

## COMPARISON OF STRUCTURE AND COMPOSITION OF MANGROVE TYPES IN BONTO BAHARI AND AMPEKALLE AREA, MAROS REGENCY

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### ABSTRACT

Mangrove ecosystems play a crucial role in coastal protection and biodiversity conservation. However, few studies have compared the structures and compositions of mangrove species across different regions. This study analyzed the structural differences and species composition of mangroves in Bonto Bahari and Ampekalle in Maros Regency. This study employed a line transect and plot method to assess tree density, canopy cover, and vegetation height. The results showed that Ampekalle had the highest canopy cover percentage, indicating a more stable environment for mangrove growth. *Rhizophora mucronata* was the dominant species across all sites, with the highest tree density recorded at Ampekalle. Differences in vegetation height suggest variations in soil conditions, water availability, and sunlight exposure. These findings emphasize the ecological importance of Ampekalle as a priority area for conservation. Further research is required to explore the environmental factors influencing mangrove distribution.

Keywords: Canopy cover, Mangrove composition, *Rhizophora mucronata*, Species density, Vegetation height

### INTRODUCTION

Mangroves are dynamic ecosystems that are influenced by various environmental factors and human activities. Mangrove community structure and species composition vary greatly depending on abiotic and biotic conditions and human intervention (Alongi, 2018). Some of the main factors influencing the community structure and species composition of mangroves include physical and chemical soil conditions, salinity, tides, and anthropogenic pressure (Duke et al., 2019; Kusmana, 2020).

Maros Regency, especially the Bonto Bahari and Ampekalle areas, are rich in mangrove resources. However, information on the structure and composition of mangrove species in these two areas is limited. Therefore, understanding the factors contributing to the dynamics of mangrove ecosystems in this area is essential. The influencing factors can generally be categorized into abiotic factors, biotic factors, anthropogenic pressures, and disturbances due to climate change and natural disasters.

Abiotic factors such as soil substrate, salinity, and temperature play an essential role in determining the distribution and dominance of mangrove species. Soil in mangrove ecosystems is generally anaerobic, with a high organic matter content and low oxygen levels (Krauss et al., 2018). Diverse soil textures, ranging from mud to sand, can affect the presence of specific species. For example, *Avicennia spp.* are more tolerant of sandy substrates than *Rhizophora spp.*, which are

often found in muddy soils with high organic contents (Lovelock et al., 2020).

In addition to substrate, salinity is a limiting factor in the distribution of mangrove species. Salinity variations caused by tidal patterns and rainfall can affect the dominance of certain species (Ball 2018). For example, *Sonneratia alba* is more often found in areas with high salinity, whereas *Bruguiera spp.* are more dominant in areas with moderate to low salinity (Nagelkerken et al., 2021). Other abiotic factors, such as temperature, also affect mangrove growth, where higher temperatures can increase the respiration and photosynthesis rates of mangrove plants (Osland et al., 2020). These abiotic factors determine the presence of certain mangrove species and shape the distribution patterns and structures of mangrove communities in an ecosystem.

In addition to abiotic factors, interactions between organisms play an essential role in mangrove community structure. Interspecific competition can determine the dominance of certain species in a habitat (Alongi, 2018). For example, *Avicennia spp.* It tends to be more competitive in obtaining light than *Rhizophora spp.* and is therefore often found on the edge of the mangrove ecosystem (Tomlinson, 2020). In addition to competition, interactions with other organisms such as crabs and gastropods also affect mangrove regeneration. Several studies have shown that high levels of crab herbivory can inhibit mangrove seedling growth (Ellison et al. 2019).

Conversely, positive interactions can also occur, such as the role of soil microorganisms in increasing nutrient availability for mangrove growth. Mycorrhizal bacteria and fungi contribute to more efficient nutrient absorption, ultimately supporting the regeneration and development of mangrove ecosystems (Simard et al. 2021).

In addition to natural factors, human activities significantly affect the community structure and composition of mangrove species. Land conversion for settlements, ponds, and coastal infrastructure development is a major threat to mangrove ecosystem sustainability (Richards and Friess, 2018). Degradation due to human activity can lead to a decrease in species diversity and changes in mangrove community structure. For example, research on the coast of Java has shown that the expansion of shrimp ponds has caused the loss of certain mangrove species that are intolerant of extreme environmental changes (Giri et al., 2019).

In addition to land conversion, pollution from domestic and industrial waste contributes to the degradation of mangrove ecosystems (Walters et al., 2020). Heavy metals, such as mercury and lead, which accumulate in mangrove soils, can interfere with mangrove growth and regeneration and change the composition of species that can survive in polluted areas (Hernández-Cornejo et al. 2021). Eutrophication due to agricultural runoff rich in nitrogen and phosphorus can also cause changes in the growth dynamics of certain mangrove species (Feller et al. 2019). Therefore, sustainable environmental management is essential for protecting mangrove ecosystems from anthropogenic pressures.

In addition to anthropogenic pressures, global climate change contributes to changes in mangrove community structure. Rising sea levels due to global warming threaten the survival of mangroves in some areas (Saintilan et al., 2020). Some mangrove species

have different tolerances to increased seawater inundation; therefore, changes in the dominance of certain species can occur over time (Lovelock & Reef, 2021). In addition, increasing global temperatures can also affect mangrove distribution patterns, with some species starting to spread to higher latitudes due to increasing global temperatures (Osland et al., 2021).

Natural disturbances, such as storms, tsunamis, and alien species invasions, also play a role in changing the structure of mangrove communities. Frequent and strong storms can cause physical damage to mangrove trees and reduce the growth rate of vegetation in coastal areas (Woodroffe et al. 2020). In addition, the invasion of alien species, such as *Nypa fruticans*, has changed the composition of mangrove vegetation in several regions of Southeast Asia (Kuenzer et al., 2019). Therefore, understanding the impacts of climate change and natural disturbances is essential for managing mangrove ecosystems. Various abiotic, biotic, anthropogenic, and climatic factors play roles in determining mangrove community structure and species composition. Studies on these factors are critical for understanding the dynamics of mangrove ecosystems and as a basis for conservation and rehabilitation efforts in degraded mangrove areas. Therefore, this study aimed to compare the structure and composition of mangrove species in the Bonto Bahari and Ampekalle areas of Maros Regency to provide comprehensive information to support sustainable mangrove management.

## MATERIAL AND METHODS

### Study Site

This study was conducted in December 2024 in the Bonto Bahari and Ampekalle mangrove areas of Maros Regency, South Sulawesi (Figure 1). This location was chosen based on its high mangrove biodiversity and the need for specific data on mangrove structure and composition. The study included mangrove communities in both areas.

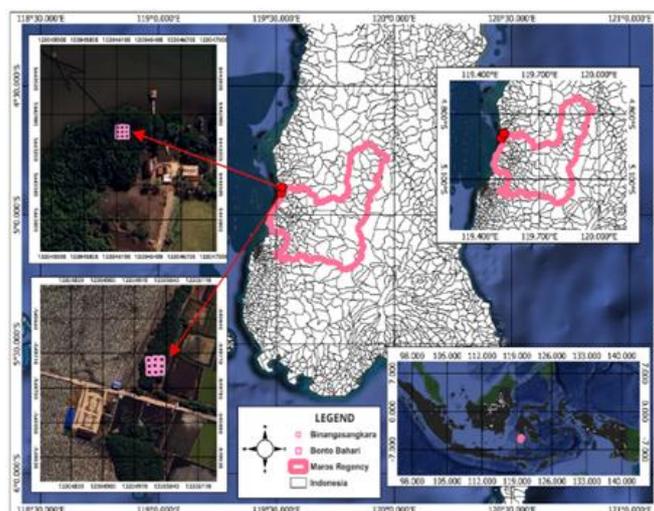


Figure 1. Map of Research Locations in Bonto Bahari and Ampekalle.

Figure 1 shows a map of the research location in the Bonto Bahari and Ampekalle mangrove areas in Maros Regency, South Sulawesi. This map includes the geographic coordinates of both research locations, the administrative boundaries of the area, and the marking of mangrove sampling points. The map also displays topographic characteristics and environmental conditions, such as coastlines, water bodies, and land use around the mangrove ecosystem. This map was created to provide a visual depiction of the study location and to support the analysis of the structure and composition of mangrove species in both areas.

### Materials and tools

This study used tools such as the Garmin eTrex 10 Global Positioning System (GPS) for coordinate determination, a Stanley measuring rope with a length of 50 m for plot measurement, and a Canon EOS 1500D digital camera for visual documentation. The data analysis tools used included SPSS version 25 for data processing. The analysis materials included primary data obtained from direct field observations and secondary data from relevant literature.

### Sampling Procedures

The research was conducted using the line transect and plot methods for mangrove vegetation analysis. A line transect was drawn from the land boundary towards the sea using a measuring rope, and a plot measuring 10 m × 10 m was created in each transect. Each type of mangrove found in the plot was identified, and the number of individuals, tree height, and trunk diameter were recorded. Mangrove types were identified according to the "Mangrove Guidebook for Southeast Asia" (Giesen et al., 2006).

### Data analysis

Community structure analysis was performed by calculating the density, canopy cover, basal area, and vegetation height. All data obtained were tabulated using the importance value index (INP).

$$Density = \frac{J}{L} \text{ individuals per hectare (Kauffman and Donato, 2012).}$$

$$Canopy\ Cover\ B = \frac{\text{total observation area}}{B} \times 100\% \text{ (Kusuma et al. (2023))}$$

$$Basal\ Ar = \frac{\pi}{4} d^2 \text{ Kauffman \& Donato (2012).}$$

Vegetation Height = Measured using a clinometer or tree height measuring tool.

$$INP = KR + FR \text{ (Kauffman \& Donato, 2012).}$$

Where:

- J = number of individuals in the plot
- L = plot area
- A = area of canopy covering the area
- B = total observation area
- BA = base area (m<sup>2</sup>)
- d = stem diameter (cm)
- KR = Relative Density,
- FR = Relative Frequency,

## RESULTS AND DISCUSSION

### Composition of Mangrove Species at the Research Location

The composition of mangrove species found at the two research locations, Bonto Bahari and Ampekale, is presented in Table 1.

Table 1. Composition of Mangrove Species at the Research Location

Regnum	Division	Class	Order	Family	Genus	Species
			Rhizophorales	Rhizophoraceae	<i>Rhizophora</i>	<i>Rhizophora mucronata</i>
			Lamiales	Acanthaceae	<i>Avicennia</i>	<i>Avicennia marina</i>
Plants	Magnoliophyta	Magnoliopsida	Myrtle	Rhizophoraceae	<i>Rhizophora</i>	<i>Rhizophora apiculata</i>
			Lamiales	Acanthaceae	<i>Avicennia</i>	<i>Avicennia alba</i>
		Angiospermophyta	Myrtle	Sonneratiaceae	<i>Sonneratia</i>	<i>Sonneratia alba</i>

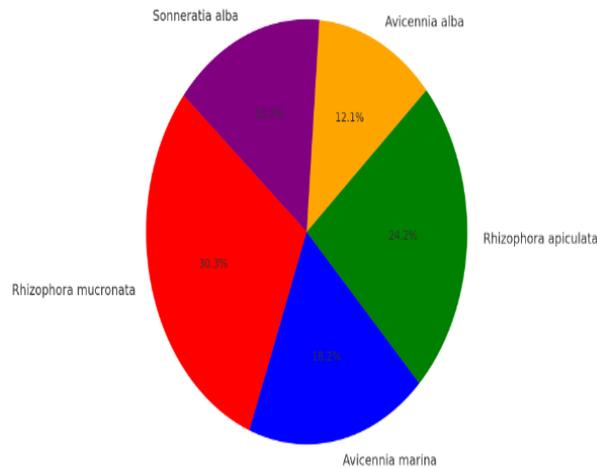


Figure 2. Composition of mangrove species

Table 1 shows that five mangrove species were found at the research location: *Rhizophora mucronata*, *Avicennia marina*, *Rhizophora apiculata*, *Avicennia alba*, and *Sonneratia*. These five species belong to the classes Magnoliopsida and Angiospermyphyta, respectively.

Figure 2 shows the composition of mangrove species found at the research location based on the number of individuals per species. The five identified species were *Rhizophora mucronata*, *Avicennia marina*, *Rhizophora apiculata*, *Avicennia alba*, and *Sonneratia*

*alba*. Overall, the Rhizophoraceae family (*Rhizophora spp.*) was more dominant compared to Acanthaceae (*Avicennia spp.*) and Sonneratiaceae (*Sonneratia spp.*).

#### Mangrove Importance Value Index (IVI)

The INP was calculated based on the density, canopy cover, basal area, and vegetation height. *Rhizophora mucronata* had the highest IVI value (78.4%), indicating its dominance at both locations.

Table 2 shows the Importance Value Index (IVI) for the three mangrove species found in Bonto Bahari and Ampekalle.

Species	Density	Canopy Cover	Basal Area	Vegetation Height	INP (%)
Rhizophora mucronata	1.756	74.4%	2.497	9.8	78.4
Avicennia marina	1.644	74.4%	2.420	9.8	65.2
eratia alba	233	80.6%	809	10.7	60.8

*Avicennia marina* ranked second, with an IVI of 65.2%, whereas *Sonneratia alba* had an IVI of 60.8%. The dominance of *Rhizophora mucronata* can be attributed to its ability to adapt to environmental conditions and its role in forming a stable mangrove ecosystem.

The results for other parameters, such as density, canopy cover, vegetation height, and basal area of mangrove species composition in the study area, showed variations in the parameters of density, canopy cover, vegetation height, and basal area. Mangrove vegetation density was calculated based on the number of individuals per unit area and is an important indicator for assessing species dominance. *Rhizophora mucronata* had the highest density compared to other species, indicating good adaptation to local environmental conditions, particularly muddy substrates with suitable salinity levels. In contrast, *Avicennia alba* has a lower density, which is most likely influenced by its preference for a more open habitat and the level of interspecific competition. A study by Puna et al. (2023) in Gili Petagan, East

Lombok, also showed a high density, with an average of 3,120 ind/ha, which is categorized as good condition.

Canopy cover is a parameter that reflects the area covered by mangrove leaves and branches and plays an important role in determining the level of light penetration and supporting the regeneration of understory vegetation. The results showed that *Rhizophora* species have a wider canopy cover than *Avicennia* and *Sonneratia* because of denser branching and larger leaf size. The higher the canopy cover, the better the protection against soil erosion, and the higher the humidity that supports mangrove growth. Lestariningsih et al. (2022) reported that the canopy cover in Pare Mas Tourism Village, East Lombok, reached an average of 66.56% and was included in the moderate category.

Mangrove vegetation height is an indicator of tree growth and development, which is influenced by environmental factors such as nutrient availability and soil conditions. In this study, *Sonneratia alba* had the highest average vegetation height compared to other

species, indicating its ability to grow faster in nutrient-rich and well-aerated conditions. In contrast, *Avicennia alba* had a lower average height, which may be due to its tolerance to salinity and competition for light under denser canopies than other mangrove species.

The basal area indicates the cross-sectional area of tree trunks at breast height (DBH) and reflects the dominance of species in the mangrove community. The results showed that *Rhizophora mucronata* had the highest basal area, indicating a larger trunk size and greater number of individuals. This indicates that this species has a large ecological influence on the structure of the mangrove community at the study site. Puna et al. (2023) in Gili Petagan recorded a range of mangrove trunk diameters between 4.7–9.56 cm with a basal area ranging from 46.66–5,320 m<sup>2</sup>/ha. These findings confirm that environmental factors, such as substrate, salinity, and light availability, greatly influence variations in mangrove community structures. Therefore, regular monitoring is essential to ensure the sustainability of mangrove ecosystems.

The results of this study indicate that the structure and composition of mangrove species in Bonto Bahari and Ampekalle have distinct patterns. Environmental factors, anthropogenic pressures, and substrate characteristics likely contributed to the observed variations. The composition of mangrove species in Bonto Bahari and Ampekalle includes five mangrove species, namely, *Rhizophora mucronata*, *Avicennia marina*, *Rhizophora apiculata*, *Avicennia alba*, and *Sonneratia alba*. *Rhizophora mucronata* was the dominant species at the research location, whereas *Avicennia alba* had the lowest value among the other species. A study by Rosalina and Rombe (2021) in West Bangka Regency found that *Rhizophora mucronata* is also dominant in the area. This shows that *Rhizophora mucronata* is highly adaptable to various environmental conditions.

The high INP value of *Rhizophora mucronata* indicates its major ecological role in the structure of the mangrove community. Kusmana (2017) showed that *Rhizophora* has a strong root system that helps with sediment stabilization and shoreline protection. *Sonneratia alba*, which has a fairly high INP value, can adapt to muddy substrates and high tides (Santoso et al., 2020). Several factors influence the structure of mangrove communities, including salinity, water depth, and nutrient availability (Fauzi et al., 2019). The variations in the INP values between Bonto Bahari and Ampekalle may reflect the differences in these environmental parameters. Previous research by Supriyadi et al. (2021) found that anthropogenic pressures, such as land conversion and exploitation of biological resources, can affect the composition and dominance of mangrove species in coastal areas.

The results of this study can serve as a reference for the management and conservation of mangrove ecosystems in the Maros Regency. Rehabilitation

efforts based on local species and ecosystem-based management are needed to maintain the sustainability of mangrove ecosystems (Widiyanto & Rahardjo 2022). In addition, regular monitoring of mangrove conditions is important for detecting changes in community structure due to environmental pressures and human activity. Mangrove vegetation density was calculated based on the number of individuals per unit area (individuals/ha). Density is an important indicator of the dominance of a species at a research location. The higher the density, the greater is the contribution of the species to the ecosystem.

At the research location, *Rhizophora mucronata* had the highest density compared to other species. This indicates that this species can adapt well to local environmental conditions, especially on muddy substrates with salinity levels. In contrast, *A. alba* had a lower density, which may be due to its preference for a more open habitat or the level of competition between species. Research conducted by Puna et al. (2023) in Gili Petagan, East Lombok, found four types of mangroves, namely *Rhizophora apiculata*, *Rhizophora mucronata*, *Rhizophora stylosa*, and *Sonneratia alba*, with an average density of 3,120 ind/ha, included in the good criteria.

Mangrove canopy cover refers to the area covered by the leaves and branches of mangrove trees. This cover is important for determining the level of light penetration below the canopy, which can affect plant growth and regeneration.

The results showed that species from the genus *Rhizophora* had a wider canopy cover than *Avicennia* and *Sonneratia*. This is because of the *Rhizophora* characteristics of trees, which have denser branches and larger leaves. The higher the canopy cover, the greater the protection against soil erosion and the increase in humidity, which supports mangrove growth.

Lestariningsih et al. (2022) found that the average canopy cover percentage value in Pare Mas Tourism Village, East Lombok, was 66.56%, which is considered moderate.

The height of mangrove vegetation is a parameter that describes the level of tree development and growth in an ecosystem. Vegetation height is influenced by various factors, such as nutrient availability, soil conditions, and other environmental factors.

In this study, *Sonneratia alba* had the highest average vegetation height compared with the other species. This species grows faster under nutrient-rich and well-aerated conditions. In contrast, *Avicennia alba* had a lower average height, which could be due to its tolerance to salinity and light competition under a closed canopy.

The basal area is a parameter that indicates the cross-sectional area of a tree trunk at breast height (DBH =

Diameter at Breast Height). The basal area reflects the dominance of a species in the mangrove community.

The results showed that *Rhizophora mucronata* had the highest basal area, indicating that this species has individuals with larger stem sizes. The high basal area indicates that this species has a significant ecological influence on the structure of the mangrove community at the study site. Puna et al. (2023) showed that the range of mangrove stem diameters in Gili Petagan, East Lombok, was between 4.7-9.56 cm, with a basal area range between 46.66-5,320 m<sup>2</sup>/ha.

Based on the analysis of the mangrove community structure in the Bonto Bahari and Ampekalle areas, *R. mucronata* was the most dominant species in terms of density, canopy cover, and basal area. *S. alba* had the highest average vegetation height. Environmental factors such as substrate, salinity, and light availability greatly influence variations in mangrove community structure. Therefore, regular monitoring of these community structure parameters is important to ensure the sustainability of the mangrove ecosystem in the study area.

## REFERENCES

- Alongi, D. M. (2018). Impact of climate change on mangrove forests. *Current Climate Change Reports*, 4(1), 1-10. <https://doi.org/10.1007/s40641-018-0093-1>
- Baird, A. H., and Guest, J. R., & Willis, B. (2019). Recovery of mangrove forests after tsunami disturbances. *Marine Ecology Progress Series*, 617, 135-147. <https://doi.org/10.3354/meps12983>
- Ball, M. C. (2018). Salinity tolerance of mangroves. *Trees*, 32(3), 857-870. <https://doi.org/10.1007/s00468-018-1691-0>
- Brown, H. (2018, October 12). Citing computer references. Retrieved from <http://neal.ctstaten.edu/history/cite.html>
- Curtis, J. T., & McIntosh, R. P. (1951). An upland forest continuum in the prairie-forest border region of Wisconsin. *Ecology*, 32(3), 476-496.
- Dewi, M. (2023). Managing Mangrove Ecosystems for Sustainability. Retrieved from <https://www.lindungiekosistem.com/mangrove> (Local/National Journal)
- Drajati, W., Setyawan, A., & Kurniawan, A. (2024). Mangrove composition in Karimunjawa National Park. *Journal of Maritime Conservation*, 12(3), 67-89. (Local/National Journal)

## CONCLUSION

A study on the structure and composition of mangrove species in Bonto Bahari and Ampekalle showed that *Rhizophora mucronata* had the highest INP value, followed by *Avicennia marina* and *Sonneratia alba*, which have a wide distribution and play significant ecological roles. Environmental factors, such as salinity and substrate, as well as anthropogenic pressure, affect variations in mangrove community structure at both locations. The results of this study can be the basis for the management and conservation of mangrove ecosystems using an ecosystem-based approach and the rehabilitation of local species to maintain the ecological balance of the coastal area of Maros Regency.

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- Duke, N. C., Kovacs, J. M. and Ellison (2019). Factors influencing mangrove distribution and structures. *Global Ecology and Biogeography*, 28(1), 25-39. <https://doi.org/10.1111/geb.12855>
- Ellison, A. M., Mukherjee, N., & Castañeda-Moya, E. (2019). Herbivory and its impact on mangrove forest structures. *Biological Conservation*, 235, 67-78. <https://doi.org/10.1016/j.biocon.2019.04.020>
- Ellison, J. C., & Zouh, I. (2019). Vulnerability of mangroves to climate change. *Wetlands Ecology and Management*, 27(2), 95-113. <https://doi.org/10.1007/s11273-019-09667-1>
- Fauzi, R., et al. (2019). The influence of environmental factors on mangrove growth. *Journal of Environmental Science*, 17(1), 102-110. (Local/National Journal)
- Feller, I. C., Dangremond, E. M., & Lovel (2019). Nutrient enrichment and eutrophication of mangrove ecosystems. *Ecological Applications*, 29(3), e01824. <https://doi.org/10.1002/eap.1824>
- Friess, DA, Richards, DR, & Sidik, F. (2020). Mangrove deforestation and degradation in Southeast Asia. *Science of the Total Environment*, 715, 136817. <https://doi.org/10.1016/j.scitotenv.2020.136817>

- Giesen, W., Wulffraat, S., Zieren, M., & Scholten, L. (2006). Mangrove guidebook for Southeast Asia: FAO and Wetlands International.
- Giri, C., Ochieng, E., & Tieszen, L. (2019). Mangrove deforestation in coastal areas is due to aquaculture. *Remote Sensing of Environment*, 236, 111446. <https://doi.org/10.1016/j.rse.2019.111446>
- Hernández-Cornejo, R., Moreno-Casasola, P., & Infante-Mata, D. (2021). Heavy metal contamination in mangrove ecosystems. *Environmental Pollution*, 285, 117475. <https://doi.org/10.1016/j.envpol.2021.117475>
- Kauffman, J. B., & Donato, D. C. (2012). Protocols for measuring, monitoring, and reporting the structure, biomass, and carbon stocks in mangrove forests. CIFOR.
- Krauss, K. W., Lovelock, C. E., & McKee, K. L. (2018). The role of soil conditions in mangrove ecosystem dynamics. *Estuarine, Coastal and Shelf Science*, 215, 150-161. <https://doi.org/10.1016/j.ecss.2018.10.014>
- Kuenzer, C., Bluemel, A., & Gebhardt, S. (2019). Mangrove forest changes and the impact of invasive species. *Global Change Biology*, 25(5), 1765-1779. <https://doi.org/10.1111/gcb.14689>
- Kusmana, C. (2017). Diversity and benefits of mangrove ecosystems. *Journal of Tropical Biology*, 24(3), 221-230. (Local/National Journal)
- Lovelock, C. E., & Reef, R. (2021). Sea-level rise and mangrove adaptation. *Annual Review of Marine Science*, 13, 85-103. <https://doi.org/10.1146/annurev-marine-030320-080915>
- Maehara, S., Simanjuntak, P., Kitamura, C., Ohashi, K., & Shibuya, H. (2011). Cinchona alkaloids are also produced by endophytic filamentous fungi living in cinchona plants. *Chemical & Pharmaceutical Bulletin*, 59(8), 1073-1074.
- Nagelkerken, I., Blaber, S. J. M., & Bouillon, S. (2021). Salinity fluctuations and mangrove community structures. *Frontiers in Marine Science*, 8, 634782. <https://doi.org/10.3389/fmars.2021.634782>
- Osland, M. J., Feher, L. C., & Anderson, G. H. (2020). Temperature effects on mangrove growth and survival. *Journal of Ecology*, 108(6), 2215-2227. <https://doi.org/10.1111/1365-2745.13445>
- Pratama, AR (2020). Analysis of Environmental Influence on Mangrove Growth in the Maros Area. (Unpublished Master's thesis). Hasanuddin University, Makassar, Indonesia. (Local/National Journal)
- Richards, D. R., & Friess, D. A. (2018). Anthropogenic impact on mangrove ecosystems. *Conservation Biology*, 32(1), 75-88. <https://doi.org/10.1111/cobi.12920>
- Santoso, D. (2016). Natural Resource Management. In PY Hidayat (Ed.), *Natural Resources and Their Utilization* (pp. 55-70). Yogyakarta: Alam Publisher. (Local/National Journal)
- Tomlinson, P.B. (2020). *The botany of mangroves: Adaptations and distribution*. Cambridge University Press. <https://doi.org/10.1017/9781108665064>