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Analysis of Biodiversity Levels in the Mangrove Ecosystem of Liya Togo Village, South Wangi-Wangi District, Wakatobi Regency

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Abstract

Mangrove ecosystems are vital components of coastal areas, serving as barriers against abrasion, sediment traps, and habitats for diverse marine biota. Land-use conversion, resource exploitation, and illegal logging have reduced the extent and quality of mangroves in various parts of Indonesia including Liya Togo Village, Wakatobi Regency thereby threatening biodiversity levels. This study aimed to assess the biodiversity of the mangrove ecosystem in Liya Togo Village, South Wangi-Wangi District, Wakatobi Regency. Conducted in January 2026 using purposive sampling with a 4% sampling intensity, the study utilized six observation plots of varying sizes: 20×20 m for trees, 10×10 m for poles, 5×5 m for saplings, and 2×2 m for seedlings. Vegetation community structure was analyzed based on density, frequency, dominance, and the Importance Value Index (INP), while biodiversity levels were assessed using the Shannon-Wiener Index (H'). The results revealed that the mangrove ecosystem in Liya Togo Village comprises four true mangrove species Rhizophora Mucronata, Rhizophora Apiculata, Brugeira Cylindrica, and Xylocarpus Granatum. with a total of 171 individuals recorded. Rhizophora mucronata dominated the tree stratum (INP 96.28), whereas Bruguiera cylindrica dominated the pole (INP 83.83), sapling (INP 96.26), and seedling (INP 63.10) strata. Biodiversity levels were classified as moderate across all growth strata, with Shannon-Wiener Index (H') values consistently ranging from 1.34 to 1.37. This indicates a relatively even distribution of individuals among species with no single species exerting absolute dominance reflecting an ecological balance that remains intact despite the pressures of illegal logging activities.

Keywords: Biodiversity, Mangrove Ecosystem, Importance Value Index, Shannon-Wiener

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Index, Community Structure.

INTRODUCTION

Mangrove ecosystems are a vital component of coastal areas, playing a significant ecological role. Mangroves serve as barriers against erosion, sediment traps, and natural filters, while also providing habitat for various marine organisms such as fish, shrimp, and crabs and coastal birds (Alongi and Murdiyarso, 2015). However, various pressures including land-use conversion, resource exploitation, and increasing human activity in coastal zones have led to a decline in both the extent and quality of mangrove forests in Indonesia.

Indonesia possesses the largest mangrove forest area in the world, covering approximately 3.36 million hectaresor about 22.6% of the global total (Ministry of Environment and Forestry, 2023). However, around 19% of this total has been degraded due to land conversion for aquaculture ponds, coastal development, and other human activities. This degradation has directly resulted in a decline in the ecological functions of mangroves, including their role in supporting coastal biodiversity (Arifanti *et al.,* 2021).

Biodiversity encompasses all forms of life including the diversity of plants, animals, microorganisms, and the ecosystems that sustain living beings and is generally categorized into three levels: genetic, species, and ecosystem diversity (Mariah *et al.,* 2023). Mangrove ecosystems in Indonesia harbor significant species diversity, including genera such as *****Rhizophora**,** Avicennia**,** Sonneratia**,** Bruguiera**,** Xylocarpus**,** Ceriops**,** and Excoecaria**,** each playing a vital ecological role in the coastal environment (Fitria, 2021). Mangrove biodiversity is assessed not only by the number of species present but also by the structure of the constituent vegetation community, which includes parameters such as density, frequency, dominance, and the Importance Value Index (INP) for each species (Bengen, 2004).

Wakatobi Regency is a coastal area in Southeast Sulawesi Province with significant mangrove ecosystem potential. The mangrove ecosystems in this region not only support coastal ecological functions but also play a vital role in sustaining the livelihoods of communities dependent on fisheries and other coastal resources. However, a decline in mangrove cover driven by logging and coastal development, as reflected in Wakatobi Regent Regulation Number 2 of 2023 concerning spatial planning threatens to reduce mangrove biodiversity in the area.

Liya Togo Village is located in the South Wangi-Wangi District of Wakatobi Regency and features a mangrove forest covering six hectares. Preliminary surveys indicate that the mangrove forest in Liya Togo Village has been affected by illegal logging activities, which pose a

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threat to the ecosystem's sustainability and biodiversity. Consequently, this study was conducted to assess the current state of mangrove ecosystem biodiversity in the area; the findings are expected to provide baseline data to assist local government and the community in planning sustainable conservation, rehabilitation, and management programs for mangrove ecosystems in Wakatobi's coastal region.

METHODS AND ANALYSIS

This study was conducted in the mangrove ecosystem of Liya Togo Village, South Wangi-Wangi District, Wakatobi Regency, Southeast Sulawesi Province located at coordinates 5°30'0" South Latitude and 123°30'0" East Longitude covering an area of 6 hectares. The research activities took place in January 2026. Quantitative data, comprising the number of individuals and mangrove species within each observation plot, were used as the basis for analyzing community structure and the level of biodiversity.

The study population comprised all mangrove vegetation within the mangrove ecosystem of Liya Togo Village across various growth strata: seedlings, saplings, poles, and trees. The study sample consisted of all individual mangrove plants located within the observation plots. A sampling intensity of 4% was employed, taking into account efficiency regarding time, cost, and labor, as well as the conditions of the study site (Ramadhani and Asmarahman, 2023). The total study area was 6 hectares (60,000 m²), resulting in a total sample area of 0.24 hectares (2,400 m²) distributed across six observation plots. The plot sizes used were 20 m × 20 m for the tree stratum, 10 m × 10 m for the pole stratum, 5 m × 5 m for the sapling stratum, and 2 m × 2 m for the seedling stratum.

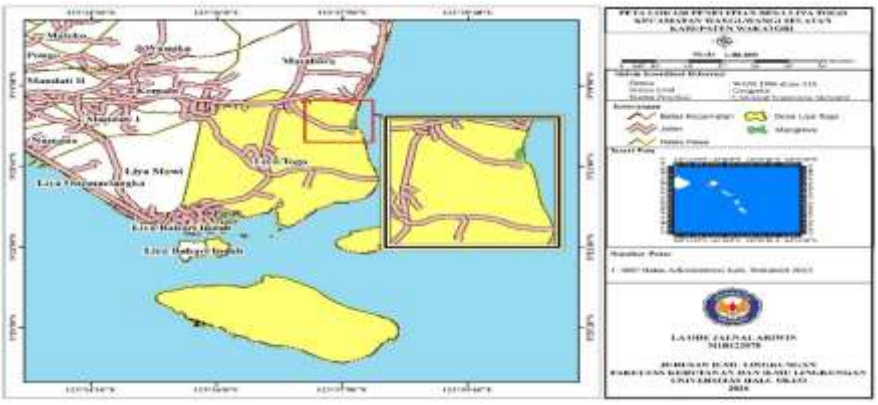


Figure 1 Map of the research location

Research sites were selected based on vegetation conditions identified during a preliminary survey. A purposive sampling method was employed; given the heterogeneous

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nature of the mangrove ecosystem, plot locations were chosen in areas deemed representative of local vegetation characteristics. Data were collected through field observations and direct measurements, involving the identification of all vegetation within the plots and the recording of individual counts for each mangrove species across different growth strata.

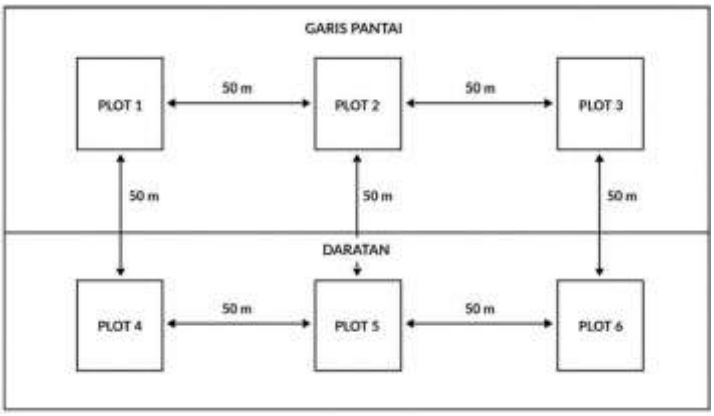


Figure 2 Field Plot Design

The data sources used consist of primary and secondary data. Primary data were obtained through direct field observations, specifically by identifying mangrove species and counting the number of individuals within each observation plot. Secondary data were gathered from literature reviews, scientific publications, and documents from relevant institutions.

Analysis of Mangrove Community Structure

An analysis of the mangrove vegetation community structure was conducted to determine the density, frequency, dominance, and Importance Value Index (INP) of each species; these values subsequently served as the basis for calculating the proportion of individuals (pi) for the Shannon-Wiener Index. The community structure was calculated using the following formula (Bengen, 2004):

Density (K) = Number of individuals of a species / Area of observation plot
Relative Density (KR) = (Density of a species / Total density) × 100%
Frequency (F) = Number of plots where a species is found / Total number of plots
Relative Frequency (FR) = (Frequency of a species / Total frequency) × 100%
Dominance (D) = Basal area of a species (m^2) / Total area of sample plots
Relative Dominance (DR) = (Dominance of a species / Total dominance) × 100%
Importance Value Index (INP) = KR + FR + DR

The INP value indicates the degree of dominance and influence of each species on the community structure; consequently, species with high INP values are considered to play a crucial

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role in ecosystem stability (Nurdin et al., 2021).

Biodiversity Analysis (Shannon-Wiener Index)

Based on the data regarding the number of individuals of each species obtained from the community structure analysis, the Shannon-Wiener Diversity Index (H') was subsequently calculated using the formula (Magurran, 1988):

$$H' = -\Sigma (pi \ln pi)$$

Information:

H' = Species diversity index

Pi = Proportion of individuals of the i-th type to the total number of individuals

Ln = Natural logarithm

The criteria used for the Shannon-Wiener diversity index values are: H' < 1 (low diversity), 1 < H' < 3 (moderate diversity), and H' ≥ 3 (high diversity). The higher the index value, the more diverse and stable the condition of the mangrove community in question (Fauzi et al., 2022).

RESULTS AND DISCUSSION

Mangrove Species Composition

Based on the identification results, the mangrove ecosystem in Liya Togo Village comprises four species of true mangroves, totaling 171 individuals, as presented in Table 1.

Table 1. Mangrove Species Composition

No	Species Name	Number of Individuals
1	*Bruguiera cylindrica*	54
2	*Rhizophora mucronata*	48
3	*Rhizophora apiculata*	38
4	*Xylocarpus granatum*	31
	Total	171

Based on Table 1, four mangrove species were found in Liya Togo Village, comprising a total of 171 individuals. The most dominant species was Bruguiera cylindrica (54 individuals), followed by Rhizophora mucronata **(**48 individuals) and Rhizophora apiculata (38 individuals), while Xylocarpus granatum was the least abundant species, with 31 individuals. The types of mangrove vegetation at the tree, pole, sapling, and seedling stages are presented in Table 2.

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Table 2. Mangrove species at the tree, pole, sapling, and seedling stages.

Types of Mangroves	Tree	Pole	Sapling	Seedling	Total
Bruguiera cylindrica	8	12	10	24	54
Rhizophora mucronata	14	12	7	15	48
Rhizophora apiculata	8	10	8	12	38
Xylocarpus granatum	7	7	5	12	31
Total	37	41	30	63	171

Based on Table 2, the mangrove vegetation was most abundant at the seedling stage (63 individuals), followed by the sapling stage (41 individuals) and the tree stage (37 individuals), with the lowest count observed at the pole stage (30 individuals).

Importance Value Index (INP)

The Importance Value Index (INP) at the tree level is presented in Table 3.

Table 3. Importance Value Index at the Tree Level

Mangrove Species	Total	LBDS	K	KR	F	FR	D	DR	INP
Rhizophora mucronata	14	0,80	58	37,84	0,17	25	3,31	33,44	96,28
Rhizophora apiculata	8	0,45	33	21,62	0,17	25	1,88	18,98	65,60
Bruguiera cylindrica	8	0,52	33	21,62	0,17	25	2,15	21,66	68,28
Xylocarpus granatum	7	0,62	29	18,92	0,17	25	2,57	25,92	69,84
Total	37	2,38	154	100	0,67	100	9,91	100	300

Based on Table 3, the highest Importance Value Index (INP) at the tree level was recorded for Rhizophora mucronata (96.28), followed by Xylocarpus granatum (69.84) and Bruguiera cylindrica (68.28), while the lowest was Rhizophora apiculata (65.60). The high INP of Rhizophora mucronata indicates that this species plays the most dominant role in the community in terms of density, frequency, and dominance.

The Importance Value Index (INP) at the pole stage is presented in Table 4.

Table 4. Importance Value Index at the Pole Stage

Mangrove Species	Total	LBDS	K	KR	F	FR	D	DR	INP
Rhizophora mucronata	12	0,24	200	29,27	0,17	25	4,04	28,58	82,85

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Bruguiera cylindrica	12	0,25	200	29,27	0,17	25	4,18	29,56	83,83
Rhizophora apiculata	10	0,20	167	24,39	0,17	25	3,41	24,09	73,48
Xylocarpus granatum	7	0,15	117	17,07	0,17	25	2,51	17,77	59,84
Total	41	0,85	683	100	0,67	100	14,15	100	300

In Table 4, the highest INP value at the pole level is Bruguiera cylindrica at 83.83, followed by Rhizophora mucronata at 82.85, Rhizophora apiculata at 73.48, and the lowest, Xylocarpus granatum, at 59.84. This shows that at the intermediate growth phase, Bruguiera cylindrica and Rhizophora mucronata have a very important role in the mangrove community.

The Importance Value Index (INP) at the sapling stage is presented in Table 5.

Table 5. Importance Value Index at the Sapling Stage

Mangrove Species	Total	LBDS	K	KR	F	FR	D	DR	INP
Bruguiera cylindrica	10	0,04	667	33,33	0,17	25	2,78	37,93	96,26
Rhizophora apiculata	8	0,03	533	26,67	0,17	25	2,28	31,20	82,86
Rhizophora mucronata	7	0,02	467	23,33	0,17	25	1,40	19,12	67,45
Xylocarpus granatum	5	0,01	333	16,67	0,17	25	0,86	11,76	53,43
Total	30	0,11	2000	100	0,67	100	7,32	100	300

Based on Table 5, the highest INP value at the sapling level is Bruguiera cylindrica at 96.26, followed by Rhizophora apiculata at 82.86, Rhizophora mucronata at 67.45, and the lowest, Xylocarpus granatum, at 53.43. The high INP value of Bruguiera cylindrica shows that this species dominates the early regeneration phase of mangroves, playing an important role in the sustainability and growth dynamics of the mangrove ecosystem at the study site.

The Importance Value Index (INP) at the seedling stage is presented in Table 6.

Table 6. Importance Value Index at the Seedling Stage

Mangrove Species	Total	K	KR	F	FR	INP
Bruguiera cylindrica	24	10000	38,10	0,17	25	63,10
Rhizophora mucronata	15	6250	23,81	0,17	25	48,81
Rhizophora apiculata	12	5000	19,05	0,17	25	44,05
Xylocarpus granatum	12	5000	19,05	0,17	25	44,05
Total	63	26250	100	0,67	100	200

Based on Table 6, the highest INP value at the seedling level is Bruguiera cylindrica at 63.10, followed by Rhizophora mucronata at 48.81, and Rhizophora apiculata and Xylocarpus

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granatum at 44.05. The high INP value of Bruguiera cylindrica at the seedling level shows that this species has excellent regeneration ability and plays a dominant role in the renewal process of the mangrove community in Liya Togo Village.

Shannon-Wiener Diversity Index (H')

The tree-level biodiversity index (H') is presented in Table 7.

Table 7. Tree-Level Biodiversity Index

Mangrove Species	Jumlah	Pi (ni/N)	LN Pi	Pi. LN Pi	H'
Rhizophora mucronata	14	0,38	-0,97	-0,37	0,37
Rhizophora apiculata	8	0,22	-1,53	-0,33	0,33
Bruguiera cylindrica	8	0,22	-1,53	-0,33	0,33
Xylocarpus granatum	7	0,19	-1,67	-0,32	0,32
Total	37	1,00	-5,70	-1,34	1,34

Based on Table 7, the biodiversity index (H') value at the tree level is 1.34, classified as moderate, with the highest contribution from Rhizophora mucronata at 0.37, followed by Rhizophora apiculata and Bruguiera cylindrica at 0.33 each, and the lowest, Xylocarpus granatum, at 0.32.

The Biodiversity Index (H') at the pole stage is presented in Table 8.

Table 8. Biodiversity Index at the Pole Stage

Mangrove Species	Total	Pi (ni/N)	LN Pi	Pi. LN Pi	H'
Rhizophora **mucronata**	12	0,29	-1,23	-0,36	0,36
Bruguiera cylindrica	12	0,29	-1,23	-0,36	0,36
Rhizophora **apiculata**	10	0,24	-1,41	-0,34	0,34
Xylocarpus granatum	7	0,17	-1,77	-0,30	0,30
Total	41	1,00	-5,64	-1,37	1,37

Based on Table 8, the biodiversity index (H') value at the pole level is 1.37, also classified as moderate, with the highest contribution from Rhizophora mucronata and Bruguiera cylindrica at 0.36 each, followed by Rhizophora apiculata at 0.34, and the lowest, Xylocarpus granatum, at 0.30.

The Biodiversity Index (H') at the sapling stage is presented in Table 9.

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Table 9. Biodiversity Index at the Sapling Stage

Mangrove Species	Total	Pi (ni/N)	LN Pi	Pi. LN Pi	H'
Bruguiera cylindrica	10	0,33	-1,10	-0,37	0,37
Rhizophora apiculata	8	0,27	-1,32	-0,35	0,35
Rhizophora **mucronata**	7	0,23	-1,46	-0,34	0,34
Xylocarpus granatum	5	0,17	-1,79	-0,30	0,30
Total	30	1,00	-5,67	-1,36	1,36

Based on Table 9, the biodiversity index (H') value at the sapling level is 1.36, classified as moderate, with the highest contribution from Bruguiera cylindrica at 0.37, followed by Rhizophora apiculata at 0.35, Rhizophora mucronata at 0.34, and the lowest, Xylocarpus granatum, at 0.30.

The Biodiversity Index (H') at the seedling stage is presented in Table 10.

Table 10. Biodiversity Index at the Seedling Stage

Mangrove Species	Total	Pi (ni/N)	LN Pi	Pi. LN Pi	H'
Bruguiera cylindrica	24	0,38	-0,965	-0,37	0,37
Rhizophora mucronata	15	0,24	-1,435	-0,34	0,34
Rhizophora apiculata	12	0,19	-1,658	-0,32	0,32
Xylocarpus granatum	12	0,19	-1,658	-0,32	0,32
Total	63	1,00	-5,72	-1,34	1,34

Based on Table 10, the biodiversity index (H') value at the seedling level is 1.34, classified as moderate, with the highest contribution from Bruguiera cylindrica at 0.37, followed by Rhizophora mucronata at 0.34, and Rhizophora apiculata and Xylocarpus granatum at 0.32 each. The H' values, ranging from 1.34–1.36 across all growth levels, indicate that the mangrove ecosystem in Liya Togo Village is in a fairly stable condition with a moderate level of species diversity.

Research findings indicate that the mangrove ecosystem in Liya Togo Village comprises four mangrove species Rhizophora mucronata, Rhizophora apiculata, Bruguiera cylindrica, and Xylocarpus granatum with a total of 171 individuals. These four species were found across all growth stages, from seedlings to mature trees, indicating an intact community structure and ongoing natural regeneration. Regarding species distribution, the Rhizophora genus dominates the seaward zone subject to frequent inundation, whereas Bruguiera and Xylocarpus are more prevalent in landward zones, reflecting a characteristic mangrove zonation pattern. The

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dominance of the Rhizophora and Bruguiera genera is a common feature of Indonesian tropical mangroves; as noted by Babo *et al.* (2020), these two genera constitute the primary mangrove groups in the Indo-Malaysian region.

Based on the Importance Value Index (INP) analysis, Rhizophora mucronata dominates the tree stratum with an INP of 96.28, reflecting high levels of density, frequency, and dominance. Its adaptability to muddy substrates and robust stilt root system render this species highly competitive; as noted by Naharuddin (2020), Rhizophora typically dominates frequently inundated mangrove zones in muddy coastal areas. At the pole, sapling, and seedling stages, Bruguiera cylindrica assumes dominance with INP values of 83.83, 96.26, and 63.10, respectively signifying natural vegetation development dynamics progressing toward community stability. The high abundance of Bruguiera cylindrica seedlings is closely linked to its viviparous nature, which allows propagules to germinate directly beneath the parent tree canopy; as stated by Ulyah *et al.* (2022), seedling dominance serves as an indicator of environmental conditions that continue to support sustainable regeneration.

Analysis of the Shannon-Wiener Diversity Index (H') revealed consistent values across all growth strata, ranging from 1.34 (trees and seedlings) to 1.36–1.37 (saplings and poles), all falling within the moderate category. This consistency indicates a relatively even distribution of individuals among species at each growth stage. In the field, this is reflected by the uniform relative frequency (25%) of each species across all strata, signifying that no single species absolutely dominates the entire plot. According to Odum (1998), H' values between 1 and 3 indicate an ecosystem in a moderate state with a maintained ecological balance. These results align with the findings of Diba *et al.* (2022) and Ulyah *et al*. (2022) regarding mangroves subjected to mild to moderate stress in Indonesian coastal areas.

The moderate diversity value observed is linked to the pressures affecting the area. Field observations revealed clear evidence of illegal logging specifically, freshly cut tree stumps particularly within several observation plots. This logging has resulted in the loss of large-diameter trees, which contribute most significantly to the diversity of the stand structure. Nanlohy and Masniar (2020) note that human-induced pressures, such as logging, can degrade ecosystem quality and disrupt community structure. Nevertheless, the presence of all growth stages from seedlings to mature trees indicates that natural regeneration is still occurring; thus, the mangrove ecosystem of Liya Togo Village remains ecologically functional, though it remains vulnerable to further degradation if illegal logging is not halted. Therefore, it is essential to strengthen monitoring against illegal logging, implement rehabilitation programs using native species such as Rhizophora mucronata and Bruguiera cylindrica, and enhance public education

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regarding the ecological role of mangroves in maintaining coastal ecosystem balance (Fikri et al., 2023).

CONCLUSION

Research findings indicate that the mangrove ecosystem in Liya Togo Village is classified as having a moderate status across all growth strata, with Shannon-Wiener Diversity Index (H') values ranging from 1.34 to 1.37. The ecosystem comprises four true mangrove species Rhizophora mucronata, Rhizophora apiculata, Bruguiera cylindrica, and Xylocarpus granatum with a total of 171 individuals recorded. Rhizophora mucronata dominates the tree stratum, whereas Bruguiera cylindrica dominates the pole, sapling, and seedling strata. The relatively even distribution of individuals among species across all strata suggests that the mangrove ecosystem in Liya Togo Village remains ecologically stable; however, conservation efforts are still required to manage pressures from illegal logging, which could otherwise reduce biodiversity levels in the future.

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