

Species composition and structure of Angke Kapuk Mangrove Protected Forest, Jakarta, Indonesia

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Manuscript received: 27 July 2021. Revision accepted: 24 August 2021.

Abstract. Rumondang AL, Kusmana C, Budi SW. 2021. Species composition and structure of Angke Kapuk Mangrove Protected Forest, Jakarta, Indonesia. *Biodiversitas* 22: 3863-3871. Angke Kapuk Mangrove Protected Forest (AKMPF) is one of the protected forests in the coastal area of DKI Jakarta, Indonesia. This area is important for the north coast of Jakarta, hence it has function to protect the land from sea abrasion, seawater intrusion, and seawater flooding. This study aims to determine the condition of forest structures and species composition in the Angke Kapuk Mangrove Protected Forest (AKMPF) to obtain useful information for sustainable mangrove forest management. Vegetation data were collected using the sampling unit of transect for tree and line plot for forest regeneration inventories. Those data were analyzed for the density, frequency, dominance, species diversity, and species distribution pattern. The obtained results show that AKMPF consists of 13 mangrove species, including 7 species of true mangrove, 5 species associated mangrove, and 1 species of palm, with the dominant species, are *Avicennia marina* for tree with its regenerations and *Acrostichum aureum* for groundcover. Overall, the species diversity index in this area was classified as low category. Mangrove trees in this area have height class between 4-28 meters formed bell-curve, while stem diameter class were between 10.00-69.75 cm formed L-curve. The distribution pattern of species in this areal generally was clumped.

Keywords: Angke Kapuk Mangrove Protected Forest, forest structure, species composition, species distribution

INTRODUCTION

Mangrove forests are forest formations located in estuarine areas with unique characteristics and influenced by tidal conditions and have a very important function for living things and humans (Snedaker 1978; Rasquinha and Mishra 2021; Eddy et al. 2019; Kantharajan et al. 2018). The existence of mangrove forests around the coastline has environmental benefits and services, such as protection of the coast from abrasion, sea storms, seawater flooding, and also as a catcher for soil sediment carried from rivers to seawater (Campo et al. 2018; Kiruba-Sankar et al. 2018; Prisambodo et al. 2019; Ruiz-Fernández et al. 2017; Rasquinha and Mishra 2021). In addition to a protective function, the presence of mangroves permanently contributes organic matter to the estuarine area, both as a food source for marine animals and wild animals such as crocodiles, birds and monkeys (Hernández et al. 2011; Campo et al. 2018). Mangroves also provide fish spawning grounds and shelter for wildlife (Raquinha and Mishra 2021; Ruiz-Fernández et al. 2017). According to the Ministry of Environment and Forestry (2017), the area of mangrove forests in the world is around 16.53 million hectares. Meanwhile, the area of mangrove forests in Indonesia based on data from BPS (2020) is around 2.4 million hectares or around 28.4% of the world's mangrove forests (Rahadian et al. 2019).

Excessive use of mangroves followed by poor and unsustainable forest management has resulted in mangrove

forest degradation (Sillanpää et al. 2017). According to Hence (2010), about 35% of mangrove forest in Indonesia were degraded from 1982 to 2000. The new information from Prasetyo (2021) states that the mangrove deforestation rate in Indonesia is about 52,000 ha/year and is mainly located in Papua, Kalimantan and Sumatra. In contrast, in Java Island, the mangrove forest area also decreased from 2019 to 2020. Information regarding forest structure and the species composition of mangrove forests is fundamental for sustainable mangrove forest management and the conservation of mangrove forest resources. Forest structure generally can be determined from three components, such as abundance which is determined by the number of species and individuals per species, vertical structure/stratification (tree height distribution), and horizontal structure (basal diameter distribution of the trunk) (Kershaw 1964; Domínguez-Cadena et al. 2016; Prisambodo et al. 2019). The structure and species composition of the mangrove forest community is strongly influenced by not only climatic factors but also site factors, such as topography, soil characteristics, and tides of seawater (Eddy et al. 2019; Azman et al. 2021).

Angke Kapuk Mangrove Protected Forest (AKMPF) is one of the mangrove forest areas located in Penjaringan District, North Jakarta. This area is the only protected forest area in DKI Jakarta Province to protect the land from sea abrasion, seawater intrusion, and seawater flooding from the north coast of Jakarta. The degradation of mangrove forests in this area is classified as high level

which is caused by the undegradable waste piles. The location of mangroves on the edge of the capital area causes a lot of garbage carried by rivers and seawater to accumulate and get trapped between mangrove roots, especially plastic waste that is difficult to degrade (Martin et al. 2019). In the Angke Kapuk area, a lot of plastic waste was found piled up among the mangrove roots, especially on the soil surface, which was about 28.09 particles/kg dry sediment for the microplastic waste category and 20 – 533 items/m² with a weight of 108.7 – 5449.7 g/m² for macro size plastic waste category (Cordova et al. 2021; Hastuti et al. 2014). Plastic that accumulates on the mangrove floor can form prolonged anoxic conditions, so that only species that are able to adapt to these conditions can survive. This will certainly affect the structure and species composition of the mangrove forest. This study aims to determine the condition of forest structures and species composition in the AKMPF to obtain useful information for its sustainable mangrove forest management.

MATERIALS AND METHODS

Study area

This study was conducted in August 2020 in the Angke Kapuk Mangrove Protected Forest, Penjaringan District, North Jakarta at the geographical location between 6° 05'–6° 10' South Latitude and 106° 43'–106° 48' East Longitude (Figure 1).

The area of Angke Kapuk Mangrove Protected Forest (AKMPF) stretches in the coastal area of Jakarta Bay with an area of 44.76 hectares. The soil texture condition in this area is dominated by clay with a percentage of more than 50%, 39% silt, and sand. BKSDA Jakarta (2015) states that the type of soil in Angke Kapuk Mangrove Protected Forest (AKMPF) area is dark gray alluvial with a silty clay texture. The climate is included in type A (Schmidt and Ferguson classification), with an average relative humidity of 82.96% and rainfall ranging from 60 mm (October) to 338 mm (January). LON-LIPI 1977 also states that the condition of seawater temperature in the Jakarta Bay area ranges from 29 °C–31.5 °C with water salinity ranging from 30–33.35 ‰.

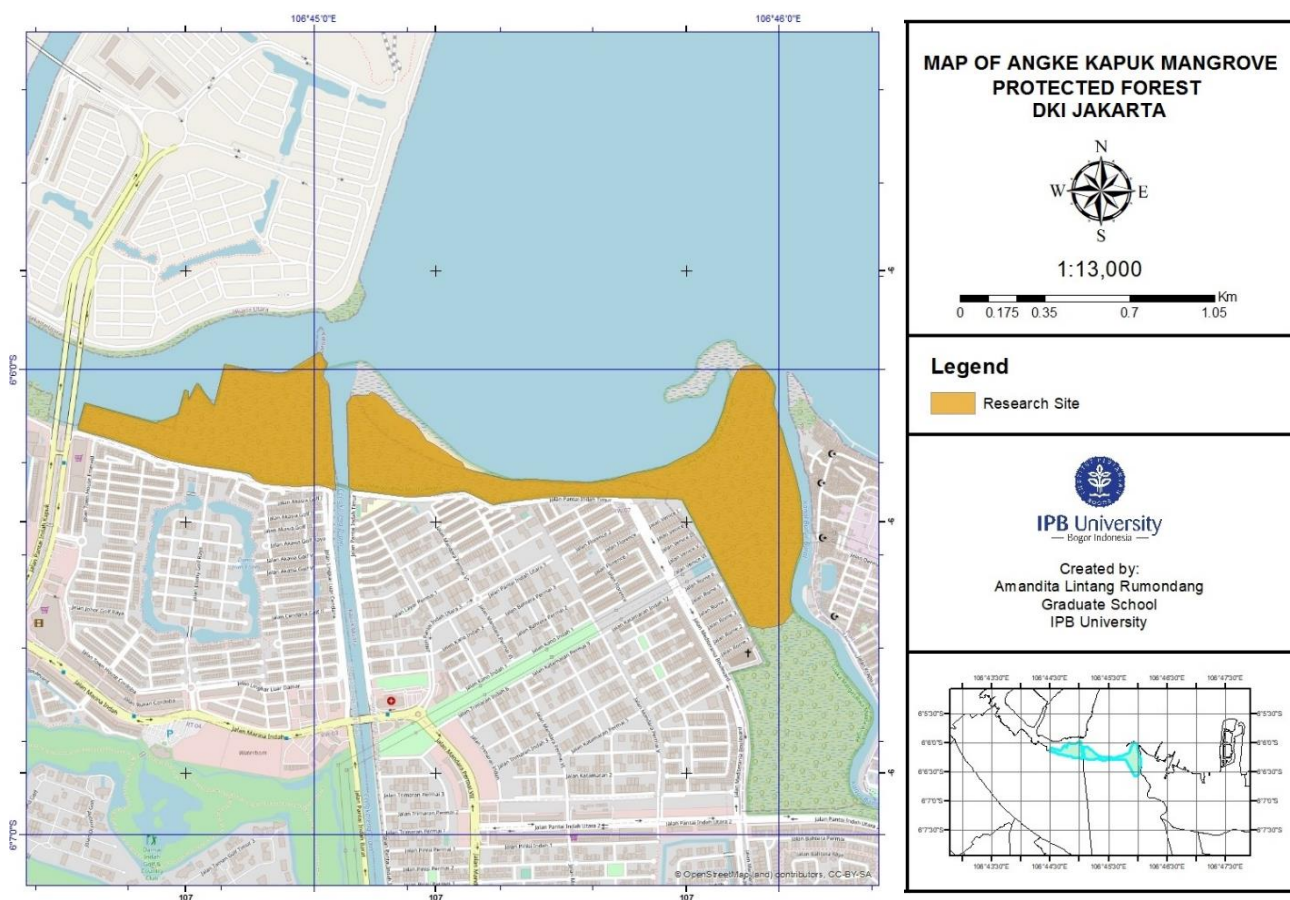


Figure 1. Location of Angke Kapuk Mangrove Protected Forest, Jakarta, Indonesia

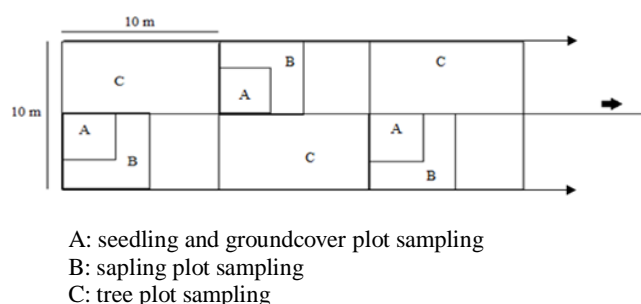


Figure 2. The design of combination between transect and quadrat plot line methods for vegetation survey

Methods

Vegetation data were collected through vegetation survey using the combination of the techniques of transect for tree inventory and quadrat plotline for tree regeneration (seedling and sapling) and groundcover. Each transect with 10 meters width and length based on the mangrove thickness were divided into plots of 10x10 meters for tree inventory and nested in those plots constructed smaller plots 5x5 meters for sapling and 2x2 meters for seedling and groundcover inventories (Figure 2). Transects were constructed in the research site perpendicularly to the coastline with a distance of 100 meters among them through the procedure of systematic sampling with random start. All plant species within those plots were inventoried, including the stem diameter at breast height (DBH) or 10 cm above the still root and the height for trees, and the number of individuals for saplings, seedlings, etc groundcover.

Data analysis

Vegetation data were analyzed to obtain density (individual/ha), frequency, dominance, importance value index (IVI), and Shannon-Wiener diversity index (H'). The importance value index (IVI) is determined by the relative density (KR) and relative frequency (FR) values for seedlings and saplings, and relative dominance (DR) for trees (Neelo et al. 2015; Kusmana 1997). Shannon-Wiener species diversity index was determined using the equation (Magurran 2004):

$$H' = -\sum_i P_i \ln(P_i)$$

Where: H' is diversity index of Shannon-Wiener; P_i is the proportion of individual species (n_i) to some individuals (N); with the classifications of diversity 0 – 1: very low; 1 – 2: low; 2 – 3: moderate; 3 – 4: high; and 3 – 4: very high (Jørgensen et al. 2005).

The vertical structure of vegetation will be presented in the form of a graph visualizing the relationship between tree height classes and tree density per hectare, while the horizontal structure of vegetation will be depicted in the form of a graph visualizing the relationship between tree diameter classes and tree density per hectare. In addition, in order to detect the spatial distribution pattern of species, Morishita's index was adopted (Morishita 1962):

$$I\delta = q \times \frac{\sum_{i=1}^n x_i(x_i - 1)}{N(N - 1)}$$

Where x_i is the number of individuals in the its plot ($i = 1, 2, \dots, q$), q is the number of plots, and T is the total number of individuals in all plots. The dispersed pattern individual is regarded as random if $I\delta = 1$, clumped if $I\delta > 1$ and uniform if $I\delta < 1$. To test the significance of $I\delta > 1$, the F-test from Morishita (1962) was adopted. The statistical test was given by:

$$F = \frac{I\delta(T - 1) + q - T}{(q - 1)}$$

If the F value is greater than the table value of F distribution with $(q - 1)$ degrees of freedom for numerator and infinity for denominator at some selected level of probability (0.05 and 0.01), individual is regarded as clumped.

RESULTS AND DISCUSSION

Species composition

All of species found on research site are presented in Table 1. The total of tree species found at the research site consisted of 13 species from 11 families. There were 7 species of true mangroves, *Avicennia marina*, *Rhizophora mucronata*, *Excoecaria agallocha*, *Avicennia alba*, *Sonneratia caseolaris*, *Rhizophora apiculata*, and *Xylocarpus moluccensis*. Others were mangrove associate species that were rarely found in this ecosystem. There were 4 species of true mangroves found at the seedling, sapling, and tree, such as *A. marina*, *R. mucronata*, *E. agallocha*, and *A. alba*. The dominant species at all growth stages is *A. marina* with IVI 71.10% (seedling), 118.88% (sapling), and 212.05% (tree). Species of mangrove associate was found in all of growth stage is *Hibiscus tiliaceus*. The species of groundcover were found 12 species from 7 families with the dominant species is *Acrostichum aureum* (90.92%) (Table 2). The diversity index at the research site at tree stage and its regeneration and groundcover are categorized as low category because of $H' < 1$ (Table 3).

Forest structure

Species abundance

The abundance of a species can be seen from the density (ind/ha) and dominance or basal area (m^2/ha) presented in Table 1. The highest density at the seedling stage is *R. mucronata* (809 ind/ha), followed by *A. marina* 607 ind/ha. While the other species have density under 200 ind/ha. At the sapling stage, the highest density is *A. marina* (650 ind/ha), while the others are under 150 ind/ha. At the tree stage, the highest density is also *A. marina* (276 ind/ha) with a 17.14 m^2/ha basal area. Other species have density of under 100 ind/ha and basal area under 2 m^2/ha .

Table 1. Density, frequency, dominance and IVI of mangrove species of tree and its regeneration in the research site

Species	Seedling			Sapling			Tree			
	Density (ind/ha)	Freq.	IVI (%)	Density (ind/ha)	Freq.	IVI (%)	Density (ind/ha)	Freq.	Dominance (m2/ha)	IVI (%)
<i>Avicennia marina</i>	607	0.110	71.10	650	0.441	118.88	276	0.787	17.14	212.05
<i>Rhizophora mucronata</i>	809	0.081	70.47	38	0.051	10.40	54	0.103	1.13	27.05
<i>Excoecaria agallocha</i>	184	0.022	17.37	138	0.081	23.56	21	0.088	0.78	15.83
<i>Hibiscus tiliaceus</i> *	165	0.015	13.74	135	0.044	18.38	2	0.015	0.05	1.97
<i>Avicennia alba</i>	129	0.007	9.18	44	0.037	8.98	23	0.176	1.48	26.63
<i>Morinda citrifolia</i> *	55	0.022	10.89	3	0.007	1.25				
<i>Delonix regia</i> *				29	0.022	5.66	9	0.022	0.49	6.27
<i>Nipah fruticans</i>	37	0.015	7.26							
<i>Sonneratia caseolaris</i>				18	0.007	2.61	6	0.044	0.23	6.06
<i>Rhizophora apiculata</i>				9	0.022	3.76	1	0.015	0.11	2.06
<i>Xylocarpus moluccensis</i>				9	0.015	2.78	1	0.007	0.06	1.05
<i>Cerbera manghas</i> *				9	0.022	3.76				
<i>Terminalia catappa</i> *							1	0.007	0.01	1.02
Total	1986		200.00	1082	0.75	200.00	393	1.26	21.49	300.00

*) Mangrove associate species

Table 2. Density, frequency, and IVI of groundcover in the research site

Species	Density (ind/ha)	Frequency	IVI (%)
<i>Acrostichum aureum</i>	3,382	0.397	90.92
<i>Acanthus illicifolius</i>	1,397	0.118	32.26
<i>Derris trifoliata</i>	827	0.125	25.42
<i>Melanthera biflora</i>	570	0.059	14.40
<i>Ruellia tuberosa</i>	460	0.022	8.71
<i>Cayratia trifolia</i>	202	0.044	7.76
<i>Ipomea maxima</i>	165	0.037	6.43
<i>Acanthus volibilis</i>	147	0.029	5.34
<i>Ageratum conyzoides</i>	74	0.015	2.67
<i>Pluchea indica</i>	129	0.007	2.57
<i>Alternanthera philoxeroides</i>	37	0.015	2.18
<i>Ipomea triloba</i>	37	0.007	1.34
Total	7426	0.88	200.00

Table 3. Shannon-Wiener Diversity index (H') of seedling, sapling, tree and ground cover in the research site

Growth stages	The number of species	Shannon-Wiener index (H')	Status category
Seedling	7	0.535	Low
Sapling	11	0.566	Low
Tree	10	0.451	Low
Groundcover	12	0.479	Low

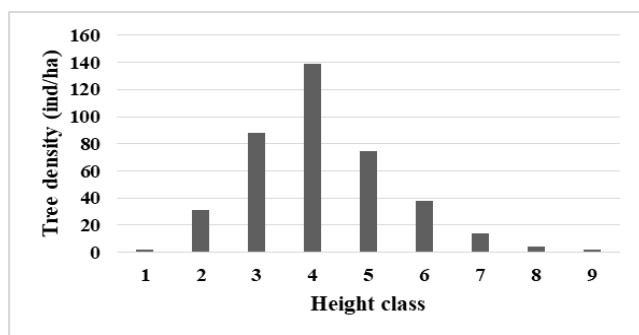


Figure 3. Height class distribution of mangrove trees in the research site

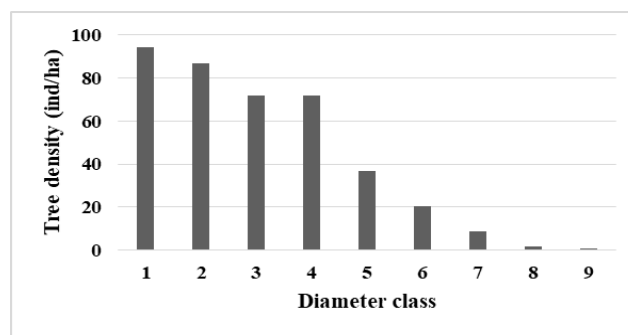


Figure 4. Stem diameter class distribution of mangrove trees in the research site

Table 4. Density (ind/ha) of trees by height class in the research site

Species	Height class (m)								
	1	2	3	4	5	6	7	8	9
<i>Avicennia marina</i>	1	18	63	86	64	32	7	3	2
<i>Rhizophora mucronata</i>	-	1	13	35	4	-	-	-	-
<i>Excoecaria agallocha</i>	-	3	1	7	2	2	4	1	-
<i>Hibiscus tiliaceus</i>	-	1	1	1	-	-	-	-	-
<i>Avicennia alba</i>	1	3	7	8	3	1	-	1	-
<i>Delonix regia</i>	1	1	-	1	-	4	3	-	-
<i>Sonneratia caseolaris</i>	-	4	1	1	-	-	-	-	-
<i>Rhizophora apiculata</i>	-	-	1	1	-	-	-	-	-
<i>Xylocarpus moluccensis</i>	-	-	-	-	1	-	-	-	-
<i>Terminalia catappa</i>	-	-	1	-	-	-	-	-	-

Table 5. Density (ind/ha) of trees by stem diameter class in the research site

Species	Diameter class								
	1	2	3	4	5	6	7	8	9
<i>Avicennia marina</i>	45	54	57	63	32	16	7	1	1
<i>Rhizophora mucronata</i>	28	22	4	-	1	-	-	-	-
<i>Excoecaria agallocha</i>	8	4	4	4	1	-	-	-	-
<i>Hibiscus tiliaceus</i>	1	1	-	-	-	-	-	-	-
<i>Avicennia alba</i>	5	3	4	4	2	3	1	-	-
<i>Delonix regia</i>	3	1	1	1	1	1	-	-	-
<i>Sonneratia caseolaris</i>	3	1	1	-	-	1	-	-	-
<i>Rhizophora apiculata</i>	-	1	-	-	1	-	-	-	-
<i>Xylocarpus moluccensis</i>	-	-	-	1	-	-	-	-	-
<i>Terminalia catappa</i>	1	-	-	-	-	-	-	-	-

Vertical structure (stratification)

The vertical stand structure can be seen from the relationship of tree density with canopy height. The height class in this location consist 9 class, such as class 1 (>5 meter), class 2 (5-7.5 meter), class 3 (8-10.5 meter), class 4 (11-13.5 meter), class 5 (14-16.5 meter), class 6 (17-19.5 meter), class 7 (20-22.5 meter), class 8 (23-25.5 meter) and class 9 (26-28.5 meter). Distributions of individual number of each species are shows in Table 4. Those individual distributions of the height class formed bell curve with the

highest density at height class 4 (11-13.5 meter) with the density 139 ind/ha (Figure 3). It can be seen that *A. marina* dominated all height classes with the highest density in the height class of 11-13.5 m (86 ind/ha), while *R. mucronata* is only found in the height class 5-16.5 m and *E. agallocha* in height class 5-25.5 meter. In the height class above 20 meters, four species were found, there is *A. marina* (20-28.5 m), *E. agallocha* (20-25.5 m), *A. alba* (23-25.5 m) and the associated mangrove species *D. regia* (20-22.5 m).

Table 6. Morishita's Index ($I\delta$) of seedling, sapling, trees and groundcover in the research site

Growth stages	No	Species	Morishita index ($I\delta$)
Trees	1	<i>Avicennia marina</i>	1.361
	2	<i>Rhizophora mucronata</i>	12.472**
	3	<i>Avicennia alba</i>	1.755
	4	<i>Excoecaria agallocha</i>	11.513
Sapling	1	<i>Avicennia marina</i>	3.295*
	2	<i>Excoecaria agallocha</i>	12.581*
	3	<i>Hibiscus tiliaceus</i>	28.120**
	4	<i>Rhizophora mucronata</i>	15.692
Seedling	1	<i>Avicennia marina</i>	7.727
	2	<i>Rhizophora mucronata</i>	18.689*
	3	<i>Excoecaria agallocha</i>	66.489*
	4	<i>Hibiscus tiliaceus</i>	83.111*
Ground cover	1	<i>Acrostichum aureum</i>	2.674
	2	<i>Acanthus ilicifolius</i>	10.880*
	3	<i>Derris trifoliata</i>	7.968
	4	<i>Melanthera biflora</i>	21.058*

Note: *) indicate significant departure from randomness at the level of 0.05. **) indicate significant departure from randomness at the level of 0.01

Horizontal structure

Horizontal stand structure can be seen from the relationship of tree density with the distribution of its diameter class. The diameter class in this location consist 9 class, such as class 1 (10.00-16.00 cm), class 2 (16.01-22.00 cm), class 3 (22.01-28.00 cm), class 4 (28.01-34.00 cm), class 5 (34.01-40.00 cm), class 6 (40.01-46.00 cm), class 7 (46.01-52.00 cm), class 8 (52.01-58.00 cm) and class 9 (>58.00 cm). The individual distribution of tree stem diameter class formed L curve (Figure 4), where the highest density is in the small-diameter class 1 (10.00-16.00 cm) with 94 ind/ha. Table 5 shows that *A. marina* is the dominant species with stem diameter distribution from 10 cm to above 58 cm. The highest density of this species is in the diameter class 28-34 cm with 63 ind/ha. Whereas *R. mucronata* is commonly found in diameter class of about 10.00-22.00 cm. Other true mangrove species such as *E. agallocha*, *A. alba* and *S. caseolaris* are found in the 10-46 cm diameter class. While associated mangrove species were found in the 10.00-22.00 cm diameter class.

Spatial distribution of Morishita's Index ($I\delta$)

From the Morishita's index value that is presented at Table 6, all Morishita's index value were $I\delta > 1$, but after the F distribution test, it was found that *R. mucronata* showed a clumped pattern in tree growth stage, while *A. marina*, *A. alba* and *E. agallocha* showed random patterns. At sapling stage, it was found that *A. marina*, *E. agallocha* and *H. tiliaceus* showed clumped patterns, while *R. mucronata* has random distribution pattern. At the seedling stage, *R.*

mucronata, *E. agallocha* and *H. tiliaceus* have clumped pattern, while *A. marina* spread randomly. At groundcover, *A. ilicifolius* and *M. biflora* have clumped patterns, while *A. aureum* and *D. trifoliata* spread randomly.

Discussion

The area of Angke Kapuk Mangrove Protected Forest (AKMPF) is a reforestation project area of DKI Jakarta Forestry Office and designated as a protected forest area based on Decree of DKI Governor number E.A. 15/1/13 dated 27th July 1970 (Kusmana 1983). Therefore, the forest condition is relatively young and dominated by one species, namely *Avicennia marina*. This species grows predominately in the area of Angke Kapuk Mangrove Protected Forest (AKMPF). *A. marina* is found in soil conditions dominated by clay (Rasquinha and Mishra 2021; Sreelekshmi et al. 2020) and water salinity above 25 ‰ (Eddy et al. 2019). This is in line with the conditions in the Angke Kapuk Mangrove Protected Forest area, which has predominantly clay soil texture and water salinity conditions above 30 ‰. *A. marina* is one of true mangrove species, well adapted in various environmental condition, so that this species is often found as pioneer species in young growing forests (Saintilan and Hashimoto 1999; Lebigre 1999; Numbere 2018).

A. marina is a species that can adapt to the disturbed conditions of AKMPF and can be found in locations with waste piles. The condition of the AKMPF area which is exposed to a lot of waste, especially plastic waste, causes the soil to be infertile and also in anoxic condition (Numbere 2018; van Bijsterveldt et al. 2021). *A. marina* can adapt and survive in this condition and invade the areas (Saenger 2002; Numbere 2018; Eddy et al. 2019). *A. marina* seedlings initially develop a heart root system, growing multiple vertical roots simultaneously, which increases stability and oxygen, so this species can grow well in this location (Al-Khayat and Alatalo 2021).

Acrostichum aureum and *Acanthus ilicifolius* are two dominant groundcover species which found in research site. Both of them are pioneer species in young mangrove forests and they are often found in association with true mangrove species. *A. aureum* is a pioneer species that becomes a marker of disturbed primary forest and is often found in landward forest areas (Eddy et al. 2019; Lebigre 1999; Numbere 2018). Mangrove ferns (*Acrostichum aureum*) is commonly found in disturbed mangrove areas. This is because the environmental pollution causes the mangrove soil to be less fertile and less saline, so that various types of groundcover can grow and thrive, especially the type of *Acrostichum aureum* (Numbere 2018). While *A. ilicifolius* is a species commonly found in association with *A. marina*. This is because the condition of *A. ilicifolius* growth site is similar to *A. marina*, such as soil with clay texture domination, high salinity and diurnal inundation (Sreelekshmi et al. 2020; Joshi and Ghose 2003).

Table 7. The number of mangrove species on several mangrove forests in Asia

Location	Communities type	Number of species	Source
Angke Kapuk Protected Forest, Jakarta, Indonesia	<i>A. marina</i>	13	<i>Present study</i>
Cilacap, Central Java, Indonesia	<i>A. marina</i> - <i>S. alba</i> , <i>R. apiculata</i> - <i>R. mucronata</i> , <i>N. fruticans</i>	14	Hidayat et al. 2017
Sundarban delta, East coast of India	<i>A. marina</i> , <i>E. agallocha</i> , <i>A. officinalis</i> , <i>A. alba</i>	27	Sreelekshmi et al. 2020
Andaman Island, India	<i>R. apiculata</i>	25	Kiruba-Sankar et al. 2018
Cochin mangroves, South-West coast, India	<i>E. agallocha</i> <i>B. cylindrica</i> - <i>B. gymnorhiza</i> <i>A. officinalis</i> - <i>R. mucronate</i> <i>R. apiculata</i> - <i>B. sexangular</i> - <i>K. kandel</i> - <i>S. caseolaris</i>	14	Rani et al. 2016
Ca Mau Cape National Park, Vietnam	<i>R. apiculate</i> , <i>A. alba</i> , <i>A. officinalis</i>	10	Tinh et al. 2009
Selangor, Peninsular, Malaysia	<i>Avicennia</i>	43	Stanley and Lewis 2009
Walu estuary, Khlung District, Chanthaburi Province, Thailand	<i>E. agallocha</i> - <i>X. granatum</i> - <i>X. moluccensis</i> <i>R. apiculate</i> <i>B. parviflora</i> - <i>S. ovata</i>	26	Suk-ueng et al. 2013
Tanjung Piai National Park and Pulau Kukup National Park, Malaysia	<i>B. cylindrica</i>	16	Tan et al. 2012
Ajuy and Pedada Bays, Panay Island, Philippine	<i>Avicennia-Sonneratia</i> <i>Avicennia-Rhizophora</i> <i>Avicennia-Excoecaria-Bruguiera-Ceriops</i> <i>Avicennia</i>	13	Shinfuego and Buot Jr. 2013

In general, Angke Kapuk Mangrove Protected Forest (AKMPF) has 13 mangrove species, both true mangrove species, and association mangrove species. This is a small number comparing with other locations, especially around Asia (Table 7). According to Shannon-Wiener diversity index (H'), this location also has a category 'very low' based on the classification of Jørgensen et al. (2005). This is because the area of Angke Kapuk Mangrove Protected Forest (AKMPF) originally came from several times reforestation that was open due to disturbances. The results of this planting will form a relatively uniform species composition. The Research results from Sofian et al. (2020) show that the mangrove area of Angke Kapuk which suffered severe damage, around 272.79 ha was converted into built-up areas, such as settlements, toll roads, and others. This conversion causes significant mangrove loss, in addition to increasing the degradation and fragmentation of mangrove ecosystems (Latiff 2012; Mayalanda et al. 2014). Fragmentation and loss were highly correlated in Southeast Asia, and this relationship was mediated by specific land-use transitions (Bryan-Brown et al. 2020). This fragmented ecosystem condition will prevent the entry of new species, so that only the species that survive in the

ecosystem will continue to develop and produce fruit to regenerate. This can be seen from the species composition where the number of species in the study location is less than mangroves in other places and is only dominated by *A. marina* species at all growth stages.

The Angke Kapuk Mangrove Protected Forest (AKMPF) has a diameter class distribution that resembles an inverted J-curve, where tree density decreases as the trunk diameter increases (Meyer 1952; Trettin et al. 2015). This shows that the mangrove forests in this area are in the form of young forests and are in a developmental phase (Joshi and Ghose 2014). The research by Trettin et al. (2015) is similar, where the diameter distribution follows the characteristics of mixed natural forest in the form of an inverted J-curve. At this area, the largest diameter distribution is in the diameter range of 10-34 cm. If seen the track record that this protected forest originates from reforestation areas with *A. marina* species which was carried out around the 1970s, it can be said that the growth in diameter increment in this location is slow. According to Anwar (2007), the diameter growth of *A. marina* is 4.04 cm for 2.5 years. Therefore, at 25 years of planting, the diameter has reached 40 cm. This condition has something

to do with the Angke Kapuk Mangrove Protected Forest (AKMPF), where many garbage piles are in the sidelines of the roots of mangrove trees, especially *A. marina* species. Cordova et al. (2021) stated that the sediments in the Angke Kapuk area contained more microplastics than other locations. Plastics buried in the sediment, especially the upper sediment, will create prolonged anoxic conditions and cause death in plants due to disruption of growth of pneumatophores (van Bijsterveldt et al. 2021).

Canopy stratification found on stands in the Angke Kapuk Mangrove Protected Forest (AKMPF) were 4 strata, namely B stratum (20-28 meter), C stratum (4-20 meter), D and E stratum which are occupied by saplings, seedlings and groundcover. The distribution graph of the high class at the research site forms a bell curve with the highest density in the diameter class of 10-13.5 m (Stratum C). This situation is normal for natural forest conditions where stratum C as regeneration will later replace the age class above it (Septiawan et al. 2017; Soerianegara and Indrawan 2016). If seen from the spatial distribution pattern, in general, the distribution pattern of species at this location is clumped, especially at the growth stages of saplings and trees. Based on Heddy et al. (1986), the clumped distribution pattern of species is due to (i) non-uniform environmental conditions; (ii) the reproductive pattern of each individual in the population; and (iii) animal behavior which is the vector for spreading the seeds which tend to form colonies. Mangrove fruit species are generally vivipary species that do not have a dormant period and will become seedlings when they fall on the surface of the sediment at low tide (Saenger 2002).

ACKNOWLEDGEMENTS

The authors thank the Ministry of Education, Culture, Research and Technology, Indonesia for support this research funding scholarship through the PMDSU scholarship with contract number 6539/IT3.L1/PN/2020, Office of Park and City Forest DKI Jakarta, for permission and supporting this research, and also thank some forest rangers for their kind support and assistance during data collection and the field survey.

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