long-term stability of coastal ecosystems, management of mangrove areas should consider the ecological benefits and values offered by dominant species while maintaining species diversity.

Other mangrove species, such as *A. alba*, *S. alba*, and *officinalis*, generally have lower densities, resulting in consistently low Importance Value Index (IVI) scores. Nevertheless, these species contribute to the overall diversity and structural stability of the ecosystem. This dominance pattern, where one or two core species dominate with high IVI values while others serve in complementary roles, is widely observed in various Indonesian mangrove ecosystems (Muli et al. 2021; Basyuni et al. 2022). The dominance of specific species, as reflected by high densities and IVI values, reflects their ecological functions, including carbon sequestration, coastal erosion mitigation, and the provision of essential habitats for diverse biota (Quadros et al. 2021; Pimple et al. 2022). Therefore, the high density of *A. marina* and *R. mucronata* at the study sites strongly supports their designation as keystone species in mangrove management and conservation initiatives (Akram et al. 2023; Haseeba et al. 2025). This information also provides a foundation for prioritizing local-scale mangrove restoration and protection strategies (Dabalà et al. 2023; Su and Gasparatos 2023).

The observations at the study site align with global findings indicating that the genera *Avicennia* and *Rhizophora* frequently become dominant mangrove ecosystems worldwide (Lu et al. 2022). Studies from China, India, and Latin America support these patterns, indicating that climatic factors, topographic characteristics, and interspecific interactions significantly influence mangrove species distribution and dominance (Sreelekshmi et al. 2020). Predictive studies indicate that some mangrove species, such as *R. apiculata*, will expand their habitats landward or to higher elevations in response to sea-level rise. In contrast, others may contract their distribution areas (Friess et al. 2022). Anthropogenic activities, including land conversion, pollution, and coastal development, pose substantial threats to the sustainability of mangrove ecosystems (Cahyaningsih et al. 2022; Lakhnarayan and Phillip 2024). A comprehensive understanding of the factors influencing mangrove species distribution and dominance is essential for formulating effective conservation strategies (Kumar et al. 2021; Banerjee et al. 2022). In the context of mangrove rehabilitation programs, selecting species suited to local environmental conditions is crucial for successful planting and long-term ecosystem sustainability (Lewis et al. 2019; Ellison et al. 2020). Furthermore, detailed species distribution mapping can inform the designation of priority areas for conservation and restoration and support the monitoring of ecosystem changes caused by natural disturbances and human activities (Strassburg et al. 2020; Miranda et al. 2021).

The dominance of certain species at the study site significantly impacts the economic and social benefits for local communities (Muli et al. 2021). In addition to their role in carbon sequestration, these species provide crucial habitats for diverse marine biota, which are vital to the livelihoods of local fishers. Healthy and diverse mangrove ecosystems, reflected in the high IVI values of several species, directly support fisheries productivity (Sari et al. 2023). These ecosystems also provide coastal protection against erosion and abrasion, and offer opportunities for ecotourism and other environmental services (Sujiwo and Nurlaili 2022). Furthermore, areas with substantial mangrove dominance can be incorporated into Payment for Ecosystem Services (PES) programs or carbon offset initiatives, increasing community income and encouraging active conservation participation. Therefore, data on mangrove species' distribution and dominance can be used to identify areas with high economic and social potential, enabling more effective planning and implementation of management interventions. Although certain dominant mangrove species provide substantial ecological and economic benefits, conservation policy implementation at the local level still faces multiple challenges. Land conversion pressures for aquaculture, agriculture, and infrastructure development often occur in areas with high IVI scores, reducing carbon sequestration capacity and leading to the loss of socioeconomic benefits (Sykes et al. 2020). Additionally, climate change projections indicate potential shifts in species distribution, with key species such as *R. mucronata* predicted to experience a reduction in suitable habitat. Additional challenges include low public awareness, ineffective regulation enforcement, and limited long-term monitoring data. Therefore, comprehensive data on mangrove species distribution and dominance is crucial for evidence-based conservation planning, prioritization of conservation areas, and the development of adaptive policy frameworks that integrate local community participation and account for climate change dynamics.

The distribution and dominance of mangrove species across the four study sites varied significantly, influenced by environmental factors, the species' intrinsic adaptive capacity, and interspecific interactions. *Avicennia marina* and *R. mucronata* emerged as the most dominant and adaptive species in most locations, which means that these mangrove species have better tolerance in Tanah Laut waters. This can be used as a reference for mangrove species for effective mangrove conservation in Tanah Laut. It is recommended to conduct regular population monitoring for both dominant species, at least once every six months. Pay attention to stand structure parameters such as the number of individuals, height, and diameter, as well as natural regeneration parameters such as the number of seedlings and saplings. Low-diversity areas, such as Muara Kintap and Muara Asam-Asam, can be prime targets for mixed-species planting programs. This approach will enhance community structure heterogeneity and ecosystem resilience. To maintain ecological sustainability and habitat suitability, local species with moderate IVI values, such as *S. caseolaris* or *A. alba*, should be considered when selecting additional species.

ACKNOWLEDGEMENTS

This research is fully supported financially by to Republic Indonesia Goverment, Indonesia Education Scholarship (BPI) Center for Higher Education Funding and Assesment (PPAT) Indonesia Endowmment Fund For Education (LPDP).

REFERENCES

Abdillah A, Widianingsih I, Buchari RA, Nurasa H, Rogayan D V. 2025. Community-based sustainable mangrove management for environmental resilience in Indonesia: A case from Sinjai, North Luwu, and Pangkep Regencies. In: Pal SC, Chatterjee U, Saha A, Ruidas D (eds). Climate Change: Conflict and Resilience in the Age of Anthropocene. Advances in Global Change Research, Vol 80. Springer, Cham. DOI: 10.1007/978-3-031-85359-3_12.

Akram H, Hussain S, Mazumdar P, Chua KO, Butt TE, Harikrishna JA. 2023. Mangrove health: A review of functions, threats, and challenges associated with mangrove management practices. Forests 14 (9): 1698. DOI: 10.3390/f14091698.

Banerjee AK, Feng H, Lin Y, Liang X, Wang J, Huang Y. 2022. Setting the priorities straight - Species distribution models assist to prioritize conservation targets for the mangroves. Sci Total Environ 806: 150937. DOI: 10.1016/j.scitotenv.2021.150937.

Basyuni M, Sasmito SD, Analuddin K, Ulqodry TZ, Saragi-Sasmito MF, Eddy S, Milantara N. 2022. Mangrove biodiversity, conservation and roles for livelihoods in Indonesia. In: Pullaiah DSC, Ashton EC (eds). Mangroves: Biodiversity, Livelihoods and Conservation. Springer Nature Singapore, Singapore. DOI: 10.1007/978-981-19-0519-3_16.

Bengen DG, Yonvitner Y, Rahman R. 2023. Pedoman Teknis Pengenalan dan Pengelolaan Mangrove. Cetakan Pertama. Institut Pertanian Bogor, Bogor. https://www.researchgate.net/publication/368476554. [Indonesian]

Cahyaningsih AP, Deanova AK, Pristiawati CM, Ulumuddin YI, Kusumawati L, Setyawan AD. 2022. Review: Causes and impacts of anthropogenic activities on mangrove deforestation and degradation in Indonesia. Intl J Bonorowo Wetlands 12 (1): 12-22.. DOI: 10.13057/bonorowo/w120102.

Dabalà A, Dahdouh-Guebas F, Dunn DC, Everett JD, Lovelock CE, Hanson JO, Buenafe KCV. Neubert S, Richardson AJ. 2023. Priority areas to protect mangroves and maximise ecosystem services. Nat Commun 14 (1): 5863. DOI: 10.1038/s41467-023-41333-3.

Dodds WK, Bruckerhoff L, Batzer D, Schechner A, Pennock C, Renner E, Tromboni F, Bigham K, Grieger S. 2019. The freshwater biome gradient framework: Predicting macroscale properties based on latitude, altitude, and precipitation. Ecosphere 10 (7): e02786. DOI: 10.1002/ecs2.2786.

Ellison AM, Felson AJ, Friess DA. 2020. Mangrove rehabilitation and restoration as experimental adaptive management. Front Mar Sci 7: 1-19. DOI: 10.3389/fmars.2020.00327.

Ferreira AC, Ashton EC, Ward RD, Hendy I, Lacerda LD. 2024. Mangrove biodiversity and conservation: Setting key functional groups and risks of climate-induced functional disruption. Diversity (Basel) 16 (7): 423. DOI: 10.3390/d16070423.

Friess DA, Adame MF, Adams JB, Lovelock CE. 2022. Mangrove forests under climate change in a 2°C world. WIREs Clim Change 13 (4): e792. DOI: 10.1002/wcc.792.

Haseeba KP, Aboobacker VM, Vethamony P, Al-Khayat JA. 2025. Significance of *Avicennia marina* in the Arabian Gulf environment: A review. Wetlands 45 (1): 16. DOI: 10.1007/s13157-025-01899-8.

Heino J, Virkkala R, Toivonen H. 2009. Climate change and freshwater biodiversity: detected patterns, future trends and adaptations in northern regions. Biol Rev 84 (1): 39-54. DOI: 10.1111/j.1469-185X.2008.00060.x.

Hu W, Wang Y, Zhang D, Yu W, Chen G, Xie T, Liu Z, Ma Z, Du J, Chao B, Lei G, Chen B. 2020. Mapping the potential of mangrove forest restoration based on species distribution models: A case study in China. Sci Total Environ 748: 142321. doi:10.1016/j.scitotenv.2020.142321.

Jia M, Wang Z, Mao D, Ren C, Song K, Zhao C, Wang C, Xiao X, Wang Y. 2023. Mapping global distribution of mangrove forests at 10-m resolution. Sci Bull (Beijing) 68 (12): 1306-1316. DOI: 10.1016/j.scib.2023.05.004.

Kumar A, Anju T, Archa V, Warrier VP, Kumar S, Goud GS, Kashyap AK, Singh S, Komal, Singh P. 2021. Mangrove forests. In: Sharma S, Singh P (eds). Wetlands Conservation. John Wiley & Sons Ltd, New Jersey. DOI: 10.1002/9781119692621.ch12.

Lakhnarayan KB, Phillip NBD. 2024. Impacts and implications of anthropogenic activities on mangrove forests: A review. Magna Sci Adv Res Rev 11 (1): 040-059. DOI: 10.30574/msarr.2024.11.1.0074.

Leeuwis RHJ, Gamperl AK. 2022. Adaptations and plastic phenotypic responses of marine animals to the environmental challenges of the high intertidal zone. In: Hawkins SJ, Lemasson AJ, Allcock AL, Bates AE, Byrne M, Evans AJ, Firth LB, Lucas CH, Marzinelli EM, Mumby PJ, Russell BD, Sharples J, Smith IP, Swearer SE, Todd PA (eds). Oceanography and Marine Biology: An Annual Review, Volume 60. CRC Press, Boca Raton.

Lewis RR, Brown BM, Flynn LL. 2019. Methods and criteria for successful mangrove forest rehabilitation. In: Perillo GME, Wolanski E, Cahoon DR, Hopkinson CS (eds). Coastal Wetlands: An Integrated Ecosystem Approach, 2nd Edn. Elsevier, Amsterdam. DOI: 10.1016/B978-0-444-63893-9.00024-1.

Lu W, Zou Z, Hu X, Yang S. 2022. Genetic diversity and mating system of two mangrove species (*Rhizophora apiculata* and *Avicennia marina*) in a heavily disturbed area of China. Diversity (Basel). 14 (2): 115. DOI: 10.3390/d14020115.

Malhi Y, Franklin J, Seddon N, Solan M, Turner MG, Field CB, Knowlton N. 2020. Climate change and ecosystems: Threats, opportunities and solutions. Phil Trans R Soc B: Biol Sci 375 (1794): 20190104. DOI: 10.1098/rstb.2019.0104.

Martínez-Díaz MG, Reef R. 2023. A biogeographical approach to characterizing the climatic, physical and geomorphic niche of the most widely distributed mangrove species, *Avicennia marina*. Divers Distrib 29 (1): 89-108. DOI: 10.1111/ddi.13643.

Md Noor N, Kasihmuddin SM, Mior Hazri MIN. 2024. Interplay of climate change on mercury in fish within mangrove ecosystems: A brief systematic literature review. Estuar Coast Shelf Sci 304: 108846. DOI: 10.1016/j.ecss.2024.108846.

Miranda L de S, Awade M, Jaffé R, Costa WF, Trevelin LC, Borges RC, Brito RM de, Tambosi LR, Giannini TC. 2021. Combining connectivity and species distribution modeling to define conservation and restoration priorities for multiple species: A case study in the eastern Amazon. Biol Conserv 257: 109148. DOI: 10.1016/j.biocon.2021.109148.

Muli E, Sulistyorini IS, Poedjirahajoe E, Faida LRW, Purwanto RH, Imanuddin I. 2021a. Structure and dominance of species in mangrove forest on Kutai National Park, East Kalimantan, Indonesia. J Trop For Manag 27 (1): 59-68. DOI: 10.7226/jtfm.27.1.59.

Nugroho HYSH, Basuki TM, Pramono IB et al. 2022a. Forty years of soil and water conservation policy, implementation, research and development in Indonesia: A review. Sustainability 14 (5): 2972. DOI: 10.3390/su14052972.

Nugroho HYSH, Nurfatriani F, Indrajaya Y, Yuwati TW, Ekawati S, Salminah M, Gunawan H, Subarudi S, Sallata MK, Allo MK, Muin N, Isnan W, Putri IASLP, Prayudyaningsih R, Ansari F, Siarudin M, Setiawan O, Baral H. 2022b. Mainstreaming ecosystem services from Indonesia's remaining forests. Sustainability 14 (19): 12124. DOI: 10.3390/su141912124.

Ondiviela B, Losada IJ, Lara JL, Maza M, Galván C, Bouma TJ, van Belzen J. 2014. The role of seagrasses in coastal protection in a changing climate. Coast Eng 87: 158-168. DOI: 10.1016/j.coastaleng.2013.11.005.

Pimple U, Leadprathom K, Simonetti D, Sitthi A, Peters R, Pungkul S, Pravinvongvuthi T, Dessard H, Berger U, Siri-on K, Kemacheevakul P, Gond V. 2022. Assessing mangrove species diversity, zonation and functional indicators in response to natural, regenerated, and rehabilitated succession. J Environ Manag 318: 115507. DOI: 10.1016/j.jenvman.2022.115507.

Quadros AF, Helfer V, Nordhaus I, Reuter H, Zimmer M. 2021. Functional traits of terrestrial plants in the intertidal: A review on mangrove trees. Biol Bull 241 (2): 123-139. DOI: 10.1086/716510.

Rahman, Lokollo FF, Manuputty GD, Hukubun RD, Krisye, Maryono, Wawo M, Wardiatno Y. 2024. A review on the biodiversity and conservation of mangrove ecosystems in Indonesia. Biodivers Conserv 33 (3): 875-903. DOI: 10.1007/s10531-023-02767-9.

Samal P, Srivastava J, Charles B, Singarasubramanian SR. 2023. Species distribution models to predict the potential niche shift and priority conservation areas for mangroves (*Rhizophora apiculata*, *R. mucronata*) in response to climate and sea level fluctuations along coastal India. Ecol Indic 154: 110631. DOI: 10.1016/j.ecolind.2023.110631.

Sari SP, Koedam N, Pamungkas A, Muftiadi MR, Van Coillie F. 2023. Unveiling the diversity of Bangka Island's mangroves: A baseline for effective conservation and restoration. Forests 14 (8): 1666. DOI: 10.3390/f14081666.

Sreelekshmi S, Nandan SB, Kaimal S V., Radhakrishnan CK, Suresh VR. 2020. Mangrove species diversity, stand structure and zonation pattern in relation to environmental factors — A case study at Sundarban delta, east coast of India. Reg Stud Mar Sci 35: 101111. DOI: 10.1016/j.rsma.2020.101111.

Strassburg BBN, Iribarrem A, Beyer HL et al. 2020. Global priority areas for ecosystem restoration. Nature 586 (7831): 724-729. DOI: 10.1038/s41586-020-2784-9.

Su J, Gasparatos A. 2023. Perceptions about mangrove restoration and ecosystem services to inform ecosystem-based restoration in Large Xiamen Bay, China. Landsc Urban Plan 235: 104763. DOI: 10.1016/j.landurbplan.2023.104763.

Suhardi RM, Rahardi W, Shih H-C, Mantiquilla JA, Wu Y-H, Shiao M-S, Chiang Y-C. 2024. A review of the mangrove ecosystem in Indonesia: Biodiversity, conservation, and challenges in sustainable management. Ecol Genet Genom 32: 100282. DOI: 10.1016/j.egg.2024.100282.

Sujiwo AS, Nurlaili N. 2022. Evaluation of ecosystem services and mangrove management based on the blue economy approach of Untung Jawa Island. Jurnal Mandiri: Ilmu Pengetahuan, Seni, dan Teknologi 6 (2): 116-136. DOI: 10.33753/mandiri.v6i2.218.

Sykes AJ, Macleod M, Eory V, Rees RM, Payen F, Myrgiotis V, Williams M, Sohi S, Hillier J, Moran D, Manning DAC, Goglio P, Seghetta M, Williams A, Harris J, Dondini M, Walton J, House J, Smith P. 2020. Characterising the biophysical, economic and social impacts of soil carbon sequestration as a greenhouse gas removal technology. Glob Chang Biol 26 (3): 1085-1108. DOI: 10.1111/gcb.14844.

Van der Stocken T, Wee AKS, De Ryck DJR, Vanschoenwinkel B, Friess DA, Dahdouh-Guebas F, Simard M, Koedam N, Webb EL. 2019. A general framework for propagule dispersal in mangroves. Biol Rev 94 (4): 1547-1575. DOI: 10.1111/brv.12514.

Wong YY, Foong SY, Wang Y, Dai L, Mao L, Goh TL. 2021. Spatiotemporal dispersal study of mangrove *Avicennia marina* and *Rhizophora apiculata* propagules. Sains Malays 51 (8): 2351-2364. DOI: 10.17576/jsm-2022-5108-02.