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# Floristic composition and structure of *Eurycoma longifolia* habitat in Muka Kuning Nature Tourism Park, Riau Islands, Indonesia

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**Abstract.** *Susilowati A, Rachmat HH, Yulita KS, Wijaya K. 2023. Floristic composition and structure of* Eurycoma longifolia *habitat in Muka Kuning Nature Tourism Park, Riau Islands, Indonesia. Biodiversitas 24: 2836-2842. Eurycoma longifolia* Jack, locally called as *pasak bumi*, is a popular medicinal plant which is known to have properties in curing various diseases. The root of *E. longifolia* is the organ that has the highest aphrodisiac content so hunting for the roots of *E. longifolia* destructively causes a significant population decline. Information regarding vegetation community around the habitat of this species is crucial in determining appropriate conservation actions. Muka Kuning Nature Tourism Park (TWA) located in Batam Island, Riau Islands Province is one of the natural habitats of *E. longifolia*, yet information regarding the state of vegetation in this area has not been obtained. This study aims to determine the floristic composition and structure of vegetation in the habitat of *E. longifolia* in Muka Kuning Nature Tourism Park focusing on the parameters of Important Value Index (IVI) and biodiversity indices. Vegetation analysis was applied using purposive sampling method based on the presence of *E. longifolia* individuals. The results showed that the IVI of *E. longifolia* at the growth stage of seedlings, saplings, poles and trees were 18.1%, 21.9%, 12.14% and 0%, respectively. No individual *E. longifolia* was found at the tree level which might be attributable to the habitus of this species which is small-sized tree or woody shrub with maximum height of 15 m. The vegetation community at the studied area had Shanon-Wienner diversity index (H') from 2.27 to 3.12 and the Evenness index from 0.88 to 0.98, which is categorized as high. The results of this study imply that the natural habitat of pasak bumi in the TWA Muka Kuning is classified as good and tighter area protection is highly recommended to protect valuable biodiversity in it including *E. longifolia*.

**Keywords:** Composition, diversity, *Eurycoma longifolia*

## INTRODUCTION

Plants are the main source of ingredients for making medicines, food, cosmeceuticals and nutraceuticals (Hendra et al. 2011) where traditionally, plants have also been used for a long time for health care in various countries including Indonesia (Sholikhah 2016). WHO recently estimated that herbal medicines are used in primary health care by more than 80% of people worldwide (2002-2005) and by 2050, it is estimated that the global market for herbal products will reach 5 trillion dollars (Malagi et al. 2014). This indicates that the global use of herbal medicines will increase exponentially (Singh and Zhao 2017).

*Eurycoma longifolia* Jack, or better known as *pasak bumi* (Indonesia) and *Tongkat Ali* (Malaysia), is one of the most popular tropical herbal medicinal plant species in various Southeast Asian countries (Aziz et al. 2021). This plant belongs to the Simaroubaceae family and is native to Indonesia, Vietnam, Malaysia, Myanmar, Laos, Cambodia, and Thailand (Bhat and Karim 2010). This plant is evergreen and tends to grow slowly, bearing fruit 2-3 years after cultivation. It is generally believed that it takes 25 years for the crop to fully mature, but for commercial use, roots are generally harvested after 4 years of cultivation (Bhat and Karim 2010; Effendy et al. 2012). Various studies state that *E. longifolia* has the potential as an aphrodisiac, anticancer, antimalarial and antimicrobial (Rehman et al. 2016; Abubakar et al. 2017). In addition, *E. longifolia* is known to help cure various diseases such as diabetes (Lahrita et al. 2015), malaria, cancer, constipation, leukemia, fever, osteoporosis (Fiaschetti et al. 2011) and diseases caused by microbes (Kong et al. 2014). Several studies also state that *E. longifolia* is beneficial in increasing male fertility (Low et al. 2013; Chen et al. 2015).

Each plant has its own medicinal potentials depending on the bioactive components that have therapeutic effects (Yaqub et al. 2016; Alamgir 2018). Some of the main metabolites found in *E. longifolia* are Quassinoids, cathin-6-one alkaloids, biphenylneolignans, squalene-type triterpenes and tirucallane-type triterpenes (Abubakar et al. 2017). Because the aphrodisiac properties and high portion of urycomanine are contained in the root part of *E. longifolia* (Jusoh et al. 2015; Abubakar et al. 2018), the harvesting of *E. longifolia* is carried out destructively by uprooting the plant, leading to a significant population decline in the wild (Susilowati et al. 2021). Further, the sustainability of *E. longifolia* is increasingly pressured with the emergence of various products that use *E. longifolia* as the main ingredient such as capsules, powders, and herbal teas (Abubakar et al. 2021).

Despite the high uses, most of the raw materials of medicinal plants traded are originated from wild harvests, while the amount of material obtained from cultivation is very small (Akalin et al. 2020). In this regard, maintaining the natural population of medicinal plants is paramount for its sustainable utilization and conservation. As a first step in conservation activities, it is important to obtain information about natural habitat conditions where environmental factors and the presence of other species are known to affect the existence of a species (Hidayat and Juhaeti 2013). These factors are particularly important for *E. longifolia* in which its populations are not only threatened by over-exploitation, but also its natural habitats are pressured by deforestation and forest degradation.

As one of Indonesia's native plants, *E. longifolia* can be found in several island areas in Indonesia, including in the Riau archipelago. The existence of *E. longifolia* and its existence as a medicinal plant in the Riau Islands has been described by Wardah and Setyawan (2021) who revealed that *E. longifolia* is found in Karimun Regency, where this species is generally used to reduce fever and increase stamina. Apart from these locations, the presence of *E. longifolia* was also reported in Batam, Riau Islands. However, information regarding the existence of *E. longifolia* in Batam has not been well documented.

Batam is an island in Riau Islands Province where *E. longifolia* has native geographical distribution. However, expansion of industrial areas has caused loss and degradation of forests in Batam. In addition, several human activities, such as farming and human settlements, are reported to have encroached on protected forest areas and have had a major impact on forest sustainability (Yuliastrin 2016). However, the remaining forests still play an important role, among others, as the preservation of genetic resources for the biodiversity of tropical plants. One natural forest remained in Batam Island is located in Muka Kuning Nature Tourism Park (*Taman Wisata Alam/TWA* Muka Kuning) where wild populations of *E. longifolia* can be found. However, until now, information regarding plant diversity and vegetation composition in the TWA Muka Kuning area has not been obtained. Therefore, this research aimed to investigate floristic diversity and community composition of vegetation of the habitat of *E. longifolia* in the Muka Kuning Nature Tourism Park area, Riau Islands, Indonesia. In particular, we looked at the position and structure of *E. longifolia* within the vegetation community using the parameters of biodiversity indices and Important Value Index (IVI). We expected the results of this study might contribute to the conservation of *E. longifolia* as monitoring tool of its population in natural habitat.

## MATERIALS AND METHODS

### Study area and period

This research was conducted in the Muka Kuning Nature Tourism Park area which is administratively located in East Batam Sub-district, Batam City, Riau Islands Province, Indonesia (Figure 1). Geographically, the research location is located at longitude 104° 0'46.53"E, latitude 1° 4'14.49"N. The research location is a conservation area which has the main function of protecting ecosystem services and conserving biodiversity. Apart from having the main function of protecting ecosystem services and flora and fauna, the Muka Kuning Nature Tourism Park is managed for ecotourism. The nature tourism park is under the management of the Riau Nature Resources Conservation Center (BBKSDA Riau) and was established on May 5, 1992 with an area of 2,065.62 Ha. Apart from being bordered by several sub-districts including Sagalung and Tanjung Piayu, Muka Kuning Nature Tourism Park is also directly adjacent to other conservation areas such as the Bukit Tiban protected forest to the west. Summarizing from the official website of BBKSDA Riau (BBKSDA Riau 2018, Muka Kuning Tourism Park contains a great flora diversity including *kempas* (*Koompasia malaccensis* Maingay), *bintangur* (*Calophyllum pulcherrimum* Wall), *riang-riang* (*Ploiarium alternifolium* (Vahl) Melch.), mangosteen-*manggis* (*Garcinia* sp.), *nibung* (*Oncosperma tiqilaria*), *pelawan* (*Tristania* sp.), *meranti* (*Shorea* sp.) and *pasak bumi*.

### Data collection

This research was conducted using the vegetation analysis method where the observation path was determined by purposive sampling, which was based on the presence of *E. longifolia* individuals at the study site. Information regarding the location of *E. longifolia* population was obtained based on local community knowledge and exploration carried out by researchers. A total of 20 (twenty) observation plots were made in this study where the observation plots had varying sizes, namely plots measuring 2x2 $m^2$, 5x5 $m^2$, 10x10 $m^2$, 20x20 $m^2$ which were used for observation of vegetation at the seedling, sapling, pole and tree. Each growth stage is differentiated based on the size of the height and diameter of the stem, where a seedling is a juvenile plant with a height of less than 1.5 m, a sapling is a juvenile plant that is ≥1.5 meters high and has a diameter of <10 cm, a pole is a young tree with a diameter of 10 cm to <20 cm and trees are mature individual trees ≥20 cm in diameter. Several parameters observed in this study included species and the number of individuals found at the seedling and sapling levels. At the pole and tree level, the parameters observed were species, number of individuals, diameter at breast high (dbh) and total height of individuals found.

### Data analysis

Primary data obtained from field observations were then analyzed to calculate relative density, relative frequency and relative dominance which were then summed to obtain the Important Value Index (IVI). The importance value index was developed by several researchers including Curtis and McIntosh (1950), Phillips (1959) and Misra (1968). The importance value index can be used to better express the relative ecological position or importance of a species within a vegetation community in terms of frequency, dominance and density (Rastogi 1999; Sharma 2003).

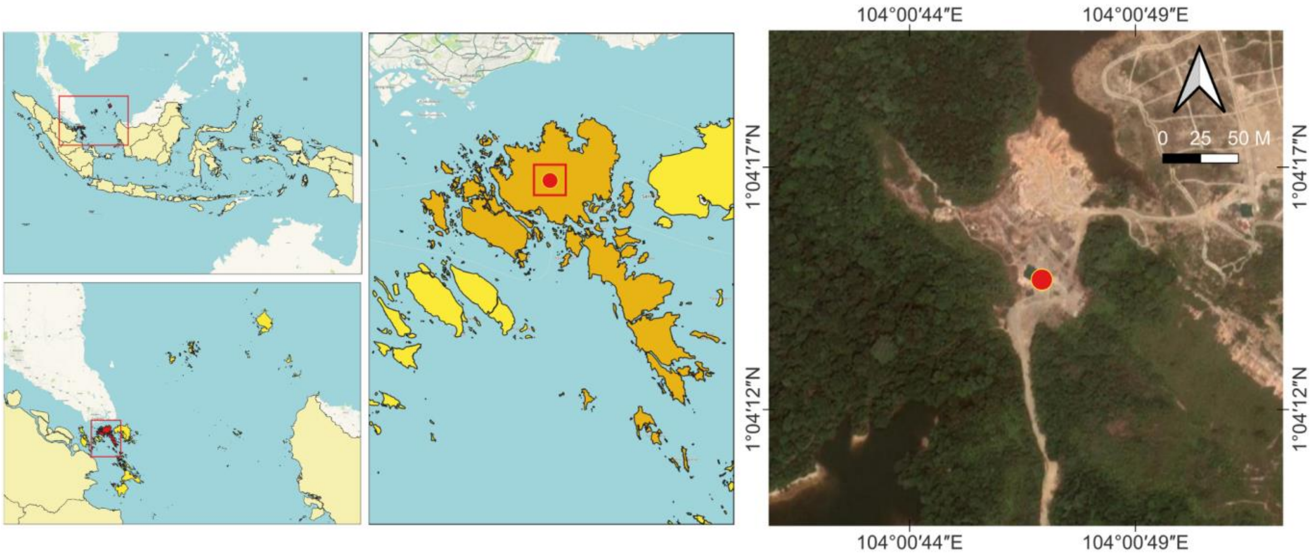


**Figure 1**. Research location in Muka Kuning Nature Tourism Park, Batam Island, Riau Islands Province, Indonesia.

Relative density shows the average value of individuals in certain species of the total number of samples at the study site (Oosting 1942; Rastogi 1999; Sharma 2003). Relative density can be calculated using the following formula:

Relative density of a species (RD) =

$$\frac{Density\ of\ a\ species}{Density\ of\ all\ species}\ x\ 100\%$$

Meanwhile, relative frequency is used to indicate the number of sampling plots based on the presence of a species (Raunkaier 1934; Rastogi 1999; Sharma 2003). Relative frequency is calculated using the following formula:

Relative frequency of a type (RF) = $\frac{Frequency\ of\ species}{Frequency\ of\ all\ species}\ x\ 100\%$

At the pole and tree level, diameter at breast height (dbh) obtained was used to calculate relative dominance or basal area. Relative dominance is the accumulated value of all individuals of a species found in the study area. Basal area refers to the stems that cover the ground (Rastogi 1999; Sharma 2003). Basal area can be calculated using the following formula:

Relative Basal Area (RBA) = $\frac{Basal\ area\ of\ species}{Basal\ area\ of\ all\ species}\ x\ 100\%$

The importance value index was obtained by adding up all the percentages of relative density, relative frequency and relative dominance (basal area) at the pole and tree level found in the observation plots in the study area. Meanwhile, for seedlings and saplings, the importance value index was obtained from the sum of the relative densities and relative frequencies obtained based on data on the number of individual species found at the study site. Important value index is a quantitative parameter used to determine the condition of a species in a plant community.

The species diversity index was calculated using the Shannon-Wienner Index (H') (Indriyanto 2006). Meanwhile, the species evenness index was determined by following Whittaker (1972). Diversity indices were analyzed to obtain information on the level of species diversity found in the study area. Meanwhile, the species evenness index was calculated to determine the level of evenness of a species in the observed environment. The species diversity index was calculated using the following formula:

$$(H') = -\sum_{i=1}^{s} Pi \ln Pi$$

Where, H' is the Shanon-Wiener diversity index, ni is the number of individuals of the i-th species, and N is the total individuals of all species found.

Meanwhile, the species evenness index was calculated using the following formula:

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

Where E is the species evenness index, H' is the species diversity index, and S is the total number of species found. The results obtained can be categorized into three categories: low if the value of $E<0.5$, moderate evenness if $0.5<E<0.6$, and high evenness if $E>0.6$.

In addition to calculating the species richness index and the species evenness index, in this study the species richness index (R) was also taken into account. The species richness index is calculated by quantifying the total number of species and the total number of individual species in a plant community. The species richness index was calculated based on the formula adapted by Ejtehadi et al. (2009) namely:

$$R = \frac{S-1}{lnN}$$

Where, R is the species richness index, S is the number of species found, and N is the total number of individuals.

## RESULTS AND DISCUSSION

### Floristic structure and composition in the study area

Natural forests tend to have a high level of vegetation heterogeneity. The heterogeneous composition of vegetation is the result of the differences in ecological requirements of each species, the physical age of each individual tree and their ability to grow (Susilowati et al. 2020). As one of the important keys in understanding the form and structure of forest communities as well as planning for conservation actions, it is important to know the species composition and floristics of forest communities (Malik 2014). Based on the results, it is known that *E. longifolia* was found to grow more dominantly at the juvenile level. According to Susilowati et al. (2019), *E. longifolia* can be found at altitudes ranging from 280 masl to 700 masl. Nonetheless, based on the herbarium materials deposited at Herbarium Bogoriense, this species was found at a more diverse altitude, namely between 0 to 700 meters above sea level. This indicates that *E. longifolia* has a wide range of growing locations and the research location has suitable habitat condition for *E. longifolia*.

Based on the results, there were 51 species of trees in the research location. Table 1 shows the 10 species with the highest IVI values for each growth stage. The results showed that at the seedling level, *E. longifolia* occupied the top position as the species with the highest IVI value of 18.01%, followed by *Calophyllum pulcherrimum* Wall. (17.90%) and *Dipterocarpus fagineus* Vesque (16.99%) (Table 1).

Of the 32 species found at the seedling level, *E. longifolia* was the most dominating species. As many as 12 individuals of *E. longifolia* were found in almost all research plots. *Eurycoma longifolia* seedlings were found growing in clusters not far from their parent trees. The narrow spread of seeds and the lack of seed spreaders are strongly suspected to be the most responsible factors for the clustering of *E. longifolia* seedlings. The dense vegetation cover causes the incoming wind to have a low speed so that it is not able to spread the seeds over a wider area. Seed morphology that does not support wind dispersal also minimizes seed dispersal. The fruit of *E. longifolia* has an oval-spherical shape, where the round shape of the fruit has distributed the wind more widely so that it is unable to move the seeds further away. This is in line with Susilowati et al. (2019) who stated that *E. longifolia* seedlings were found living in groups not far from their parent tree. In addition, *E. longifolia* fruit is known to have a bitter taste so it tends to not favorable by various animals that act as seed-dispersing agents.

The results showed that there was a significant decrease in the number of species at the sapling level. A total of 10 species were found at this growth stage and *E. longifolia* together with *Santiria laevigata* Blume ranked second as the species with the highest IVI value of 21.09 after *D. fagineus* with IVI of 34.18 (Table 1). Interestingly, there is an increase in the number of species at the pole level. A total of 27 species were found at the pole level and *E. longifolia* only had an IVI value of 12.14% and ranked ten. The presence and absence of certain species at higher growth stages can be caused by environmental factors, such as light under the canopy which directly affect the physiological processes of plants. This causes plants that cannot survive in certain conditions to disappear but are found to reappear in a more suitable environment. According to Valladares et al. (2016), plants have varying abilities to grow and survive at different strata in the vegetation canopy where light availability tends to vary. Vegetation succession and dynamics that occur in many communities are mainly driven by interspecific differences in resource uptake and stress tolerance, where light is often the main discriminant factor (Jucker et al. 2015; Zhang et al. 2015).

**Table 1.** Ten species with the highest IVI values at the seedling, sapling, pole and tree levels in Muka Kuning Nature Tourism Park, Riau Islands Province, Indonesia

| Species | RD | RF | RBA | IVI (%) |
|---|---|---|---|---|
| **Seedling** | | | | |
| *Eurycoma longifolia* | 12.24 | 5.77 | | 18.01 |
| *Calophyllum pulcherrimum* | 10.20 | 7.69 | | 17.90 |
| *Dipterocarpus fagineus* | 11.22 | 5.77 | | 16.99 |
| *Shorea curtisii* | 8.16 | 7.69 | | 15.86 |
| *Shorea ovalis* | 8.16 | 7.69 | | 15.86 |
| *Koompassia malaccensis* | 5.10 | 7.69 | | 12.79 |
| *Hopea beccariana* | 5.10 | 3.85 | | 8.95 |
| *Shorea parvifolia* | 5.10 | 3.85 | | 8.95 |
| *Calophyllum soulattri* | 4.08 | 1.92 | | 6.00 |
| *Rhodamnia cinerea* | 2.04 | 3.85 | | 5.89 |
| **Sapling** | | | | |
| *Santiria laevigata* | 16 | 18.18 | | 34.18 |
| *Eurycoma longifolia* | 12 | 9.09 | | 21.09 |
| *Dipterocarpus fagineus* | 12 | 9.09 | | 21.09 |
| *Calophyllum pulcherrimum* | 10 | 9.09 | | 19.09 |
| *Elaeocarpus gifritianum* | 10 | 9.09 | | 19.09 |
| *Shorea curtisii* | 10 | 9.09 | | 19.09 |
| *Bacaurea stipulata* | 8 | 9.09 | | 17.09 |
| *Koompassia malaccensis* | 8 | 9.09 | | 17.09 |
| *Syzygium palembanicum* | 8 | 9.09 | | 17.09 |
| *Polyalthia hypoleuca* | 6 | 9.09 | | 15.09 |
| **Pole** | | | | |
| *Shorea curtisii* | 15.91 | 10 | 16.49 | 42.40 |
| *Ochanostachys amentacea* | 6.82 | 5 | 7.72 | 19.54 |
| *Vitex pubescens* | 4.55 | 5 | 6.78 | 16.33 |
| *Calophyllum canum* | 4.55 | 5 | 5.64 | 15.19 |
| *Dipterocarpus fagineus* | 4.55 | 5 | 4.81 | 14.35 |
| *Alangium ridleyi* | 4.55 | 5 | 4.06 | 13.60 |
| *Shorea ovalis* | 4.55 | 5 | 3.11 | 12.65 |
| *Barringtonia racemosa* | 4.55 | 5 | 2.86 | 12.41 |
| *Polyalthia hypoleuca* | 4.55 | 5 | 2.84 | 12.38 |
| *Eurycoma longifolia* | 4.55 | 5 | 2.59 | 12.14 |
| **Tree** | | | | |
| *Calophyllum pulcherrimum* | 15.63 | 10.71 | 9.83 | 36.17 |
| *Shorea ovalis* | 9.38 | 10.71 | 7.86 | 27.95 |
| *Calophyllum incrassatum* | 9.38 | 10.71 | 3.58 | 23.67 |
| *Pometia tomentosa* | 6.25 | 7.14 | 7.46 | 20.85 |
| *Dipterocarpus fagineus* | 6.25 | 3.57 | 10.81 | 20.63 |
| *Ixonanthes icosandra* | 3.13 | 3.57 | 12.89 | 19.58 |
| *Shorea parvifolia* | 3.13 | 3.57 | 12.58 | 19.28 |
| *Syzygium palembanicum* | 6.25 | 7.14 | 3.70 | 17.09 |
| *Santiria laevigata* | 6.25 | 7.14 | 2.84 | 16.23 |
| *Koompassia malaccensis* | 3.13 | 3.57 | 6.58 | 13.27 |

At the tree level, a total of 19 species were recorded but none *E. longifolia* was found at this growth stage. There are many factors that may have contributed to the absence *E. longifolia* at the tree level, including overexploitation of *E. longifolia* which is strongly suspected to be the main reason for the loss of this species as it matures. However, no information regarding *E. longifolia* collection was found at the study site. The morphological characteristics of *E. longifolia* which tend to have small stature were thought to be the strongest factor in the absence of *E. longifolia* individuals at the tree level in Muka Kuning Nature Tourism Park. *Eurycoma longifolia* is classified as woody shrub or small-sized tree plant which are rarely found at a large trunk diameter (DBH), so that mature individuals were often categorized as saplings or poles due to their small DBH size. Although until now there is no clear information regarding the maximum stem size of mature *E. longifolia*, several researchers have stated that *E. longifolia* is a small tree species (Kuo et al. 2003; Low et al. 2013; Lee et al. 2015) so that individual *E. longifolia* with a diameter of >20 cm (tree category) are not ever reported. In addition, *E. longifolia* was also reported as a species that has slow growth (Kuo et al. 2003), so it takes a very long time for *E. longifolia* to reach the adult stage and has a large stem size. In contrast to several other natural habitats, such as in the Rumbio Forest, Riau, reported by Hasibuan et al. (2016) and in the Batang Lubu Sutam Forest of North Sumatra, reported by Susilowati et al. (2019), adult individuals of *E. longifolia* were reported to be absent as a result of illegal exploitation due to the large root size, making them more profitable. Therefore, as Muka Kuning Tourism Park is considered to be sufficiently protected from illegal exploitation, it is hoped that *E. longifolia* individuals found in both the juvenile and pole stages can increase the number and maintain the sustainability of this species.

Overall, the results showed that the study site was dominated by the Dipterocarpaceae family, namely *Dipterocarpus borneensis* Slooten, *D. fagineus, D. rigidus* Ridl., *Shorea curtisii* Dyer ex King, *S. ovalis* (Korth.) Blume and *S. parvifolia* Dyer. Although not found in all growth stages, the dominance of these species indicates that the study site has a suitable habitat to support the growth of dipterocarp species. On the other hand, this also illustrates that *E. longifolia* has a habitat similar to dipterocarp species, where it is suspected that there is a strong relationship between these species in a habitat. This is supported by research conducted by Susilowati et al. (2021) which stated that *E. longifolia* had the highest association with *S. leprosula* Miq. at the seedling and sapling stages with Ochiai Index of 0.85 and 0.94, respectively. Thus, the presence of these various species is thought to play a role in the preservation of *E. longifolia*. However, further research is needed to determine exactly the relationships among such species.

**Species diversity**

The diversity index is an indicator that integrates the abundance of individuals and the richness of each species which reflects the level of stability and heterogeneity of vegetation community (Anbarashan and Parthasaranthy 2013). Generally, natural forests have a high level of species diversity supported by the complexity of the ecosystem which is still maintained. However, as disturbances occur, which can be both caused by biotic and abiotic factors, the diversity may change. Wilsey and Sterling (2007) stated that there are two basic components of diversity, namely the number of species in a certain area (richness) and how relative abundance or biomass is distributed among species (evenness). As a natural forest, Muka Kuning Nature Tourism Park has a fairly complex vegetation composition, where the diversity and evenness indices of species in the studied area varied, ranging from 2.27 to 3.12 and 0.88 to 0.98, respectively (Table 2).

Based on the research results, it was found that the highest diversity index was at the pole level with 3.12 and the lowest was at the sapling level with 2.27 (Table 2). The H' value shows a directly proportional relationship where the higher the H', the species diversity tends to be higher. The high diversity index at the pole level indicates that there was a higher variety of species with a relatively fewer number of individuals compared to other growth stages. The absolute number of species found in the population of interest indicates the species richness as explained by Daly et al. (2018). The increase of diversity index at the pole level from the saplings indicated that there were more species that were able to survive until they developed and emerged at a more mature stage.

On the hand, the diversity index from pole level to trees decreased. In fact, trees provide resources and habitat for almost all other forest species so the diversity and richness of tree species is fundamental to forest biodiversity (Malik 2014). The fluctuating number of species may be caused by various factors, where local environmental conditions are thought to be the most responsible for this as revealed by Zhang et al. (2014). According to Luo and Chen (2011), the declining number of species is caused by local extinctions which depend on several factors including the short-lived age of the species, intolerant to shade and early succession. In addition, Tilk et al. (2017) stated that habitat heterogeneity as represented by environmental factors can be associated with the diversity of seedling and tree species.

In contrast to the diversity index, the analysis results on the species evenness index showed that the highest value was at the sapling level with 0.98, while the lowest score was at the seedling level with only 0.88 (Table 2). The species evenness index shows the level of individual distribution of a species in a community. The evenness index ranges from 0 to 1, in which the value closer to 1 indicates the individuals of a species tend to be evenly distributed. The results showed that the values obtained at all four growth stages tended to be high (>0.80), indicating that the species present in the community tended to be evenly distributed and no species dominated and clustered. The high evenness value in natural forest is normal since natural forest generally has a complex floristic composition so that it has a dispersed distribution of individuals. This is closely related to the adaptability and tolerance of species to environmental conditions. As stated by Wang et al. (2020) that natural forests usually have higher evenness and diversity of trees compared to plantation forests and secondary forests.

**Table 2.** Species diversity, evenness and richness indices at seedlings, saplings, poles and trees stages in Muka Kuning Nature Tourism Park, Riau Islands, Indonesia

| Biodiversity index | Seedling | Sapling | Pole | Tree |
|---|---|---|---|---|
| Diversity index (H') | 3.04 | 2.27 | 3.12 | 2.79 |
| Evenness index (E) | 0.88 | 0.98 | 0.95 | 0.95 |
| Richness index (R) | 6.76 | 2.3 | 6.87 | 5.19 |

Compared to another natural habitat of *E. longifolia* in the Batang Lubu Sutam Forest, North Sumatra which is located at the mainland of Sumatra, there are differences related to the floristic diversity. The study conducted by Susilowati et al. (2019) showed that the species diversity, evenness and richness indices in the Batang Lubu Sutam Forest tend to be high and stable where the values obtained at each growth level were not significantly different. Meanwhile, our study showed that various indicators of floristic composition including species diversity, evenness and richness indices in Muka Kuning Nature Tourism Park significantly fluctuated across growth stages. Beside the significant differences in the overall species diversity indicators, the composition of the vegetation recorded in the two habitats of *E. longifolia* also tends to be different. Susilowati et al. (2019) found that there were various tree species and families in the habitat of *E. longifolia* in the Batang Lubu Sutam Forest, while the vegetation in Muka Kuning Nature Tourism Park tended to be dominated by the Dipterocarpaceae family. The difference in floristic composition in the two habitats is thought to be caused by environmental factors which tend to form certain vegetation community. Muka Kuning Nature Tourism Park is located at a low altitude so certain species have been grouped within an area. Likewise, the Batang Lubu Sutam Forest, which has an altitude of 250-700 masl, is thought to have formed a distinctive vegetation composition. Beside the difference in altitude, the climates also differ which likely have significant influence on the abundance of vegetation. This is explained by Kromer et al. (2013) that species richness and composition depend directly on altitude which affect air pressure and temperature, as well as other factors such as cloud cover and rainfall.

Despite several species that coexist with *E. longifolia*, dipterocarps species from *Shorea* spp. were found in the two habitats. The indication of *Shorea* spp. as plant group associated with *E. longifolia* is further strengthened by the finding by Susilowati et al. (2021) where *E. longifolia* formed the strongest association with *S. leprosula*. The wide range of Dipterocarp habitats is thought to have led to the wide distribution of the species. Ashton (1982) stated that Dipterocarpaceae grow abundantly in the lowlands with an altitude range of 300 to 1200 meters above sea level with an annual average rainfall of 1000-2000mm. Thus, as plants that have a wide range of habitats, the dominance of Dipterocarpaceae species in habitats at low altitudes is very likely to occur as found in Muka Kuning Nature Tourism Park.

Although the results of our study suggest that the habitat of *E. longifolia* in Muka Kuning Nature Tourism Park has good floristic diversity indicated by stable diversity and evenness index, forest damage caused by both biotic and abiotic factors is still very likely to occur. The sustainability of natural forests is highly dependent on the presence of trees as natural seed producers and other organisms, such as seed-dispersing animals. The existence of *E. longifolia* in Muka Kuning Nature Tourism Park can be used as the rationale for strict area protection considering that this species is a promising target for exploitation. Nature conservation is important to restore complex vertical structures of forest vegetation (Wang et al. 2020). Natural forests with many functions are the result of long-term interactions between environmental variables and species (Dai et al. 2017). Explicit evaluation of species structure and composition is an important way to monitor the fate of species in the future as an effort to protect biodiversity under climate change (Jian et al. 2018).

In conclusion, in Muka Kuning Nature Tourism Park, *E. longifolia* was found to dominate at the seedling level with an IVI value of 18.01% followed by *C. pulcherrimum* (17.90%) and *D. fagineus* (16.99%). At the sapling level, *E. longifolia* ranked second with an IVI value of 21.09% after *S. laevigata* (34.18%). At the pole level, *E. longifolia* had an IVI value of 12.14% which ranked tenth. However, none *E. longifolia* individual was found at the tree level. Dipterocarp species were the dominant species in the study area. The highest diversity and evenness indices were at pole stage with 3.12 and 0.98, respectively. The results of vegetation analysis suggest that the exploitation of *E. longifolia* in Muka Kuning Nature Park was likely to be minimal so the floristic diversity in its natural habitat was relatively good.

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## REFERENCES

Abubakar BM, Salleh FM, Wagiran A. 2017. Chemical composition of *Eurycoma longifolia* (*Tongkat ali*) and the quality control of its herbal medicinal products. J Appl Sci 17 (7): 324-338. DOI: 10.3923/jas.2017.324.338.

Abubakar BM, Izham NHM, Salleh FM, Omar MSS, Wagiran A. 2018. Comparison of different DNA extraction methods from leaves and roots of *Eurycoma longifolia* plant. Adv Sci Lett 24 (5): 3641-3645. DOI: 10.1166/asl.2018.11456.

Abubakar BM, Salleh FM, Wagiran A, Abba M. 2021. Comparative evaluation of different DNA extraction methods from *E. longifolia* herbal medicinal product. eFood 2 (1): 21-26. DOI: 10.2991/efood.k.210202.001.

Akalin E, Gurdal B, Olcay B. 2020. General overview on the conservation of medicinal plants in Turkey. Turk J Biod 3 (2): 86-94. DOI: 10.38059/biodiversity.726745.

Alamgir ANM. 2018. Therapeutic Use of Medicinal Plants and Their Extracts: Phytochemistry and Bioactive Compounds. Springer, Cham. DOI: 10.1007/978-3-319-92387-1.

Anbarashan M, Parthasarathy N. 2013. Diversity and ecology of lianas in tropical dry evergreen forests on the Coromandel Coast of India under various disturbance regimes. Flora 208 (1): 22-32. DOI: 10.1016/j.flora.2012.12.004.

Ashton PS. 1982. Dipterocarpaceae. In: Steenis (eds). Flora Malesiana Series I. National Herbarium of the Netherlands, Netherlands.

Aziz NAA, Hasham R, Sarmidi MR, Suhaimi SH, Idris MKH. 2021. A review on extraction techniques and therapeutic value of polar bioactives from Asian medicinal herbs: Case study on *Orthosiphon aristatus*, *Eurycoma longifolia* and *Andrographis paniculata*. Saudi Pharm J 29 (2): 143-165. DOI: 10.1016/j.jsps.2020.12.016.

BBKSDA Riau [Balai Besar Konservasi Sumberdaya Alam Riau]. 2018. Taman Wisata Alama (TWA) Muka Kuning. https://bbksda-riau.id/index.php?r=post&id01=4&id02=23&id03=54&token=c549dca03714dabbc3f4f399fa2f69ff.

Bhat R, Karim AA. 2010. *Tongkat ali* (*Eurycoma longifolia* Jack): A review on its ethnobotany and pharmacological importance. Fitoterapia 81 (7): 669-679. DOI: 10.1016/j.fitote.2010.04.006.

Chen Y, Phang WM, Mu AKW, Chan CK, Low BS, Sasidharan S, Chan KL. 2015. Decreased expression of alpha-2-HS glycoprotein in the sera of rats treated with *Eurycoma longifolia* extract. Front Pharmacol 6: 211. DOI: 10.3389/fphar.2015.00211.

Dai L, Li S, Zhou W, Qi L, Zhou L, Wei Y, Li J, Shao G, Yu D. 2017. Opportunities and challenges for the protection and ecological functions promotion of natural forests in China. For Ecol Manag 410: 187-192. DOI: 10.1016/j.foreco.2017.09.044.

Daly AJ, Baetens JM, De Baets B. 2018. Ecological diversity: Measuring the unmeasurable. Mathematics 6 (7): 119. DOI: 10.3390/math6070119.

Ejtehad H, Sepehri A, Akefi HR. 2009. The Measuring Way of Biodiversity. Ferdosi University of Mashhad, Mashhad.

Effendy MN, Mohamed N, Muhammad N, Naina Mohamad I, Shuid AN. 2012. *Eurycoma longifolia*: Medicinal plant in the prevention and treatment of male osteoporosis due to androgen deficiency. Evid Based Complement Alternat Med 2012: 125761. DOI: 10.1155/2012/125761.

Fiaschetti G, Grotzer MA, Shalaby T, Castelletti D, Arcaro A. 2011. Quassinoids: from traditional drugs to new cancer therapeutics. Curr Med Chem 18 (3): 316-328. DOI: 10.2174/092986711794839205.

Hasibuan S, Suhesti E, Insusanty E. 2016. Kajian ekologi pasak bumi (*Eurycoma longifolia* jack) dan pemanfaatan oleh masyarakat di sekitar hutan larangan adat Rumbio, Kabupaten Kampar, Provinsi Riau. Wahana Forestra Jurnal Kehutanan 11 (2): 112-126. DOI: 10.31849/forestra.v11i2.152. [Indonesian]

Hendra R, Ahmad S, Oskoueian E, Sukari A, Shukor MY. 2011. Antioxidant, anti-inflammatory and cytotoxicity of *Phaleria macrocarpa* (Boerl.) scheff fruit. BMC Complement Altern Med 11: 110. DOI: 10.1186/1472- 6882-11-110.

Hidayat S, Juhaeti T. 2013. Asosiasi *Alstonia* spp. di Taman Nasional Ujung Kulon. Bionatura-Jurnal Ilmu-Ilmu Hayati dan Fisik 15 (1): 44-48. [Indonesian]

Indriyanto. 2006. Ekologi Hutan. Bumi Aksara, Jakarta. [Indonesian]

Jian F, Yangjing P, Shaohua X, Guofa C. 2018. Evaluation of the species protected value of nature reserves in northeast China. Acta Ecol Sin 38: 6473-6483.

Jucker T, Bouriaud O, Coomes DA. 2015. Crown plasticity enables trees to optimize canopy packing in mixed-species forests. Funct Ecol 29 (8): 1078-1086. DOI: 10.1111/1365-2435.12428.

Jusoh S, Ghani RA, Abdul Kadir WRW, Ishak MF. 2015. Phytochemical assessment of multi-locational *tongkat ali* (*Eurycoma longifolia*) in Peninsular Malaysia. Jurnal Teknologi 77 (3): 87-91. DOI: 10.11113/jt.v77.6011.

Kong C, Yehye WA, Rahman NA, Tan MW, Nathan S. 2014. Discovery of potential anti-infectives against *Staphylococcus aureus* using a *Caenorhabditis elegans* infection model. BMC Complement Altern Med 14: 4. DOI: 10.1186/1472-6882-14-4.

Kuo PC, Shi LS, Damu AG, Su CR, Huang CH, Ke CH, Wu JB, Lin AJ, Bastow KF, Lee KH, Wu TS. 2003. Cytotoxic and antimalarial β-carboline alkaloids from the roots of *Eurycoma longifolia*. J Nat Prod 66 (10): 1324-1327. DOI: 10.1021/np030277n.

Lahrita L, Kato E, Kawabata J. 2015. Uncovering potential of Indonesian medicinal plants on glucose uptake enhancement and lipid suppression in 3T3-L1 adipocytes. J Ethnopharmacol 168: 229-236. DOI: 10.1016/j.jep.2015.03.082.

Lee TA, Kamal NM, Poay TH, Roslan I. 2015. Notes on morphological characteristics of *Eurycoma* spp. and its status in Peninsular Malaysia. Reinwardtia 14 (2): 259-263. DOI: 10.14203/reinwardtia.v14i2.1669.

Low BS, Das PK, Chan KL. 2013. Standardized quassinoid-rich *Eurycoma longifolia* extract improved spermatogenesis and fertility in male rats via the hypothalamic-pituitary-gonadal axis. J Ethnopharmacol 145 (3): 706-714. DOI: 10.1016/j.jep.2012.11.013.

Luo Y, Chen HYH. 2011. Competition, species interaction and ageing control tree mortality in boreal forests. J Ecol 99 (6): 1470-1480. DOI: 10.1111/j.1365-2745.2011.01882.x.

Malagi KJ, Kamath M, Adiga SH. 2014. Herb-drug interaction in diabetes: A bane or a boon. J Diabetes Metab Disord Control 1 (3): 00013. DOI: 10.15406/jdmdc.2014.01.00013.

Malik ZA, Hussain A, Iqbal K, Bhatt IB. 2014. Species richness and diversity along the disturbance gradient in Kedarnath Wildlife Sanctuary and its adjoining areas in Garhwal Himalaya, India. Intl J Curr Res 6: 10918-10926.

Rehman SU, Choe K, Yoo HH. 2016. Review on a traditional herbal medicine, *Eurycoma longifolia* Jack (*Tongkat ali*): Its traditional uses, chemistry. Molecules 21 (3): 331. DOI: 10.3390/molecules21030331.

Sholikhah EN. 2016. Indonesian medicinal plants as sources of secondary metabolites for pharmaceutical industry. J Med Sci 48 (4): 226-239. DOI: 10.19106/JMedSci004804201606. [Indonesian]

Singh A, Zhao K. 2017. Herb-drug interactions of commonly used Chinese medicinal herbs. Intl Rev Neurobiol 135: 197-232. DOI: 10.1016/bs.irn.2017.02.010.

Susilowati A, Rachmat HH, Elfiati D, Hasibuan MH. 2019. The composition and diversity of plant species in pasak bumi's (*Eurycoma longifolia*) habitat in Batang Lubu Sutam forest, North Sumatra, Indonesia. Biodiversitas 20 (2): 413-418. DOI: 10.13057/biodiv/d200215.

Susilowati A, Elfiati D, Rachmat HH, Yulita KS, Hadi AN, Kusuma YS, Batu SAL. 2020. Vegetation structure and floristic composition of tree species in the habitat of *Scaphium macropodum* in Gunung Leuser National Park, Sumatra, Indonesia. Biodiversitas 21 (7): 3025-3033. DOI: 10.13057/biodiv/d210720.

Susilowati A, Rachmat HH, Yulita KS, Elfiati D, Ginting IM. 2021. Distribution and association pattern of pasak bumi (*Eurycoma longifolia*) in Batang Lubu Sutam Sub-district, Padang Lawas, North Sumatra. IOP Conf Ser Earth Environ Sci 912: 012056. DOI: 10.1088/1755-1315/912/1/012056.

Tilk M, Tulus T, Ots K. 2017. Effects of environmental factors on the species richness, composition and community horizontal structure of vascular plants in Scots pine forests on red sand dunes. Sylva Fennica 51 (3): 1-18. DOI: 10.14214/sf.6986.

Valladares F, Laanisto L, Niinemets U, Zavala MA. 2016. Shedding light on shade: Ecological perspectives of understorey plant life. Plant Ecol Divers 9: 237-251.

Wardah, Setiawan M. 2021. An ethnobotanical study of tongkat ali (*Eurycoma longifolia* Jack) on Malay ethnic group in Tanjung Balai, Karimun, Riau Islands. J Trop Ethnobiol 4 (1): 58-65. DOI: 10.46359/jte.v4i1.92.

Wang Y, Yu J, Xiao L, Zhong Z, Wang Q, Wang W. 2020. Dominant species abundance, vertical structure and plant diversity response to nature forest protection in northeastern China: Conservation effects and implications. Forests 11 (3): 295. DOI: 10.3390/f11030295.

Whittaker RH. 1972. Evolution and measurement of species diversity. Taxon 21 (2/3): 213-251. DOI: 10.2307/1218190.

Wilsey B, Stirling G. 2007. Species richness and evenness respond in a different manner to propagule density in developing prairie microcosm communities. Plant Ecol 190: 259-273. DOI: 10.1007/s11258-006-9206-4.

WHO [World Health Organization]. 2002. Programme on Traditional Medicine. 2002. WHO traditional medicine strategy 2002-2005.

Yaqub S, Farooq U, Shafi A, Akram K, Murtaza MA, Kausar T, Siddique F. 2016. Chemistry and functionality of bioactive compounds present in persimmon. J Chem 2016: 3424025. DOI: 10.1155/2016/3424025.

Yuliastrin A. 2016. Threating Ecosystems Degradation of Protected Forest in Batam. Prodising Seminar Nasional II 2016, Kerjasama Prodi Pendidikan Biologi FKIP dengan Pusat Studi Lingkungan dan Kependudukan (PSLK) Universitas Muhammadiyah Malang. Universitas Muhammadiyah Malang, Malang, 26 Maret 2016. [Indonesian]

Zhang Y, Chen HYH, Taylor A. 2014. Multiple drivers of plant diversity in forest ecosystems. Glob Ecol Biogeogr 23 (8): 885-893. DOI: 10.1111/geb.12188.

Zhang Q, Zhang TJ, Chow WS, Xie X, Chen YJ, Peng CL. 2015. Photosynthetic characteristics and light energy conversions under different light environments in five tree species occupying dominant status at different stages of subtropical forest succession. Funct Plant Biol 42 (7): 609-619. DOI: 10.1071/FP14355.