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Species Composition, Structural Patterns, and Environmental Drivers of a Low-Diversity Mangrove Ecosystem in Toima Village, Banggai, Indonesia

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Abstract

Background: *Mangrove ecosystems are increasingly threatened by land-use change, coastal development, and other anthropogenic disturbances that can reduce biodiversity and impair ecosystem functions. Recent information, species composition and vegetation structure in Toima Village remains limited. This study aimed to analyze species composition, vegetation structure, and environmental factors associated with the mangrove ecosystem in Toima Village, Banggai Regency.* **Methodology:** *Data were collected using purposive sampling approach combined with line-transect plots at 2 sampling stations, comprising 9 plots representing seedling, sapling, and tree growth stages. Vegetation analyses included the Important Value Index (IVI), Shannon–Wiener diversity index (H'), evenness index (E), dominance index (C), and environmental parameters.* **Findings:** *The results revealed that the mangrove community consisted of only 3 species: Rhizophora apiculata, Sonneratia alba, and Sonneratia caseolaris. Species diversity was low across all growth stages (H'= 0.84–0.89), whereas Evenness was relatively high (E= 0.76–0.81). S. caseolaris exhibited the highest IVI values, reaching 134.36% at the tree stage, 179.41% at the sapling stage, and 128.67% at the seedling stage, indicating strong dominance and regeneration capacity. Environmental conditions supported mangrove growth, with salinity ranging from 23–24 ppt, temperatures around 30°C, and neutral pH levels. However, differences in substrate characteristics, with mixed mud–sand substrates supporting better mangrove growth than predominantly sandy substrates. Anthropogenic activities, particularly port development and land conversion, were associated with reduced mangrove diversity in the Toima area.* **Contribution:** *These findings highlight the importance of substrate heterogeneity and species-specific adaptive capacity in shaping mangrove community structure within low-diversity ecosystems and provide a scientific basis for locally adapted mangrove conservation, management, and restoration strategies.*

Keywords: *Banggai; Mangrove Ecosystem; Structural Composition; Toima Village; Vegetation*

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INTRODUCTION

Mangrove ecosystems worldwide are increasingly threatened by land-use change, coastal infrastructure development, natural resource exploitation, pollution, and other anthropogenic activities (Tai et al., 2020; Turschwell et al., 2020; Rasquinha & Mishra, 2021). Ongoing mangrove degradation has led to biodiversity loss, reduced carbon storage capacity, and a decline in ecosystem services that are essential for coastal communities (Carugati et al., 2018; Blowes et al, 2022). Consequently, mangrove conservation and management have become global priorities for maintaining coastal ecosystem resilience and supporting climate change mitigation efforts.

As one of the most productive coastal ecosystems, mangroves provide important ecological, economic, and social functions. They serve as natural barriers against coastal erosion, shoreline retreat, and extreme wave events, while also providing habitat, nursery grounds, and feeding areas for a wide range of aquatic organisms (Barbier, 2016; Saragi & Desrita, 2018; Naharuddin, 2020; Redjeki et al., 2017; Haruna et al., 2022). In addition, mangrove ecosystems support the livelihoods of coastal communities through the provision of various ecosystem services and natural resources.

Banggai Regency, located in Central Sulawesi, Indonesia, possesses substantial mangrove resources and biodiversity. Previous studies recorded 53 mangrove species, consisting of 25 true mangrove species and 28 associated species belonging to 32 families (Katili et al., 2019; Utina et al., 2019). Dominant species reported in the region include *Rhizophora apiculata*, *R. mucronata*, *Bruguiera gymnorrhiza*, *B. sexangula*, *Xylocarpus granatum*, *Sonneratia alba*, *Avicennia alba*, *Ceriops decandra*, and *Nypa fruticans* (Kalsum et al., 2022; Karim et al., 2023; Haruna et al., 2024). Despite this high biodiversity, mangrove ecosystems in Banggai Regency have experienced significant declines in both extent and quality. Paino, (2019) reported a decrease in mangrove cover from 8,935 ha in 2006 to 7,427 ha in 2007, while Utina et al., (2019) documented a further decline to 5,652 ha. These losses have been attributed to land conversion for agriculture, aquaculture, and plantations, mangrove timber exploitation, pollution associated with mining and oil-gas activities, and limited public awareness regarding mangrove conservation (Putranto et al., 2017; Kalsum et al., 2022; Haruna et al., 2018; Rasquinha & Mishra, 2021).

Pressure on mangrove ecosystems in Banggai Regency continues to increase with the expansion of mining activities and coastal infrastructure development. According to the Ministry of Energy and Mineral Resources, at least 21 active Mining Business Operation Production Permits (*Izin Usaha Pertambangan Operasi Produksi*; IUP OP) were recorded in Banggai Regency (Pemerintah Sulawesi Tengah, 2022). In addition, the construction of ports and other coastal infrastructure has contributed to changes in mangrove land cover. These pressures may affect mangrove community structure, regeneration processes, and species distribution patterns.

Previous studies have documented mangrove species composition in Banggai Regency (Utina et al., 2019; Karim et al., 2023) and analyzed vegetation structure in several locations (Haruna et al., 2024). Other studies have investigated mangrove degradation associated with human activities in the region (Kalsum et al., 2022). However, most of these studies have focused primarily on species inventories or ecosystem conditions at broader spatial scales. Information on vegetation structure, species dominance patterns, regeneration dynamics, and environmental factors influencing species distribution at the local scale remains limited.

Toima Village, located in Bunta District, represents one of the coastal areas with considerable mangrove potential in Banggai Regency. However, updated information on mangrove species composition, vegetation structure, and ecological conditions in this area as been available since the last report published around 2004–2008 (Badan Pusat Statistik Kabupaten Banggai, 2009). Furthermore, TuK Indonesia (2022) reported that many mangrove areas in Banggai Regency have not been comprehensively mapped in terms of distribution, extent, management status, and potential threats. This information gap hinders the development of evidence-based conservation and rehabilitation strategies.

In response to existing knowledge gaps, this study aims to provide an analysis of the composition of mangrove species in Toima Village, as well as to examine the vegetation structure and patterns of mangrove dominance at the seedling, sapling, and tree levels. This study also assesses how environmental factors influence the distribution of mangrove species in Toima Village, Banggai Regency, Indonesia. The results of this research are expected to provide baseline information on the condition of mangrove ecosystems at the local level, enrich mangrove ecology studies in the coastal region of Central Sulawesi, and serve as a scientific foundation for more effective and sustainable mangrove management and rehabilitation.

METHOD

This study employed a descriptive-exploratory research design through a field survey to investigate species composition, vegetation structure, and environmental factors associated with the mangrove ecosystem in Toima Village, Banggai Regency, Indonesia. The descriptive approach was used to characterize the current condition of mangrove communities based on vegetation parameters, while the exploratory approach was applied to obtain ecological information from an area where scientific data remain limited. Data collection involved direct observations of mangrove vegetation and measurements of environmental variables at the study site.

Site Observation and Sampling Point Determination

Based on preliminary surveys, Toima Village is a coastal area covering approximately 10.00 km², with a forest area of about 585.00 m². Initial observations were conducted along the coastal zone of Toima Village, Banggai Regency, to obtain baseline information and determine suitable sampling locations. In addition, interviews with village authorities were conducted to collect supporting information regarding environmental conditions and land-use characteristics in the surrounding area. Sampling locations were determined using a purposive sampling method following Fachrul, (2007). Site selection was based on vegetation density and field conditions observed during the preliminary survey. Two mangrove sampling stations were established: Station I at 122°21'49.269"E, 0°46'40.800"S and Station II at 122°21'20.022"E, 0°46'58.944"S (Figure 1).

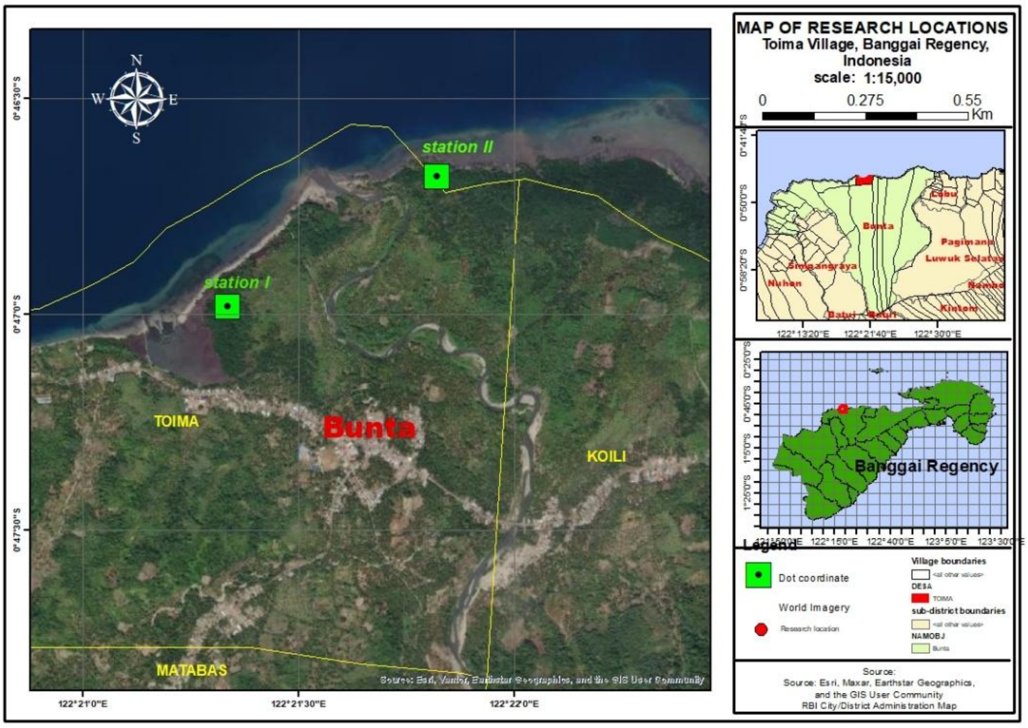

Figure 1. Map of research locations

Vegetation Data Collection

Mangrove vegetation data were collected using the line-transect plot method. Species identification was based on morphological characteristics, including leaf arrangement, stem characteristics, root structures, flowers, and reproductive organs. Each mangrove species encountered was documented photographically for verification purposes.

Sampling Procedure

Data collection was conducted using the line transect method Kusmana, (1997), At each station, a 150-m transect line was established perpendicular to the shoreline. Five observation plots were established at Station I, whereas four plots were established at Station II. Plots were arranged systematically along the transect line at 10-m intervals. Different plot sizes were used according to mangrove growth stages: 20 × 20 m for trees, 10 × 10 m for saplings, and 5 × 5 m for seedlings. The survey focused on true mangrove species. All individuals occurring within the plots were identified and counted according to growth stage (seedling, sapling, and tree). Specimens that could not be identified in the field were collected for further examination. Samples included leaves, stems, flowers, and propagules or fruits when available. Species identification was conducted using morphological characteristics following *A Guide to Mangroves of Indonesia* (Noor et al, 2012) and was verified by researchers experienced in mangrove taxonomy and ecology.

Environmental Measurements

Environmental variables were measured simultaneously with vegetation sampling at each observation station. Parameters included salinity, soil pH, water pH, water temperature, air temperature, relative humidity, and substrate characteristics. Salinity was measured using a refractometer, soil pH using a soil tester, and water pH and water temperature using a water quality checker. Air temperature and relative humidity were measured using a hygrometer. Prior to field measurements, all instruments were inspected and calibrated according to the manufacturers' instructions to ensure measurement accuracy and reliability. Substrate characteristics were assessed directly within each observation plot based on the dominant sediment texture observed in the field. Substrates were then classified descriptively into sand, mud, or mixed sand–mud categories based on visual observations and sediment physical characteristics, following procedures commonly applied in mangrove vegetation studies (Noor et al, 2012).

Data Analysis

Diversity Index (H')

The diversity index is calculated using *the Shannon-Wienner* index (Fachrul, 2007).

$$H' = -\sum = Pi \ \text{In} \ Pi \quad \text{.. (1)}$$

Information :
H = Diversity index. Shannon-Wienner.
Pi = Relative abundance of species i (ni/N).
Ni = Number of individuals of a species.
N = Total number of individuals of all species.

The results obtained can then be categorized into 3 categories, namely:

- If Ĥ < 1 then the diversity index is categorized as Low.
- If Ĥ 1 < Ĥ < 3 then the diversity index is categorized as Medium.
- If the result Ĥ > 3 then the diversity index is categorized as High.

Dominance Index (C)

Species dominance was calculated using Simpson's dominance index (Odum (1998):

$$C = \frac{1}{N^2} \sum n_1^2 \quad \text{.. (2)}$$

Information :
C : Simpson dominance index
N*i*: amount of individuals of species *i*
N: total of individuals of all species

Categories refers to Fachrul (2007), namely:

$0 < C \leq 0{,}5$: Low dominance
$0{,}5 < C \leq 0{,}75$: Medium dominance
$0{,}75 < C \leq 1{,}0$: High dominance

Evenness Index (E)

Species evenness was calculated fsollowing Ludwig & Reynolds, (1988).

$$E = \frac{H'}{H'max} \qquad H'\,max = In\ S \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Information:
E = evenness index
H’ = diversity index
H’max = maximum diversity index
S = amount of species

Evenness values were categorized as:

- $0 < E \leq 0.50$: low evenness
- $0.50 < E \leq 0.75$: moderate evenness
- $0.75 < E \leq 1.00$: high evenness

Species Density

Species density was calculated according to Ludwig & Reynolds, (1988).

$$K = \frac{ni}{A} \times 10.000 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Information :
K = Species density (Ind/m^2)
ni = Total number of individuals of species i
A = Total area of sample observation area (m^2)

Vegetation analysis

Vegetation analysis was conducted using the Important Value Index, calculated as the sum of Relative Density s(RD), Relative Frequency (RF), and Relative Dominance (RDo) following Fachrul, (2007). The Importance Value Index for this species ranges from 0% - 300%. This value is helpful for getting information or an overview of how big the influence or role of each mangrove species is in structuring the mangrove community environment.

$$\text{Density (K)} = \frac{\text{Number of Individuals (species plant)}}{\text{Sample Plot Area}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

$$\text{Frequency (F)} = \frac{\text{The number of plots found for a species}}{\text{Number of all sample plots}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

$$\text{Dominance (D)} = \frac{\text{The basic area of a species}}{\text{The area of the entire sample plot}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

$$\text{Relative density (KR)} = \frac{\text{Density of a species}}{\text{Total density of all species}} \times 100\,\% \ldots\ldots\ldots\ldots\ldots\ldots (8)$$

$$\text{Frequency relatif (FR)} = \frac{\text{Frequency of a species}}{\text{Frequency all species}} \times 100\,\% \ldots\ldots\ldots\ldots\ldots\ldots (9)$$

$$\text{Dominance relatif (DR)} = \frac{\text{Dominance of a species}}{\text{Dominance all species}} \times 100\,\% \ldots\ldots\ldots\ldots\ldots (10)$$

Important Value Index (INP) = KR + FR + CR............................ (11)

RESULT AND DISCUSSION

Species Composition

Vegetation identification conducted across all sampling stations revealed that the mangrove community consisted of only three species: *Rhizophora apiculata*, *Sonneratia caseolaris*, and *Sonneratia alba.* The data presented in Figure 2 revealed differences in mangrove species composition and dominance among growth stages and sampling stations. At the tree stage, *Sonneratia caseolaris* was the dominant species at Station I, with 152 individuals accounting for 77.16% of the total individuals recorded. In contrast, species composition at Station II was more evenly distributed, with *Sonneratia alba* being the most abundant species, represented by 47 individuals (48.96%).

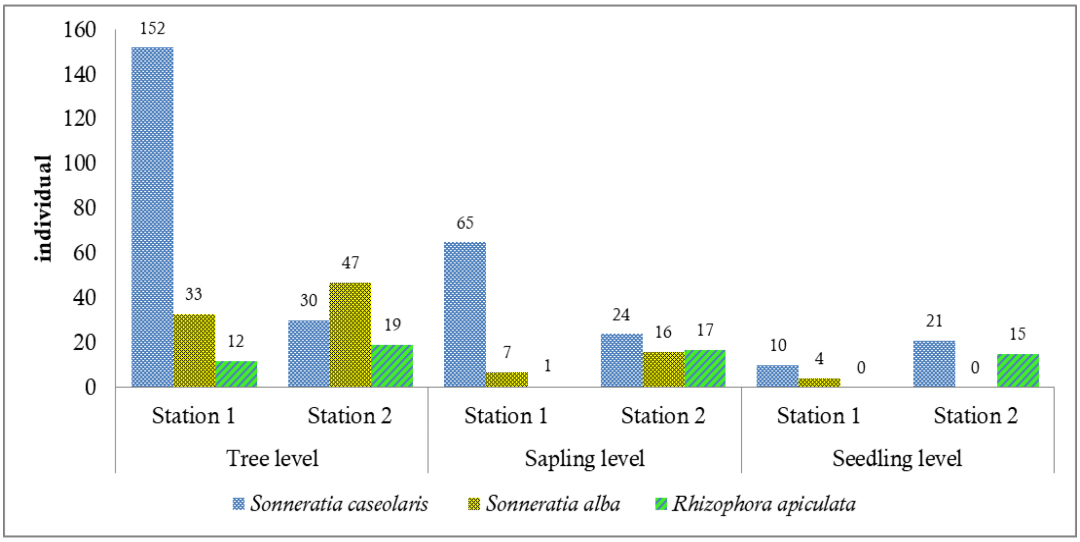

Figure 2. Differences in the Number of Individuals of Each Species at Station I and Station II

At the sapling stage, *Sonneratia caseolaris* remained dominant at Station I, with 65 individuals comprising 89.04% of the total population. In comparison, *Rhizophora apiculata* and *Sonneratia alba* contributed only 1.37% and 9.59% of the total individuals, respectively. At Station II, species abundance was relatively balanced, with *Sonneratia caseolaris*, *S. alba*, and *Rhizophora apiculata* contributing 42.11%, 28.07%, and 29.82% of the total individuals, respectively.

At the seedling stage, the number of individuals recorded was lower than that observed at the tree and sapling stages. At Station I, *Sonneratia caseolaris* remained dominant with 10 individuals (71.4%), while *Sonneratia alba* accounted for 4 individuals (28.6%) and *Rhizophora apiculata* was absent. Conversely, Station II contained 21 individuals of *Sonneratia caseolaris* (58.3%) and 15 individuals of *Rhizophora apiculata* (41.7%), whereas *Sonneratia alba* was not recorded at the seedling stage. These findings indicate that *Sonneratia caseolaris* was the dominant species across most growth stages, particularly at Station I, whereas the mangrove community at Station II exhibited a more balanced species composition and a relatively more even community structure.

Vegetation Structure

The results of the vegetation analysis and community structure assessment for the tree, sapling, and seedling stages at both sampling stations are presented in the following table 1. The vegetation analysis at the tree stage identified three mangrove species: *Rhizophora apiculata*, *Sonneratia alba*, and *Sonneratia caseolaris*. Based on the Important Value Index (IVI), *Sonneratia caseolaris* was the most dominant species, with an IVI of 134.36%, followed by *Sonneratia alba* (117.04%) and *Rhizophora apiculata* (48.60%). Species density (K) indicated that *Sonneratia caseolaris* had the highest density (0.0506 ind m^{-2}), followed by *Sonneratia alba* (0.0222 ind m^{-2}) and *Rhizophora apiculata* (0.0086 ind m^{-2}). However, the highest basal area was recorded for *Sonneratia alba* (21.86 m^2 ha^{-1}), suggesting a larger average stem diameter than the other species.

Table 1. Vegetation Analysis of Mangroves at the Tree Stage

No	Spesies	Basal Area (m^2/ha)	K (Ind/m^2)	INP (%)	H'	E	C
1	*Rhizophora apiculata*	6,79	0,0086	48,60			
2	*Sonneratia alba*	21,86	0,0222	117,04	0,89	0,81	0,47
3	*Sonneratia caseolaris*	14,34	0,0506	134,36			

Table 1 also shows that the Shannon–Wiener diversity index (H′) was 0.89. According to the classification criteria used in this study, an H′ value of less than 1 indicates low species diversity. This result suggests that the mangrove community was characterized by a limited number of species and was largely composed of *Sonneratia caseolaris*, *Sonneratia alba*, and *Rhizophora apiculata*. The Simpson dominance index (C) was 0.47, which falls within the low dominance category ($0 < C \leq 0.50$). This finding indicates that no single species exhibited absolute dominance within the community, although *Sonneratia caseolaris* played a greater ecological role based on its IVI value. The evenness index (E) was 0.81, which is classified as high evenness ($0.75 < E \leq 1.00$). This indicates that individuals were relatively evenly distributed among species and that no marked imbalance in species abundance occurred within the mangrove community.

Table 2. Vegetation Analysis of Mangroves at the Sapling Stage

No	Spesies	Basal Area (m^2/ha)	K (Ind/m^2)	INP (%)	H'	E	C
1	*Rhizophora apiculata*	0,2921	0.0200	43.64			
2	*Sonneratia alba*	0,4348	0.0256	76.95	0.84	0.76	0.52
3	*Sonneratia caseolaris*	1,6780	0.0989	179.41			

Based on Table 2, the mangrove community at the sapling stage consisted of three species: *Rhizophora apiculata*, *Sonneratia alba*, and *Sonneratia caseolaris*. According to the Important Value Index (IVI), *Sonneratia caseolaris* exhibited the highest value (179.41%), followed by *Sonneratia alba* (76.95%) and *Rhizophora apiculata* (43.64%). These results indicate that *Sonneratia caseolaris* played the most prominent ecological role in the mangrove community at the sapling stage. The highest species density (K) was also recorded for *Sonneratia caseolaris* (0.0989 ind m^{-2}), followed by *Sonneratia alba* (0.0256 ind m^{-2}) and *Rhizophora apiculata* (0.0200 ind m^{-2}). Similarly, *Sonneratia caseolaris* exhibited the largest basal area (1.6780 m^2 ha^{-1}), indicating a greater contribution to stand structure compared with the other species.

Table 2 further shows that the Shannon–Wiener diversity index (H′) was 0.84, which falls within the low diversity category ($H' < 1$). This finding indicates that species diversity at the sapling stage remained limited. The Simpson dominance index (C) was 0.52, corresponding to the moderate dominance category ($0.50 < C \leq 0.75$), suggesting the presence of species dominance within the community, particularly by *Sonneratia caseolaris*. Meanwhile, the evenness index (E) was 0.76, which is classified as high evenness ($0.75 < E \leq 1.00$), indicating a relatively even distribution of individuals among species despite the observed dominance pattern.

Table 3. Vegetation Analysis of Mangroves at the Seedling Stage

No	Spesies	K (Ind/m^2)	INP (%)	H’	E	C
1	*Rhizophora apiculata*	0.0667	46.67			
2	*Sonneratia alba*	0.0178	24.67	0.86	0.78	0.48
3	*Sonneratia caseolaris*	0.1378	128.67			

The results presented in Table 3 indicate that the mangrove community at the seedling stage consisted of three species: *Rhizophora apiculata*, *Sonneratia alba*, and *Sonneratia caseolaris*. Based on the Important Value Index (IVI), *Sonneratia caseolaris* recorded the highest value (128.67%), followed by *Rhizophora apiculata* (46.67%) and *Sonneratia alba* (24.67%). These results indicate that *Sonneratia caseolaris* was the most dominant species during the early regeneration stage. Species density (K) exhibited a similar pattern, with *Sonneratia caseolaris* showing the highest density (0.1378 ind m^{-2}), followed by *Rhizophora apiculata* (0.0667 ind m^{-2}) and *Sonneratia alba* (0.0178 ind m^{-2}).

The Shannon–Wiener diversity index (H′) was 0.86, which falls within the low diversity category ($H' < 1$), indicating limited species diversity at the seedling stage. The Simpson dominance index (C) was 0.48, corresponding to the low dominance category ($0 < C \leq 0.50$), suggesting that no single species exerted overwhelming dominance within the community. Meanwhile, the evenness index (E) was 0.78, which is classified as high evenness ($0.75 < E \leq 1.00$), indicating a relatively uniform distribution of individuals among species.

Environmental Factors

Mangrove growth is influenced by various environmental conditions, including substrate characteristics, salinity, water and air temperature, humidity, soil pH, and water pH. The results of environmental measurements at each sampling station are presented in Table 4. Environmental measurements were conducted concurrently with mangrove vegetation sampling. The results indicate that environmental conditions at both stations were generally similar. Salinity ranged from 23 to 24 ppt, soil pH was 7.2, and water pH ranged from 7.3 to 7.5, indicating neutral to slightly alkaline conditions. Water temperature was recorded at 30°C at both stations, while air temperature ranged from 29 to 30°C and relative humidity ranged from 60% to 61%. These environmental conditions generally fall within the range suitable for mangrove growth.

Table 4. Environmental Parameters Recorded at the Study Sites

Station	Salinity (ppt)	Soil pH	Water pH	Water Temperature (°C)	Air Temperature (°C)	Relative Humidity (%)	Substrate Type
I	23	7,2	7,3	30	30	60	Sandy substrate
II	24	7,2	7,5	30	29-30	60-61	Sandy-clay substrate

The primary difference between the two stations was substrate type. Station I was dominated by sandy substrate, whereas Station II was characterized by a mixed substrate consisting of mud and sand. This variation in substrate characteristics may be associated with differences in mangrove distribution and growth observed between the two locations.

DISCUSSION

The results of this study revealed that the mangrove vegetation in Toima Village, Banggai Regency, consisted of only three species: *Rhizophora apiculata*, *Sonneratia alba*, and *Sonneratia caseolaris*. Mangrove communities occurring within a particular site may exhibit monospecific or species-poor assemblages (Martin et al., 2019; Hanggara et al., 2021). he relatively low number of species recorded in the present study indicates a low level of mangrove diversity. This finding was further supported by the Shannon–Wiener diversity index (H′), which remained below 1 across all growth stages (tree, sapling, and seedling). Similar results have been reported in other mangrove ecosystems. For example, Babo et al., (2020) reported diversity index values ranging from 0.59 to 0.69 in Bone Baru Village, Banggai Laut Regency, Central Sulawesi, which were also categorized as low diversity. Likewise, Haruna et al., (2024), found low diversity at the seedling stage in the mangrove ecosystem of Ranga-Ranga Village, Banggai Regency, where the community was dominated by a limited number of species. Low species diversity generally reflects environmental pressures or ecosystem disturbances arising from anthropogenic activities or specific ecological conditions (Blowes et al, 2022; Stamin & Cosmulescu, 2025). Human-induced disturbances such as eutrophication, resource exploitation, harvesting, and land-use conversion can alter community structure by changing species abundance and distribution patterns (Blowes et al., 2020;

Newbold et al., 2015; Stamin & Cosmulescu, 2025), ultimately leading to biodiversity loss.

These findings are also consistent with field observations indicating that the mangrove area in Toima Village has likely decreased due to the construction of a jetty, which resulted in the clearing and conversion of portions of the mangrove habitat. In recent years, rehabilitation efforts have been implemented through mangrove planting programs, primarily involving *Rhizophora* species. However, planting success appeared to be limited in several locations based on field observations. In contrast, naturally established mangroves that persisted in the area were generally found in muddier habitats, particularly around aquaculture ponds, where species of the genus *Sonneratia* were dominant. This pattern suggests a potential influence of habitat characteristics on mangrove growth and species distribution. Nevertheless, the relationship between substrate characteristics and mangrove rehabilitation success in Toima Village was not statistically evaluated in the present study and therefore warrants further investigation. The success of mangrove rehabilitation depends not only on planting activities but also on habitat suitability, including substrate characteristics, hydrological conditions, and sediment dynamics that influence mangrove establishment, growth, and survival (Lewis III, 2005; Winterwerp et al., 2025). Khanbo et al, (2026) further emphasized that matching planting materials with their native coastal habitats can enhance the long-term resilience of mangrove forests.

The low diversity values observed in this study also suggest that the ecosystem may be relatively vulnerable and increasingly dominated by species with high environmental tolerance. Numerous studies have demonstrated a positive relationship between species diversity and ecosystem stability, indicating that declines in biodiversity can reduce community stability and promote the dominance of highly adaptive species (García-Palacios et al., 2018; She et al., 2023). Furthermore, dominant species capable of adapting to environmental fluctuations are known to play a critical role in shaping community structure and ecosystem stability (Hou et al., 2023; Bazzichetto et al., 2024).

Species dominance within the mangrove community was clearly reflected by the Important Value Index (INP), with *Sonneratia caseolaris* exhibiting the highest values across all growth stages (tree, sapling, and seedling). This finding suggests that the species possesses a strong capacity to adapt to local environmental conditions, particularly those related to substrate characteristics and salinity. Species within the genus *Sonneratia* are known to tolerate harsh intertidal environments, including areas with elevated salinity, and generally exhibit rapid growth rates (Rahim & Bakar, 2018; Zhong et al., 2020; Li et al., 2017). Furthermore, several *Sonneratia* species have been reported to exhibit invasive characteristics due to their high tolerance to environmental stress, strong competitive ability, and rapid growth (Wen-Bo et al., 2004; Feng et al., 2025).

Sonneratia is recognized as one of the ecologically important and dominant mangrove genera (Khanbo et al, 2026). Species dominance within a community reflects ecological selection processes, whereby species with greater adaptive capacity tend to become more prevalent. In the present study, the dominance of *Sonneratia caseolaris* was evidenced not only by its high INP and density values but also by its substantial contribution to basal area, which reflects stem size and biomass. However, at the tree stage, *Sonneratia alba* exhibited the highest basal area despite having fewer individuals. This finding indicates that *S. alba* attained larger stem diameters and potentially greater biomass than the other species. These results emphasize that species dominance is determined not only by abundance but also by tree size, as species with relatively few individuals but larger stems may contribute disproportionately to ecosystem biomass and ecological functioning (Mandagi et al., 2024; Lwin et al., 2025). Large trees often provide greater ecological contributions relative to their abundance within the community (Ahmed et al., 2023).

The dominance index (C) exhibited different patterns across mangrove growth stages. At the tree and seedling stages, dominance values were classified as low, indicating that no single species exerted overwhelming dominance within the community. This pattern suggests that relatively balanced interspecific interactions may facilitate species coexistence within the mangrove ecosystem. Positive interspecific interactions, such as mutualism and facilitation, have been shown to play important roles in enhancing community stability and promoting species coexistence (Li et al., 2023). Moreover, the structure of interspecific interactions, whether positive or negative, influences both community stability and long-term coexistence dynamics (Zhang et al., 2022). n mangrove ecosystems, communities characterized by more complex and heterogeneous interactions generally exhibit higher levels of species coexistence than degraded communities (Guo et al., 2024). In addition, increasing species diversity and interspecific interactions during mangrove succession have been shown to strengthen community stability and support the persistence of multiple species within the same ecosystem (Guo et al., 2025).

In contrast, the sapling stage exhibited a moderate dominance value, indicating an emerging tendency toward dominance by particular species, especially *Sonneratia caseolaris*. Moderate dominance reflects active competitive dynamics within the community but does not indicate complete competitive exclusion by a single species (Hasibuan et al., 2025). This pattern suggests that competition among individuals becomes more pronounced during intermediate growth stages, allowing better-adapted species to gain advantages in resource acquisition and utilization. Nevertheless, the moderate dominance observed in this study indicates that the community still maintained a relatively balanced structure and retained the capacity to support species diversity (Retnaningdyah et al., 2024).

Differences in dominance values among growth stages indicate dynamic changes in mangrove community structure driven by regeneration and competitive processes. At the seedling stage, low dominance reflects an early regeneration phase in which opportunities remain available for the establishment of multiple species. At the sapling stage, competition becomes more intense, resulting in a more pronounced dominance pattern. In contrast, dominance decreased again at the tree stage, suggesting a more balanced community structure following natural selection processes. This pattern indicates that the mangrove community in the study area remains dynamic while maintaining a relatively balanced species composition across growth stages.

The high evenness index (E) observed across all growth stages indicates that individuals were relatively evenly distributed among species. This finding suggests that, despite the limited number of species present, there were no extreme disparities in species abundance. High evenness is often associated with a relatively balanced distribution of individuals within a community, although it does not necessarily imply high species diversity. In mangrove ecosystems, high evenness may occur even under conditions of low diversity, particularly in monospecific stands or areas characterized by strong environmental zonation (Efriyeldi et al., 2023; Ucat & Tampus, 2024; Hasibuan et al., 2025).

The regeneration structure represented by the seedling, sapling, and tree stages exhibited a consistent pattern, with *Sonneratia caseolaris* dominating throughout all growth stages. Successful regeneration is a key indicator of mangrove ecosystem sustainability because seedling establishment and survival strongly influence future community structure. Previous studies have demonstrated that regeneration success is highly dependent on environmental conditions, including substrate characteristics, hydrological regimes, and disturbance factors, which collectively determine recruitment success and the dominance of particular species (Numbere, 2021; Xiong et al., 2021). n many mangrove ecosystems, species that successfully establish and adapt during the early stages of development tend to remain dominant through later growth stages (Xiong et al., 2021). Effective natural regeneration contributes to the development of more resilient and sustainable mangrove communities, with successful seedling recruitment serving as an important indicator of ecosystem health. Moreover, regeneration processes influence community dynamics by favoring species with superior colonization ability and growth performance (Chatterjee & Bhandari, 2025; Basyuni et al., 2025; Zhang et al., 2025; López-Adame et al., 2026).

Environmental conditions at the study site generally remained suitable for mangrove growth, with salinity ranging from 23 to 24 ppt, neutral pH conditions, and temperatures of approximately 30°C. Nevertheless, habitat characteristics differed between the two sampling stations, particularly with respect to substrate type. Station I was dominated by sandy substrate, whereas Station II was characterized by a mixed mud–sand substrate. Species such as *Sonneratia caseolaris* are commonly reported to tolerate muddy and mixed substrates, which may contribute to their greater abundance under such conditions. Previous studies have shown that substrate composition (sand, mud, or mixed substrates) and salinity variation are closely associated with mangrove species distribution and zonation patterns because individual species differ in their environmental tolerances (Dharmayasa et al., 2025; Wickramasingha & Weerasinghe, 2024; Aznawi et al., 2026). In particular, *Sonneratia caseolaris* tends to thrive under low to moderate salinity conditions and in muddy or mixed substrates (Wintah et al., 2023; Wickramasingha & Weerasinghe, 2024). These characteristics may enhance its ability to tolerate environmental fluctuations, including oxygen-deficient soils, thereby increasing its competitive advantage and ecological importance within the mangrove community (Liu et al., 2025).

CONCLUSION

This study demonstrated that the mangrove ecosystem in Toima Village, Banggai Regency, was characterized by low species diversity, with only three mangrove species recorded: *Rhizophora apiculata*, *Sonneratia alba*, and *Sonneratia caseolaris*. The mangrove community was dominated by *Sonneratia caseolaris* across all growth stages, indicating its strong adaptive capacity and regeneration potential under local environmental conditions. Although environmental conditions generally remained suitable for mangrove growth, differences in habitat characteristics observed between sampling stations were associated with variations in species composition and dominance patterns. These findings suggest that mangrove community structure in low-diversity ecosystems is largely shaped by species capable of adapting to local habitat conditions. Therefore, mangrove rehabilitation and management efforts in the coastal areas of Banggai should consider species–habitat suitability to improve restoration success and long-term ecosystem sustainability. This study was limited to two sampling stations and did not statistically evaluate the relationships between environmental variables and species distribution. Future research employing multivariate analytical approaches is recommended to identify the environmental factors most strongly associated with mangrove community structure.

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