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Journal of Tropical Science

Research Article

Vegetation Diversity in Mangrove Forest Area of Mojo Village, Ulujami District, Pemalang Regency, Central Java

Aisyah Fajar Kartika[1], Nabela Fikriyya[1]*, & Rizmoon Nurul Zulkarnaen[2]

[1] Aquatic Resource Management, Faculty of Fisheries and Marine Science, Jenderal Soedirman University, Purwokerto 53122, Central Java, Indonesia
[2] Research Center for Applied Botany, National Research and Innovation Agency, Cibinong, Bogor 16911, West Java, Indonesia

*Corresponding author: nabela.fikriyya@unsoed.ac.id

ABSTRACT

Mangrove forests are vital for coastal protection, biodiversity, and local livelihoods but face significant threats such as erosion, land-use changes, sedimentation, and waste pollution. This study assessed the diversity, dominance, and evenness of the mangrove ecosystem in Mojo Village, Ulujami District, Pemalang Regency, an area impacted by coastal abrasion. The research, conducted from August to September 2023, used purposive sampling with quadrant transects at four stations. Three plot sizes (10 m × 10 m, 5 m × 5 m, and 2 m × 2 m) were employed to analyze different mangrove growth stages (tree, sapling, and seedling). The mangrove diversity index ranged from 0 to 1.232, with the highest value observed in the tree stage (1.232) and the lowest in the seedling stage (0). The species *Avicennia alba* exhibited the highest dominance across all stages. The evenness index varied between 0 and 0.95209, indicating high evenness in trees and saplings, while the seedling stage exhibited low evenness. Water quality parameters were found to be supportive of mangrove growth. They included temperature (28.8–30.5°C), salinity (25–30 ppt), pH (5.90–6.21), and dissolved oxygen (5.5–14.9 mg/l). The results highlighted variations in diversity and evenness across the mangrove ecosystem's growth stages. The findings provide valuable insights into the current state of mangroves in the area and underscore the urgent need for continued monitoring and sustainable management to restore and conserve the mangrove forests in Mojo Village.

Keywords: mangrove vegetation diversity, Mojo village, Ulujami

Introduction

Mangrove forests are vital coastal ecosystems that thrive in tropical regions, characterized by their ability to withstand high salinity and grow in muddy substrates (Chandra et al., 2011). Positioned in intertidal zones, mangroves are influenced by complex interactions between marine, brackish, riverine, and terrestrial waters, resulting in high biodiversity of both flora and fauna (Martuti, 2013). These ecosystems offer essential physical, chemical, ecological, and economic functions. Physically, mangroves mitigate coastal erosion by trapping sediment and preventing seawater intrusion. Chemically, they filter pollutants and generate oxygen. Ecologically, mangroves serve as critical habitats for marine species, functioning as nurseries, feeding, and spawning grounds. Economically, they have the potential for ecotourism development (Alwi et al., 2019).

The mangrove ecosystems along the northern coast of Central Java, including Pemalang Regency, provide significant diversity due to varying coastal conditions and environmental factors. Pemalang Regency is home to extensive mangrove forests, particularly in Mojo Village, Ulujami District with a coastline of 76.63 km. The ecosystem grows on newly formed land, attracting attention for its ecotourism potential (Mutia & Rahdriawan, 2014). However, Pemalang Regency faces severe coastal abrasion, impacting an area of 445 hectares, with Mojo Village experiencing 200 hectares of erosion since 1999 with an annual loss of 2–2.5 hectares. This erosion threatens local mangrove forests, aquaculture, and settlements, underlining the need for sustainable coastal management (Muali, 2020).

In addition to abrasion, mangroves in Mojo Village are affected by land-use changes, sedimentation from the Comal River, flooding, and waste accumulation, all of which degrade the ecosystem (Mutia & Rahdriawan, 2014). Given the critical role of soil and water quality in mangrove survival, it is necessary to assess land suitability for mangrove rehabilitation. These environmental challenges have diminished the quality and quantity of mangrove vegetation, highlighting the need for research into mangrove diversity as foundation for sustainable management policies.

Previous studies by Renta et al. (2016) revealed that Mojo Village's mangroves are dominated by *Avicennia marina* and *Rhizophora mucronata*, followed by *Avicennia alba*. However, updated assessments are necessary to capture changes in ecosystem conditions and inform effective management strategies. This study aimed to assess the diversity, dominance, and evenness of mangrove vegetation in relation to environmental conditions. Specifically, it evaluated mangrove biodiversity and water quality within the Mojo Village mangrove ecosystem, providing updated data crucial for conservation and management efforts in Pemalang Regency.

Materials and Methods

Study Area

This study was conducted from August to September 2023 in the mangrove forest area of Mojo Village, Ulujami District, Pemalang Regency (Figure 1). Four stations were selected based on initial problem identification process, followed by field data collection. The identification of mangrove species was performed using the identification guide *Panduan Mangrove Estuari Perancak* (Sidik et al., 2018).

Materials

The tools used in this study included a refractometer for measuring water salinity, a Lutron water quality checker for assessing water parameters, and a Garmin GPS map for locating station coordinates. Quadrant transects were utilized to quantify mangrove vegetation stands, and the results were systematically recorded. A measuring cylinder was employed to collect seawater samples, while a digital camera was used to visually document the study site and research activities. The primary materials comprised of the mangrove vegetation community observed at the site.

Sample Collection Techniques

Seawater samples (250 ml) were collected using a measuring cylinder and submerged carefully to avoid air bubbles. The water sample's temperature, pH, and dissolved oxygen (DO) were measured using the Lutron water quality checker, while salinity was determined using a refractometer by placing a few drops of the sample on the device. All results were recorded accordingly.

Vegetation data was collected using nested plot sampling method (Figure 2). In the study area, transect lines were established perpendicular to the coastline to capture environmental gradients and variability in mangrove vegetation. Each transect was divided into sampling

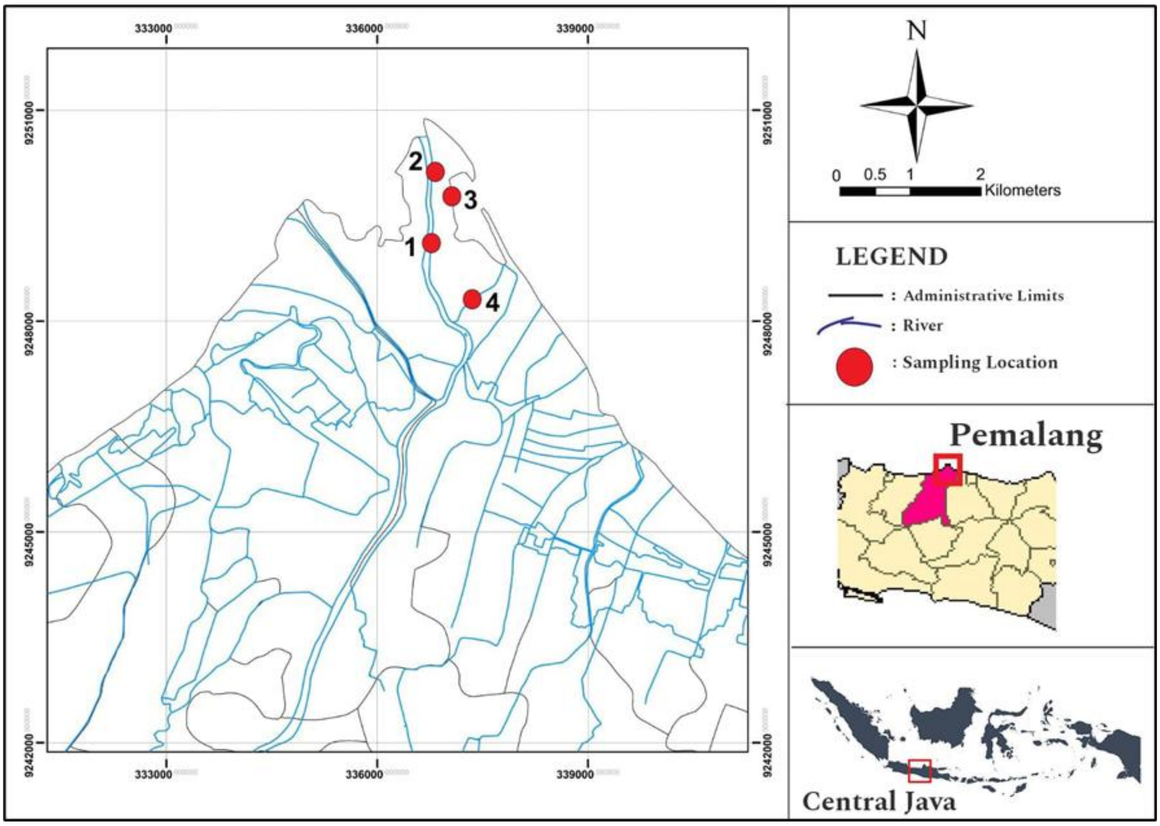

Fig. 1. Research map location of mangrove forest area in Mojo Village, Ulujami District, Pemalang Regency, Central Java.

intervals, with nested plots placed systematically at regular distances along the transects. Each nested plot consisted of three sizes: a 10 m × 10 m plot for trees (trunk diameter ≥4 cm), a 5 m × 5 m plot nested within it for saplings (trunk diameter 1–4 cm and height >1 m), and a 2 m × 2 m plot within the sapling plot for seedlings (height <1 m). Plot boundaries were marked using stakes or flags, and GPS coordinates were recorded for precise mapping and reproducibility. This layout ensured that all growth stages were systematically sampled, providing comprehensive data on mangrove vegetation (Fikriyya et al., 2024; Renta et al., 2016).

Data Analysis

To assess the ecological condition, diversity, dominance, and evenness indices were calculated. The Shannon-Wiener diversity index (H') was used to measure species diversity, which reflects the variety of species within a community (Magurran, 2004; Odum, 1993), with higher values indicating a more stable ecosystem (Suheriyanto, 2008). Dominance (D) and evenness (e') indices were also calculated to analyze the distribution and balance of species across the growth stages. These indices provided comprehensive insights into the ecological structure of the mangrove vegetation.

Diversity Index

The diversity index is a measure that characterizes the level of biodiversity within a community (Odum, 1993). According to Shannon and Wiener (1963), the Shannon-Wiener diversity index is categorized into three levels: a low diversity index (H'<1), a moderate diversity index (1≤H'≤3), and a high diversity index (H'>3), with each classification reflecting the extent of species variety present in the community. The Shannon-Wiener diversity index (H') is calculated based on the number of mangrove species (s) and the proportion of individuals of the i-th species (pi) relative to the total number of mangroves (N), expressed as pi = ni/N (Magurran, 2004).

$$H' = -\sum_{i=1}^{s}[pi\, ln\, pi]$$

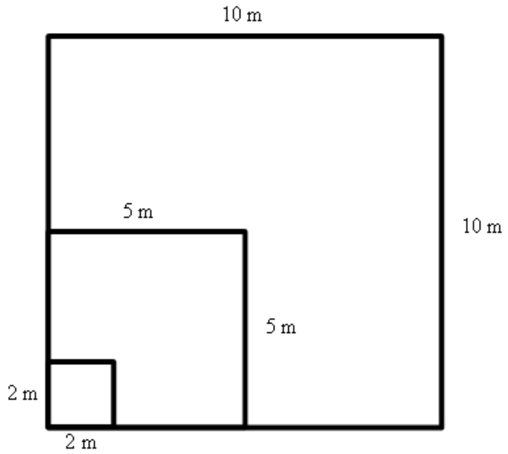

Fig. 2. Stages of mangrove vegetation data collection in Mojo Village, Ulujami District, Pemalang Regency, Central Java.

Dominance Index

The dominance index (D) is used to indicate the dominance level of a species within a community (Odum, 1993). According to Simpson (1949), as cited in Odum (1993), the dominance index is classified as follows: 0<D<0.5 indicates no dominant species, while 0.5<D<1 indicates the presence of a dominant species.

$$D = \sum_{i=1}^{s}[P_i^{\,2}]$$

D represents the dominance index, s is the total number of mangrove species, and Pi is the proportion of individuals of the i-th species (ni) relative to the total number of mangroves (N), expressed as Pi = ni/N (Krebs, 1989).

Evenness Index

The evenness index (e') reflects the distribution of individuals among species within a community. An evenness value approaching 1 indicates that the number of individuals in each species is relatively similar, while a value close to 0 suggests a significant disparity in the number of individuals among species. According to Odum (1993), the Simpson evenness index is categorized as follows: e' = 0 – 0.30 for low evenness, e' = 0.31 – 0.60 for moderate evenness, and e' = 0.61 – 1.0 for high evenness. The evenness index is calculated using the formula:

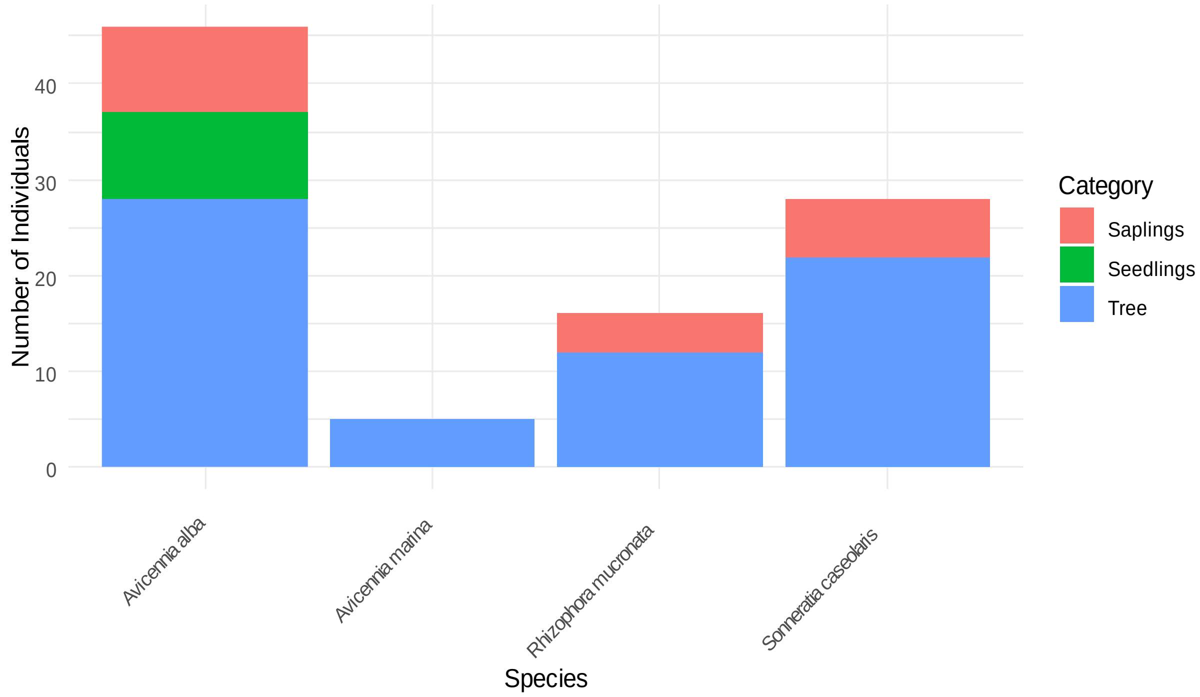

Fig. 3. Distribution of mangrove individuals by species and growth stage in Mojo Village, Ulujami District, Pemalang Regency, Central Java.

$$e' = \frac{H'}{ln\ s}$$

e' is the evenness index, H′ represents the Shannon-Wiener diversity index, and s is the total number of species (Magurran, 2004).

Table 1. Vegetation structure of mangroves in Mojo Village, Ulujami District, Pemalang Regency, Central Java.

Growth stages	H'	D	e'
Seedling	0	1	0
Sapling	1.046	0. 36842	0.95209
Tree	1.232	0. 32012	0.8887

H = diversity index, D = dominance index, e' = evenness index

Correlation Analysis

Pearson correlation analysis was used to assess relationships between environmental factors (salinity, pH, and dissolved oxygen) and ecological indices (diversity, dominance, and evenness), offering insights into how these variables shape mangrove ecosystems (Li et al., 2019). Salinity and dissolved oxygen significantly influenced species richness and diversity (Suresh et al., 2021). Environmental parameters were measured at each research station and analyzed to determine the degree of linear association using the Pearson correlation coefficient (*r*). A significance level of $p<0.05$ was set as the criterion for statistical significance, aligning with conventional thresholds for ecological studies. A positive *r* value indicates a positive relationship between two variables, while a negative *r* value indicates a negative relationship. This analysis provides insights into how environmental factors influence the structure and dynamics of mangrove communities.

Results and Discussion

Vegetation Structure and Regeneration Dynamics of Mangrove Species

The vegetation structure of mangrove species in the study area highlights variations in abundance and regeneration across different growth stages (Figure 3). *A. alba* exhibited the highest number of mature trees (28 individuals) and demonstrated robust regeneration potential, with a significant presence of saplings (9) and seedlings (9). *Sonneratia caseolaris* followed with 22 mature trees and 6 saplings, indicating moderate regeneration capacity. Conversely, *A. marina* was represented by only 5 mature individuals, reflecting poor regeneration. *R. mucronata* had 12 mature trees and 4 saplings but no seedlings, suggesting intermediate regeneration success. These findings reflect the differing ecological statuses and regeneration dynamics of the mangrove species in the study area.

The mangrove vegetation in Mojo Village consisted of three growth stages: seedlings, saplings, and trees, each contributing uniquely to the ecosystem structure (Table 1). Among these stages, trees exhibited the highest diversity index (H' = 1.232), signifying a healthy and stable population of mature mangroves. Saplings presented a moderate diversity index (H' = 1.046), indicating a promising transitional phase from younger to mature stages. However, the seedling stage showed no diversity (H' = 0), highlighting significant challenges in the early stages of regeneration.

The lack of diversity among seedlings raised a critical concern about the long-term sustainability of the mangrove ecosystem. Factors such as environmental stressors, anthropogenic pressures, and habitat degradation might hinder seedling survival and growth. While the tree and sapling stages exhibited relative stability, the underperforming seedling population emphasized the urgent need for targeted conservation measures. Addressing these challenges through habitat restoration, protection of juvenile growth stages, and mitigation of external pressures are vital to ensuring the natural regeneration and resilience of the mangrove ecosystem.

Influence of Environmental Conditions and Mangrove Diversity

Environmental conditions and mangrove exploitation significantly influenced species diversity in Mojo Village. Stations I, II, and III demonstrated moderate species diversity, reflecting favorable conditions for mangrove adaptation. In contrast, Station IV exhibited low diversity, which is likely attributable to frequent boat traffic and its associated disturbances. These findings align with Heddy and Kurniaty (1996) in Suwondo et al. (2006), who reported that low diversity often signals ecosystem stress, particularly impacting seedlings. Additionally, human activities, such as aquaculture expansion and land-use changes, further exacerbated these pressures on mangrove ecosystems (Darmayani et al., 2022; Setyawan et al., 2005).

The dominance index (D), which measures the extent to which a species dominates a community, varied across growth stages. Seedlings displayed the highest dominance (D = 1), indicating the overwhelming presence of *A. alba* in this stage (Table 1). This strong dominance reflects the adaptability of *A. alba* to muddy substrates prevalent in the area (Rodtassana & Poungparn, 2012). In comparison, trees and saplings exhibited lower dominance values (D = 0.32012 and 0.36842, respectively), indicating a more balanced distribution of species (Table 1).

The evenness index (e'), reflecting the uniformity of species distribution, ranged from 0 to 0.95209. Trees (e' = 0.8887) and saplings (e' = 0.95209) exhibited high evenness, suggesting relatively equal species representation (Table 1). In contrast, the seedling stage showed zero evenness (e' = 0), consistent with the dominance of *A. alba* (Table 1). High evenness is generally associated with lower dominance, whereas low evenness indicates that a single species predominates, as observed in the seedling stage (Wahyuningsih et al., 2019).

Water Quality Parameters and Mangrove Growth

Environmental parameters, including temperature, salinity, pH, and dissolved oxygen (DO), were measured to assess their impact on mangrove ecosystems (Table 2). Water temperature ranged from 28.8°C to 30.5°C, within the optimal range for mangrove growth (28–32°C) (Kementerian Lingkungan Hidup, 2004). Variations in temperature were likely influenced by canopy density, sunlight exposure, and measurement timing (Aksornkoae, 1993). Salinity levels (25–30 ppt) were also within optimal ranges, supporting the growth of dominant species such as *A. alba* and *S. caseolaris*, consistent with prior studies (MacNae, 1968).

Table 2. Parameter of water quality of mangrove ecosystems in Mojo Village, Ulujami District, Pemalang Regency, Central Java.

Parameters	Station				
	I	II	III	IV	Average
Temperature (°C)	28.8	30.5	29.8	29.5	29.68
Salinity (ppt)	30	25	29	29	28.25
pH	6.21	5.90	5.98	6.06	6.04
DO (mg/l)	9.8	7.6	5.5	14.9	9.45

However, pH levels (5.90–6.21) fell below the ideal range (6.5–8.5), likely due to the decomposition of mangrove litter, which releases detritus and contributes to acidic conditions (Adeleke et al., 2016). Finally, DO levels varied significantly (5.5–14.9 mg/l), with low values at Station III potentially resulting from the shading effect of dense canopies, which limited photosynthetic oxygen production (Table 2).

Statistical analysis revealed significant correlations between environmental parameters and vegetation indices. Species diversity (H') showed a positive correlation with salinity ($r = 0.72$, $p<0.05$), indicating that moderate salinity (25–30 ppt) supports higher biodiversity. In contrast, acidic pH negatively correlated with diversity ($r = -0.68$, $p<0.05$), suggesting that low pH hinders seedling regeneration. Dominance was highest in the seedling stage (D = 1), associated with high salinity and DO levels, which favored the growth of *A. alba*. Conversely, the tree and sapling stages, with lower dominance indices, indicated more balanced species distributions under similar conditions. Evenness (e') positively correlated with DO ($r = 0.65$, $p<0.05$), suggesting that adequate oxygen levels promote species coexistence. However, the seedling stage, affected by sedimentation and anthropogenic pressures, displayed low evenness due to the predominance of *A. alba*.

Implications for Ecosystem Sustainability
These findings underlined the critical role of environmental conditions in shaping mangrove diversity, dominance, and evenness. High salinity and DO levels favored dominant species like *A. alba*, while low pH and sedimentation challenged the regeneration of a balanced community structure. Targeted conservation efforts, including habitat restoration, water quality improvement, and sedimentation control, are essential to promote natural regeneration and enhance the sustainability of the mangrove ecosystem in Mojo Village.

Conclusion

This study revealed significant variations in the structure and diversity of mangrove vegetation in Mojo Village, highlighting ecological imbalances and their underlying causes. The highest diversity index (H') was observed in the tree category (1.232), followed by the sapling category (1.04598), while the seedling category exhibited no diversity (H' = 0). *A. alba* dominated all growth stages, with *S. caseolaris* emerging as the second most dominant species in the tree and sapling categories. Evenness indices reflected a relatively balanced species distribution in the tree (e' = 0.8887) and sapling (e' = 0.95209) stages, but zero evenness in seedlings indicated a concerning ecological imbalance at the regeneration level.

Water quality parameters, including temperature (28.8–30.5 °C), salinity (25–30 ppt), pH (5.90–6.21), and dissolved oxygen (5.5–14.9 mg/l), were generally within ranges conducive to mangrove growth. However, acidic pH and sedimentation were identified as significant stressors impacting regeneration, particularly in the seedling stage. These findings highlighted the critical role of environmental conditions in shaping mangrove diversity, dominance, and evenness.

The study underscored the urgent need for targeted conservation measures to address the ecological challenges faced by the mangrove ecosystem in Mojo Village. Priorities should include improving water quality, mitigating sedimentation, and protecting juvenile growth stages to enhance natural regeneration. Sustainable management practices are essential to restore the ecological balance and ensure the long-term health and resilience of the mangrove ecosystem.

Conflict of Interest

We confirm that we have no conflict of interest regarding any financial, personal, or other affiliations with individuals or organizations related to the subject matter discussed in the manuscript.

Acknowledgement

The authors thank Jenderal Soedirman University and LPPM for funding this research through the 2023 Research and Development Competence (RPK) scheme.

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