Species composition and structure of mangrove forest exposed to plastic waste in Angke Kapuk mangrove protected forest, Jakarta

A L Rumondang*, C Kusmana and S W Budi
Department of Silviculture, Faculty of Forestry and Environment of IPB University.
Kampus IPB Darmaga, Bogor, West Java, Indonesia 16680
E-mail: amandita130796@gmail.com

Abstract. Angke Kapuk Mangrove Protected Forest (AKMPF) is one of the protected mangrove forests in the coastal area of DKI Jakarta exposed to plastic marine debris. This study aims to determine species composition and forest structures of mangrove forest exposed to plastic waste which is important as basic information for sustainable mangrove forest management in Angke Kapuk mangrove protected forest. Vegetation data were collected using the sampling unit of transect for tree and line plot for forest regeneration inventories. Those data were analysed for the density, frequency, dominance, species diversity, and species distribution pattern. The results show that the area of AKMPF exposed to plastic waste consists of 9 mangrove species, including 6 species of true mangrove, 2 species associated mangrove, and 1 species of palm, with the dominant species are Avicennia marina for tree with its regeneration and Acrostichum aureum for groundcover, which are species that live in disturbed mangrove areas. Mangrove trees in this area have a height class between 4 – 25 meters, while stem diameter class were between 10.00 – 69.75 cm. The most distribution pattern of species in this area generally was regular, except the sapling of Avicennia marina, seedling of Rhizophora mucronata, and Acrostichum aureum distributed randomly.

1. Introduction
Mangrove forest is a forest formation located in an intertidal area [1], which is an area affected by tides and is a distinctive and unique formation. The existence of mangrove forests is very important in protecting coastal areas from abrasion, wind and storms, and other natural disturbances. The spread of mangrove forests along the coastline in the tropics and subtropics, about 75% of the coastline is covered by mangroves [2]. In line with the Ministry of Environment and Forestry [3], mangrove forests in Indonesia in 2017 had an area of 3 489 140.68 Ha and this area is equal to 23% of the world's mangrove forest ecosystem which has an area of 16 530 000 Ha. In line with Hence [4], approximately 35% of mangrove forests in Indonesia were degraded from 1982 to 2000. One of the threats to the existence of mangroves comes from anthropogenic activities [5]. The decline of mangrove habitat is an alarm regarding the impact of human behaviours/anthropogenic disturbances and climate change [6].

The Angke Kapuk protected forest is one of the conservation regions that has the feature of defensive land inside the DKI Jakarta area from abrasion and seawater intrusion from the north coast of Jakarta. The area of mangroves on the edge of the capital location causes a number of rubbish carried with the aid of rivers and seawater to accumulate and get trapped among mangrove roots, specifically plastic waste this is hard to degrade [7]. In the Angke Kapuk area, quite a few plastic waste turned into determined piled up most of the mangrove roots, particularly on the soil floor, which turned
into approximately 28.09 debris kg\(^{-1}\) dry sediment for the microplastic waste category and 20 – 533 items m\(^{-2}\) with a weight of 108.7 – 5449.7 g m\(^{-2}\) for macro size plastic waste category [8, 9]. Plastic that accumulates at the mangrove floor can shape extended anoxic conditions, in order that most effective species which can be capable of adapting to these conditions can live on. This may sincerely affect the structure and species composition of the mangrove woodland. This studies targets to discover the effect of plastic waste piles on the AKMPF ground at the forest structure and species composition.

2. Method

2.1. Research site
The research was conducted on August 2020 at Pos 2 and Pos 3 of Angke Kapuk protected forest, Penjaringan District, North Jakarta at the geographical location between 6\(^\circ\)05' - 6\(^\circ\)10' South Latitude and 106\(^\circ\)43' - 106\(^\circ\)48' East Longitude as shown in Figure 1.

![Figure 1. Location of Angke Kapuk Mangrove Protected Forest (AKMPF).](image)

2.2 Procedure
Vegetation data were accumulated through plants survey using the combination between 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 duration based totally at the mangrove thickness were divided to the plots of 10x10 meters for tree inventory and nested in the ones plots built smaller plots 5x5 meters for sapling and 2x2 meter for seedling and groundcover inventories (Figure 2). Transects have been constructed in the studies site perpendicularly to the coastline with the gap of one hundred meters among them via the process of systematic sampling with random start. All plant species within those plots were inventoried consisting of the stem diameter at breast peak (DBH) or 10 cm above the nevertheless root (for Rhizophora spp.) as well as the height for timber, and the variety of individuals for saplings, seedlings and groundcover.
2.3 Data analysis

Vegetation data have been analysed to gain density (individual according to ha), frequency, dominance, importance value index (IVI), and Shannon-Wiener diversity index (H'). The importance value index (IVI) was decided with the aid of the relative density (KR) and relative frequency (FR) values for seedlings and saplings, and relative dominance (DR) for trees [10, 11]. Shannon-Wiener species diversity index became decided using the equation as discovered by way of Magurran [12]:

\[
H' = - \sum_{i=1}^{n} P_i \ln(P_i)
\]

in which: H' is diversity index of Shannon-Wiener; Pi is the proportion of individual species (ni) to some individuals (N); with the classifications of diversity 0 – 1: bad status; 1 – 2: poor status; 2 – 3: moderate status; 3 – 4: good status; and 3 – 4: high status as refer to Jørgensen et al. [13].

The vertical structure of vegetation validated within the form of a graph which visualizing the relationship among tree height classes and tree density consistent with hectare, at the same time as the horizontal structure of vegetation became depicted in the shape of a graph visualizing the relationship between tree diameter classes and tree density in step with hectare. Similarly, which will hit upon the spatial distribution pattern of species, Morishita’s index changed into calculated as method proven by way of Morishita [14]:

\[
I_\delta = q \times \frac{\sum_{i=1}^{n} x_i(x_i - 1)}{N(N - 1)}
\]

in which xi is the quantity of individuals inside the its plot (i = 1, 2, ...., q), q is the quantity of plots, and T is the whole quantity of individuals in all plots. The dispersed sample individual is appeared as random if I\(\delta = 1\), clumped if I\(\delta > 1\) and regular if I\(\delta < 1\). To test the significance of I\(\delta > 1\), the F-test from Morishita [14] was followed. If the F value is more than the table value of F distribution with (q – 1) degrees of freedom for numerator and infinity for denominator at a few selected degree of probability (0.05 and 0.01), the individual is appeared as clumped.

\[
F = \frac{I_\delta(T - 1) + q - T}{(q - 1)}
\]

3. Result and Discussion

3.1. Species composition
Primarily based on the analysis of vegetation outcomes, the total of tree species discovered at the research site consisted of 9 tree mangrove species, including 6 tree species of true mangrove, 2 tree species associated mangrove, and 1 species of palm. There were 3 tree species of true mangroves
discovered at the seedling, sapling, and tree, including *Avicennia marina*, *Rhizophora mucronata*, and *Avicennia alba*. The dominant species at all of growth stage is *A. marina* with IVI 77.11% (seedling), 113.57% (sapling) and 198.86% (tree) proven in Table 1.

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

| No | Species                     | Seedling | Sapling | Tree |
|----|-----------------------------|----------|---------|------|
| 1  | *Avicennia marina*           | 951      | 710     | 310  |
| 2  | *Rhizophora mucronata*      | 1514     | 51      | 4    |
| 3  | *Hibiscus tiliaceus*        | 317      | 259     | 4    |
| 4  | *Avicennia alba*             | 246      | 68      | 23   |
| 5  | *Excoecaria agallocha*      | 85       | 20      | 2    |
| 6  | *Sonneratia caseolaris*     | 34       | 10      | 3    |
| 7  | *Rhizophora apiculata*      | 17       | 3       | 2    |
| 8  | *Nipah fruticans*           | 70       | 17      | 2    |
| 9  | *Cerbera manghas*           | 6        | 6       | 2    |

Note: *) mangrove associate species

The dominant species found at the research site were *Avicennia* (*Avicennia marina* and *Avicennia alba*), both at the growth rate of seedlings, saplings and trees. The soil condition in the mangrove area where there are piles of plastic waste is a prolonged anoxic condition [15]. A study by Number [16] found that *Avicennia* tree species was more adaptive in disturbed mangrove areas than other mangrove tree species. It showed that those tree species can be found in the areas with a lot of waste. The study also informed, the discovery of palm species was also an indication that the mangrove area is affected by anthropogenic activities. Increased anthropogenic activities around mangroves lead to the invasion *Nipah fruticans*.

There were seven species were found as groundcover which was the dominant species of *Acrostichum aureum* (131.21%) (Table 2). *Acrostichum aureum* is a pioneer species that emerge as marker of disturbed primary forest and is often discovered in landward forest area [17, 18]. other than *Acrostichum aureum*, there are numerous other types of weeds, mainly vines. Mangrove ferns (*Acrostichum aureum*) and vines are generally discovered in disturbed mangrove areas. this is because the environmental pollutants that takes place causes the mangrove soil to be less fertile and much less saline, in order that numerous types of groundcover can grow and thrive, mainly the type of *Acrostichum aureum* [16].
Table 2. Density, frequency, dominance and IVI parameters of groundcover in the research site

| No | Species                | Density (ind ha⁻¹) | Frequency | IVI (%) |
|----|------------------------|--------------------|-----------|---------|
| 1  | Acrostichum aureum     | 2993               | 0.34      | 131.21  |
| 2  | Melanther biflora      | 493                | 0.04      | 19.17   |
| 3  | Derris trifoliata      | 246                | 0.06      | 15.99   |
| 4  | Cayratia trifolia      | 211                | 0.04      | 12.61   |
| 5  | Ageratum conyzoides    | 141                | 0.03      | 8.41    |
| 6  | Ipomea maxima          | 141                | 0.03      | 8.41    |
| 7  | Ipomea triloba         | 70                 | 0.01      | 4.20    |
|    | **Total**              | **4296**           | **1.00**  | **100** |

3.2. Shannon-Wiener’s diversity index

The Diversity Index is used to look at the level of diversity of plant species in a forest community. In line with Shannon-Wiener diversity index (H'), this area became in a category ‘bad status’ primarily based on the classification evolved by means of Jørgensen et al. [13] (Table 3).

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

| No | Growth stages | The quantity of species | Shannon-Wiener index (H') | Status category |
|----|---------------|-------------------------|---------------------------|-----------------|
| 1  | Seedling      | 7                       | 0.535                     | Bad             |
| 2  | Sapling       | 8                       | 0.566                     | Bad             |
| 3  | Tree          | 5                       | 0.451                     | Bad             |
| 4  | Groundcover   | 7                       | 0.479                     | Bad             |

In fact, mangroves have been disturbed, which lead the mangrove species should be adapted on the conditions of the location, such as Avicennia tree species and associated mangrove species. That is Hibiscus tiliaceus. Meanwhile, the Rhizophora tree species seemed difficult to adapt the site environment disturbed [15]. In addition, several species that we’re able to adapt, such as Avicennia species and Nypah fruticans, will thrive and invade mangrove areas due to anthropogenic activities and cause other mangrove species to be depressed [1, 16, 17].

3.3. Forest stand structure

Horizontal stand structure found out from the relationship of tree density with the distribution of its diameter class. The individual distribution of tree stem diameter class became no longer in L shaped curve (Figure 3). It became possibly, due to the fact the quantity of tree diameter class ((10-16.5 cm) increased. The highest density was discovered within the tree diameter class (16.51-23.00 cm) with 145 ind ha⁻¹ and after that class diameter, the quantity of trees reduced with the increasing stem diameter. The vertical stand structure were additionally inside the relationship of tree density with canopy height. The ones individual distributions of the height class shaped bell curve with the highest density at height class of 11-13.5 meter (183 ind ha⁻¹) (Figure 4).

Canopy stratification discovered on stands inside the research site had been 4 strata, specifically B stratum (20 – 25.5 meter), C stratum (4 – 20 meter), D and E stratum which have been occupied through saplings, seedlings and groundcover. Canopy stratification dominated with the aid of C stratum (11-13.5 meter). Trees in C stratum had a continuous canopy, low trees, small, and lots of branches [19]. This case is an ordinary phenomenon for natural forest conditions where stratum C as regeneration will later replace the age class above it [20]. This canopy stratification came about because of crucial things experienced by using plants in their alliance with other plants, specifically the life of competition among the plants and tolerance of tree species to the intensity of sunlight [21].
Figure 3. Stem diameter class distribution of mangrove trees in the research site

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

3.4. Spatial distribution of Morishita’s index (Iδ)
Spatial distribution pattern of Angke Kapuk Protected Forest exposed to plastic waste based on value of Morishita’s index (Table 4). The result demonstrated that most species of dominant and codominant at any growth stage distributed regularly, but sapling of *Avicennia marina*, seedling of *Rhizophora mucronata*, and *Acrostichum aureum* distributed randomly. Random dispersal patterns occurred when individuals distributed in several places and clustered at the other place [22]. Almost all species at all growth stages and groundcover spread regularly. This indicated that the overall conditions at the research sites were the same, so that the growth was regularly distributed, not clumped.

Table 4. Morishita’s Index (Iδ) of seedling, sapling, trees and groundcover in the research site

| Growth stages | Species               | Morishita index (Iδ) | Category |
|---------------|-----------------------|-----------------------|----------|
| Trees         | *Avicennia marina*    | 0.420043              | regular  |
|               | *Rhizophora mucronata*| 0.307691              | regular  |
|               | *Avicennia alba*      | 0.001277              | regular  |
| Sapling       | *Avicennia marina*    | 1.29825*              | random   |
|               | *Hibiscus tiliaceus*  | 0.642371              | regular  |
|               | *Excoecaria agallocha*| 0.084049              | regular  |
| Seedling      | *Rhizophora mucronata*| 2.411181*             | random   |
|               | *Avicennia marina*    | 0.426594              | regular  |
Growth stages | Species | Morishita index (Iδ) | Category
--- | --- | --- | ---
Groundcover | *Hibiscus tiliaceus* | 0.408046 | regular
 | *Acrostichum aureum* | 1.240889* | random
 | *Melantha biflora* | 0.452107 | regular
 | *Derris trifoliata* | 0.038477 | regular

*) Iδ > 1, but not significantly different from random distribution at level 0.05

4. Conclusion
Mangrove area at Angke Kapuk protected forest that exposed with plastic debris consisted of 9 tree mangrove species, including 6 species of true mangrove, 2 species of associated mangrove, and 1 species of palm. Dominated species are *Avicennia marina* for tree species and *Acrostichum aureum* for groundcover species. The diversity index of Shannon-Wiener is bad category status. The highest density of diameter class is 16.51-23.00 cm and the highest density of height class is 11-15.5 meter. Stratification trees canopy dominated by C stratum (4-20 meter). The spatial distribution mostly distributed regularly, but sapling of *Avicennia marina*, seedling of *Rhizophora mucronata*, and *Acrostichum aureum* distributed randomly.

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