Int J Adv Life Sci Res. Volume 6(3) 10-18
https://doi.org/10.31632/ijalsr.2023.v06i03.002

International Journal of Advancement in Life Sciences Research

Online ISSN: 2581-4877

Journal homepage http://ijalsr.org

Original Article

Floristic Composition and Species Richness of Mangrove Ecosystems in Pantai Panjang– Pulau Baai Nature Park, Bengkulu Province, Indonesia

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Abstract

Bengkulu Province is located in a coastal area with numerous mangroves. Pantai Panjang –Pulau Baai Nature Park is one of the mangrove regions in Bengkulu City. This study aims to analyze the floristic composition and species richness of mangrove ecosystems in Pantai Panjang-Pulau Baai Nature Park, Bengkulu City. Three stations with diverse ecological conditions were sampled using the transect lines method. Nested observation plots were made along the transect line with a size of 10mx10m for tree strata, 5mx5m for sapling strata, and 1mx1m for seedling strata.103 plots were established across the three stations to identify species and the number of individual mangrove plants, diameter measurement, soil pH, salinity, and substrate type. The analysis found 1741 mangrove plants from 8 species of true mangrove plants belonging to 6 families. The most common species found was *Rhizhopora mucronata* which belongs to the Rhizophoraceae family. *Casuarina equisetifolia*, a species discovered at Station 1, is categorized as a coastal rather than a mangrove plant. The species diversity index (Shannon-Wiener) at the three stations is moderate. The species richness index, however, is low at all three stations. The index of species evenness is high across all three stations, except for the seedling stratum at Station 3, where it is moderate. The study found that the soil pH levels ranged between 5.3 and 6, while the salinity levels ranged from 4.3 to 9.3. The substrate types were identified as muddy and sandy mud.

Keywords:- diversity, evenness, mangrove, richness.

Introduction

Mangrove ecosystems are coastal vegetation communities that can grow in tidal areas and muddy beaches. Mangroves are recognized for their significant contribution to both aquatic and terrestrial ecosystems. Mangroves offer various ecosystem services such as wave barriers, fuel sources, food sources, recreational areas, faunal habitats, and the most abundant carbon stocks, particularly in tropical regions (Barbier *et al*. 2011; Donato *et al*. 2012; Blankespoor *et al*. 2017).) Mangrove forests have the highest carbon content (Donato *et al*., 2011; Alongi, 2012), with a significant proportion of carbon being allocated underground (Kristensen *et al*., 2008; Mcleod *et al*., 2011). Despite covering less than 0.1% of Earth's continental surface, mangroves play a significant role in the export of terrestrial carbon to the ocean, accounting for 10-11% of the total export, and in the deposition of carbon in coastal sediments, contributing 8-15% of the carbon deposited (Joshua *et al*., 2012).

Indonesia is a vast archipelagic countrywith 17,504 islands and a coastline spanning approximately 95,181 km, characterized by a wide range of biophysical environmental and climatic conditions (Kusmana, 2011). Mangrove forest ecosystems dominate Indonesia's coastal areas. Mangroves are widely distributed across Indonesia, encompassing both large and small islands. Indonesia possesses

Received on :23rd April 2023; Revised version received on :6th June 2023; Accepted: 29th June 2023

the most extensive mangrove expanse globally. Indonesia boasts the largest mangrove area in the world, covering 3.1 million hectares or 22.6% of the global area (Giri *et al*., 2011; Hamilton & Casey, 2016).

Furthermore, Indonesia is recognized as a nation with the most abundant mangrove species globally (Spalding et al., 2010). Indonesia, nevertheless, holds the unenviable distinction of being the country with the most significant depletion of mangrove forests globally(Spalding et al., 2010; Giri et al., 2011;Hamilton and Casey, 2016).Human activities have been the main cause of the increased stress on Indonesia's mangroves in recent years (Ilman *et al*., 2016). Land conversion, logging, land clearing, and pollution all contribute to the devastation of Indonesia's mangroves (Thomas *et al.,* 2017).

The vulnerability of coastal regions will be amplified by the confluence of these factors, along with the escalation of sea levels and storm surges (Blankenspoor *et al*., 2017). Climate change-induced sea-level rise and sea-surface temperature rise threaten mangroves (Kauffman *et al*., 2016; Lovelock et al., 2015).The conversion of mangroves to fishponds is the leading cause of their demise. It is estimated that the expansion of aquaculture ponds and oil palm plantations will continue to be the leading cause of mangrove loss in Indonesia over the next two decades (Richards and Friess, 2015; Ilman *et al*., 2016).

The diversity and richness of plant species in mangrove ecosystems vary greatly influenced by many environmental factors, including salinity, soil pH, substrate type, tides, light intensity, and temperature. Each mangrove ecosystem has a typical and dominant plant species that adapts to its environmental conditions. Studying plant species composition is crucial in determining the dynamics of mangrove ecosystems, which exhibit significant variability.

Most of Bengkulu Province is located in coastal regions with mangrove ecosystems. Pantai Panjang–Pulau Baai Nature Park is well-known among the people of Bengkulu as one of the mangrove areas. This area is relatively accessible, allowing it to serve as a destination for community activities such as tourism and fishing. The mangrove areas are at risk of being disturbed by human activities. It can affect the environment and habitat of mangrove plants regarding the growth of constituent plant species. Therefore, the research was conducted to determine species diversity, richness, and distribution (evenness) of mangrove plants in the region.

Material and Methods

Study area

The study was conducted in Pantai Panjang – Pulau Baai Nature Park in Bengkulu City, Indonesia. The research site was divided into three stations. Station 1 was located at Panjang Beach, Station 2 was in Jenggalu, and Station 3 was in Kandang. Stations 1 and 2 are tourist areas, while Station 3 is a conservation area. However, the national government designated all three areas as a nature park. The three stations have different environmental conditions, such as pH, salinity, and substrate type.The coordinates of each sampling station are shown in Figures 1 - 3.

Figure 1. Research Station 1 (Pantai Panjang)

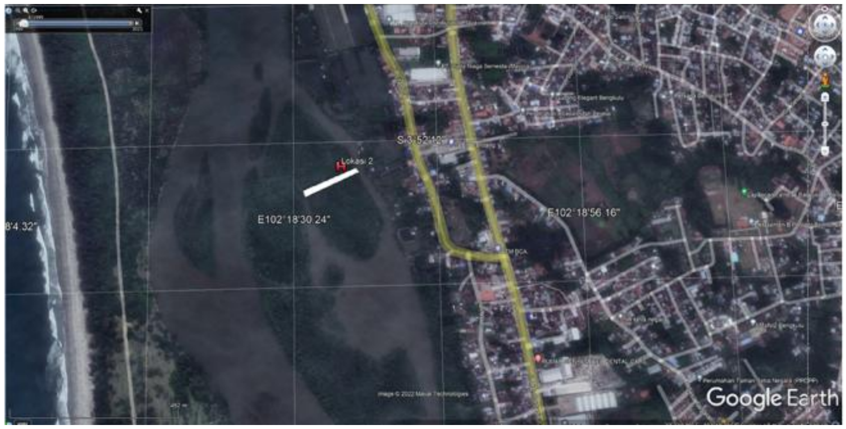

Figure 2. Research Station 2 (Jenggalu)

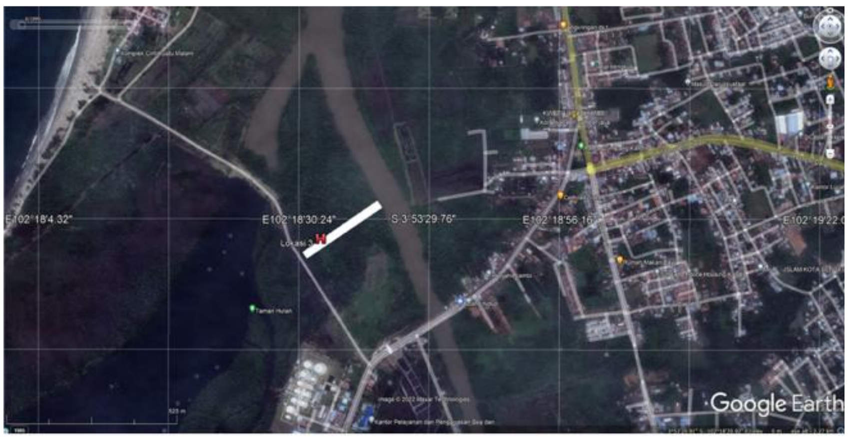

Figure 3. Research Station 1 (Kandang)

Sampling and data collection

Sampling was conducted using the line transect method by creating nested plots measuring 10mx10m for tree level, 5mx5m for poles, and 1mx1 m for seedlings. The number of plots at each station varied according to the station's size. Stations 1, 2, and 3 have belt lengths of 150m, 320m, and 558m, respectively. The number of plots at Stations 1, 2, and 3 was 15 plots, 32 plots, and 56 plots, respectively. In each plot, the diameter (except the seedlings), type and amount of plant, pH, salinity, and substrate type were measured. The transect lines and plots were established perpendicularly from the estuary to the offshore boundary.

Data analysis

Species diversity

Identification of mangrove species using guidelines from Noor et al. (2012).Species diversity is a valuable parameter for comparing two communities, especially to study the effect of biotic disturbances to determine the level of succession or stability of a community. Species diversity is determined using the Shannon-Wiener Diversity Index formula (Krebs, 2014):

$$H' = -\Sigma\left(\frac{ni}{N}\right)\log\left(\frac{ni}{N}\right)$$

H' < 1.5 indicates low species diversity, H' between 1.5 - 3.5 indicates moderate species diversity and H' > 3.5 indicates high diversity.

Species richness

Species richness is the number of species in a given area. Margalef proposed a species richness index combined with the abundance/density value of individuals in each sample unit of the same size placed in the same habitat or community. The calculation method is called the Margalef Richness Index with the following formula (Magurran, 2004):

$$R = \frac{S - 1}{\ln (N)}$$

R1 < 3.5 indicates low species richness, R1 between 3.5 - 5.0 indicates moderate species richness, and R1 > 5.0 is high.

Species Evenness

Species evenness between habitat types (land use) is calculated with the following formula:

$$J' = \frac{H'}{\ln(S)}$$

The value of J is classified into three categories, including low species evenness (J<0.03), moderate species evenness (0.3<J<0.6), and high species evenness (J>0.6).

Notes:

H' = Species diversity (Shannon-Wiener Index)
ni = Number of individuals per species
N = Number of individuals of all species
R= Species richness (Margalef Index)
S = Number of species
J'= Species evenness (Pielou Index)

Results and Discussion

A total of 1741 mangrove plants, comprising 9 species from 7 families, were collected from 103 plots distributed among three observation stations. Certain plant species exhibited station-specific growth patterns, with some species thriving exclusively at particular stations and not at others. *Acrostichum aureum* was absent solely at Station 1. Four plant species, namely *A.aureum, Casuarina equisetifolia, L. racemosa*, and *X.granatum*, were absent at Station 2. At Station 3, it was observed that three plant species, namely*A. marina, C.equisetifolia*, and *L.racemosa*, were not found.

Table 1. Floristic composition and number of species

Species	Family	Research Station									Total
		1			2			3			
		TR	SA	SE	TR	SA	SE	TR	SA	SE	
Acrostichum aureum	Pteridaceae	-	-	-	-	-	-	-	-	1	**1**
Avicennia marina	Acanthaceae	22	21	-	55	11	1	-	-	-	**110**
Brugueira parviflora	Rhizophoraceae	5	21	2	40	226	37	31	100	31	**493**
Casuarina equisetifolia	Casuarinaceae	-	1	2	-	-	-	-	-	-	**3**
Lumnitzera racemosa	Combretaceae	24	22	9	-	-	-	-	-	-	**55**
Rhizopora apiculata	Rhizophoraceae	4	12	9	-	22	15	10	25	1	**98**
Rhizopora mucronata	Rhizophoraceae	4	5	2	10	129	44	132	320	85	**731**
Sonneratia alba	Lythraceae	37	31	12	39	17	4	22	14	-	**176**
Xylocarpus granatum	Meliaceae	16	8	2	-	-	-	33	15	-	**74**
Total		**112**	**121**	**38**	**144**	**405**	**101**	**228**	**474**	**118**	**1741**

Note: TR = trees; SA = saplings; SE = seedlings

Table 1 shows that *Rhizopora mucronata, Brugueira parviflora*, and *Sonneratia alba*are the most abundant species, with 731, 493, and 176 plants. All the stations had these species. It indicates that the mangrove species exhibit favorable growth adaptation to their surroundings. However, certain plant species, namely *Avicennia marina, Lumnitzera racemosa, Rhizopora mucronata*, and *Xylocarpus granatum*, exhibited a greater prevalence of tree strata than saplings and seedlings strata. Figure 4 shows that the family Rhizhoporaceae is the most dominant among the seven families of mangrove plants, accounting for approximately 76% of the total growing area across the three stations. This total number came from 3 species, namely *Brugueira parviflora, Rhizopora apiculate*, and *Rhizopora mucronata*, belonging to the family Rhizhoporaceae. Moreover, *Sonneratia alba* of the Lythraceae family and *Avicennia marina* of the Acanthaceae family are observed at approximately 10% and 6%, respectively.

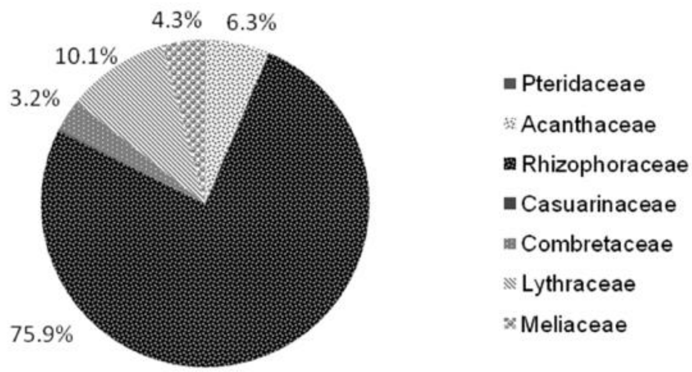

Figure 4.Number of mangrove plants by family

The proportion of *Xylocarpus granatum* belonging to the Meliaceae family and *Lumnitzera racemosa* belonging to the Combretaceae family were approximately 4% and 3%, respectively. The proportion of the family Pteridaceae, which includes *Acrostichum aureum,* and the family Casuarinaceae, which includes *Casuarina equisetifolia*, was less than 1% for each family. The Casuarinaceae family is classified as a coastal rather than a mangrove species. The species was exclusively detected at Station 1, a coastal region contiguous to the mangrove ecosystem. *Casuarina equisetifolia* can thrive and proliferate in mangrove regions due to its ability to acclimate and flourish in sandy substrates. *C. equisetifolia* thrives in its natural habitat in coastal regions with sandy soil types. Polidoro *et al*. (2010) stated that true mangrove species are restricted to intertidal habitats and do not proliferate in terrestrial regions. These organisms have adapted their morphology and physiology to thrive in environments characterized by salinity and inundation effectively.

Species diversity and species richness

A community can be classified as having high species diversity if it comprises many species. Conversely, a community is considered to have low species diversity if it comprises only a few species with a limited number of dominant species. The relationship between diversity and species richness is positively correlated, whereby an increase in diversity is associated with an increase in the number of species present. This correlation is contingent upon the aggregate abundance of individuals within each species.

The diversity values of each station are depicted in Figure 5, exhibiting variations among the different species. Station 1 exhibits a comparatively high H' value, with Stations 2 and 3 following in descending order. The H' values of Stations 1 and 2 and the H' value of the tree stratum at Station 3 fall within the moderate category. At Station 3, the H' values exhibit low values solely within the sapling and seedlings strata. The H' value observed at Station 1 is comparatively greater than the other two stations, owing to conducive environmental conditions that facilitate the proliferation of diverse mangrove species. The pH levels of Station 1, Station 2, and Station 3 are 6, 5.7, and 5.3, respectively. According to Murdiyanto *et al.* (2015), the pH levels of mangrove soils typically fall within the range of 6-7, with occasional drops to below 5. It can be attributed to the high concentration of organic matter in mangrove regions, resulting in acidic soil conditions.

The salinity measurements indicated that Station 1 exhibited a value of 5.3, Station 2 displayed a value of 4.3, whereas Station 3 recordeda maximum value of 9.3. Jamili (2009) suggested that salinity is a significant environmental factor in controlling mangrove zonation due to its correlation with tidal water inundation levels. Areas have low salinity due to limited exposure to seawater, while areas close to seawater have higher salinity. Mangroves thrive in salinity levels of 10-30 ppt in the seawater brackish water zone and 0-10 ppt in the brackish water zone to fresh water (Bengen, 2001). Station3 has the highest salinity due to its proximity to seawater, whereas Stations 1 and 2 are located at a greater distance from the seawater, resulting in lower salinity levels.

The level of species diversity is affected by the interaction dynamics among species and communities and their capacity to sustain community stability, which is considered moderate.A high diversity index in a community indicates a high complexity because of higher species interactions. So in a community with high diversity, species interactions will involve energy transfer or food webs, predation, competition, and the division of theoretically more complex niches. Diversity can be used to measure community stability, namely, a community that can keep itself stable despite disturbances to its components.

This study's measurement of substrate environmental parameters showed that the soil conditions at the study site have a type of substrate from silt to sandy mud. The distribution of mangrove species in the study site follows the type of substrate for mangrove growth in general. This substrate sediment texture is strongly related to the type of mangrove that lives and dominates in the area. Station 1 has a dominant sandy mud substrate, while Stations 2 and 3 have a dominant muddy substrate.

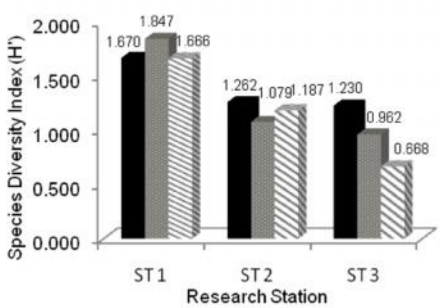

Fig5. Species Diversity (Shannon-Wiener) Index

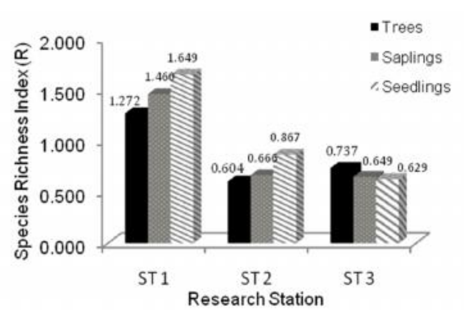

Fig 6. Species Richness (Margalef) Index

Figure 6 shows that the species richness index of the three stations is low (<3.5).According to Magurran (2004), the Margalef index is susceptible and effective in detecting variations in species richness. A high number of species results in a high value of the Margalef index. Increasing the number of species is necessary to obtain a sensitivity of plant species diversity on the Margalef index. According to Odum (1996), stable communities exhibit greater diversity than those subject to seasonal or periodic disturbances caused by natural and human factors. Human and predator activities can lead to decreased diversity and increased monoculture.

Acrostichum aureum was present as seedlings only at Station 3 and was not observed as saplings or trees at any of the stations. It suggests that the species is unable to compete effectively for growth. Inbreeding can lead to a reduction in the quality of a species. Fragmented forests lead to inbreeding and reduced genetic diversity, decreasing species quality (Obayashi *et al.*, 2002). According to Graudal *et al.* (2014), reduced population size and fragmentation are significant factors in the decline of genetic diversity.

Low diversity in an area suggests instability, which can be attributed to natural and human-induced stressors (Sreelekshmi *et al.*, 2020). Stations 2 and 3 may have experienced natural (tidal) and anthropogenic disturbances, such as tree felling and use as a fishing ground, which could have impacted their species' diversity and richness.

Species Evenness

The evenness index assesses the uniformity of species abundance within a community. Evenness refers to the equilibrium between different communities. An evenness value of one indicates a more even distribution in a community, whereas zero indicates more unevenness (Magurran, 2004). The distribution of individuals across different species determines plant evenness within a community. Evenness measures the prevalence of dominant traits within each species in a given community. Differences in evenness values among communities suggest the existence of dominant species or those with high individual values (Nahlunnisa *et al.,* 2016).

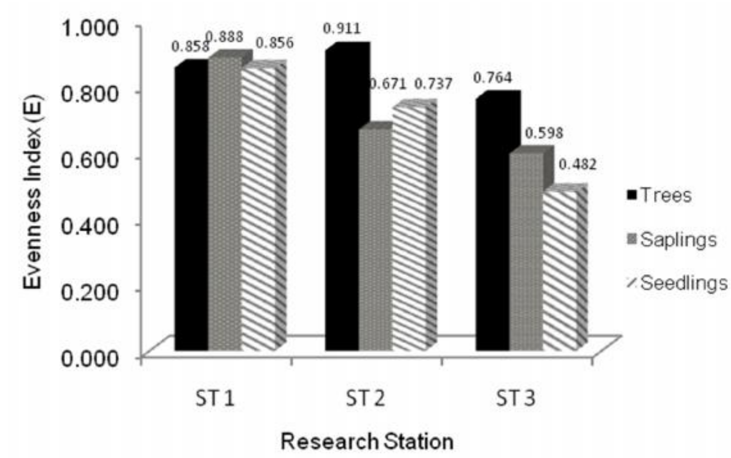

Figure 7.Species Evenness (Pielou) Index

The variation in plant evenness among the three stations depicted in Figure 7 can be attributed to differences in the distribution of individuals across species at each station. The evenness index serves as a measure of dominance exhibited by individual species within a given community. Stations exhibiting different evenness values suggest the existence of species that are dominant or possess elevated individual values. Station 1 exhibits high evenness (0.856-0.888) due to the relatively equal distribution of individuals among species in the area. Station 2 exhibits a high evenness value (0.671-0.911) comparable to the observation above. Station 3 exhibits high evenness values at the tree and sapling strata (0.764 and 0.598, respectively) and a medium evenness value at the seedling stratum (0.482). The decline in evenness is attributed to the prevalence of dominant species with a high abundance, resulting in an uneven distribution of individuals across species. The low evenness value is attributed to the wide range of individual counts per species, ranging from 1 to 85.

Conclusion

The species composition of mangrove plants in 103 plots at the three observation stations varied. However, *Rhizopora mucronata, Brugueira parviflora*, and *Sonneratia alba* were the most common species found. The diversity index was moderate, the species richness was low, and the evenness index was high.

Acknowledgement

The authors thank the Doctoral Program in Natural Resources Management, Faculty of Agriculture at the University of Bengkulu for the financial support of this research. We thank the Natural Resources Conservation Office of Bengkulu for granting us access to the conservation area. Appreciation is extended to the technical team in the field, including Remondo, Rian, Randi, Fitra, Guntur, and Daniel.

Conflict of interest

The authors declare no conflict of interest.

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