Mangrove community structure and physicochemical factors in Cilacap mangrove forest, Indonesia

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Abstract. Mangrove forest is a general term used to describe a variety of tropical coastal communities dominated by several distinctive tree species that can grow in high salinity. One area that has mangrove vegetation is the Cilacap mangrove forest. The population utilizes the Cilacap mangrove forest as a source of income, especially for mangrove wood. This will place pressure on mangrove forests in the area. This study aims to determine the structure of mangrove communities and provide important information on changes in mangrove ecosystems. This study was conducted in Cilacap Regency, Central Java Province, Indonesia. Three sampling Stations were selected: Station 1 (ST1), Station 2 (ST2), and Station 3 (ST3). The mangrove sampling method at each Station made a plot of 10x10 m^2 for the tree category, 5x5 m^2 for the sapling category, and 1x1 m^2 for the seedling category. Environmental parameters were determined in situ: pH, water temperature, salinity, phosphorus, nitrogen, and organic matter. The mangrove community structure's highest tree density was found in Station 1 (333 ind/ha), the highest sapling density was found in Station 1 (11,233 ind/ha), and the highest seedling density was found in Station 1 (4,070 ind/ha). The species importance value at Station 1 (ST1) and Station 2 (ST2) is *Rhizophora stylosa* Griff. species with values (ST1 158%) and (ST2 162%), and Station 3 has a species importance value of 157% is *Rhizophora mucronata* Poir. species. physicochemical factors were found in the Cilacap mangrove area; soil pH ranged from 6.73-7.20, water temperature ranged from 28.58°C-29.17°C, salinity ranged from 22.25-24.34‰, Phosphorus ranged from 0.30-0.53%, nitrogen ranged from 2.21-3.23%, and organic matter ranged from 14.29-15.27%.

Key Words: mangrove, density, community structure, physicochemical factors.

Introduction. Southeast Asia has the most extensive mangrove forests, one of which is Indonesia, which accounts for one-fifth of the world's total mangrove area (Husna et al 2023). Indonesia has the largest number of mangroves in the world, although there is still a risk of deforestation and degradation (Pratama et al 2024). Mangrove forests are important ecosystems and environmental buffers for coastal areas (Abubakar et al 2024). Mangrove forests provide an important source of support for fisheries. Mangrove forests also serve as natural habitats for many species of crabs, fish, and shrimp, as spawning grounds, feeding grounds, and nursery grounds (Siswoyo et al 2024).

Coastal ecosystems are important in providing habitat for various marine communities (Mulyana et al 2022). Mangroves have important ecological support for maintaining fisheries productivity as well as an important economic function (Fitri et al 2018; Wintah et al 2021), offering significant ecological, social, and financial benefits (Arifanti et al 2022; Wintah et al 2023). The environmental function of mangroves is as a food source for fish, crabs, shrimp, and other associated biota (Kauffman et al 2011). Ecological functions as a habitat for shelter, feeding, spawning, and nursery ground for coastal biotas such as mangrove crabs, shrimp, and seashells (Sunarni et al 2019). Mangroves also have a role as a habitat for mangrove association biota (Wintah et al 2022). The physical function is as a breakwater, coastal abrasion preventer, and sediment trap. The economic function of mangroves is fruit which is widely used as a processed food product and is used as a natural coloring for textile fabrics (Sunarni et al 2019).

Mangroves grow in areas with salinity and are still affected by tides or are commonly called the littoral area (Drajati et al 2024). Mangroves can grow in intertidal and saline areas. These plants are found in coastal areas, river estuaries, and deltas. Mangroves grow on muddy substrates and are inundated by seawater. Mangroves are ecosystems that have an important role in coastal areas (Rahmad et al 2020). Mangroves have an important role and function to fulfill the needs of the surrounding biota. Mangrove resources are valuable and can contribute to slowing the impact of climate change (Sidik et al 2018; Wang et al 2021), protecting marine ecosystems (Chee et al 2023), filtering pollutants (Zhao et al 2022; Rosmiati et al 2022), carbon sequestration (Alongi 2022), protecting coastal communities from erosion (Meera et al 2021; Ritohardoyo et al 2017), reduces the impact of coastal erosion (Raju & Arockiasamy 2022), provides economic value (Feti et al 2020; Hochard et al 2021; Kawuryan et al 2022), and is home to various animal species (Ritohardoyo et al 2017), reduces the impact of coastal erosion (Raju & Arockiasamy 2022), provides economic value (Feti et al 2020; Hochard et al 2021; Kawuryan et al 2022), and is the habitat for various animal species. The existing mangrove vegetation has decreased in function, and degradation is quite high.

Mangrove vegetation is a type of plant community that is different from other plants, mangroves thrive in the intertidal zone along the coastline, strongly associated with environmental factors (Nurjaman et al 2017). Mangroves, which grow in muddy coastal landscapes, sheltered bays, deltas, and small islands, show remarkable adaptability to different conditions (Rahardian et al 2019; Tumangger 2019). Mangroves are key to environmental balance (Kochoni et al 2023). Mangrove communities are typically characterized by three different components: major, minor, and associate. Major components are uniquely adapted to mangrove ecosystems and are not found in terrestrial vegetation communities (Rusydi et al 2015).

The potential of vegetation in the mangrove ecosystem in Cilacap consists of several mangrove vegetation that form patterns of adaptation, association, and zoning to potential biodiversity, building the community structure of the mangrove ecosystem. The existence and completeness of the community structure will describe the level of ecosystem stability (Hilmi et al 2015).

Deforestation has mostly damaged mangrove habitats in Cilacap. The condition of their habitat, including bottom sediment and water quality, influences the composition and structure of mangrove communities. A decline in the productivity of mangrove ecosystem waters can also indirectly affect the condition of the mangrove community structure. Therefore, this study was conducted to determine the structure of mangrove communities and the role of physicochemical factors in the environment.

Material and Method. The study was conducted using a survey method, and the sampling method was random sampling. The study area is located in Cilacap District, Central Java Province, Indonesia, and the study was conducted from November to December 2020. The study area includes three sampling points: Station 1 (ST1) with coordinates 108°58'36.34" E and 07°43'6.820" S, Station 2 (ST2) coordinates 108°57' 35.32" E and 07°42'6.720" S, and Station 3 (ST3) coordinates 108°56'34.32" E and 07°44'6.810" S. Measurements of mangrove vegetation at the study site for each Station which includes each plot of 10x10 m^2 for the tree category, 5x5 m^2 for the sapling category, and 1x1 m^2 for the seedling category. From each plot, mangrove vegetation data was taken by counting the number of species and the number of individuals of the species. Each species of mangrove vegetation was identified based on Kitamura et al (1997) and Giesen et al (2006).

Environmental parameters. The ecological parameters were determined in situ. The physicochemical parameters of the environment were soil pH, water temperature, salinity, phosphorus, nitrogen, and organic matter. Sediments were also collected from three replicates of each Station.

Data analysis. Mangrove species richness analysis based on a reference from Santoso et al (2008) is species richness by counting the number of species in an area. Mangrove density is calculated based on the references from Krebs (2009), density is the number of individuals in each sampling area. Mangrove density is measured with the equation:

$$Di = \Sigma\ ni/L$$

Where:
Di - Species density/density
Ni - Number of individuals of species i
L - Area of plot

The relative density of species (RDi), which is the ratio between the total amount of individuals of species-i (ni) and the total amount of individuals of all species of individuals of all species:

$$RDi\ (\%) = (ni\ /\ \Sigma\ n) \times 100$$

Where:
RDi - the relative density of species i (%);
ni - the number of individual species i;
Σn - the total number of individuals of all species.

Relative Frequency of Species (RFi), which is the ratio between the frequency of type-i (Fi) and the total frequency of all species: ∑ × 100%

$$RFi\ (\%) = (Fi\ /\ \Sigma\ F) \times 100$$

Where:
RFi - the relative frequency of species i (%);
Fi - the frequency of species i;
Σ F - the total frequency of all species.

Species Relative Cover (RCi) is the ratio of between the area of closure of species i (Ci) and the total area of closure for all species. area of cover for all species.

$$RCi\ (\%) = (Ci\ /\ \Sigma\ C) \times 100$$

Where:
RCi - the relative coverage of species i (%);
Ci - the ith species' areal of coverage;
Σ C - the total area of all species' coverage.

Species Importance Value (IVi) is the sum of the values of relative density (RDi), relative frequency of species (RFi), and relative species closure (RCi):
IVi = RDi + RFi + RCi

Results and Discussion

Mangrove species richness. The mangroves at the study site consist of natural mangrove forests, primarily from the *Rhizophoraceae* and *Avicenniaaceae* families. Overall, the mangrove species richness in Cilacap was determined to be five species from two families: *Rhizophora stylosa* Griff., *Rhizophora mucronata* Poir., *Rhizophora apiculata* Blume, *Avicennia marina* (Forssk.) Vierh., and *Avicennia alba* Blume. Species richness in this area is lower compared to other natural mangrove areas, such as the Philippines, which has eight species (Bitantos et al 2017), the mangrove regions in North Sumatra with seven species (Siswoyo et al 2024), and the mangrove areas in Karimunjawa National Park, which has nine species (Drajati et al 2024). The limited species richness found in Cilacap is largely attributable to illegal logging in the community's mangrove area.

Species density. The density of species found in Cilacap is classified as rare. Based on (Ministry of Environment Regulation (No. 201) 2004) Kepmen LH No.201 Year 2004, the condition of mangroves with a density <1.000 is categorized as a state of damage with the criteria rarely. The species density of each Station for tree level is presented in (Figure 1), sapling level (Figure 2), and seedling level (Figure 3).

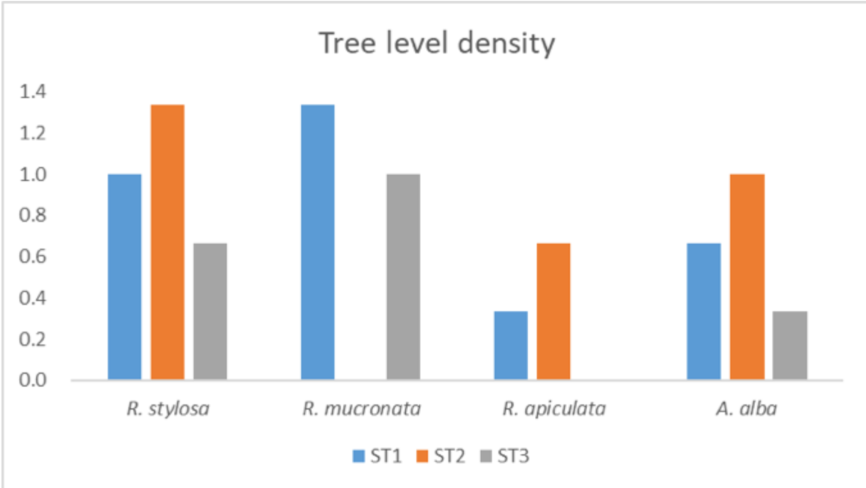

Figure 1. Species density at tree level at each Station.

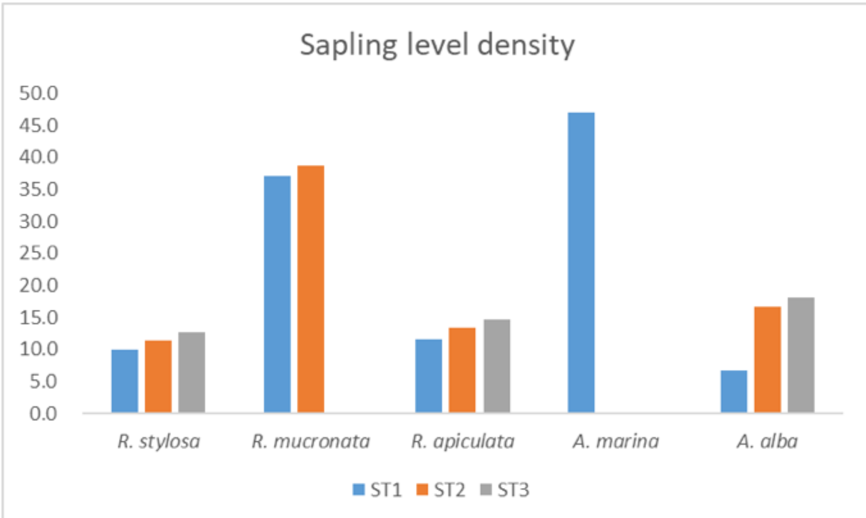

Figure 2. Species density at sapling level at each Station.

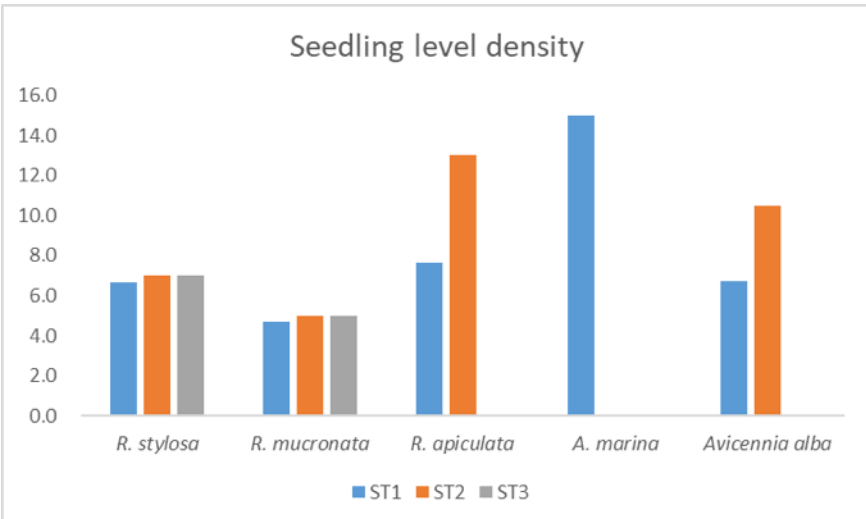

Figure 3. Species density at the seedling level at each Station.

Mangrove density for the tree level in the Cilacap mangrove area at each Station shows that Station 1 (ST1) 333 ind/ha is more densely compared to Station 2 (ST2), 300 ind/ha, and Station 3 (ST3) 200 ind/ha. Mangrove density for sapling level Station 1 (ST1) was 11,233 ind/ha more densely compared with Station 2 (ST2), 8,000 ind/ha, and Station 3 (ST3), 4,533 ind/ha. Mangrove density for seedling level Station 1 (ST1), 4,070 ind/ha, is more densely compared to Station 2 (ST2), 3,550 ind/ha, and Station 3 (ST3), 1,200 ind/ha. Mangrove density in Cilacap District is partly damaged because of illegal logging, causing a reduction in mangrove area. Winarno et al (2016) stated that changes in mangrove areas are due to a decrease in the ecological function of the mangrove ecosystem. Mangrove density is caused by the number of individuals. The more individuals found in an area, the higher the density.

Species importance value. Species importance value (IVi) describes the influence or role of a mangrove species in an observed mangrove community. The higher the importance value of a species, the higher the role of the mangrove species in the mangrove community. The importance values of mangrove species are presented (Table 1).

Table 1

Species importance value at tree level at each Station

Station	*Species*	*RDi (%)*	*RFi (%)*	*RCi (%)*	*IVi*
ST1	*Rhizophora stylosa* Griff.	30	28.57	99.66	158
	Rhizophora mucronata Poir.	40	28.57	0.23	69
	Rhizophora apiculata Blume	10	14.29	0	24
	Avicennia marina (Forssk.) Vierh.	0	0	0	0
	Avicennia alba Blume	20	28.57	0.11	49
	Total	100	100	100	300
ST2	*Rhizophora stylosa* Griff.	44.4	37.5	80.16	162
	Rhizophora mucronata Poir.	0	0	0	0
	Rhizophora apiculata Blume	22.2	25	0	47
	Avicennia marina (Forssk.) Vierh.	0	0	0	0
	Avicennia alba Blume	33.3	37.5	19.83	91
	Total	100	100	100	300
ST3	*Rhizophora stylosa* Griff.	33	40	0	73
	Rhizophora mucronata Poir.	50	40	66.67	157
	Rhizophora apiculata Blume	0	0	0	0
	Avicennia marina (Forssk.) Vierh.	0	0	0	0
	Avicennia alba Blume	17	20	33,33	70
	Total	100	100	100	300

The important value of species for the tree level in the Cilacap mangrove area at Station 1 (ST1) and Station 2 (ST2) is the *R. stylosa* species with an important value of 158% and 162%, Station3 (ST3) is the *R. mucronata* species with an important value of 157%. The important value of species indicates the role or the effect of a species of mangrove vegetation in the community. *Rhizophora* sp is a type of mangrove that is often found. *Rhizophora* sp species like tidal waters that have a strong freshwater intake influence permanently. This is in accordance with the statement that *R. apiculata* dominance level can reach 90% of the vegetation that grows at a location, growing on muddy, smooth, and flooded soils during normal tides (Surayah et al 2024).

Environmental parameters

pH. The pH value of the study site ranged from 6.73 to 7.20. The degree of acidity is still neutral. This condition is still within the range of water quality standards. The study results were found in the Kuala Indragiri mangrove with a pH of 6.1 (Surayah et al 2024). The degree of acidity of the soil at the study site is by the environmental quality standards of mangrove waters. The degree of acidity at the study site is still by the quality standards of the chemical factors of the mangrove water environment, namely 7.0-8.5 (Government Regulation of the Republic Indonesia (No. 22) 2021). The degree of acidity that increases becomes acidic due to the influence of an increase in bacteria that decompose organic compounds. Wintah (2022) states that mangroves will grow well within the pH range of 6.5-8.

Temperature. The water temperature at the study site ranged from 28.58 to 29.17^{0}C. The temperature in the area is not much different from the temperature in the mangrove area of Karimunjawa National Park ranging from 29-33C (Drajati et al 2024). The temperature at the study site is in accordance with the Government Regulation of the Republic Indonesia (No. 22) (2021) concerning environmental quality standards for mangrove waters ranging from 28-32°C. Temperature plays an important role in the process of respiration and photosynthesis. The optimum temperature range for Avicennia is between 18-20°C, Rhizophora 26-28°C, Bruguiera 27°C, and Xylocarpus 21-26°C (Kusmana 2000).

Salinity. Salinity at the study site ranged from 22.25-24.34‰. Salinity at the study site is lower than the mangrove area in Karimunjawa National Park ranging from 31-33‰ (Drajati et al 2024). Salinity in the study site is lower due to rainwater runoff. Salinity at the study site is still at the tolerance limit. Salinity will increase during the day and hot weather. Salinity at the study site is still in normal condition in accordance with the environmental quality standards of mangrove waters with a salinity range between 5-34‰ (Government Regulation of the Republic Indonesia (No. 22) 2021). These conditions can still be tolerated by mangroves. Mangroves can grow optimally at salinities between 10-30‰ (Kusmana 2000).

Phosphorous. Soil phosphorus at the study site ranged from 0.30% to 0.53%. Phosphorus at the study site is higher compared to the results of a study by Rizal et al (2017), which found phosphorus in the mangrove Rancabuaya Garut region to range from 0.29% to 0.38%. The high phosphorus levels observed at the study site are thought to be influenced by the decomposition of mangrove litter into organic matter. Both high and low phosphorus levels affect the amount of litter and mangrove biomass content. Mangrove biomass serves as a source of organic matter (Nugroho et al 2013). Phosphorus is utilized by plants and is an essential element for higher plants and algae. It significantly influences water productivity, making it a limiting factor for plant growth (Schaduw 2018).

Nitrogen. Soil nitrogen at the study site ranged from 2.21 to 3.23%. Nitrogen in the study site is still relatively high when compared to the results of a study by Rizal et al (2017) Nitrogen in Pancabuaya Coastal Garut ranged between 1.38-2.12%. Total nitrogen is a combination of nitrate (NO_3) and ammonium (NH_4). Nitrogen is the main macronutrient that plants need in large quantities. Nitrogen is one of the important elements in the mangrove ecosystem. Nitrogen and phosphorus nutrients affect mangrove productivity. The environmental conditions of mangroves, tides, intake of organic and inorganic materials, and decomposition of mangrove animals and plants are factors that affect the high level of nitrogen (Partaya & Setiati 2019).

Organic matter. The organic matter content at the study site ranged from 14.29% to 15.27%. The organic matter at the study site was lower than the results of the study by Barus et al (2019) organic matter in Banyuasin South Sumatra ranged from 10.52% to 17.92%. Organic matter in Karimunjawa National Park ranged from 14.45-28.63% (Drajati et al 2024). The highest organic matter in Station 1 was 15.27%. The content of organic matter at Station 1 is higher because the location has a lot of decomposed leaves and plants that have been weathered, this is supported by canopy cover in mangroves. Canopy cover will affect the amount of litter produced through the decomposition process, which will produce organic matter. In addition, the location of Station 1 is adjacent to the river so that it gets enough nutrient supply.

Conclusions. The species richness of mangroves in Cilacap found five species from 2 families, *Rhizophoraceae* (3 species), and *Acanthaceae* (2 species). The highest species density at the tree, sapling, and seedling levels was found at Station 1. Species importance value at Station 1 and Station 2 was *R. stylosa* species, and Station 3 was *R. mucronata* species. Physicochemical factors found in the Cilacap mangrove area, such as pH, temperature, and salinity, fulfill seawater quality standards. The amount of litter and mangrove biomass content influences phosphorus content. Nitrogen is one of the important elements in the mangrove ecosystem. Organic matter is influenced by the decomposition process of mangrove leaf litter, which produces organic matter.

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