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Mangrove Diversity as An Indicator of Ecosystem Health on Ambon Island, Indonesia

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Abstract. The research aims to determine the species richness, diversity and distribution of mangrove populations in forest areas, which is one of the parameters of forest health in the Passo Village's mangrove forest. It was conducted from July to August 2023 on Ambon Island using the Forest Health Monitoring Field Methods Guide. The research covered 2 hectares of mangrove forest with 3 clusters of 12 observation plots. It was found that seven species of mangroves were found in the area, namely *Sonneratia alba*, *Rhizophorastylosa*, *Avicennia marina*, *Aegiceras corniculatum*, *Bruguiera gymnorrhyza* and *Bruguiera parviflora*. Cluster 1 had 260 trees. Cluster 2 had 321 trees, and Cluster 3 had 193 trees. The highest value of mangrove species richness was at the sapling level of 1,003. Meanwhile, the species diversity was classified as low at only 0.701 at the seedling level. The highest density of the Sonneratia alba species was 4,290, the species dominance of the *Sonneratia alba* was 22,240, and the highest importance index occupied by the *Sonneratia alba* was 160.95. Considering the low level of mangrove forest biodiversity on Ambon Island, rehabilitation and reforestation efforts are needed to maintain the quality and health of the ecosystem, especially in facing the impact of climate change on small islands.

Keywords: biodiversity; distribution; forest health; mangroves; small island

INTRODUCTION

Indonesia is an archipelagic country consisting of 17,504 islands and has the largest mangrove forest area in the world at 2.7 million ha in 2020 (Meng et al., 2022).Mangrove forests in Indonesia are spread across its 34 provinces, with most of their areas being spread across its Eastern part (Tian et al., 2023). The country is a home to 157 species of mangrove flora, consisting of 52 species of the trees (true mangroves), 21 species of shrubs, 13 species of lianas, seven species of palms, 14 species of grasses, eight species of herbaceous plants, three species of parasites, 36 species of epiphytes, and three species of ferns. Approximately 122 species of invertebrates, 45 species of fish, and 148 species of terrestrial fauna were found in Indonesian mangroves (Owuor et al., 2019). In regard to global warming, mangrove forests play some role in its mitigation because they can store carbon (C) (Durán & Barbosa, 2019). The carbon that mangrove forests can store is over three times the average carbon stored per hectare by mainland tropical forests. The optimal carbon absorption by mangroves can reach 77.9%. The absorbed carbon is stored in mangrove biomass in several parts, such as the stems, leaves and roots. Mangrove ecosystems provide significant ecological and economic impacts with high biomass levels and economic value. It also provides a habitat for marine biota, food, and breeding grounds for terrestrial and marine organisms, including many commercial species, young corals, and fish. Mangrove forests are a highly productive ecosystem with a primary production rate equivalent to tropical forests. (Maiti & Chowdhury, 2013)

Habitat loss is usually associated with loss of biodiversity. Ecological scientists predict that biodiversity can affect ecosystem function despite the contrasting results from correlative investigations and manipulation of active experiments. (Wu et al., 2019). Human activity can have a significant impact on the biodiversity of mangrove ecosystems (Tian et al., 2023) Activities such as deforestation, aquaculture, and urbanization can destroy or degrade mangrove habitats, which in turn can cause a decline in the diversity of vegetation and animal species that depend on these ecosystems. The relationship between biodiversity and marine ecosystem function is most often positive. Thus, biodiversity loss might result in

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reduced ecosystem function and, consequently, the capacity of ecosystems to provide goods and services to humans. (Landis et al., 2019). Healthy mangrove forest is formed when the biotic and abiotic factors in the forest do not limit the achievement of the goals of sustainable forest management for the current time and in the future (Cardoso et al., 2019).

The mangrove forest in Passo Village on Ambon Island is a valuable ecosystem that requires immediate efforts to rehabilitate and reforest areas to ensure its ecological health. After the health level is determined, it can, then, be used, among other things, to manage coastal areas on small islands such as the many cases related to the health of Mangrove forests in Maluku. In these islands, the coverage area of mangrove forests changes by 10% to 15% per year, as characterized by the loss of forest cover.(Salsabila et al., 2021). In the last decade, the biodiversity of the 20-hectare mangrove forest in Passo Village has become increasingly worrying as a result of anthropogenic damage carried out by humans. Therefore, efforts to protect mangrove forest areas are needed, especially in facing the impacts of climate change and the impacts of anthropogenic pressure. Passo Village's mangrove forest is a potential source of physical, economic, and ecological benefits that need to be preserved through sustainable forest management. The research aims to determine the species richness, diversity and distribution of mangrove populations in forest areas, which is one of the parameters of forest health

METHODS

The research was carried out in the mangrove forest of Passo Village, Ambon Island, from July through September 2023. The mangrove forest of Passo Village is located on Ambon Island, surrounded by the sea to its east or Southeast with Monsoon climate. Research was only carried out at the tree level The sampling was carried out in 3 observation clusters, on 0.4 ha-wide area respectively, with each cluster consisting of 4 subplots on a total observation location area of 1.2 ha. The research area is divided into 3 clusters because the 4th cluster and so on have the same type and grow in the sea so they like to be penetrated.This research was only carried out at tree level mangroves and only in 3 clusters because the other clusters in the location were of the same type and were difficult to reach because the water was always experiencing high tides. The research locations for the mangrove forest in Passo Village are shown in the map. (Figure 1).

Data Analysis

The data were analyzed on ecological indicators based on the cluster design according to figure 1. The mangrove forest health was assessed using a flora biodiversity approach. The cluster of mangrove forests was designed using the biodiversity approach as shown in figure 2.

To determine the potential and level of biodiversity in mangrove forests, several biodiversity-based approaches were used, namely species density, species frequency, species dominance, important value index, species richness, abundance and species diversity. The formula used to calculate mangrove diversity was adopted from Shanon and Wiener (Mouchet et al., 2010)

Vegetation Diversity: $H' = -\sum \left(\frac{ni}{N} \times ln\ \frac{ni}{N}\right)$ …(1)

Relative density: $RD = \frac{ni}{\sum N} \times 100\%$ … (2)

Evenness index $(E) = \frac{H'}{\ln(s)}$ … (3)

Vegetation Dominance: $C = \sum \left(\frac{ni}{N}\right)^2$ … (4)

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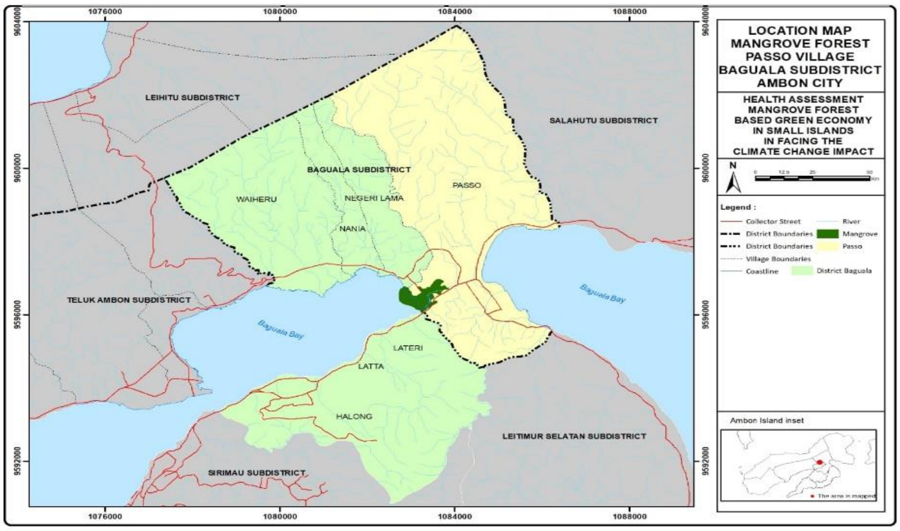

Figure 1. Research location map

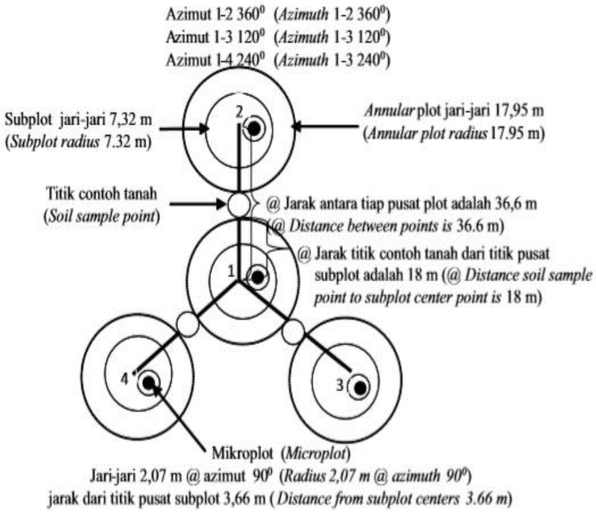

Figure 2. Cluster design of mangrove forests health

RESULTS AND DISCUSSION

Mangrove Density and Dominance

According inventorying the mangroves in the 3 mangrove forest clusters in Passo Village, several dominant mangrove species, namely *Sonneratia alba*, *Rhizophora stylosa*, *Avicennia marina*, *Aegiceras corniculatum*, *Aegiceras corniculatum*, and *Bruguiera gymnorrhyza* were found with a total of 260 individuals in cluster 1, 321 individuals in cluster 2, and 193 tree- level individuals in cluster 3. The tree-level mangrove population in the forest area is shown in Figures 3 and 4.

Figure 5 shows that *Sonneratia alba* has the highest dominance index of 22,240, meaning that this species dominates the mangrove forest area compared to other types, where the proportion of mangrove forests in the research area is predominantly covered by *Sonneratia alba*. The mangrove inventory also found that the *Sonneratia alba* species from the Lythraceae family had the highest number of individuals amount 429 individuals with a density value of 4.290 individuals/ha and a dominance value of 22.240 individuals /ha. This species had huge stems with a harsh bark and high resistance during high and low tides. Its roots were cable-shaped underground and emerged to the surface as respiratory roots shaped like a blunt cone and could reach a height of 25 cm.

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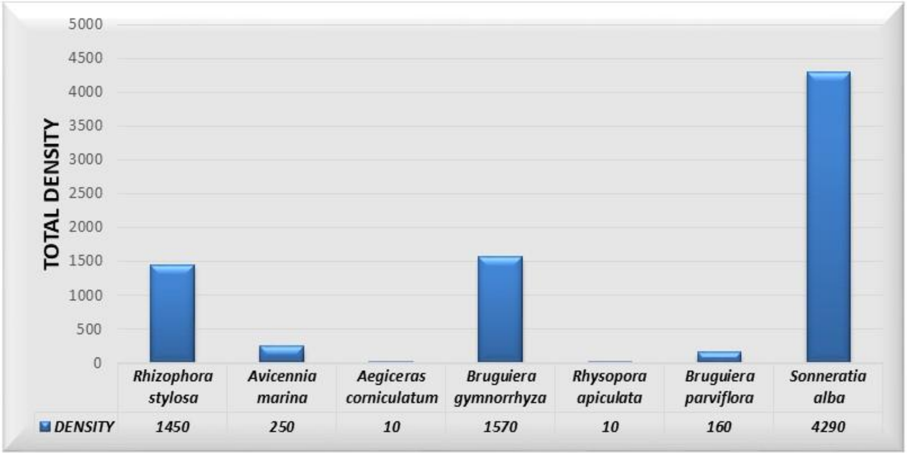

Figure 3. Total density of mangrove population in Passo Mangrove Forest

Based on the standard criteria regarding mangrove damage in Ministerial Decree of Environment Number 201 of 2004, the density of mangroves in the area fell in the low to very high category, which was occupied by *Sonneratia alba*. The species density showed the number of individuals of a species per unit area. The species density was influenced by the species' ability to adapt to environmental factors, seed dispersal and seedling growth (Bai et al., 2021). The species with the highest density had a strong resistance to survive because of the environmental conditions and the opportunity to live and reproduce well compared to other species. This was the reason why *Sonneratia alba* could dominate the entire mangrove forest area of Passo Village.

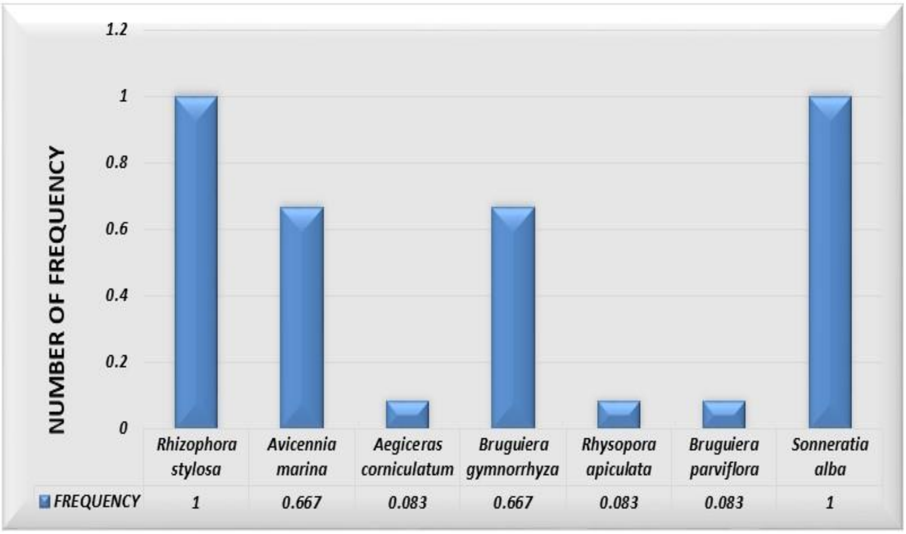

Figure 4. Frequency of mangrove presence in Passo Mangrove Forest

Mangrove forests play a crucial role in coastal ecosystems by protecting seagrasses and coral reefs from sedimentation hazards. They also provide physical, economic, and ecological benefits to the surrounding areas. However, due to increasing anthropogenic pressure, mangrove forests are at risk of damage. Therefore, it is important to implement sustainable forest management practices, including ecological monitoring efforts, to maintain the health of mangrove communities. The preservation of biodiversity is vital to the well-being of mangrove ecosystems.

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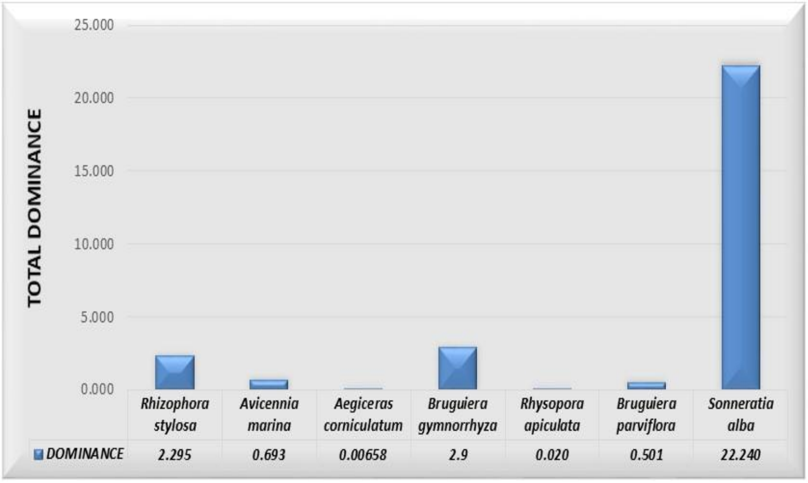

Figure 5. Tree Dominance in Passo Mangrove Forest

The intricate interplay between various species inhabiting the mangrove forest is responsible for regulating nutrient cycling, carbon sequestration, and water quality. Moreover, biodiversity contributes significantly to the provision of ecosystem services like pollination, seed dispersal, and natural pest control. Thus, safeguarding biodiversity in mangrove forests is indispensable to sustain their ecological balance and ensure the continued delivery of these invaluable services.

Conducting research on mangrove diversity is crucial for understanding the intricacies of these complex ecosystems. Mangroves are home to a diverse range of species, each playing a vital role in maintaining the ecological balance of the forest. By studying the various species that inhabit mangroves. Additionally, research on mangrove diversity In Passo Village can aid in identifying species that are threatened or endangered, and take measures to protect them. Hence, it is essential to continue conducting research on mangrove diversity to safeguard these valuable ecosystems for future generations.

The study found that *Aegiceras corniculatum* had a minimal number of individuals, 100 individuals /ha, with an attendance frequency of 0.083 individuals /ha and dominance of trees of 0.00658 individuals/ha. This species was an evergreen shrub that grew straight at a height of up to 6 m. The leaves were light and shiny green above and pale green below, often mixed with a slightly reddish tint. The relatively dense mangrove vegetation was rich in nutrients, which was a good place for survival. The presence of a species in vegetation indicated that, naturally, that species was considered suitable for the vegetation. (Siddig et al., 2016). The limiting factors, including water temperature, water, pH and salinity, influenced the mangrove development. The soil pH within the 7.4-7.5 range was suitable for mangrove growth in Passo Village because it would affect the decomposition of organic matter to allow it to produce humus, increasing the cation exchange capacity. Generally, the response to good height growth was obtained at low salinity. The acidity or pH at ground level was higher than in the layers below due to litter undergoing decomposition on the surface. The soil contained materials. High organic matter was what made soil sediments acidic.

This occurred because mangroves did not need salt, rather they were tolerant to salt. This tolerance is a unique adaptation of mangroves, allowing them to survive in environments with high salt content. The land to cultivate mangroves was smooth textured, had low maturity levels, low salt and high alkalinity, and often contained a layer of sulfate acid or sulfidic materials. The general

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clay or dust content was high, except for soil or fragments of coral reef. A peat layer with high salt content was sometimes found in mangrove soils in coral reef areas and the region where clay precipitated. Mangrove forests have different physical and chemical characteristics from other ecosystems, resulting in life forms and making the plants and animals unique. The soil in the mangrove area was significantly influenced by salinity, where plants in the area would adapt to levels of salt or salinity of sea water when there was a tide and environmental ecology, such as the ambient temperature of that area. The mangrove density was also influenced by water quality parameters. In this case, the water quality parameter was macrobenthos fauna (Siddig et al., 2016)

The mangroves in Passo Village were considered capable of providing shade to reduce changes in temperature and humidity, with its forest floor having a muddy substrate rich in organic matter as a food source for various species of animals, primarily molluscs and crustaceans. The results of calculating the importance value index of mangroves in Passo Village can be seen in the figure below. The highest dominance index was occupied by *Sonneratia alba*, where the higher the dominance index of a species, the higher the dominance in the community where that species grows. In a forest community, competition exists between individuals of one species or different species because they have the exact needs to obtain nutrients, minerals, water, light and space. This competition made certain species more dominant than other species and vice versa. *Sonneratia alba* had the highest dominance index because this species could grow, and reproduction was a significant value for the survival of marine biota. Salinity was essential to mangrove species' growth, resistance and zoning. The mangrove density in the forest was suspected to be influenced by the organic material content. The C-organic content of mangrove land was higher than other lands because of the decomposition of plants and animal residues in the mangrove area. The decomposition of organic matter in Mangrove lands significantly affected the substrate's frequency, soaking time, and particle size distribution. High organic C content resulted from mangrove roots, fallen leaves and twigs (litter), leading decomposition to occur.

Figure 6 shows that *Sonneratia alba* had the highest important value index in the area, indicating that *Sonneratia alba* was very important in creating a balance of mangrove forests, able to maintain the ecological function and role of the mangrove forest area in Passo Village, especially in the process of decomposition and mineralization of organic material that entered the waters, as well as occupying several trophic levels in a food chain. The critical value index was a value to obtain one species' dominance over another at each stage or level of growth. The highest important value index characterized the species that played a role in a forest area. The highest value was the one that could be used as an indicator to see the role. The higher the critical value index of a species is, the higher the control in the community where that species grows would be. In a forest community, competition exists between individuals, one or several species, because they share the exact needs for obtaining nutrients, minerals, water, light and space. Competition makes certain species more dominant than other species, and vice versa.

Richness and Diversity of Mangrove

Species richness refers to the total number of species in a mangrove ecosystem. At the same time, diversity accounts for the number of species and the balance or evenness of their distribution. A mangrove ecosystem with a high species richness does not necessarily mean it has high diversity. For instance, if the species richness is high but one species dominates the area, the diversity could be low. Understanding these dynamics is essential in mangrove conservation and management strategies. Species diversity measures a community's ability to restore environmental conditions to balance when disruption or change occurs.

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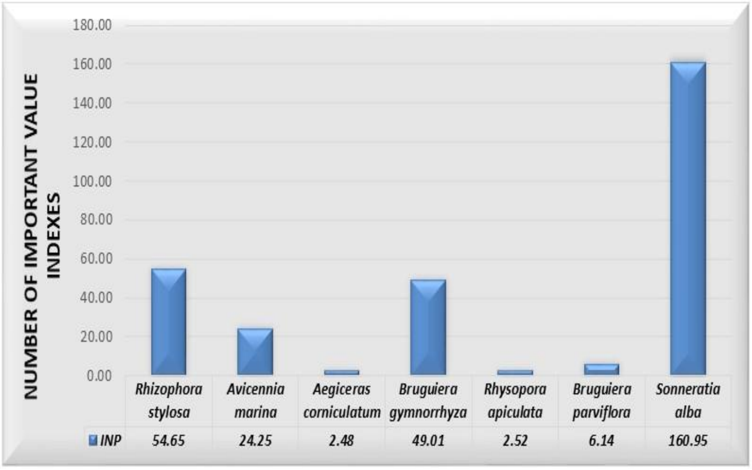

Figure 6. Mangrove Important Value Index in Passo Village

Figure 7 shows that mangrove biodiversity in Passo Village has the highest species richness found at the tree level and the lowest at the seedling level, with the highest vegetation diversity at the tree level and the lowest at the sapling level straight, with a tree height reaching 6 m. *Bruguiera gymnorrhyza* had dark green leaves, light green in the middle and reddish on the bottom. The leaf stalk was 17-35 mm long and reddish. It had a narrow ellipse shape with a tapered tip and leathery leaves with undeveloped glands at the base of the leaf stalk. The leaf stalk was 6-15 mm long, inverted, oval with a rounded tip. The three dominant species of mangroves in Passo Village's forest area were found. They formed the richness and diversity of species in the forest—the value of species richness and diversity of mangrove species in Passo Village.

Figure 8 shows that mangrove species diversity has a low value of about 0.701 at the seedling level or an H' value < 1. The results indicated that the variation in vegetation species diversity was very low. The species diversity is a community-level characteristic based on its biological organization. A community is said to have high species diversity if the community is composed of many species. Conversely, a community is said to have low species diversity if the community comprises a few species and only a few dominant species. The low species diversity was used as an indicator of forest health because it was (1) sensitive to change, (2) an ecological system indicator, and (3) spatial, temporal and trophic heterogeneity. Apart from that, diversity can indicate the condition of an ecosystem contained within it (Cardoso et al., 2019).

The community of mangrove species in the area was shallow and needed help to support the stability of the mangrove forest ecosystem in Passo Village. The diversity of mangrove species was related to the evenness of species in the area. It was found that mangroves in Passo Village had a low level of distribution (E < 0.6), where at the seedling level the distribution was higher than the tree and sapling levels in the three clusters.

The greater the evenness index value is, the more evenly distributed the species composition would be. It means that it was not dominated by just one species. This showed the high level of distribution and adaptation of each family to the physical conditions of the forest environment. It allowed several of the same species to be found in the observation plots. It was suspected that physical environmental conditions such as air temperature, humidity, salinity, soil pH and intensity of sunlight affected the level of distribution of mangrove in the forest.

Healthy forest is characterized by fertile, productive vegetation, accumulation of biomass and fast nutrient cycles, and absence of damage by pests. (Cardoso et al., 2019).

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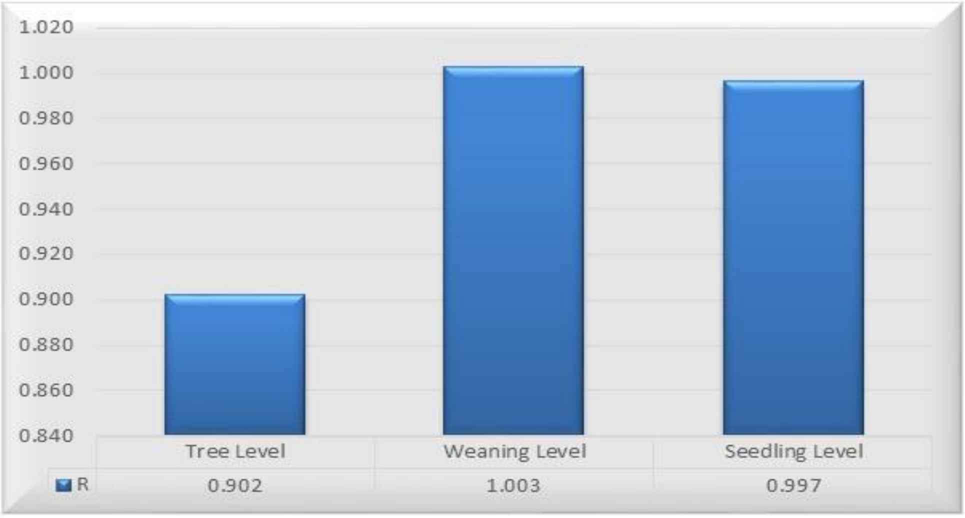

Figure 7. Mangrove Species Richness in Passo Mangrove Forest

The forest health program is directed at reducing the population rate of pathogens. In the long term, it will lower the pathogen population explosions. It is essential because mangrove forests are in demand for high productivity. Thus, any damage to them must be prevented and carefully attended to. Therefore, anticipatory steps through early diagnosis efforts related to biodiversity must be carried out to allow the acquisition of data and information for consideration in making policies. According to the *forest health monitoring field methods guide*, one of the indicators for assessing the health of mangrove forests is the biodiversity approach. Employing the approach, the biodiversity parameters can be used to determine the health level of mangrove forest ecosystems. (Schulze et al., 2019).

Figure 9 shows that species diversity can be used to express a community's structure of species diversity. A high diversity of species indicates that the community is complex due to the many interactions occurring in the community. Mangrove forests are a typical type of forest found along beaches or river estuaries. Sea tides influence them and grow adjacent to land at the highest tide range. Therefore, this ecosystem is a transitional area whose existence is also influenced by land and sea factors. (Latumahina et al., 2015).

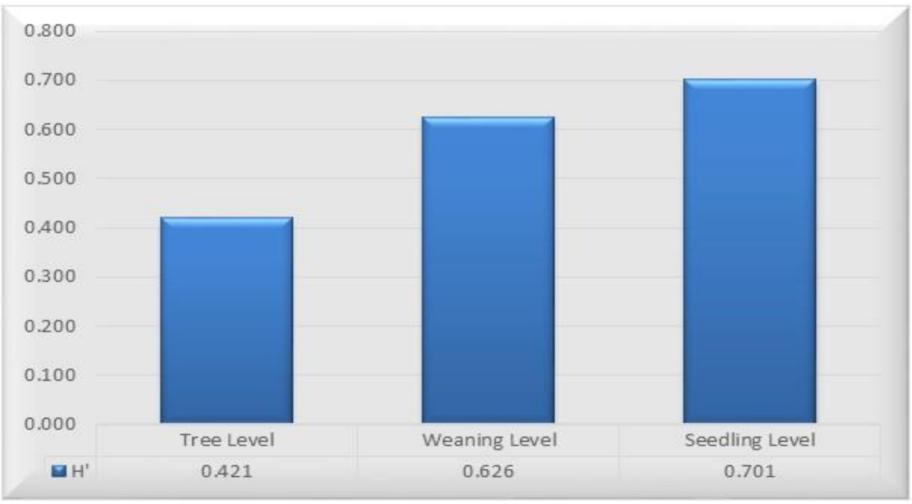

Figure 8. Diversity of Mangrove Species in Passo Mangrove Forest

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The health of the mangrove ecosystems might influence the condition of two other ecosystems in coastal areas, namely seagrass and coral reefs (Gray et al., 2016). Physically, the typical mangrove root system protects seagrasses and coral reefs from sedimentation hazards. (Lossou et al., 2019). Thus, when mangroves are damaged due to the increasingly high anthropogenic pressure, management efforts are needed, including ecological monitoring of the condition of mangrove communities in an area. (Matos-Maraví et al., 2018).

The mangrove forest in Passo was an ecosystem with high physical, economic and ecological potentials. Hence, they needed to be maintained through sustainable forest management. The research concluded that the diversity of vegetation in the forest area was still low. For this reason, efforts to rehabilitate and reforest areas must be carried out immediately. As an essential indicator of forest health, thanks to its ability to show the level of resilience of the forest ecosystem, biodiversity could be used to assess forest health through the species diversity index. (Nuraeni et al., 2020).

The research found that the value of the diversity of mangrove species in the Passo Village mangrove forest was still low. It showed a moderate level of stability in the forest ecosystem. It means that Passo Village's mangrove forest area would not be easily damaged and would not quickly lose its function and role in maintaining the ecological health of mangrove forests on Ambon Island.

Since healthy forests will support better quality and quantity of forests, this research can be a reference in making the right decisions in managing mangrove forests to allow the best possible results, especially for small islands in Maluku facing the impacts of climate change, because mangrove ecosystems in small islands often face various challenges, including impacts from human activities, destructive use of the environment, and natural environmental factors such as global warming and natural disasters.(Chowdhury et al., 2014).

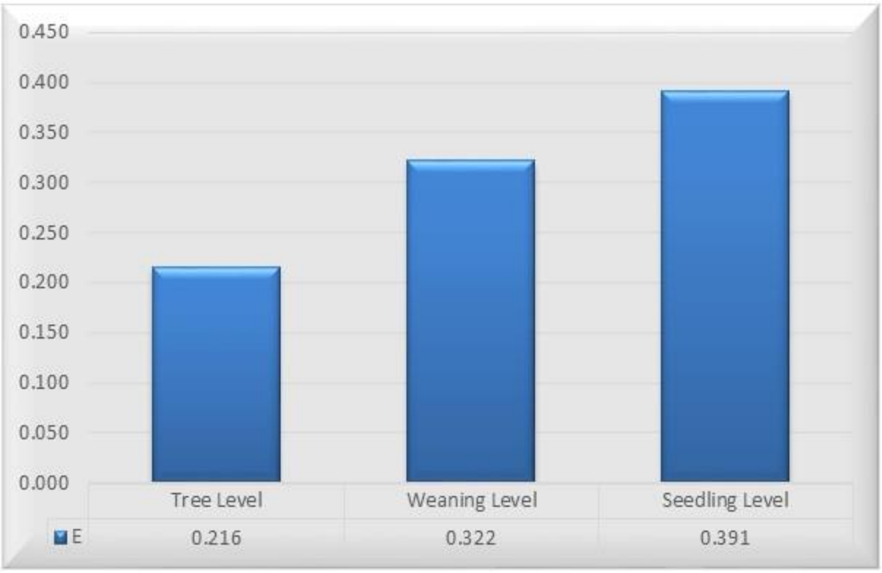

Figure 9. Evenness of Mangrove Species in Passo Village

Reduction of area and decline in the quality of ecosystem waters mangroves are a severe threat to an area where the population depends on some resources in the mangrove ecosystem. (Safe'i Rahmat et al., 2019). Mangrove ecosystems play a vital role in coastal areas by influencing the condition of two other ecosystems, namely seagrass and coral reefs (Mouchet et al., 2010). The root systems of mangroves provide physical

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protection to seagrasses and coral reefs against sedimentation hazards (Bai et al., 2021). However, the increasing anthropogenic pressure on these ecosystems has resulted in the damage and degradation of mangroves (Titisari et al., 2022). Thus, management efforts are required to maintain the ecological health of mangrove communities in an area, which includes ecological monitoring and sustainable forest management practices.

Passo Village's mangrove forest is a potential source of physical, economic, and ecological benefits that need to be preserved through sustainable forest management. It is essential to prioritize sustainable forest management practices and implement measures to reduce anthropogenic pressure on mangrove ecosystems to protect their biodiversity and maintain their ecological health. Regular ecological monitoring must be conducted to assess the condition of mangrove communities in an area. Healthy forests will support better quality and quantity of forests and can be a reference in making informed decisions when managing mangrove forests, particularly for small islands.

CONCLUSION

Our research concludes that the diversity of vegetation in forest areas is still low and requires immediate rehabilitation and reforestation efforts to maintain the ecological health of mangrove forests on Ambon Island. Species richness refers to the total number of species in a mangrove ecosystem. At the same time, diversity accounts for the number of species and the balance or evenness of their distribution. The results of the research found that mangrove diversity had a high level of diversity at the sapling level with a value of 1.003 and was classified as medium. This indicates that the health of the Passo Village mangrove forest is in a healthy condition where the vegetation community has a stable environment. A mangrove ecosystem with a high species richness does not necessarily mean it has high diversity. For instance, the diversity could be low if the species richness is high but one species dominates the area. Understanding these dynamics is essential in mangrove conservation and management strategies. Mangrove conservation is paramount, considering the integral role these ecosystems play in our environment. Mangroves act as a buffer zone, protecting coastal areas from erosion, storm surges, and tsunamis. They are a crucial habitat for a diverse range of species, many of which are endangered, contributing towards maintaining biodiversity. Most impressively, mangroves are powerful carbon sinks, absorbing and storing large amounts of carbon dioxide, thereby playing a crucial role in mitigating climate change. Therefore, the preservation of mangroves is not just an environmental need but also a planetary requirement. Through a focus on conservation, we can safeguard these ecosystems and ensure they continue to provide their invaluable services.

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