

Assessment of Floristic Composition of Kilim Geoforest Park, Langkawi, Malaysia

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Abstract

The present study was carried out to analyze the species diversity and quantitative analysis of mangrove forest in three riverine ecosystems at River Kisap, River Ayer Hangat and River Kilim at Kilim Geoforest Park. One hundred plots, each of size 20 m × 20 m, were established at a distance of 250 m apart along the three rivers. Every existing species that occurred within the plot and trees of diameter at breast height of 1 cm and above were enumerated and identified. The data were analyzed for species richness, diversity and evenness. The species richness were computed based on the Jackknife method, species diversity index were calculated using Simpson's Index, Shannon-Wiener Index and Brillouin's Index. The evenness indexes were measured by Simpson's measure of evenness, Camargo's index of evenness and Smith and Wilson's index of evenness. A total of 11488 individual trees representing 58 species, 39 genus, and 23 families were recorded. The most abundant species was *Rhizophora apiculata* (3449) and *Ceriops tagal* (2060). The diversity results show that Shannon-Wiener, Simpson's index of diversity and Brillouin index was high (2.0 to 3.0), (0.7 to 0.8), to (2.0 to 3.0) respectively and the evenness index however was low (0.1 to 0.2).

Keywords: Floristic composition, Mangrove forest, Diversity index, Kilim Geoforest Park, Langkawi

1. Introduction

Langkawi is an archipelago of 104 islands situated at 6°21'N; 99°48'E to the north of the Straits of Malacca. The total area is about 47,848 ha. The topography of Langkawi is mainly flat to mountainous, rising up to 881 meter height, which is the highest peak at Gunung Raya. Langkawi Geoforest Park comprising all of the 99 islands and the total land area of Kilim Geoforest Park is about 478 square kilometers comprises of three main river basins i.e. River Kilim, River Ayer Hangat and River Kisap. Kilim Geoforest Park experiences dry season lasting two to three months between December and March, which may influences the flora to have an affinity to those happened in Burma and Thailand. The ecosystems of the old limestone rock formation, the caves, the mudflats and the seas that surround it have three main types of vegetation i.e. the mangroves, the vegetation of the limestone hills and the flora of the mudflats and beaches.

Mangroves are defined as plants, shrubs, palms and ferns that are growing within the inter-tidal region of coastal and estuarine environments in the tropics and subtropics. The important of mangroves in the world was given by Tomlinsons (1986). Mangrove areas in Langkawi cover approximately 3142 ha (JPSM, 2003) and the largest area is at the Kisap Forest Reserve with 1336 ha of mangrove forest. Mangroves of Langkawi are considered as unique and rare occurrence, in the sense that they are found on shallow limestone substratum areas. Japar (1994) reported that Malaysia has 38 exclusive, 57 non-exclusive and more than 10 associated mangrove biota. Thus, this data proved Malaysia as one of the diverse mangrove population in the world.

Mangrove forest promotes a unique root system with a physiology of the plant species that are capable of preventing soil erosion and cleaning water contaminated with metallic pollutants (Norhayati & Latiff, 2001). The mangrove also serves as breeding grounds to many species of fishes, prawn and other sea life. The mangrove vegetation in this area is quite diverse and includes many important species; some with medicinal properties. The limestone hills of the area have a rich diversity of species of ornamental plants such as the cycads and orchids, the limestone rocks also support many bryophytic flora, lichens and macro fungi (Norhayati & Latiff, 2001). Nowadays, shorelines are one of the most rapidly changing areas on the Earth. Based on literatures as many as 3 billion people inhabit within 60 km of a shoreline areas (Woodroffe, 2002). Because of this huge populations that inhabit in the areas near the coast to take benefit of valuable marine resources and also to participate in seaborne

trade with other countries. Thus this activities reaping socio-economic benefits to the communities directly and to the country indirectly. In terms of ecology aspect, the coast and its adjacent areas may form a unique ecosystem. This is due to combine influence of both fresh and saline water. Because of this interaction the coastal landforms could support a large diversity of flora and fauna, which are crucial to the food chain. Hence, this is one of the important resources that the coast offers is the mangrove ecosystem, which is amongst the world's most productive ecosystems (Mitsch & Gosselink 1993; Odum *et al.* 1982).

Since the mangrove forests of Langkawi especially at Kilim Geoforest Park areas are facing impacts from increasing of boat traffic, coastal development such as reclamation, erosion, accretion and sedimentation, which are mostly for ecotourism activities. Hence, the objective of this study is to assess floristic composition and diversity of Kilim Geoforest Park. This study is necessary to begin conservation assessment that will provide baseline ecological data for sustainable management of the mangrove forest in Malaysia.

2. Methodology

2.1 Description of study area

The study area is situated between latitude of 6°29' 33.20'' to 6°23' 6.24'' North and between longitude 99°48' 0.34'' to 99°55' 30.86'' East at the northeast of Langkawi Island within the state of Kedah, Malaysian. The study area was divided into three study sites i.e. River Kisap, River Kilim and River Ayer Hangat of Kilim Geoforest Park. These three riverine were rich with mangrove forest, flourished on limestone formation, which is a rare occurrence. The topography varies from flat coastal plains, hilly areas to rugged mountains.

2.2 Methods

The field survey for the ecological study was conducted in November 2009 until February 2010. The study areas were visited three times during the study periods. In this study, a total of 100 study plots of about 20 m × 20 m quadrats (400 sq m) size were established. About 40 plots were placed at the elevation 6.4 m a.s.l and the intervals of 250 m along River Kilim and 30 study plots along River Kisap and River Ayer Hangat each. Data were gathered from each quadrat. All the trees in the plot with diameter at breast height (DBH) >1cm were enumerated, measured and identified. Other parameters recorded were species name and height (HT). In this study, the specimens, both mangrove and non-mangroves, were collected, placed in transparent plastic bag and labeled properly. They were then brought back to the laboratory in Faculty of Forestry of University Putra Malaysia. Samples were preserved as Herbaria and a few of them were dissected to identify the specimens. They were identified using the mangrove identification manuals and standard Floras (Ng & Sivasothi, 1999; Ng 1978;1989; Whitmore, 1972;1973). The specimens whose identity could not be confirmed were sent to experts for further identification and verification. Precise GPS locations were recorded from all the field areas visited.

2.2.1 Quantitative analysis

Important quantitative analysis such as density, frequency and abundance of tree species and non trees species were calculated based on the method that was suggested by Curtis and McIntosh, (1950).

Density

Density is an expression of the numerical strength of a species where the total number of individuals of each species in all quadrats is divided by the total number of quadrats studied.

$$\text{Density} = \frac{\text{Total number of individuals of a species in all quadrats}}{\text{Total number of quadrats studied}}$$

Frequency (%)

This refers to the degree of dispersion of individual species in an area and expressed in terms of percentage occurrence.

$$\text{Frequency (\%)} = \frac{\text{Number of quadrats in which the species occurred}}{\text{Total number of quadrats studied}} \times 100$$

Abundance

Referring to the number of individuals of different species in the community per unit area.

$$\text{Abundance} = \frac{\text{Total number of individuals of a species in all quadrats}}{\text{Total number of quadrats in which the species occurred}}$$

Important Value Index

This index is used to determine the overall importance of each species in the community structure. To calculate this index, the percentage values of the relative frequency, relative density and relative dominance are summed up together and designated as Important Value Index (IVI) of the species (Curtis, 1959).

$$\text{Relative density} = \frac{\text{Number of individual of the species}}{\text{Number of individual of all the species}} \times 100$$

$$\text{Relative frequency} = \frac{\text{Number of occurrence of the species}}{\text{Number of occurrence of all the species}} \times 100$$

$$\text{Relative dominance} = \frac{\text{Total basal area of the species}}{\text{Total basal area of all the species}} \times 100$$

Data for computing species richness, evenness and diversity indices were analyzed using Ecological Methodology Software (Krebs, 1998) formula as below:

Species richness

Jackknife estimate

$$\hat{S} = s + \left(\frac{n-1}{n}k\right)$$

Where:

$\hat{s}$ = jackknife estimate of species richness

s = total number of species present in quadrates

n = total number of quadrates samples

k = number of unique species (species which occur in only one quadrate)

Species diversity

Simpson's Index

$$\hat{D} = 1 - \sum P_i^2$$

Where:

$\hat{D}$ = Simpson's index

P_i = proportion of species i in the community

Shannon-Weiner measure

$$H' = \sum (P_i)(\log P_i)$$

Where:

H' = information content of sample (bits/individual) and index of diversity

s = number of species

P_i = proportion of total sample belonging to i species

Species evenness

Simpson's measure of evenness

$$E_{1/D} = (1/\hat{D})/s$$

Where:

$E_{1/D}$ = Simpson measure of evenness

S = number of species in the sample

$\hat{D}$ = Simpson index

Smith and Wilson's index of evenness

$$E_{var} = 1 - [2/(\pi \arctan \{ \sum_{i=1}^s (\log_e(n_i) - \sum_{j=1}^s (\frac{\log_e(n_j)}{s})^2 / s \})]$$

Where:

E_{var} = Smith and Wilson's index of evenness

n_i = Number of individuals in species i in sample ($i = 1, 2, \dots, s$)

n_j = Number of individuals in species j in sample ($j = 1, 2, \dots, s$)

s = Number of species in entire sample

3. Results

3.1 Main Floristic Attributes and Dominance

A total of 11488 individual were recorded from the three locations i.e. River Kisap, River Ayer Hangat and River Kilim. These trees belonged to 23 families, 39 genus and 58 species (Table I and II). Avicenniaceae, Rhizophoraceae, Moraceae, Lythraceae, Polygalaceae and Meliaceae were distributed in most study areas. However, Ebenaceae and Euphorbiaceae were appeared at least in two different locations in this study. On the other hand the rest of the family were appeared only in one location.

(Note 1)

At River Ayer Hangat, 16 species of plant was recorded and the most abundant species were *Xylocarpus granatum*, with 1517 of individual, and this was followed by *Rhizophora apiculata* (1109), *Ceriops tagal* (429), *Rhizophora mucronata* (265) and *Bruguiera parviflora* (91). On the other hand, the highest number of plant species was recorded in River Kisap which consisting of 48 species. The total individual in this area was 3832 individuals. The abundant species recorded in River Kisap were *Rhizophora apiculata* (1114), *Bruguiera cylindrica* (1110), *Ceriops tagal* (367), *Bruguiera parviflora* (311), *Xylocarpus granatum* (253) and *Rhizophora mucronata* (244). The highest number of individuals was recorded in River Kilim consisted of 4051 of individual. In this area the abundant species were *Ceriops tagal* (1264), *Rhizophora apiculata* (1226), *Bruguiera sexangula* (465), *Rhizophora mucronata* (455), *Bruguiera parviflora* (424) and *Xylocarpus granatum* (124).

3.2 Mangrove Composition and Dominance

For mangrove composition assessment, a total of 11148 trees were recorded in 100 study plots belonged to 4 families, 7 genera and 12 species (Table III and IV). Among the families in the plot, Rhizophoraceae was the most diverse with 3 genera and eight species respectively. This result is not surprising since this family is the largest family of mangrove trees in Malaysia. (Note 2)

Rhizophoraceae accupied 80.37% of total population which is the most diverse family in the study areas. This was followed by Avicenniaceae, Euphorbiaceae and Meliaceae; 18.58%, 1.01 % and 0.04%, respectively. Interestingly, mostly mangrove species such as *Rhizophora apiculata*, *Rhizophora mucronata*, *Xylocarpus granatum* and *Ceriops tagal* were found distributed fairly in all study areas. These species of mangrove were also identified as dominance species in the study area. On the other hand, 5 mangrove species such as *Xylocarpus rumphii* and *Ceriops decandra* were only appeared in River Ayer Hangat and River Kisap, respectively. Similar situation was observed on *Avicennia officinalis*, *Bruguiera gymnorhiza* and *Bruguiera sexangula*, where they only recorded in River Kilim.

3.3 Important Species and Species Diversity

Data on important species of Kilim Geopark Langkawi were summarized in Table V and VI. In the study area, eight species of true and associate mangroves were identified as the most important species, they were *Rhizophora apiculata*, *Ceriops tagal*, *Xylocarpus granatum*, *Rhizophora mucronata*, *Bruguiera cylindrica*, *Bruguiera parviflora*, *Bruguiera sexangula* and *Avicennia marina* with their IVI values were 87.55, 45.55, 40.45, 30.28, 22.60, 22.12, 11.29 and 7.79, respectively. These species were also high in terms of density per hectare and frequency.

(Note 3)

Rhizophora apiculata, *Rhizophora mucronata*, *Ceriops tagal*, *Xylocarpus granatum* and *Bruguiera parviflora* were the important species of mangrove trees in River Ayer Hangat, River Kilim and River Kisap. These species of mangrove trees life abundantly in those areas make up of more than 50% of total population. On the other hand, *Avicennia marina*, *Avicennia officinalis* and *Bruguiera cylindrica* were only important in selected areas. For instance, *Avicennia marina* were only appeared at River Ayer Hangat and River Kisap. *Avicennia officinalis* and *Bruguiera cylindrica* were only recorded in River Kilim and River Kisap, respectively.

In terms of family value index (FVI), Rhizophoraceae was the most important mangrove family in the Kilim Geopark with FVI value of 224.77 (Table VII). This was followed by Meliaceae and Avicenniaceae with FVI values of 46.84 and 10.66, respectively. On the other hand, aassociate mangrove family were exhibited in a small population in the study areas.

(Note 4)

For species diversity study, three parameters were used namely species richness, heterogeneity and evenness (Table VIII). According to Jackknife index, River Kisap (62.9) was the richest area with mangrove species in the

Kilim Geopark as compared to River Ayer Hangat (25.7) and River Kilim (24.7). River Kisap contain 15 unique mangrove species.

For species heterogeneity assessment, Simpson's index, Shannon-Wiener index and Brillouin index were used in this study. All index showed that River Kisap was the most diverse area in Kilim Geopark and followed by River Kilim and River Ayer Hangat. River Kilim has the most evenness index in the Kilim Geopark and followed by River Ayer Hangat and River Kisap.

4. Discussion and Conclusion

Langkawi Geoforest Park is positioned as an archipelago of 99 islands. In 2007, it was awarded the Geopark status by the United Nations Educational, Scientific and Cultural Organisation (Unesco) for its geological history dating back some 500 million over years. Hence, the findings of this study were very important in order to conserve this world heritage area, in terms of management of mangrove diversity. Based on our findings, *Rhizophora apiculata* and *Rhizophora mucronata* were two dominant species in the Kilim Geopark. Our findings are parallel with the previous study conducted by Norhayati and Latiff (2001) in the Kisap Forest Reserve. Their study revealed that *Rhizophora apiculata* is the most dominant species together with other nine mangrove species.

In our study, we found that the total number of individual of *Rhizophora* in Kilim Geopark is far greater; 1109 trees per ha were recorded in River Ayer Hangat, 1114 trees per ha in River Kisap and 1226 trees per ha at River Kilim as compared to Kisap Forest Reserve; 557 trees per ha (Norhayati and Latiff, 2001) and 819 trees per ha in Balok River, Pahang (Rozainah and Mohamad, 2006). In comparison Matang Forest Reserve however recorded the highest total number of *Rhizophora* trees with 2190 per ha (Gong and Ong, 1995). According to Lokman and Sulong (2001), Peninsular Malaysia has one of the most diverse mangrove assemblages in the world, with at least 38 exclusive and 57 non-exclusive and associate mangrove species. Interestingly, in our findings, Kilim Geopark, contain at least 52 mangrove species of which 14 species are true mangrove and 38 are associate mangrove species. As comparison in River Balok, Pahang, at least 16 mangrove species were recorded of which four species are associate mangrove.

Similar study in the Pondicherry State of South India by Balachandran *et al.* (2009) revealed that 41 species of mangrove were recorded of which 18 species are true mangrove and 23 species are associate mangrove. In their report showed that *Rhizophora sp.* is one of the dominant species and this is also true in our study areas. However, in Purna Estuary Gujarat, India seven species of true mangrove species were reported (Bhatt *et al.* 2009). They were *Avicennia marina* var. *marina*, *Sonneratia apetala*, *Acanthus ilicifolius*, *Rhizophora mucronata*, *Ceriops tagal*, *Bruguiera cylindrica* and *Aegiceras corniculatum* and most of the species were also reported in our study. This is proved that main important mangrove species were still present intact in the study areas and their existent must be protected and managed properly for our future generation.

According to Curtis and McIntosh (1951), if the IVI is more than 10, it shows that the species is dominant to that area. In our findings showed that Kilim Geoforest Park mangrove forest can be considered as *Rhizophora-Ceriops* zone. The diversity estimated using Shannon-Wiener, Simpson's index of diversity and Brillouin index was high and the evenness index however was low (0.1 to 0.2). The Smith and Wilson's index of evenness is more preferred compared the others because it is independent of species richness and sensitive to both and rare common species (Krebs, 1999).

The reduction of mangrove forests have been observed in most states in the Peninsular of Malaysia (Latiff, 2004). In spite of their immense role in protecting human resource and biodiversity, these unique mangrove forest have been facing tremendous threats such as exploitation of mangrove resources for multiple uses such as fodder, fuel wood, timber for building material, alcohol, paper, charcoal and medicine (Upadhyay *et al.* 2002). Apart from those, conversion of forest areas to aquaculture and agriculture sites, construction of port and harbour, extension of human inhabitation, over-grazing, urbanization, industrialization and pollution are major common occurrences that dwindle mangrove forest in the world (Blasco & Aizpuru 1997; Naskar 2004; Upadhyay *et al.* 2002). In Langkawi itself, uncontrolled land development activities such as development of Langkawi cable car as well as tourism arrivals to Langkawi up to 1.88 million people every year may threaten natural environment of the study areas in the long run. Steps have been taken by Forestry Department to conserve some of mangrove forests as forest reserve area such as Kisap Forest Reserve.

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Notes

Note 1. Table I and Table II are placed here

Note 2. Table III and Table IV are placed here

Note 3. Table V and Table VI are placed here

Note 4. Table VII is placed here

Table 1. Summary of the floristic composition of Kilim, Geopark, Malaysia assessed from November 2009 until February 2010

Area	Species	Genus	Family	No. of Stem
River Kilim	1. <i>Avicennia officinalis</i>	1. <i>Avicennia</i>	1. Avicenniaceae	20
	2. <i>Bruguiera gymnorhiza</i>	2. <i>Bruguiera</i>	2. Rhizophoraceae	17
	3. <i>Bruguiera parviflora</i>			424
	4. <i>Bruguiera sexangula</i>			465
	5. <i>Ceriops tagal</i>	3. <i>Ceriops</i>		1264
	6. <i>Cycas siamensis</i>	4. <i>Cycas</i>	3. Cycadaceae	3
	7. <i>Memecylon edule</i> Roxb. var. <i>ovatum</i>	5. <i>Memecylon</i>	4. Lythraceae	1
	8. <i>Memecylon pauciflorum</i>			1
	9. <i>Murraya paniculata</i>	6. <i>Murraya</i>	5. Rutaceae	2
	10. <i>Pentaspadon curtisii</i>	7. <i>Pentaspadon</i>	6. Anacardiaceae	3
	11. <i>Rhizophora apiculata</i>	8. <i>Rhizophora</i>	7. Rhizophoraceae	1226
	12. <i>Rhizophora mucronata</i>			455
	13. <i>Streblus ilicifolius</i>	9. <i>Streblus</i>	8. Moraceae	19
	14. <i>Streblus laxiflorus</i>		9. Moraceae	1
	15. <i>Xanthophyllum discolor</i>	10. <i>Xanthopyllum</i>	10. Polygalaceae	8
	16. <i>Xylocarpus granatum</i>	11. <i>Xylocarpus</i>	11. Meliaceae	124
	17. <i>Xylocarpus moluccensis</i>			18
	Total			4051
River Kisap	1. <i>Avicennia marina</i>	1. <i>Avicennia</i>	1. Avicenniaceae	55
	2. <i>Bruguiera cylindrica</i>	2. <i>Bruguiera</i>	2. Rhizophoraceae	1110
	3. <i>Bruguiera parviflora</i>			311
	4. <i>Ceriops decandra</i>	3. <i>Ceriops</i>		1
	5. <i>Ceriops tagal</i>			367
	6. <i>Cinnamomun</i> sp.	4. <i>Cinnamomun</i>	3. Lauraceae	4
	7. <i>Diospyros ismailii</i>	5. <i>Diospyros</i>	4. Ebenaceae	21
	8. <i>Elaeocarpus griffithii</i>	6. <i>Elaeocarpus</i>	5. Elaeocarpaceae	1
	9. <i>Erythroxylum cuneatum</i>	7. <i>Erythroxylum</i>	6. Erythroxylaceae	9
	10. <i>Excoecaria agallocha</i>	8. <i>Excoecaria</i>	7. Euphorbiaceae	4
	11. <i>Fagraea curtisii</i>	9. <i>Fagraea</i>	8. Loganiaceae	7
	12. <i>Fernando adenophylla</i>	10. <i>Fernando</i>	9. Bignoniaceae	10
	13. <i>Ficus deltoidea</i>	11. <i>Ficus</i>	10. Moraceae	5
	14. <i>Ficus rumpii</i>			2
	15. <i>Ficus superba</i>			4
	16. <i>Flacourtia rukam</i>	12. <i>Flacourtia</i>	11. Flacourtiaceae	3
	17. <i>Heritiera littoralis</i>	13. <i>Heritiera</i>	12. Sterculiaceae	4
	18. <i>Hydnocarpus ilicifolia</i>	14. <i>Hydnocarpus</i>	13. Flacourtiaceae	4
	19. <i>Lagerstroemia floribunda</i>	15. <i>Lagerstroemia</i>	14. Lythraceae	9
	20. <i>Macaranga</i> sp.	16. <i>Macaranga</i>	15. Euphorbiaceae	1
	21. <i>Mallotus brevipetiolatus</i>	17. <i>Mallotus</i>		4
	22. <i>Mallotus dispar</i>			2
	23. <i>Memecylon edule</i> Roxb. var. <i>ovatum</i>	18. <i>Memecylon</i>	16. Lythraceae	18
	24. <i>Memecylon pauciflorum</i>			35
	25. <i>Microcos</i> sp.	19. <i>Microcos</i>	17. Tiliaceae	1
	26. <i>Pentace</i> sp.	20. <i>Pentace</i>		3
	27. <i>Pentaspadon curtisii</i>	21. <i>Pentaspadon</i>	18. Anacardiaceae	9
	28. <i>Pentaspadon velutinis</i>			1
	29. <i>Phyllanthus pulcher</i>	22. <i>Phyllanthus</i>	19. Euphorbiaceae	15
	30. <i>Psychotria angulata</i>	23. <i>Psychotria</i>	20. Rubiaceae	1
	31. <i>Pterospermum lanceaefolium</i>	24. <i>Pterospermum</i>	21. Sterculiaceae	5
	32. <i>Radermachera pinnata</i>	25. <i>Radermachera</i>	22. Bignoniaceae	11
	33. <i>Radermachera stricta</i>			3
	34. <i>Rhizophora apiculata</i>	26. <i>Rhizophora</i>	23. Rhizophoraceae	1114
	35. <i>Rhizophora mucronata</i>			244
	36. <i>Schefflera heterophylla</i>	27. <i>Schefflera</i>	24. Araliaceae	2
	37. <i>Spatodea companulata</i>	28. <i>Spatodea</i>	25. Bignoniaceae	9
	38. <i>Spondias pinnata</i>	29. <i>Spondias</i>	26. Anacardiaceae	2

	39. <i>Sterculia augustifolia</i>	30. <i>Sterculia</i>	27. Sterculiaceae	17
	40. <i>Sterculia lancaviensis</i>			19
	41. <i>Streblus ilicifolius</i>	31. <i>Streblus</i>	28. Moraceae	41
	42. <i>Syzgium</i> sp.	32. <i>Syzgium</i>	29. Myrtaceae	3
	43. <i>Terminallia triptera</i>	33. <i>Terminallia</i>	30. Combretaceae	5
	44. <i>Vitex pinnata</i>	34. <i>Vitex</i>	31. Verbenaceae	1
	45. <i>Xanthophyllum affine</i>	35. <i>Xanthophyllum</i>	32. Polygalaceae	3
	46. <i>Xanthophyllum discolor</i>			3
	47. <i>Xylocarpus granatum</i>	36. <i>Xylocarpus</i>	33. Meliaceae	253
	48. <i>Xylocarpus moluccensis</i>			76
	Total			3832
River Ayer Hangat	1. <i>Avicennia marina</i>	1. <i>Avicennia</i>	1. Avicenniaceae	37
	2. <i>Bruguiera cylindrica</i>	2. <i>Bruguiera</i>	2. Rhizophoraceae	62
	3. <i>Bruguiera parviflora</i>			91
	4. <i>Ceriops tagal</i>	3. <i>Ceriops</i>		429
	5. <i>Diospyros ferrea</i>	4. <i>Diospyros</i>	3. Ebenaceae	1
	6. <i>Excoecaria agallocha</i>	5. <i>Excoecaria</i>	4. Euphorbiaceae	1
	7. <i>Ficus superba</i>	6. <i>Ficus</i>	5. Moraceae	1
	8. <i>Pentaspadon motleyi</i>	7. <i>Pentaspadon</i>	6. Anacardiaceae	1
	9. <i>Rhizophora apiculata</i>	8. <i>Rhizophora</i>	7. Rhizophoraceae	1109
	10. <i>Rhizophora mucronata</i>			265
	11. <i>Sonneratia alba</i>	9. <i>Sonneratia</i>	8. Lythraceae	1
	12. <i>Streblus ilicifolius</i>	10. <i>Streblus</i>	9. Moraceae	5
	13. <i>Xanthophyllum affine</i>	11. <i>Xanthophyllum</i>	10. Polygalaceae	4
	14. <i>Xylocarpus granatum</i>	12. <i>Xylocarpus</i>	11. Meliaceae	1517
	15. <i>Xylocarpus moluccensis</i>			27
	16. <i>Xylocarpus rumphii</i>			54
	Total			3605
	Grand Total			11488

Table 2. Floristic composition and dominance family of Kilim, Geoforest Park, Malaysia assessed from November 2009 until February 2010

Family	Genera	Species	No. of Stem	Percent (%)
Anacardiaceae	2	4	16	0.14
Araliaceae	1	1	2	0.02
Avicenniaceae	1	2	112	0.97
Bignoniaceae	3	4	33	0.29
Combretaceae	1	1	5	0.04
Cycadaceae	1	1	3	0.03
Ebenaceae	1	2	22	0.19
Elaeocarpaceae	1	1	1	0.01
Erythroxylaceae	1	1	9	0.08
Euphorbiaceae	4	5	27	0.24
Flacourtiaceae	2	2	7	0.06
Lauraceae	1	1	4	0.03
Loganiaceae	1	1	7	0.06
Lythraceae	3	4	65	0.57
Meliaceae	1	3	2069	18.01
Moraceae	1	5	78	0.68
Myrtaceae	1	1	3	0.03
Polygalaceae	1	2	18	0.16
Rhizophoraceae	3	8	8954	77.94
Rubiaceae	1	1	1	0.01
Rutaceae	1	1	2	0.02
Sterculiaceae	2	4	45	0.39
Tiliaceae	2	2	4	0.03
Verbenaceae	1	1	1	0.01
Total	37	58	11488	100.00

Table 3. List of true mangrove species together with their taxonomical rank of Kilim, Geoforest Park, Malaysia

Area	Species	Genus	Family	No. of Stem
River Kilim	1. <i>Avicennia officinalis</i>	1. <i>Avicennia</i>	1. Avicenniaceae	20
	2. <i>Bruguiera gymnorhiza</i>	2. <i>Bruguiera</i>	2. Rhizophoraceae	17
	3. <i>Bruguiera parviflora</i>			424
	4. <i>Bruguiera sexangula</i>			465
	5. <i>Ceriops tagal</i>	3. <i>Ceriops</i>		1264
	6. <i>Rhizophora apiculata</i>			1226
	7. <i>Rhizophora mucronata</i>			455
	8. <i>Xylocarpus granatum</i>	4. <i>Xylocarpus</i>	3. Meliaceae	124
	9. <i>Xylocarpus moluccensis</i>			18
	Total			4013
River Kisap	1. <i>Avicennia marina</i>	1. <i>Avicennia</i>	1. Avicenniaceae	55
	2. <i>Bruguiera cylindrica</i>	2. <i>Bruguiera</i>	2. Rhizophoraceae	1110
	3. <i>Bruguiera parviflora</i>			311
	4. <i>Ceriops decandra</i>	3. <i>Ceriops</i>		1
	5. <i>Ceriops tagal</i>			367
	6. <i>Excoecaria agallocha</i>	4. <i>Excoecaria</i>	3. Euphorbiaceae	4
	8. <i>Heritiera littoralis</i>	5. <i>Heritiera</i>	4. Sterculiaceae	4
	9. <i>Rhizophora apiculata</i>	6. <i>Rhizophora</i>	5. Rhizophoraceae	1114
	10. <i>Rhizophora mucronata</i>			244
	11. <i>Xylocarpus granatum</i>	7. <i>Xylocarpus</i>	6. Meliaceae	253
	12. <i>Xylocarpus moluccensis</i>			76
	Total			3539
River Ayer Hangat	1. <i>Avicennia marina</i>	1. <i>Avicennia</i>	1. Avicenniaceae	37
	2. <i>Bruguiera cylindrica</i>	2. <i>Bruguiera</i>	2. Rhizophoraceae	62
	3. <i>Bruguiera parviflora</i>			91
	4. <i>Ceriops tagal</i>	3. <i>Ceriops</i>		429
	5. <i>Excoecaria agallocha</i>	4. <i>Excoecaria</i>	3. Euphorbiaceae	1
	6. <i>Rhizophora apiculata</i>	5. <i>Rhizophora</i>	4. Rhizophoraceae	1109
	7. <i>Rhizophora mucronata</i>			265
	8. <i>Sonneratia alba</i>	6. <i>Sonneratia</i>	5. Lythraceae	1
	9. <i>Xylocarpus granatum</i>	7. <i>Xylocarpus</i>	6. Meliaceae	1517
	10. <i>Xylocarpus moluccensis</i>			27
	11. <i>Xylocarpus rumphii</i>			54
	Total			3593
	Grand Total			11145

Table 4. True mangrove species composition and dominance family of Kilim, Geoforest Park, Malaysia

Family	Genera	Species	No.of Stem	Percent (%)
1. Rhizophoraceae	3	8	8954	80.22
2. Meliaceae	1	3	2069	18.54
3. Avicenniaceae	1	2	112	1.00
4. Euphorbiaceae	4	5	27	0.24
Total	9	18	11162	100

Table 5. Overall importance value index (IVI), density and frequency of true mangrove and associate species assessed in Kilim, Geoforest Park, Malaysia

Species	Family	Density	Frequency	IVI
<i>Avicennia marina</i>	Avicenniaceae	92	48	7.80
<i>Avicennia officinalis</i>	Avicenniaceae	20	12	2.87
<i>Bruguiera cylindrica</i>	Rhizophoraceae	1171	82	22.60
<i>Bruguiera gymnorhiza</i>	Rhizophoraceae	17	2	4.95
<i>Bruguiera parviflora</i>	Rhizophoraceae	826	167	22.13
<i>Bruguiera sexangula</i>	Rhizophoraceae	465	49	11.30
<i>Ceriops decandra</i>	Rhizophoraceae	1	1	0.08
<i>Ceriops tagal</i>	Rhizophoraceae	2060	228	45.85
<i>Cinnamomum</i> sp.	Lauraceae	4	3	0.33
<i>Cycas siamensis</i>	Cycadaceae	3	1	0.10
<i>Diospyros ferrea</i>	Ebenaceae	1	1	0.09
<i>Diospyros ismailii</i>	Ebenaceae	21	5	0.59
<i>Elaeocarpus griffithii</i>	Elaeocarpaceae	1	1	0.08
<i>Erythroxylum cuneatum</i>	Erythroxylaceae	9	6	0.61
<i>Excocaria agollacha</i>	Euphorbiaceae	5	4	0.38
<i>Fagraea curtisii</i>	Loganiaceae	7	1	0.14
<i>Fernando adenophylla</i>	Bignoniaceae	10	5	0.76
<i>Ficus deltoidea</i>	Moraceae	5	3	0.35
<i>Ficus rumpii</i>	Moraceae	2	1	0.11
<i>Ficus superba</i>	Moraceae	5	3	0.21
<i>Ficus superba</i>	Moraceae	3	2	0.11
<i>Flacourtia rukam</i>	Flacourtiaceae	4	3	0.18
<i>Heritiera littoralis</i>	Sterculiaceae	4	1	0.43
<i>Hydnocarpus ilicifolia</i>	Flacourtiaceae	9	5	0.12
<i>Lagerstroemia floribunda</i>	Lythraceae	1	1	0.61
<i>Macaranga</i> sp.	Euphorbiaceae	4	3	0.08
<i>Mallotus brevipetiolatus</i>	Euphorbiaceae	2	2	0.28
<i>Mallotus dispar</i>	Euphorbiaceae	1	6	0.08
<i>Memecylon edule</i> Roxb. var. <i>ovatum</i>	Lythraceae	19	13	0.77
<i>Memecylon pauciflorum</i>	Lythraceae	36	1	1.59
<i>Microcos</i> sp.	Tiliaceae	2	2	0.09
<i>Murraya paniculata</i>	Rutaceae	3	2	0.16
<i>Pentace</i> sp.	Tiliaceae	1	1	0.19
<i>Pentaspadon motleyi</i>	Anacardiaceae	12	5	0.09
<i>Pentaspadon curtisii</i>	Anacardiaceae	1	1	0.79
<i>Pentaspadon velutinis</i>	Anacardiaceae	15	7	0.09
<i>Phyllanthus pulcher</i>	Euphorbiaceae	1	1	0.80
<i>Psychotria angulata</i>	Rubiaceae	5	3	0.08
<i>Pterospermum lanceaefolium</i>	Sterculiaceae	11	6	0.26
<i>Radermachera pinnata</i>	Bignoniaceae	3	1	0.91
<i>Radermachera stricta</i>	Bignoniaceae	14	326	0.19
<i>Rhizophora apiculata</i>	Rhizophoraceae	3449	144	87.57
<i>Rhizophora mucronata</i>	Rhizophoraceae	964	2	30.29
<i>Schefflera heterophylla</i>	Araliaceae	1	1	0.18
<i>Sonneratia alba</i>	Lythraceae	9	5	0.16
<i>Spatodea companulata</i>	Bignoniaceae	11	1	0.66
<i>Spondias pinnata</i>	Anacardiaceae	2	6	0.16
<i>Sterculia lancaviensis</i>	Sterculiaceae	19	6	1.62
<i>Streblus ilicifolius</i>	Moraceae	65	15	1.84
<i>Streblus laxiflorus</i>	Moraceae	1	1	0.08
<i>Syzygium</i> sp.	Myrtaceae	3	2	0.21
<i>Terminallia triptera</i>	Combretaceae	5	3	0.29
<i>Vitex pinnata</i>	Verbenaceae	1	1	0.10
<i>Xanthophyllum discolor</i>	Polygalaceae	11	5	0.49
<i>Xanthophyllum affine</i>	Polygalaceae	7	3	0.30
<i>Xylocarpus granatum</i>	Meliaceae	1894	171	40.47
<i>Xylocarpus moluccensis</i>	Meliaceae	121	35	5.18
<i>Xylocarpus rumphii</i>	Meliaceae	54	6	1.19
Total		11488	1422	300.00

Table 6. Importance value index (IVI) of true mangrove and associate species assessed in River Kilim, River Kisap and River Ayer Hangat of Kilim, Geoforest Park, Malaysia

Species	River Kilim	River Kisap	River Ayer Hangat
<i>Avicennia marina</i>	nd	10.39	14.3
<i>Avicennia officinalis</i>	7.99	nd	nd
<i>Bruguiera cylindrica</i>	nd	58.21	7.72
<i>Bruguiera gymnorhiza</i>	13.32	nd	nd
<i>Bruguiera parviflora</i>	28.48	23.29	14.24
<i>Bruguiera sexangula</i>	32.07	nd	nd
<i>Ceriops decandra</i>	nd	0.22	nd
<i>Ceriops tagal</i>	70.42	24.37	42.2
<i>Cinnamomum</i> sp.	nd	0.91	nd
<i>Cycas siamensis</i>	0.29	nd	nd
<i>Diospyros ferrea</i>	nd	nd	0.3
<i>Diospyros ismailii</i>	nd	1.63	nd
<i>Elaeocarpus griffithii</i>	nd	0.22	nd
<i>Erythroxylum cuneatum</i>	nd	1.66	nd
<i>Excocaria agollacha</i>	nd	0.82	0.27
<i>Fagraea curtisii</i>	nd	0.38	nd
<i>Fernando adenophylla</i>	nd	2.37	nd
<i>Ficus deltoidea</i>	nd	0.97	0.38
<i>Ficus rumpii</i>	nd	0.29	nd
<i>Ficus superba</i>	nd	0.58	nd
<i>Flacourtia rukam</i>	nd	0.49	nd
<i>Heritiera littoralis</i>	nd	1.19	nd
<i>Hydnocarpus ilicifolia</i>	nd	0.35	nd
<i>Lagerstroemia floribunda</i>	nd	1.68	nd
<i>Macaranga</i> sp.	nd	0.22	nd
<i>Mallotus brevipetiolatus</i>	nd	0.75	nd
<i>Mallotus dispar</i>	nd	0.44	nd
<i>Memecylon edule</i> Roxb. var. <i>ovatum</i>	0.26	1.88	nd
<i>Memecylon pauciflorum</i>	0.25	4.16	nd
<i>Microcos</i> sp.	nd	0.24	nd
<i>Murraya paniculata</i>	0.48	nd	nd
<i>Pentace</i> sp.	nd	0.52	nd
<i>Pentaspadon motleyi</i>	nd	nd	0.31
<i>Pentaspadon curtisii</i>	0.29	1.91	nd
<i>Pentaspadon velutinis</i>	nd	0.24	nd
<i>Phyllanthus pulcher</i>	nd	2.20	nd
<i>Psychotria angulata</i>	nd	0.22	nd
<i>Pterospermum lanceaefolium</i>	nd	0.72	nd
<i>Radermachera pinnata</i>	nd	0.54	nd
<i>Radermachera stricta</i>	nd	2.52	nd
<i>Rhizophora apiculata</i>	89.84	79.04	95.31
<i>Rhizophora mucronata</i>	36.9	26.45	27.06
<i>Schefflera heterophylla</i>	nd	0.49	nd
<i>Sonneratia alba</i>	nd	nd	0.55
<i>Spatodea companulata</i>	nd	1.57	nd
<i>Spondias pinnata</i>	nd	0.44	nd
<i>Sterculia augustifolia</i>	nd	2.24	nd
<i>Sterculia lancaviensis</i>	nd	2.24	nd
<i>Streblus ilicifolius</i>	1.27	3.37	0.67
<i>Streblus laxiflorus</i>	0.24	nd	nd
<i>Syzygium</i> sp.	nd	0.57	nd
<i>Terminallia triptera</i>	nd	0.78	nd
<i>Vitex pinnata</i>	nd	0.27	nd
<i>Xanthophyllum discolor</i>	0.87	0.56	nd
<i>Xanthophyllum affine</i>	nd	0.49	0.4
<i>Xylocarpus granatum</i>	12.86	0.56	89.53
<i>Xylocarpus moluccensis</i>	4.17	26.76	2.73
<i>Xylocarpus rumphii</i>	nd	8.14	4.03
Total	300	300	300

Note: nd = not detected

Table 7. Overall family value index (FVI), density, frequency and basal area of true mangrove and associate species assessed in Kilim Geoforest Park, Malaysia.

Family	Density	Frequency	Basal Area	FVI
Anacardiaceae	16	8	0.279	1.13
Araliaceae	2	2	0.014	0.18
Avicenniaceae	112	60	3.591	10.66
Bignoniaceae	33	17	0.693	2.53
Combretaceae	5	3	0.021	0.29
Cycadaceae	3	1	0.002	0.10
Ebenaceae	22	6	0.039	0.67
Elaeocarpaceae	1	1	0.002	0.08
Erythroxylaceae	9	6	0.069	0.61
Euphorbiaceae	27	17	0.177	1.62
Flacourtiaceae	7	3	0.022	0.31
Lauraceae	4	3	0.057	0.33
Loganiaceae	7	1	0.003	0.14
Lythraceae	65	25	0.521	3.12
Meliaceae	2069	212	9.130	46.84
Moraceae	78	23	0.268	2.70
Myrtaceae	3	2	0.027	0.21
Polygalaceae	18	8	0.048	0.79
Rhizophoraceae	8954	999	50.270	224.77
Rubiaceae	1	1	0.001	0.08
Rutaceae	2	2	0.001	0.16
Sterculiaceae	45	18	0.430	2.31
Tiliaceae	4	3	0.021	0.28
Verbenaceae	1	1	0.013	0.10
Total	11488	1422	65.699	300.00

Table 8. Species diversity of mangrove forest were assessed in three areas at Kilim, Geoforest Park, Malaysia from November 2010 until February 2011.

a) Species Richness

Diversity indices	River Kilim	River Kisap	River Ayer Hangat
Jackknife estimates of species richness	24.7	62.6	25.7
Number of unique species	8	15	8

b) Species Heterogeneity

Diversity indices	River Kilim	River Kisap	River Ayer Hangat
Simpson's index of diversity (1-D)	0.773	0.806	0.695
Shannon-Wiener index of diversity H'	2.44	3.004	2.084
Brillouin index of diversity	2.427	2.971	2.072

c) Species Evenness

Diversity indices	River Kilim	River Kisap	River Ayer Hangat
Simpson's measure of evenness	0.259	0.108	0.205
Camargo's index of evenness	0.251	0.139	0.201
Smith and Wilson's Index of Evenness	0.101	0.178	0.092