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# Stand Structure and Degradation Level of Mangrove Vegetation in Pongkar Village, Karimun Regency, Kepulauan Riau, Indonesia

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## ABSTRACT

**Background:** *Mangrove ecosystems are globally significant for biodiversity, carbon storage, and coastal protection, yet they are increasingly threatened by anthropogenic activities. Indonesia, which hosts the world's largest mangrove area, also experiences one of the highest degradation rates, making site-specific assessments essential. This study investigates the stand structure and degradation level of mangrove vegetation in Pongkar Village, Karimun Regency, Riau Islands Province, where ecological importance intersects with human pressures.* **Methodolgy:** *Field surveys were conducted using five 100 m transects with 10 × 10 m plots for vegetation analysis and a 1 ha plot to assess degradation levels following the Indonesian Ministry of Environment Decree No. 201/2004. Vegetation parameters, including density, frequency, dominance, and Importance Value Index (IVI), were measured.* **Results:** *Nine mangrove species were identified, comprising seven true mangroves and two associated species. Rhizophora apiculata dominated the community (density 0.078 ind/m²; IVI 121.15%). Diversity indices revealed medium diversity (H' = 1.45–1.89), low to medium richness (Dmg = 1.28–1.78), high evenness (E = 0.81–0.86), and low dominance (D = 0.18–0.26). Stand density reached 1,181 trees/ha, classified as medium. These results suggest that ecological functions remain active, but moderate diversity and richness indicate vulnerability to disturbance and degradation risks.* **Contribution:** *The study provides empirical evidence to inform conservation planning, emphasizing the need for regular monitoring, rehabilitation of underrepresented species, and community-based management to sustain the Pongkar mangrove ecosystem*

**Keywords**: *Biodiversity; Mangrove; Pongkar; Stand Structure; Vegetation Degradation*



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## INTRODUCTION

Mangrove ecosystems are globally recognized as one of the most productive and valuable coastal habitats, providing critical ecological services such as carbon sequestration, shoreline stabilization, nutrient cycling, and nursery grounds for marine species (Donato et al., 2011; Barbier et al., 2011; Alongi, 2015). In addition to their ecological role, mangroves support socio-economic benefits through fisheries, timber, and ecotourism, thereby contributing to both environmental sustainability and human livelihoods (Spalding & Parrett, 2019). However, global mangrove forests are experiencing alarming rates of loss, estimated at 0.3–0.7% annually, mainly due to aquaculture, coastal development, and pollution (Bhowmik et al., 2022). This degradation not only threatens biodiversity but also undermines the resilience of coastal communities that depend on mangrove ecosystem services.

Indonesia, which hosts the largest mangrove area in the world (~3.36 million hectares), faces a paradox: despite vast coverage and high species diversity, the country experiences one of the fastest degradation rates worldwide (Arifanti et al., 2022) National data categorize Indonesia's mangroves into good (93%), moderate (5%), and poor (2%) conditions, with significant declines reported particularly in provinces such as the Riau Islands (Efendi & Harahap, 2014). Here, mangrove ecosystems are increasingly threatened by land conversion for settlements, docks, agriculture, plantations, and oil and gas exploitation (Efendi et al., 2025; Rinika et al., 2023). These patterns mirror pressures observed in Pongkar Village, Karimun Regency, where rapid coastal changes raise concerns about long-term ecological stability.

Previous studies have employed various approaches to assess mangrove condition. For instance, Efendi et al., (2025) analyzed vegetation structure through field-based ecological surveys, while Rinika et al., (2023) utilized remote sensing techniques to detect changes in mangrove cover. Both approaches provide valuable insights but remain limited when applied in isolation. Furthermore, Chairul & Jannah (2024) emphasized the importance of integrating stand structure analysis with degradation assessments to better understand ecosystem resilience. Despite these advances, localized studies that combine quantitative field measurements with national policy standards remain scarce, especially in small coastal villages such as Pongkar.

The mangrove vegetation in Pongkar Village illustrates a dynamic interaction between ecological potential and anthropogenic pressures. Yet, threats from land conversion, pollution, and low community awareness continue to compromise its sustainability. Conservation efforts therefore require an evidence-based understanding of stand structure, species composition, and degradation levels to guide targeted management interventions (Gufron et al., 2024). This study addresses that gap by analyzing the stand structure and degradation level of mangrove vegetation in Pongkar Village, employing field-based vegetation metrics aligned with the Indonesian Ministry of Environment Decree No. 201/2004. By integrating ecological data with national standards, this research contributes both to scientific understanding and to practical strategies for sustainable mangrove management at the local level.

## METHOD

### Study Area

This research was conducted along the coastal area of Pongkar Village, Karimun Regency, Riau Islands Province, Indonesia. The location was selected because of its diverse mangrove conditions and the increasing anthropogenic pressures, including land conversion, settlement development, and pollution, which make it a relevant site for analyzing vegetation structure and degradation levels.

### Sampling Design

A purposive sampling design was employed to represent the gradient of mangrove vegetation from the seaward to the landward zone. Five transects, each measuring 100 m in length, were established perpendicular to the shoreline. Along each transect, 10 × 10 m plots were systematically placed at 10 m intervals, resulting in a total of 50 plots. This layout ensured representative coverage of different ecological zones and stand structures across the study area.

### Data Collection and Measurements

This purposive placement ensured coverage of different ecological zones and habitat conditions within the study area, allowing for a representative assessment of species composition and stand structure. The transect coordinates were as follows: Transect 1: 1°04′40″N, 103°23′03″E, Transect 2: 1°04′39″N, 103°23′04″E, Transect 3: 1°04′39″N, 103°23′04″E, Transect 4:1°04′38″N, 103°23′05″E, Transect 5: 1°04′38″N, 103°23′05″E.

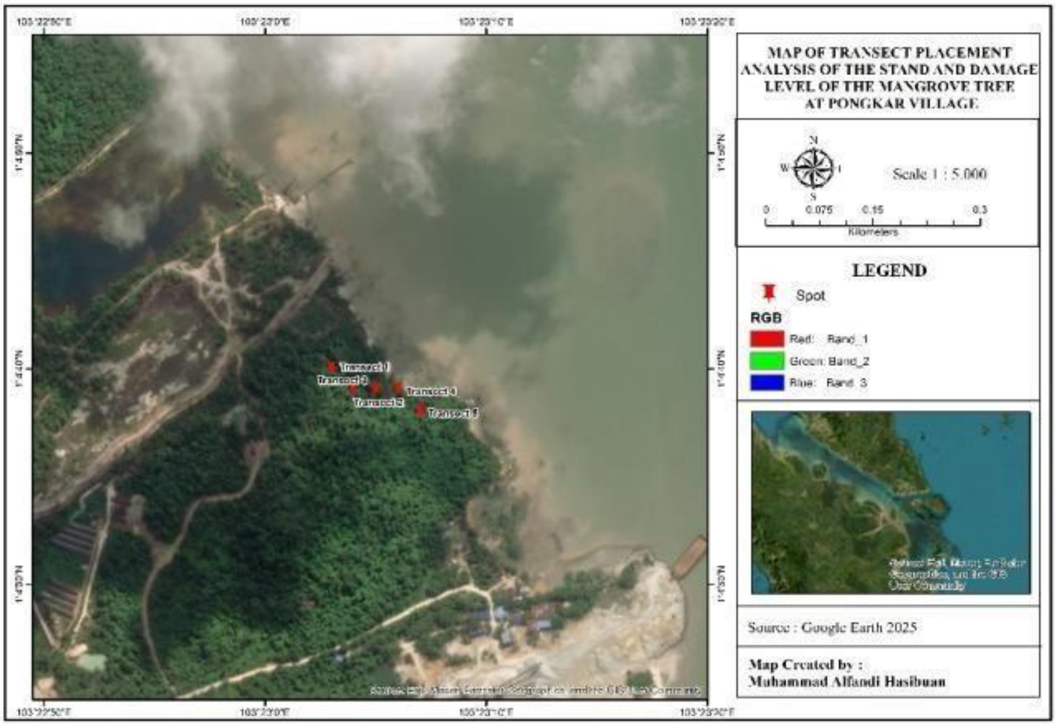


**Figure 1.** Map of the study area in Pongkar Village, Karimun Regency, Indonesia

### Data Analysis Vegetation Analysis

The following formulas were used to assess vegetation parameters by Krebs (2014) formula:

$$\text{Density (K)} = \frac{\text{Number of individuals of a species}}{\text{Plot area}} \quad \ldots\ldots (1)$$

$$\text{Relative Density (RD)} = \frac{\text{Density of a species}}{\text{Total density of all species}} \text{ X } 100\ \% \quad \ldots\ldots (2)$$

$$\text{Frequency (F)} = \frac{\text{Number of plots containing a species}}{\text{Total number of plots}} \quad \ldots\ldots (3)$$

$$\text{Relative Frequency (RF)} = \frac{\text{Frequency of a species}}{\text{Total frequency}} \text{ X } 100\ \% \quad \ldots\ldots (4)$$

$$\text{Dominance (D)} = \frac{\text{Total basal area of a species}}{\text{Total plot area}} \quad \ldots\ldots (5)$$

$$\text{Relative Dominance (RDm)} = \frac{\text{Dominance of a species}}{\text{Total dominance}} \text{ X } 100\ \% \quad \ldots\ldots (6)$$

$$\text{Importance Value Index (IVI)} = \text{RD} + \text{RF} + \text{RDm} \quad \ldots\ldots (7)$$

### Community Structure

The Diversity measured by The Shannon Diversity Index (Shannon-Wiener Index), (Asadi & Pambudi, 2020) is a way to measure the diversity of species in a community. this index is calculated as:

$$H = -\Sigma\ pi * \ln(pi) \quad \ldots\ldots (8)$$

Formula description:
H' = diversity index
ni = number of individuals of species i
N = total number of individuals of all species

Range of the Shannon-Wiener diversity index by Shannon & Wiener (1949) where If the H' value < 2.3026 describe the low diversity and low community stability, If the value 2.3026 < H' < 6.9078 describe the moderate diversity; and If H' > 6.9078 describe the high diversity and high community stability. Species Richness measured by Margalef Species Richness Index (Dmg) (Ludwig & Reynolds, 1988), thuis index is calculated as :

$$D = \frac{(S-1)}{\text{Ln (N)}} \quad \ldots\ldots (9)$$

Where: D= is the Margalef index
S= is the number of species found
N= is the total number of individuals in the sample.

### Pielou's Evenness Index

Evenness Index (E), is defined as a measure that takes into account the number of species and their relative abundance in a community (Help et al., 1998). It is calculated using the following formula 10. Interpretation of the Evenness Index value refers to Herrmann et al., (2022): where the E value < 0.4 indicates Low Evenness, If 0.4 ≤ E ≤ 0.6 indicates Moderate Evenness, If the E value > 0.6 indicates High Evenness.

$$E' = \frac{H'}{H\ max} \quad \text{......} \quad (10)$$

Where :

E' = Evenness Index
H' = Diversity Index
H Max = Maximum Species Diversity
S = Number of Species in the Sample

### Species Dominance Index (Simpson's)

The Dominance Index is calculated using the Simpson's dominance index on formula 11 refers to Odum & Barrett (2021). The dominance index ranges from 0 to 1, where a smaller value indicates that no species is dominating, while a larger value signifies the presence of a particular species dominating the community Simpson's Dominance Index (D) (Kitikidou et al., 2024).

$$D = \left(\frac{Ni}{N}\right) \text{\textasciicircum} 2 \quad \text{......} \quad (11)$$

Description:
D = Simpson's Dominance Index
Ni = Number of Individuals per species
N = Total Number of Individuals across all species

### Mangrove Degradation Level

Mangrove degradation levels were determined using the Ministry of Environment Decree No. 201/2004 on Mangrove Damage Standards by Kementerian Negara Lingkungan Hidup (2004), which classify stand density as: Very dense: ≥1,500 trees/ha; Medium: 1,000–<1,500 trees/ha; Sparse: <1,000 trees/ha. For this purpose, A 1-hectare (10,000 m²) plot was used to census all mangrove trees within the area, where each individual was mapped and measured using Diameter at Breast Height (DBH ≥ 4 cm) and classified into appropriate age or size classes to determine stand density and structural composition.

## RESULT AND DISCUSSION

### Species Composition

The vegetation survey identified nine mangrove species across the five transects. Seven were classified as true mangroves (*Lumnitzera sp., Rhizophora apiculata,* *Sonneratia alba, Avicennia marina, Ceriops decandra, Bruguiera gymnorhiza,* and *Pandanus tectorius*), while two were associated species (*Nypa fruticans* and *Hibiscus tiliaceus*). The *R. apiculata* was the most dominant species, likely due to favorable substrate conditions. The Rhizophoraceae family — comprising *R. apiculata, B. gymnorhiza,* and *C. decandra* — dominated the study area. This finding aligns with Utina et al., (2019) and Sheue et al., (2012), who highlighted the wide distribution and ecological importance of this family in tidal zones.

**Table 1.** Species Composition of Mangroves in Pongkar Village, Karimun Regency

| No. | **Species** | **Local Name** | **IUCN Status** |
|---|---|---|---|
| 1 | *Lumnitzera sp.* | Teruntum | Not protected |
| 2 | *Rhizophora apiculata* | Bakau minyak | Not protected |
| 3 | *Sonneratia alba* | Perepat | Not protected |
| 4 | *Avicennia marina* | Api-api | Not protected |
| 5 | *Ceriops decandra* | Bido-bido | Not protected |
| 6 | *Nypa fruticans* | Nipah | Not protected |
| 7 | *Hibiscus tiliaceus* | Waru laut | Not protected |
| 8 | *Bruguiera gymnorhiza* | Tumu | Not protected |
| 9 | *Pandanus tectorius* | Pandan laut | Not protected |
| 10 | *Lumnitzera sp.* | Teruntum | Not protected |

**Vegetation Structure**

Cumulative analysis of all transects revealed nine mangrove species with density, frequency, dominance, and Importance Value Index (IVI) values shown in Table 2. The vegetation analysis identified nine mangrove species with varying compositions, dominated by *Rhizophora apiculata*. This species recorded the highest density (0.078 ind/m²; 47.17 %), frequency (22.64 %), and dominance (51.34 %), resulting in the highest Importance Value Index (121.15 %). Such dominance reflects its strong adaptation to local environmental conditions, particularly its tolerance to fluctuating tidal inundation and muddy substrates with moderate salinity. Other species, including *Lumnitzera* sp. and *Ceriops decandra*, showed broader distribution despite lower densities, which may be related to their adaptability to slightly higher salinity and elevated substrates. In contrast, *Bruguiera gymnorhiza* and *Pandanus tectorius* exhibited both low density and dominance, suggesting limited tolerance to the prevailing tidal regime and substrate conditions in the study area.

Variation in frequency values among species indicates differences (Fachrul, 2007), The dominance of *Rhizophora apiculata* observed in Pongkar is consistent with findings from Kelasa Island, where this species showed the highest density and importance value due to its adaptability to muddy–rocky substrates and tidal exposure (Akhrianti et al., 2025). Similar patterns were reported in Chaungkaphee Forest, Myanmar, where *R. apiculata* reached an Importance Value Index above 160% under regular inundation regimes (Forests, 2024). In Malaysia, the structural role of *R. apiculata* has been linked to root complexity that enhances sediment accumulation and stabilizes substrates (Raheman et al., 2023), while soil nutrient studies further demonstrate how substrate characteristics influence its growth and dominance (Jamaludin et al., 2022). These comparisons reinforce that the ecological success of *R. apiculata* in Pongkar is strongly shaped by tidal dynamics, salinity gradients, and substrate conditions, confirming its role as the structural backbone of the local mangrove ecosystem.

**Tabel 2.** Vegetation Analysis of Mangroves in Pongkar Village

| No. | Species | Individuals | Density | RD (%) | Frequency | RF (%) | Dominance | RDm (%) | IVI (%) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | *Lumnitzera sp.* | 195 | 0.039 | 23.52 | 20 | 18.87 | 104.76 | 21.04 | 63.43 |
| 2 | *R. apiculata* | 391 | 0.078 | 47.17 | 24 | 22.64 | 255.6 | 51.34 | 121.2 |
| 3 | *S. alba* | 31 | 0.006 | 3.74 | 9 | 8.49 | 33.08 | 6.64 | 18.87 |
| 4 | *A. marina* | 32 | 0.006 | 3.86 | 9 | 8.49 | 36.52 | 7.34 | 19.69 |
| 5 | *C. decandra* | 111 | 0.022 | 13.39 | 18 | 16.98 | 43.34 | 8.71 | 39.08 |
| 6 | *N. fruticans* | 23 | 0.005 | 2.77 | 10 | 9.43 | 7.43 | 1.49 | 13.7 |
| 7 | *H. tiliaceus* | 30 | 0.006 | 3.62 | 7 | 6.6 | 9.75 | 1.96 | 12.18 |
| 8 | *B. gymnorhiza* | 10 | 0.002 | 1.21 | 6 | 5.66 | 6.11 | 1.23 | 8.09 |
| 9 | *P. tectorius* | 6 | 0.001 | 0.72 | 3 | 2.83 | 1.23 | 0.25 | 3.8 |

**Biodiversity Indices**

The Shannon–Wiener diversity index (H′) for mangrove vegetation in Pongkar Village ranged from 1.45 to 1.89, indicating a medium diversity level (Table 3). This reflects a balanced species composition, where no single species completely dominates, although Rhizophora apiculata remains ecologically influential. Such diversity suggests ecosystem stability and resilience to moderate environmental pressures (Asadi & Pambudi, 2020).

**Tabel 3.** Shannon–Wiener Diversity Index of Mangrove Vegetation

| Transect | Species (S) | Individuals (N) | H′ | Diversity Category |
|---|---|---|---|---|
| 1 | 9 | 210 | 1.89 | Medium |
| 2 | 8 | 132 | 1.72 | Medium |
| 3 | 6 | 129 | 1.45 | Medium |
| 4 | 9 | 181 | 1.84 | Medium |
| 5 | 7 | 182 | 1.61 | Medium |

The Shannon–Wiener diversity index (H′) values for the mangrove vegetation in Pongkar Village ranged from 1.45 to 1.89, which falls within the medium diversity category. This range indicates a relatively balanced species composition, where no single taxon completely dominates the community, although Rhizophora apiculata remains the most ecologically influential species. Medium diversity levels suggest that the ecosystem maintains a stable structure and possesses the resilience to withstand moderate environmental pressures without significant shifts in species composition. Such conditions are often found in mangrove ecosystems that experience both natural regeneration and anthropogenic influences (Odum & Barrett, 2021).

The observed variation in H′ across transects may reflect microhabitat differences, tidal influences, and species-specific adaptability. According to Dahdouh-Guebas (2011), mangrove systems with moderate diversity can still sustain essential ecological functions—such as shoreline stabilization, nutrient cycling, and habitat provision—provided that dominant species do not disproportionately limit the recruitment of other taxa. In Pongkar Village, the coexistence of several true mangrove and associated species, despite the dominance of *R. apiculata*, suggests that ecological interactions remain functional. However, maintaining or enhancing this diversity will require conservation actions that prevent overdominance and support the regeneration of less abundant species.

**Species Richness**

Margalef's species richness index (Dmg) ranged from 1.28 to 1.78, with the highest values observed in Transects 1 and 4 (Table 4). These values indicate low to medium species richness, suggesting that while the ecosystem supports multiple species, species numbers are still limited compared to pristine mangrove habitats. Margalef's species richness index (Dmg) values for the Pongkar Village mangrove vegetation ranged from 1.28 to 1.78, with the highest values recorded in Transects 1 and 4. These results indicate low to medium species richness, suggesting that although the ecosystem supports several mangrove species, the total species count remains limited when compared to undisturbed or pristine mangrove systems. Low richness values in certain transects, such as Transect 3 (Dmg = 1.38), may be attributed not only to anthropogenic disturbances and competitive dominance by *Rhizophora apiculata* but also to site-specific environmental parameters, including lower soil pH, higher salinity levels, and reduced mud depth, which can constrain seedling establishment and species recruitment.

**Table 4.** Margalef Species Richness Index of Mangrove Vegetation

| Transect | Species (S) | Individuals (N) | Dmg | Richness Category |
|---|---|---|---|---|
| 1 | 9 | 210 | 1.78 | Medium |
| 2 | 8 | 132 | 1.7 | Medium |
| 3 | 6 | 129 | 1.38 | Low |
| 4 | 9 | 181 | 1.84 | Medium |
| 5 | 7 | 182 | 1.56 | Medium |

Species richness is a key indicator of ecosystem complexity and functional diversity. As noted by Alongi (2015), higher richness often enhances ecological resilience by supporting a wider range of functional traits and adaptive capacities. In mangrove habitats, richness levels are influenced by salinity gradients, tidal inundation patterns, sediment type, and human activities (Nagelkerken et al., 2008). In the case of

Pongkar, maintaining and improving species richness may require targeted restoration efforts that prioritize the reintroduction and protection of less common species, thereby improving ecosystem redundancy and resilience.

### Evenness

Evenness (E) values ranged from 0.81 to 0.86, indicating a high level of evenness (Table 5). This means that individuals are relatively well distributed among species, which supports stable species interactions and ecosystem resilience (Kamal et al., 2024). Evenness (E) values for the Pongkar Village mangrove vegetation ranged from 0.81 to 0.86, classifying the community as having a high level of evenness. This indicates that individuals are relatively well distributed among the recorded species, without extreme dominance by a single taxon. High evenness supports stable interspecific interactions, reduces competition pressure, and promotes ecosystem resilience under environmental fluctuations (Magurran, 2005). In mangrove systems, such distribution patterns can help maintain ecological functions such as nutrient cycling, habitat provision, and shoreline protection, even when overall species richness is moderate.

**Table 5.** Evenness Index of Mangrove Vegetation

| Transect | Species (S) | H′ | ln(S) | E | Evenness Category |
|---|---|---|---|---|---|
| 1 | 9 | 1.89 | 2.2 | 0.86 | High |
| 2 | 8 | 1.72 | 2.08 | 0.83 | High |
| 3 | 6 | 1.45 | 1.79 | 0.81 | High |
| 4 | 9 | 1.84 | 2.2 | 0.84 | High |
| 5 | 7 | 1.61 | 1.95 | 0.83 | High |

The consistently high evenness across all transects suggests that, despite *Rhizophora apiculata* being the most ecologically influential species, other mangrove species still maintain stable population proportions. As Barlow et al., (2007) highlight, ecosystems with high evenness often demonstrate greater functional redundancy, meaning that multiple species can perform similar ecological roles, thereby buffering the system against species loss. For Pongkar's mangrove ecosystem, this balance between dominance and distribution may provide a foundation for longterm stability, especially if conservation efforts maintain the current structural composition while promoting recruitment of less abundant species.

### Dominance

Simpson's dominance index (D) ranged from 0.18 to 0.26 (Table 6). Most transects showed low dominance, meaning no extreme monopoly by a single species, except for Transect 3 which had moderate dominance due to the strong presence of *R. apiculata*. Simpson's dominance index (D) values for the Pongkar Village mangrove vegetation ranged from 0.18 to 0.26, indicating low dominance in most transects. This suggests that no single species overwhelmingly monopolizes community structure, allowing for balanced species interactions and reduced competitive exclusion. However, Transect 3 recorded a moderate dominance value (D = 0.26), largely due to the strong presence of *Rhizophora apiculata*, which holds both ecological and structural influence in the area. Low dominance levels generally correlate with more stable and resilient ecosystems, as species coexistence is maintained without severe suppression of less abundant taxa (Ludwig & Reynolds, 1988).

**Table 6.** Dominance Category per Transect

| Transect | Species (S) | D | 1 – D | Dominance Category |
|---|---|---|---|---|
| 1 | 9 | 0.18 | 0.82 | Low |
| 2 | 8 | 0.21 | 0.79 | Low |
| 3 | 6 | 0.26 | 0.74 | Medium |
| 4 | 9 | 0.2 | 0.8 | Low |
| 5 | 7 | 0.23 | 0.77 | Low |

In mangrove ecosystems, low dominance is often associated with a balanced distribution of ecological functions across multiple species, enhancing ecosystem redundancy and buffering against environmental changes (Clarke et al., 2001). The Pongkar mangrove's low to moderate dominance profile reflects a community capable of sustaining key ecological processes, even under varying environmental pressures. However, continuous monitoring is essential to ensure that dominant species like *R. apiculata* do not increase in prevalence to the detriment of community diversity, particularly in transects already showing signs of moderate dominance.

## Stand Density and Degradation Level

The mangrove stand density in Pongkar was 1,181 trees/ha, placing it in the medium density category according to the Ministry of Environment Decree No. 201/2004 (Table 7). Although ecological functions remain active, this density suggests a vulnerability to degradation if no conservation actions are implemented (Efendi, 2013; Muningsih et al., 2019; Efendi et al., 2025).

## Conservation Implications

The dominance of *R. apiculata* and low representation of species like *A. marina* and *S. alba* indicate an imbalance in species composition that could reduce ecological resilience (Rahim & Balderan, 2017). Such patterns may result from environmental changes or anthropogenic pressures, including land conversion and pollution. If left unmanaged, these trends pose risks of habitat degradation, including reduced recruitment opportunities for less competitive species, loss of biodiversity, and increased vulnerability to coastal erosion. In the long term, such imbalances could diminish key ecosystem functions such as carbon storage, nutrient cycling, and fishery support, thereby undermining both ecological sustainability and community livelihoods.

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**Table 7.** Number of Mangrove Stands (Per Hectare)

| No. | Species | Local Name | Number of Stands |
|---|---|---|---|
| 1 | *Lumnitzera sp.* | Teruntum | 218 |
| 2 | *Rhizophora apiculata* | Bakau minyak | 673 |
| 3 | *Sonneratia alba* | Perepat | 19 |
| 4 | *Avicennia marina* | Api-api | 14 |
| 5 | *Ceriops decandra* | Bido-bido | 149 |
| 6 | *Nypa fruticans* | Nipah | 35 |
| 7 | *Hibiscus tiliaceus* | Waru laut | 29 |
| 8 | *Bruguiera gymnorhiza* | Tumu | 28 |
| 9 | *Pandanus tectorius* | Pandan laut | 16 |
| | **Total** | | **1,181** |

These findings underscore the importance of aligning local management with national policies such as the Indonesian Ministry of Environment and Forestry's mangrove rehabilitation programs, as well as global commitments under SDG 14 (Life Below Water) and SDG 15 (Life on Land), which emphasize the protection of coastal ecosystems, biodiversity conservation, and sustainable use of natural resources. To sustain the Pongkar mangrove ecosystem, recommended strategies include regular monitoring of vegetation structure and species composition, targeted rehabilitation of underrepresented species, and community-based conservation initiatives to raise awareness and reduce destructive activities.

## CONCLUSION

The mangrove ecosystem in Pongkar Village, Karimun Regency, Riau Islands Province, is composed of nine species dominated by *Rhizophora apiculata*. The community is characterized by a medium diversity index (H′ = 1.45–1.89), low to medium species richness (Dmg = 1.28–1.78), high evenness (E = 0.81–0.86), and low dominance (D = 0.18–0.26), indicating a relatively balanced distribution of individuals with moderate ecological stability. However, the limited species richness suggests potential vulnerability to environmental disturbances, emphasizing the need for targeted conservation to maintain biodiversity and ecosystem functions. The stand density of 1,181 trees/ha categorizes the mangroves as having medium density according to the Ministry of Environment Decree No. 201/2004, suggesting that while ecological functions remain active, the ecosystem is susceptible to degradation without intervention. This finding fills a critical gap in localized assessments of mangrove condition in small coastal villages such as Pongkar, where site-specific data are scarce. The novelty of this research lies in integrating field-based stand structure analysis with national policy standards, thereby providing empirical evidence that not only characterizes the ecological status of the ecosystem but also supports targeted conservation and management strategies.

These findings underline the need for proactive conservation measures, including rehabilitation of less dominant species, continuous monitoring, and community-based management programs to maintain ecological balance and prevent further degradation. By implementing targeted conservation efforts, the Pongkar mangrove ecosystem can continue to serve as a vital natural buffer, habitat, and carbon sink for the region. Nonetheless, this study is limited by its focus on vegetation structure and does not incorporate other ecological parameters such as soil properties, hydrological dynamics, or faunal associations that may further influence ecosystem resilience. Future research should integrate multi-disciplinary approaches, including remote sensing, soil and water quality assessments, and long-term monitoring, to provide a more comprehensive understanding of mangrove ecosystem dynamics and strengthen the basis for sustainable management.

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