Journal of Aquatic Biology & Fisheries Egyptian
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 29(4): 2037 – 2052 (2025)
www.ejabf.journals.ekb.eg

Mangrove Ecosystem Vegetation on the Coast of the Makassar Strait, Indonesia

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ARTICLE INFO

Article History:
Received: May 30, 2025
Accepted: July 17, 2025
Online: July 31, 2025

Keywords:
R. stylosa,
Mangrove,
Density,
Majene,
Blue economy

ABSTRACT

The mangrove forest ecosystem is a vital habitat for marine organisms and holds significant economic potential. This article aimed to assess the condition of mangrove ecosystem vegetation along the Makassar Strait Coast. The findings of this study would serve as a foundation for future research and ecosystem management efforts. The data analyzed include species composition and vegetation structure within the mangrove ecosystem. The analytical methods used consist of calculations for species density (Di), relative density (RDi), species frequency (Fi), relative frequency (RFi), species dominance (Ci), relative dominance (RCi), and the Importance Value Index (INP). The results identified 19 mangrove species across 12 families, with the Rhizophoraceae family being the most dominant, represented by six species. The highest vegetation density was recorded for *Rhizophora stylosa* in Majene, with 2,169 individuals per hectare. The corresponding ecological indices were: Di = 21.69, RDi = 26.75, Fi = 1.0, RFi = 13.51, Ci = 374,566.96, RCi = 41.26, and INP = 101.00. This level of density falls into the "good" category based on standard vegetation assessment criteria. The outcomes of this study can serve as a valuable reference for formulating a sustainable development model for mangrove ecosystems, particularly one aligned with the principles of the blue economy on the Makassar Strait Coast.

INTRODUCTION

Mangrove forests are often referred to as such because species of the Rhizophoraceae family typically dominate these ecosystems. Common species within this family include *Rhizophora mucronata* Lamk., *R. apiculata* Bl., and *R. stylosa* Griff. Other frequently found species include *Bruguiera gymnorrhiza* (L.) Lamk., *Ceriops tagal* (Perr.) C.B.

Robinson, *C. decandra* (Griff.) Ding Hou, among others. Several mangrove plant species inhabit specific types of habitat **(Soerianegara & Indrawan, 1988)**.

In muddy habitats, species such as *R. mucronata*, *R. apiculata*, *Avicennia marina* (Forsk.) Vierh., *A. alba* Blume, *B. gymnorrhiza*, *C. tagal*, and *Acanthus ilicifolius* (L.) Lamk. are typically found. In contrast, coral and sandy coral habitats are often inhabited by *Sonneratia alba* (L.) Blanco. In drier habitats, species such as *Lumnitzera racemosa* Willd., *Xylocarpus moluccensis* (Lam.) M. Roem., *Aegiceras corniculatum* (L.) Blanco, and *Heritiera littoralis* Dryand. in Aiton are more commonly present. This ecological differentiation reflects a phenomenon known as mangrove zonation.

Zonation refers to the spatial arrangement of plant communities with similar or differing characteristics that occur along environmental gradients. These vegetation zones may exhibit distinct or overlapping boundaries, depending on environmental variations that influence plant distribution **(Anwar *et al*., 1984)**.

Mangrove forests typically develop landward zonation patterns **(Bengen, 2004)**. In Indonesia, a typical zonation begins with *Avicennia* spp. in the outermost zone, often growing on sandy substrates, usually alongside *Sonneratia* spp. This is followed by a zone dominated by *Rhizophora* spp. and *Bruguiera* spp., while the transition zone between land and sea is frequently inhabited by *Nypa fruticans*. The primary factors influencing zonation include soil properties, salinity, tidal inundation frequency, and species-specific resistance to waves and currents **(Anwar *et al*., 1984)**.

This zonation structure is not only ecologically significant but also offers economic value to communities living near mangrove ecosystems. The diversity of mangrove vegetation provides nutrients and forms a secure, resource-rich habitat for various fauna that depend on these ecosystems for survival.

However, the structure of mangrove vegetation is susceptible to change. Alterations in physical and ecological functions—often driven by human activities—can significantly impact mangrove composition and distribution. According to **Setyawan *et al*. (2020)**, activities such as land drying, construction of irrigation canals, use of fertilizers in aquaculture, and other anthropogenic pressures can lead to degradation of mangrove habitats.

The Makassar Strait Coast holds a significant expanse of mangrove forest. As of 2017, the mangrove area in South Sulawesi Province was recorded at approximately 214,000 hectares, while West Sulawesi Province had about 691,561.52 hectares **(jagalaut.id, 2023)**. Given ongoing anthropogenic activities, these figures are likely to have changed.

Based on these concerns, the authors are motivated to conduct research on "Mangrove Ecosystem Vegetation on the Coast of the Makassar Strait." This study aimed to assess the current condition of mangrove vegetation in the region, with a focus on its ecological structure, zonation patterns, and vulnerability to environmental and human-induced changes.

MATERIALS AND METHODS

1. Study area and sampling

This research examined the condition of mangrove ecosystem vegetation along the Makassar Strait Coast, focusing on two provinces: South Sulawesi and West Sulawesi. The selection of study sites within each province was based on the ratio between the largest and smallest recorded mangrove areas. In South Sulawesi Province, sampling was conducted in Takalar Regency, which has a mangrove area of 7,579 ha, and Pare-pare City, with a significantly smaller mangrove area of 0.035 ha. In West Sulawesi Province, sampling locations included Mamuju Regency with 166,325 ha of mangrove area, and Majene Regency, which has 0.58 ha. These contrasting site selections were used to represent the range of mangrove ecosystem conditions across the coastal regions of the Makassar Strait (Fig. 1).

2. Data collection

The data used in this study were obtained through direct field observations, focusing on the presence and distribution of mangrove vegetation. Observations were conducted using the transect plot method, also known as the "plot count method", as described by **Mueller-Dombois and Ellenberg (1974)**. According to **Rusdi *et al*. (2019)**, this method involves laying a transect line perpendicular to the coastline and extending inland into the mangrove area.

Along each transect, nested measurement plots were established according to plant size classes. These included:

- 1 × 1 m^2 plots for seedlings (stem diameter < 2 cm),
- 5 × 5 m^2 plots for saplings or stakes (stem diameter 2–10 cm), and
- 10 × 10 m^2 plots for mature trees (stem diameter ≥ 10 cm) (Fig. 2).

This hierarchical plot system allows for detailed vegetation analysis across all growth stages of mangrove species.

Mangrove vegetation data processing is as follows:

a) Density of species (Di)

Density of species (Di) is the number of stands of species i in a unit area. Di was calculated using the following formula:

$$Di = \frac{Ni}{A}$$

Where:

Di = Density of species I

Ni = Total number of stands of species I

A = Total area of sampling area (m^2)

b) Relative density (RDi)

Relative density (RDi) is the ratio of the density of the i-th species to the total density of all species. RDi was calculated using the following formula:

$$RDi = \frac{Di}{\sum Di} \times 100\%$$

Description:

RDi = Relative density

Di = Density of the i-th species

∑Di = Total density of all species

c) Species frequency (Fi)

Species frequency (Fi) is the probability of finding a species i in all sample plots compared to the total number of sample plots created. The Fi value was calculated using the formula:

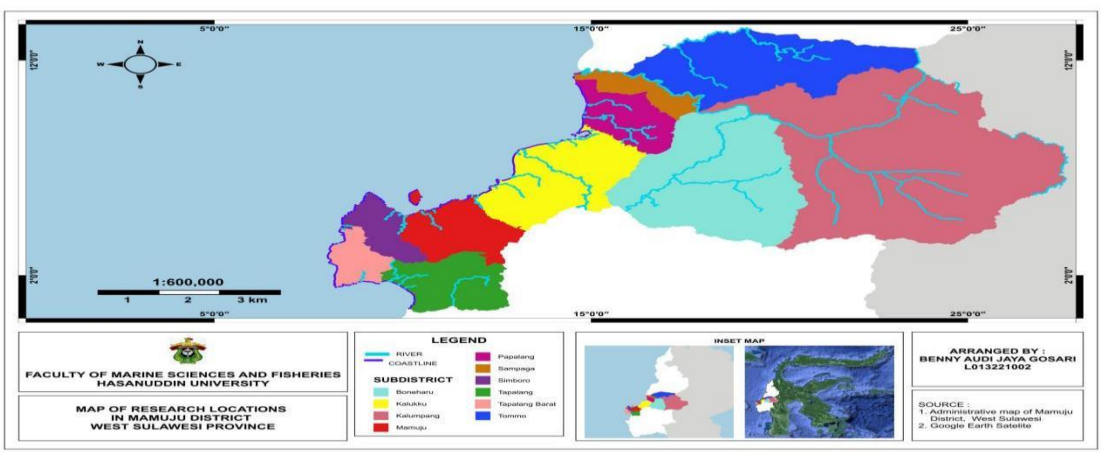
$$Fi = \frac{Pi}{\sum Pi}$$

Where:

Fi = Frequency of the i-th species

Pi = Number of sample plots where the i-th species was found

∑Pi = Total number of plots observed



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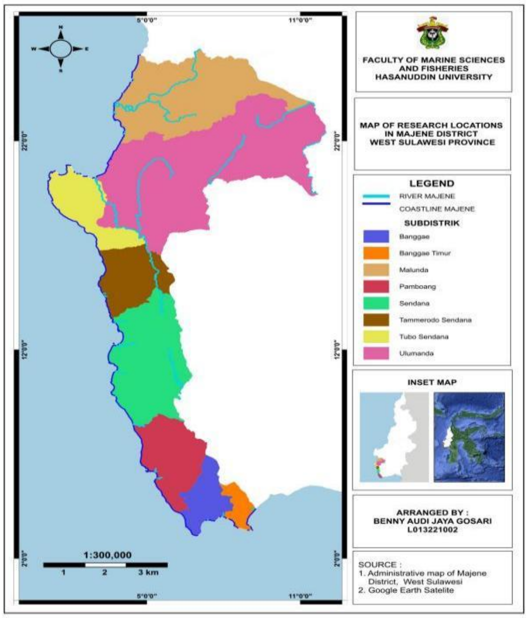

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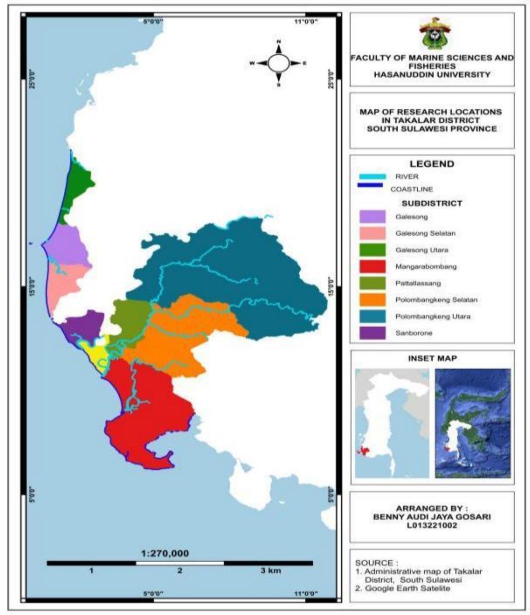

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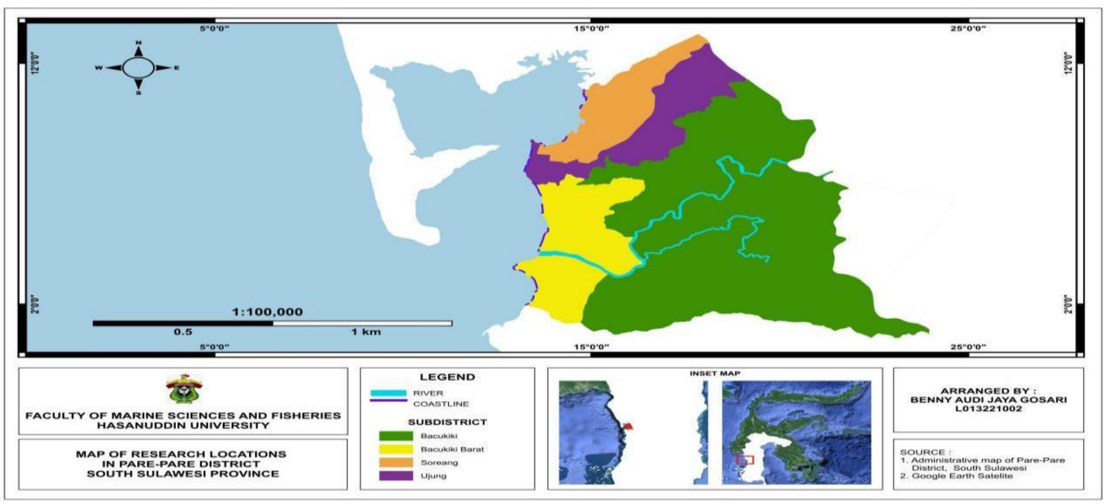

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Fig. 1. Research location: **A.** Mamuju, **B.** Majene, **C.** Takalar and **D.** Pare-pare

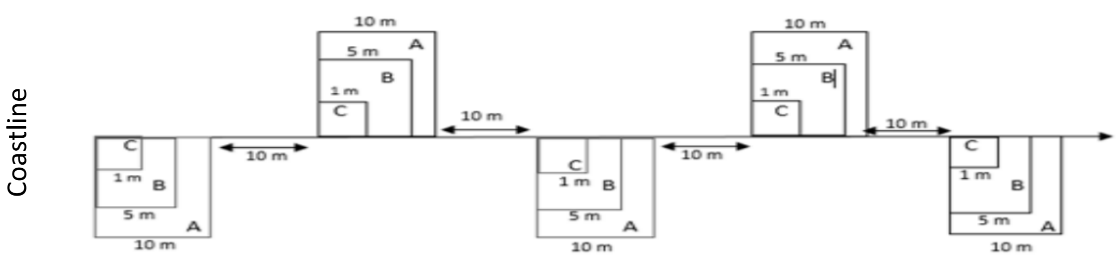

Fig. 2. Plot framework for measuring mangrove density in research locations **(Mueller-Dumbois & Ellenberg, 1974)**. Description: A: Tree plot, size 10 x 10 m^2, B: Sapling plot, size 5 x 5 m^2, C: Seedling plot, size 1 x 1 m^2

d) Relative frequency (RFi)

Relative frequency (RFi) is the ratio of the frequency of the i-th species to the sum of the frequencies of all species. The RFi was calculated using the following formula:

$$RFi = \frac{Fi}{\sum Fi} \times 100\%$$

Where:

RFi = Relative frequency of species

Fi = Frequency of the i-th species

∑Fi = Sum of frequencies for all species

e) Species dominance (Ci)

Species dominance is the area of coverage of the i-th species in a certain area unit. The Ci value was calculated using the following formula:

$$Ci = \frac{\sum B\ A}{A}$$

Where:

Ci = Species dominance

∑B A = $\pi d^2/4$ (d=stem diameter at breast height, π=3.14)

A = Area of the sampled area (1 m^2)

f) Relative dominance (RCi)

Relative dominance (RCi) is the comparison of the cover of the i-th species with the total cover area for all species. The RCi value was calculated using the following formula:

$$RCi = \frac{Ci}{\sum Ci}$$

Where:

RCi = Relative cover

Ci = Cover of the i-th species

∑Ci = Total number for all species

g) Important value index (INP)

Through the important value index value, the condition or characteristics of a mangrove ecosystem can be estimated. The important value index was obtained using the following formula:

INP = RCi + RDi + RFi

Description:

INP = Important value index
RCi = Relative cover
RDi = Relative density
RFi = Relative frequency of species

Vegetation analysis is a method used to study the species composition and structural characteristics of vegetation within an ecosystem **(Soerianegara & Indrawan, 1998)**. This analysis is essential for evaluating key ecological parameters, including species density (Di), relative density (RDi), species frequency (Fi), relative frequency (RFi), species dominance (Ci), relative dominance (RCi), and the Importance Value Index (INP) **(Mueller-Dombois & Ellenberg, 1974)**.

In addition, the assessment of mangrove ecosystem health—specifically damage levels—is conducted based on the guidelines provided in the Decree of the Minister of State for the Environment No. 201 of 2004, which outlines standard criteria and guidelines for determining mangrove degradation. These criteria are summarized in Table (1).

Table 1. Criteria for assessing mangrove vegetation

No.	Criterion	Cover	Density (trees/ha)
1	Good	≥75	≥1500
2	Moderate	≥50 - <75	≥1000 - <1500
3	Damaged	<50	< 1000

RESULTS

Nineteen mangrove species from 12 families were found at the study sites (Table 2). The Rhizophoraceae family was the dominant family identified, comprising six mangrove species. Among them, *Rhizophora stylosa* and *Rhizophora mucronata* were consistently found at each study site. *Ceriops decandra*, however, was only observed in Takalar Regency, indicating its more localized distribution. In the Arecaceae family, only a single species—*Nypa fruticans*—was recorded, but it was present at all study sites, highlighting its widespread occurrence across the Makassar Strait Coast.

Table 2. The presence of mangrove species in each research location

Family	Type of Mangrove	Distribution			
		Pare-pare	Takalar	Majene	Mamuju
Rhizophoraceae	*Bruguiera gymnorrhiza*	-	+	+	+
	Ceriops tagal	+	+	+	-
	C. decandra	-	+	-	-
	Rhizophora stylosa	+	+	+	+
	R. apiculate	-	+	+	+
	R. mucronate	+	+	+	+
Sonneratiaceae	*Sonneratia alba*	-	+	+	+
	S. caseolaris	-	-	+	+
Lythraceae	*Phempis acidula*	-	+	-	-
Combretaceae	*Lumnitzera racemose*	-	+	-	-
Avicenniaceae	*Avicennia alba*	+	+	+	+
	A. marina	-	-	+	+
Arecaceae	*Nypa fruticans*	+	+	+	+
Bombacaceae	*Camtostemon philippinense*	-	-	+	-
Primulaceae	*Aegiceras corniculatum*	-	-	+	-
Goodeniaceae	*Scaevola taccada*	-	-	+	-
Acanthaceae	*Acanthus ilicifolius*	-	-	+	-
Meliaceae	*Xyllocarpus granatum*	-	+	-	-
Euphorbiaceae	*Exocoecaria agallocha*	-	+	-	-

Description: found(+); not found(-). Primary data processed 2024.

Table 3. Analysis of mangrove vegetation in Pare-pare

Type of Mangrove	N	Di	RDi	Fi	RFi	Ci	RCi
Tree Strata							
C. tagal	21	0.21	1.50	0.2	9.09	35.11	0.08
R. stylosa	540	5.40	38.54	0.8	36.36	23216.56	54.14
R. mucronate	360	3.60	25.70	0.4	18.18	10318.47	24.06
A. alba	210	2.10	14.99	0.4	18.18	3511.15	8.19
N. fruticans	270	2.70	19.27	0.4	18.18	5804.14	13.53
Subsidiary Strata							
R. stylosa	120	4.80	48.00	0.6	37.50	1146.50	70.24
R. mucronate	30	1.20	12.00	0.2	12.50	71.66	4.39
A. alba	60	2.40	24.00	0.4	25.00	286.62	17.56
N. fruticans	40	1.60	16.00	0.4	25.00	127.39	7.80
Seedling Strata							
R. stylosa	93	93.00	64.14	0.6	50.00	688.61	89.62
R. mucronate	16	16.00	11.03	0.2	16.67	20.38	2.65
A. alba	25	25.00	17.24	0.2	16.67	49.76	6.48
N. fruticans	11	11.00	7.59	0.2	16.67	9.63	1.25

Description: Primary data processed 2024.

Table 4. Analysis of mangrove vegetation in Takalar

Type of Mangrove	N	Di	RDi	Fi	RFi	Ci	RCi
Tree Strata							
B. gymnorrhiza	30	0.30	0.60	0.2	3.70	71.66	0.02
C. tagal	70	0.70	1.41	0.4	7.41	390.13	0.11
C. decandra	210	2.10	4.23	0.4	7.41	3511.15	0.96
R. stylosa	1430	14.30	28.80	1.0	18.52	162810.51	44.59
R. apiculate	180	1.80	3.63	0.2	3.70	2579.62	0.71
R. mucronate	540	5.40	10.88	0.6	11.11	23216.56	6.36
S. alba	160	1.60	3.22	0.4	7.41	2038.22	0.56
P. acidula	89	0.89	1.79	0.2	3.70	630.65	0.17
L. racemose	126	1.26	2.54	0.2	3.70	1264.01	0.35
A. alba	1260	12.60	25.38	0.8	14.81	126401.27	34.62
N. fruticans	720	7.20	14.50	0.6	11.11	41273.89	11.30
X. granatum	90	0.90	1.81	0.2	3.70	644.90	0.18
E. agallocha	60	0.60	1.21	0.2	3.70	286.62	0.08
Subsidiary Strata							
C. tagal	20	0.80	2.02	0.4	8.33	31.85	0.18
C. decandra	70	2.80	7.07	0.4	8.33	390.13	2.21
R. stylosa	360	14.40	36.36	0.8	16.67	10318.47	58.56
R. apiculate	10	0.40	1.01	0.2	4.17	7.96	0.05
R. mucronate	60	2.40	6.06	0.4	8.33	286.62	1.63
S. alba	20	0.80	2.02	0.2	4.17	31.85	0.18
P. acidula	10	0.40	1.01	0.2	4.17	7.96	0.05
L. racemose	20	0.80	2.02	0.2	4.17	31.85	0.18
A. alba	270	10.80	27.27	0.8	16.67	5804.14	32.94
N. fruticans	70	2.80	7.07	0.6	12.50	390.13	2.21
X. granatum	20	0.80	2.02	0.2	4.17	31.85	0.18
E. agallocha	60	2.40	6.06	0.4	8.33	286.62	1.63
Seedling Strata							
C. tagal	22	22.00	2.86	0.2	4.76	38.54	0.39
C. decandra	77	77.00	10.03	0.4	9.52	472.05	4.72
R. stylosa	279	279.00	36.33	0.6	14.29	6197.53	61.99
R. apiculate	14	14.00	1.82	0.2	4.76	15.61	0.16
R. mucronate	45	45.00	5.86	0.4	9.52	161.23	1.61
S. alba	26	26.00	3.39	0.2	4.76	53.82	0.54
P. acidula	17	17.00	2.21	0.2	4.76	23.01	0.23
L. racemose	23	23.00	2.99	0.2	4.76	42.12	0.42
A. alba	186	186.00	24.22	0.8	19.05	2754.46	27.55
N. fruticans	47	47.00	6.12	0.4	9.52	175.88	1.76
X. granatum	28	28.00	3.65	0.2	4.76	62.42	0.62
E. agallocha	4	4.00	0.52	0.4	9.52	1.27	0.01

Description: Primary data processed 2024.

Table 5. Analysis of mangrove vegetation in Majene

Type of Mangrove	N	Di	RDi	Fi	RFi	Ci	RCi
Tree Strata							
B. gymnorrhiza	240	2.40	2.96	0.6	8.11	4585.99	0.51
C. tagal	120	1.20	1.48	0.4	5.41	1146.50	0.13
R. stylosa	2169	21.69	26.75	1.0	13.51	374566.96	41.26
R. apiculate	270	2.70	3.33	0.4	5.41	5804.14	0.64
R. mucronate	720	7.20	8.89	0.8	10.81	41273.89	4.55
S. alba	210	2.10	2.59	0.6	8.11	3511.15	0.39
S. caseolaris	90	0.90	1.11	0.2	2.70	644.90	0.07
A. alba	1980	19.80	24.42	1.0	13.51	312133.76	34.39
A. marina	810	8.10	9.99	0.6	8.11	52237.26	5.75
N. fruticans	1170	11.70	14.43	1.0	13.51	108988.85	12.01
C.philippinense	70	0.70	0.86	0.2	2.70	390.13	0.04
A. corniculatum	60	0.60	0.74	0.2	2.70	286.62	0.03
S. taccada	40	0.40	0.49	0.2	2.70	127.39	0.01
A. ilicifolius	160	1.60	1.97	0.2	2.70	2038.22	0.22
Subsidiary Strata							
B. gymnorrhiza	40	1.60	2.17	0.4	5.88	127.39	0.21
C. tagal	60	2.00	2.72	0.4	5.88	199.04	0.33
R. stylosa	630	25.20	34.24	1.0	14.71	31600.32	52.06
R. apiculate	30	1.20	1.63	0.4	5.88	71.66	0.12
R. mucronate	90	3.60	4.89	0.8	11.76	644.90	1.06
S. alba	30	1.20	1.63	0.2	2.94	71.66	0.12
S. caseolaris	20	0.80	1.09	0.2	2.94	31.85	0.05
A. alba	540	21.60	29.35	1.0	14.71	23216.56	38.25
A. marina	180	7.20	9.78	0.6	8.82	2579.62	4.25
N. fruticans	160	6.40	8.70	1.0	14.71	2038.22	3.36
C. philippinense	20	0.80	1.09	0.2	2.94	31.85	0.05
A. corniculatum	10	0.40	0.54	0.2	2.94	7.96	0.01
S. taccada	10	0.40	0.54	0.2	2.94	7.96	0.01
A. ilicifolius	30	1.20	1.63	0.2	2.94	71.66	0.12
Seedling Strata							
B. gymnorrhiza	11	11.00	0.79	0.2	3.13	9.63	0.02
C. tagal	55	55.00	3.93	0.4	6.25	240.84	0.59
R. stylosa	594	594.00	42.40	1.0	15.63	28092.04	69.11
R. apiculate	27	27.00	1.93	0.4	6.25	58.04	0.14
R. mucronate	63	63.00	4.50	0.6	9.38	316.00	0.78
S. alba	39	39.00	2.78	0.2	3.13	121.10	0.2\30
S. caseolaris	26	26.00	1.86	0.2	3.13	53.82	0.13
A. alba	369	369.00	26.34	1.0	15.63	10840.84	26.67
A. marina	81	81.00	5.78	0.6	9.38	522.37	1.29
N. fruticans	57	57.00	4.07	1.0	15.63	258.68	0.64
C. philippinense	24	24.00	1.71	0.2	3.13	45.86	0.11
A. corniculatum	12	12.00	0.86	0.2	3.13	11.46	0.03
S. taccada	16	16.00	1.14	0.2	3.13	20.38	0.05
A. ilicifolius	27	27.00	1.93	0.2	3.13	58.042	0.14

Description: Primary data processed 2024

Table 6. Analysis of mangrove vegetation in Mamuju

Type of Mangrove	N	Di	RDi	Fi	RFi	Ci	RCi
Tree Strata							
B. gymnorrhiza	160	1.60	2.49	0.4	8.33	2038.22	0.32
R. stylosa	1890	18.90	29.39	1.0	20.83	284402.87	43.97
R. apiculate	240	2.40	3.73	0.2	4.17	4585.99	0.71
R. mucronate	630	6.30	9.80	0.6	12.50	31600.32	4.89
S. alba	180	1.80	2.80	0.4	8.33	2579.62	0.40
S. caseolaris	40	0.40	0.62	0.2	4.17	127.39	0.02
A. alba	1620	16.20	25.19	0.8	16.67	208949.04	32.31
A. marina	740	7.40	11.51	0.4	8.33	43598.73	6.74
N. fruticans	930	9.30	14.46	0.8	16.67	68861.46	10.65
Subsidiary Strata							
B. gymnorrhiza	20	0.80	1.61	0.2	4.76	31.85	0.10
R. stylosa	460	18.40	37.10	0.8	19.05	16847.13	50.82
R. apiculate	20	0.80	1.61	0.2	4.76	31.85	0.10
R. mucronate	80	3.20	6.45	0.6	14.29	509.55	1.54
S. alba	30	1.20	2.42	0.2	4.76	71.66	0.22
S. caseolaris	10	0.40	0.81	0.2	4.76	7.96	0.02
A. alba	420	16.80	33.87	0.8	19.05	14044.59	42.36
A. marina	110	4.40	8.87	0.4	9.52	963.38	2.91
N. fruticans	90	3.60	2.26	0.8	19.05	644.90	1.95
Seedling Strata							
R. stylosa	342	342.00	40.62	0.8	23.53	9312.42	57.52
R. apiculate	18	18.00	2.14	0.2	5.88	25.80	0.16
R. mucronate	72	72.00	8.55	0.6	17.65	412.74	2.55
S. alba	36	36.00	4.28	0.2	5.88	103.18	0.64
S. caseolaris	12	12.00	1.43	0.2	5.88	11.46	0.07
A. alba	275	275.00	32.66	0.8	23.53	6021.10	37.19
A. marina	48	48.00	5.70	0.4	11.76	183.44	1.13
N. fruticans	39	39.00	4.63	0.2	5.88	121.10	0.75

Description: Primary data processed 2024.

Table 7. Important value index (IVI) of mangrove vegetation tree strata in each research location

Type of Mangrove	Important Value Index (IVI)			
	Pare-pare	Takalar	Majene	Mamuju
B. gymnorrhiza	-	4.33	11.58	11.14
C. tagal	10.59	8.93	7.01	-
C. decandra	-	12.61	-	-
R. stylosa	129.08	92.03	81.24	94.20
R. apiculate	-	8.05	9.38	8.61
R. mucronate	67.96	28.38	24.26	27.18
S. alba	-	11.20	11.09	11.53
S. caseolaris	-	-	3.89	4.81
P. acidula	-	5.46	-	-
L. racemose	-	6.44	-	-
A. alba	41.37	74.91	72.46	74.17
A. marina	-	-	23.88	26.58
N. fruticans	51.00	36.97	40.01	41.78
C. philippinense	-	-	3.61	-
A. corniculatum	-	-	3.48	-
S. taccada	-	-	3.21	-
A. ilicifolius	-	-	4.90	-
X. granatum	-	5.70	-	-
E. agallocha	-	4.99	-	-

Description: Primary data processed 2024

Table 8. Important value index (IVI) of mangrove vegetation Subsidiary strata in each research location

Type of Mangrove	Important Value Index (IVI)			
	Pare-pare	Takalar	Majene	Mamuju
B. gymnorrhiza	-	-	8.27	6.47
C. tagal	-	10.53	8.93	-
C. decandra	-	17.62	-	-
R. stylosa	155.74	111.59	101.00	106.96
R. apiculate	-	5.22	7.63	6.47
R. mucronate	28.89	16.02	17.72	22.27
S. alba	-	6.37	4.69	7.40
S. caseolaris	-	-	4.08	5.59
P. acidula	-	5.22	-	-
L. racemose	-	6.37	-	-
A. alba	66.56	76.88	82.30	95.28
A. marina	-	-	22.86	21.30
N. fruticans	48.80	21.78	26.76	28.25
C. philippinense	-	-	4.08	-

A. corniculatum	-	-	3.50	-
S. taccada	-	-	3.50	-
A. ilicifolius	-	-	4.69	-
X. granatum	-	6.37	-	-
E. agallocha	-	16.02	-	-

Description: Primary data processed 2024.

Table 9. Important value index (IVI) of mangrove vegetation Seedling strata in each research location

Type of Mangrove	Important Value Index (IVI)			
	Pare-pare	Takalar	Majene	Mamuju
B. gymnorrhiza	-	-	3.93	-
C. tagal	-	7.81	10.77	-
C. decandra	-	23.18	-	-
R. stylosa	212.33	113.119	127.13	121.66
R. apiculate	-	6.20	8.32	8.18
R. mucronate	25.51	16.30	14.65	28.75
S. alba	-	7.81	6.21	10.80
S. caseolaris	-	-	5.11	7.38
P. acidula	-	6.20	-	-
L. racemose	-	7.81	-	-
A. alba	36.65	71.11	68.63	93.38
A. marina	-	-	16.44	18.60
N. fruticans	25.51	16.30	20.33	11.26
C. philippinense	-	-	4.95	-
A. corniculatum	-	-	4.01	-
S. taccada	-	-	4.32	-
A. ilicifolius	-	-	5.19	-
X. granatum	-	7.81	-	-
E. agallocha	-	16.30	-	-

Description: Primary data processed 2024.

DISCUSSION

Majene had the highest species richness, with 14 mangrove species recorded (Table 2), while Pare-pare had the lowest, with only five species. Four species—*Rhizophora stylosa*, *Rhizophora mucronata*, *Avicennia alba*, and *Nypa fruticans*—were observed at all study sites, indicating their broad ecological tolerance and adaptability to various coastal environments.

Several uncommon species, such as *Ceriops philippinense*, *Aegiceras corniculatum*, *Scaevola taccada*, and *Acanthus ilicifolius*, were found exclusively in Majene. This suggests that Majene may serve as a critical habitat for the conservation of less common mangrove species. Mangrove species richness is influenced by factors such as tidal range, salinity, and anthropogenic disturbance **(Kartika *et al*., 2020; Fatmasari *et al*., 2021)**. A high diversity of mangrove species typically reflects a well-functioning and resilient ecosystem **(Setyawan *et al*., 2020; Sari *et al*., 2022)**.

Mangrove vegetation is commonly assessed through indicators such as density and canopy cover. These evaluations follow criteria outlined in the Decree of the Minister of Environment (KLHK) No. 201 of 2004, which establishes standards for evaluating mangrove conditions (Table 1). Tree-level assessments showed that *R. stylosa* was the most abundant species across all study sites, with the highest recorded density of 2,169 trees per hectare in Majene (Table 5). This species consistently exceeded the good condition threshold of ≥1,500 trees per hectare (Tables 3–6), and its canopy coverage was classified as "good" (≥75%) based on Ministry of Environment criteria.

The prevalence of *R. stylosa* is likely related to favorable environmental conditions. In the study areas, *R. stylosa* was typically found growing on sandy mud substrates. This finding aligns with **Saru *et al*. (2007)**, who reported that *R. stylosa* thrives in sandy mud environments. *A. alba* was also observed growing in similar conditions and was often found in association with *R. stylosa* and occasionally with *Sonneratia alba*.

The high abundance of *R. stylosa* reflects its ability to dominate across multiple locations. **Ihwan *et al*. (2025)** noted that mangrove forests in the study area are largely monodominant, raising concerns about the ecosystem's long-term resilience. This observation is consistent with **Rahmadani *et al*. (2020)**, who reported that the dominance of a single species across all forest strata suggests strong adaptability but also potential vulnerability due to reduced species diversity. **Sari *et al*. (2022)** emphasized that while dominant species may indicate regeneration success, ecosystem stability is best maintained through species diversity. Therefore, despite the successful regeneration of *R. stylosa*, conservation efforts should prioritize promoting species diversity to enhance ecological resilience and ensure the mangrove ecosystem can adapt to environmental changes **(Wahyuni & Pranowo, 2021; Putri *et al*., 2023; Gosari *et al*., 2024)**.

R. stylosa consistently had the highest importance value index (IVI) scores across all locations: Pare-pare (129.08), Takalar (92.03), Majene (81.24), and Mamuju (94.20) (Table 7). These high IVI scores confirm its ecological dominance and foundational role in structuring the mangrove community, consistent with previous studies **(Fatmasari *et al*., 2021)**.

Other species, such as *A. alba* and *R. mucronata*, also had relatively high and consistent IVI values in all locations except Pare-pare (Tables 8, 9). For instance, *A. alba* recorded IVI values above 70 in Takalar, Majene, and Mamuju. These findings suggest that *R. stylosa*, *A. alba*, and *R. mucronata* form the core of the mangrove community structure. This core group plays a vital role in supporting the ecological health of the region and holds potential for sustainable economic development through ecosystem services **(Gosari *et al*., 2022; Sari *et al*., 2022; Firman *et al*., 2023)**.

CONCLUSION

In this study, a total of 19 mangrove species from 12 different families were identified. The Rhizophoraceae family was the most dominant, comprising six species. The highest vegetation density was recorded for *Rhizophora stylosa* in Majene, with 2,169 individuals per hectare. The species also demonstrated strong ecological metrics, including a species density (Di) of 21.69, relative density (RDi) of 26.75, frequency (Fi) of 1.0, relative frequency (RFi) of 13.51, dominance (Ci) of 374,566.96, relative dominance (RCi) of 41.26, and an Importance Value Index (INP) of 101.00. According to standard criteria, this level of density falls into the "good" category for mangrove condition.

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