ASM Sc. J., 14, Special Issue 1, 2021 for ICSTSS2018, 126-134

Floristic Composition and Stand Structure of Freshwater Swamp Forest at Parit Forest Reserve, Perak, Malaysia

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Freshwater swamp forests in Malaysia are gradually decreasing due to land use and land cover changes, which affect their populations and become vulnerable to extinction. A study was conducted to determine the tree species composition and stand structure in the remnants of freshwater swamp forests located at Parit Forest Reserve, Perak, Malaysia. For this purpose, transect lines with random start method were established at two sites (i.e., wet condition and dry condition). The width of transect lines was 20 m and the length varied from 40-200 m. Distance between transect lines was 50 m apart. Transect lines were gridded into subplots (20 m × 20 m). All trees (DBH > 10 cm) were measured and identified at species level. From the study, a total of 1,263 trees, representing 179 species in 109 genera from 41 families were enumerated in the study area. Two dominant families in the study locations are Euphorbiaceae and Sapotaceae. Tree species such as *Artocarpus scortechinii* and *Nephelium lappaceum* were among the important parts of the floristic composition in the study areas. The Shannon-Weiner diversity index (*H'*) is uniform for both study sites, (i.e., 2.39), which is within the range of other studies in freshwater swamp forests. In terms of stand structure, the diameter distribution of trees displayed the characteristic of an inverse J distribution, indicating the presence of regeneration at both study sites. The results from this study are useful in providing a valuable reference for conservation of biodiversity of freshwater swamp forests.

Keywords: floristic composition; freshwater swamp forest; stand structure

I. INTRODUCTION

Malaysia is endowed with richness in biodiversity of the tropical rain forests (Woodruff, 2003; Mittermeier *et al*., 2005). The major types of forest in Malaysia are peat swamp forest, mangrove forest, lowland dipterocarp forest, hill dipterocarp forest and montane forest. The total forested area in Malaysia is 21.01 million ha that occupies about 63% of the land area in the country. The small percentage of it is forested wetlands (i.e., peat swamp forest, freshwater swamp forest and riparian forest) that are about 4.39 million ha and only 2.5% of the areas belong to freshwater swamps forests (Ministry of Natural Resources and Environment, 2014).

In Malaysia, freshwater swamp forest has received scant attention due to the less economic values. In addition, deforestation and urban expansion lead to the reduction of the habitat (Pfaff *et al*., 2013) which turn freshwater swamp forest into critically threatened habitats. This forest is very peculiar and unique because it gives rise to a habitat from the surrounding lowland dipterocarp forests (Suratman *et al*., 2014). Thus, the reduction of this forest gives an impact to endemic tree species that need specific habitat requirements.

Information on density, species composition, diversity of tree species and species-rich communities are of primary importance in the planning and implementation of biodiversity conservation efforts. To conserve the forests from declining, it is essential to examine the current status of species diversity as it will provide useful information for

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the management of the forest. Therefore, this study was conducted to determine the floristic composition of freshwater swamp forests of Parit Forest Reserve and to assess the stand structure in this area. Information from this study will provide a valuable knowledge in identifying ecologically useful species as well as species of special concerns to determine conservation efforts required for sustaining forest biodiversity.

II. MATERIALS AND METHOD

A. Description of Study Area

This study was conducted at freshwater swamp forest remnants at Parit Forest Reserve, Perak, Malaysia (Figure 1). The study area lies between the latitude of 4° 21' 21" N and longitude of 100° 57' 14" E with the elevation ranges from 20-45 m above sea level. The climate is characterized by permanent high temperatures range from 20-35°C. The weather is dry and warm from January till March with the lowest rainfall occurs in January (60-100 mm of rainfall). The highest rainfall occurs in October to November (i.e., 230-350 mm) (Department Meteorology Malaysia, 2016).

Figure 1. Location of the study area

This forest is classified as freshwater swamp forest and the entire forest reserve is surrounded by fragments of secondary forests within the district of Perak Tengah, Perak. Much of the area has been developed into urban sites leaving very small patches of isolated swamps. From the field observation, it is apparent that the area belongs to two conditions of distinct microhabitat (i.e., wet condition and dry condition) as shown in Figures 2 and 3, respectively. The total size of area covers an area about 12.39 ha (7.73 ha for wet condition and 4.66 ha for dry condition). The two habitats support different tree communities due to a variation in habitat characteristics.

Figure 2. Wet condition study site of freshwater forest at Parit Forest Reserve, Perak

Figure 3. Dry condition study site of freshwater forest at Parit Forest Reserve, Perak

Due to the water logged condition of this forest that is caused by rainfall runoff, the trees exhibit different strategies for survival which include the growth of buttresses and stilt roots. The hydrophytic trees (i.e., *Ficus* spp., *Macaranga* spp. and *Syzygium* spp.) dominate the vegetation type in the forest. Other than that, *Livistona saribus* palm is frequently occurred in the area. In terms of stratification, the forest comprises irregular canopies that range from 10-25 m height and the emergent trees range between 30-35 m height.

B. Data Collection

Transect lines with the width of 20 m were established systematically using random start method. The length of transect lines varies from 40-200 m depending on the length of study sites. Distance between transect lines were 50 m apart. Each transect line was gridded into subplots, 20 m × 20 m in size, as workable units. Each subplot was inventoried by measuring all trees within a diameter at breast height (DBH) ≥ 10 cm. All trees were identified at the species level. If field identification was not possible, the botanical specimens were taken to the herbarium section of the Forest Research Institute Malaysia (FRIM) for identification and confirmation.

C. Data Analysis

Data of all tree species were summarized to describe the species composition, abundance and diversity of the tree communities. The abundance data include determination of density, frequency and basal area. In order to determine the most important species in the communities, the Important Value Index (*IVI*) was calculated by summing up the values of relative density (RD), relative dominance (RDo) and relative frequency (RF) of each species or family (Brower *et al.*, 1997). Different species richness in terms of indices was calculated using Margalef's diversity index (DMg) (Margalef, 1972) and Menhinick's diversity index (DMn) (Menhinick, 1964). The Shannon-Wiener's Diversity Index (H') (Shannon and Weaver 1949) and Simpson's Diversity Index (D) (Simpson, 1949) were used to determine the species diversity in a community. Maximum diversity possible is indicated as Hmax.

Shannon's equitability (EH) was used to measure the evenness, which indicates the similarity of species abundance, whereas Sörensen's Similarity Index (Ss) was used to measure community similarity between the two study sites (Kent & Coker, 1992).

In this study, the stand structure was described based on the number of individual trees per hectare, basal area and distribution of trees by diameter classes. Therefore, the basal area was calculated based on the equation from Husch *et al.* (1982), in that the data of DBH were classified into diameter classes which gave a frequency of trees and used to draw bar chart graphs.

D. Statistical Analysis

For data analysis, an independent t-test was performed to determine any statistical differences between the means of variables of floristic composition between the two conditions of microhabitat in the study area. The analysis of the data was performed using Statistical Analysis System (SAS) software version 9.3.

III. RESULTS AND DISCUSSION

A. Floristic Composition

1. Taxonomic Composition

A total of 1263 trees representing 179 species in 109 genera from 41 families were enumerated from wet and dry conditions of the study areas. Table 1 shows a summary of floristic composition in two conditions of study sites (i.e., wet condition and dry condition). The total number of 600 trees in wet condition study site belonged to 38 families, 88 genera and 135 species, whilst the dry condition consisted of a total of 663 trees that belonged to 36 families, 79 genera and 100 species.

Table 1. Summary of floristic composition in two study sites

Study site	No. of families	No. of genera	No. of species
Wet condition	38	88	135
Dry condition	36	79	100

Different size of study sites may have affected the number of taxa present between both locations. The larger area of study site in wet condition (7.73 ha) might tend to contain higher number of families, genera and species as compared to dry condition which was half of the area of wet condition site (i.e., 4.66 ha). Moreover, a high number of taxa present in wet condition could be due to the higher moisture in the wet condition locations. Furthermore, based on a study by Mishra *et al.* (2004) showed that moderately or slightly disturbed tropical forests such as wet condition tend to support more number of species in comparison with a forest which is dense and undisturbed.

2. Species Diversity

Biodiversity is one of the primary interests of ecologists, but quantifying the species diversity of ecological communities is complicated. Species diversity is an important measure to be determined in an ecological community. It has two separate components which are the number of species present (species richness) and their relative abundances (evenness). A summary of the analysis for five indices of diversity, richness and evenness for the two study sites is presented in Table 2. A comparison of the mean of species diversity between the two site conditions (i.e., wet condition and dry condition) indicated that there were no significant differences between them except for Simpson's diversity ($p \leq 0.05$).

Table 2. Summary of species diversity for two study sites

Variables	Study sites	
	Wet condition	**Dry condition**
Simpson's diversity (*D*)	0.95a	0.91b
Shannon-Weiner index (*H'*)	2.39a	2.39a
Margalef's diversity index (D_{Mg})	4.22a	4.05a
Menhinick's diversity index (D_{Mn})	3.07a	2.77a
Shannon's equitability (E_H)	0.93a	0.92a

Note: Means with the same letters are not significantly different ($p \leq 0.05$)

Results from t-test indicated that the Simpson's diversity for wet condition was significantly higher than dry condition (0.95 vs. 0.91) ($p \leq 0.05$). The higher number of Simpson's diversity in wet condition could be due to the higher number of species present in wet condition compared to dry condition. However, when compared to the Shannon-Weiner index, there was no significant difference between both conditions. This could be attributed to the Simpson's diversity index that is heavily weighted towards the most dominant species in the sample, while being less sensitive to species richness (Magurran, 2004). In this study, the wet condition recorded higher value of *IVI* for *Artocarpus scortechinii* (28.44) which contributed to higher Simpson's diversity as compared to dry condition with *Macaranga hypolueca* as a dominant species (*IVI*=24.73).

There was no significant difference in the Shannon-Weiner index between study sites ($p \leq 0.05$) (Table 2). According to Magurran (2004) high species diversity refers to a highly complex community. Therefore, this value indicates that both study sites in this study have equal complexity and diversity in terms of species composition. Even though dry condition has a higher number of individual than wet condition, it might be balanced by a higher number of species in wet condition. Furthermore, the Shannon-Weiner index increases as both the richness and the evenness of the community increase.

Species richness refers to the number of species in a particular area (Magurran, 2004). In this study, similar patterns were found for species richness which was computed using Margalef's diversity index (DMg) and Menhinick's diversity index (DMn). As shown in Table 2, the values of Margalef's diversity index were 4.22 and 4.05 while the values of Menhinick's diversity index were 3.07 and 2.77 for wet and dry conditions, respectively. Both indices show that the wet condition had higher species richness as compared to dry condition. However, the t-test shows that there was no significant difference in the means of species richness between both study sites for both indices ($p \geq 0.05$). The values in both species richness indices are in agreement with the number of species in the study areas of which, the number of species in wet condition was higher than dry condition. The same trend was observed in the result of Simpson's diversity and evenness, thus conforming that the community in wet condition was more stable than dry condition. This finding suggests that species richness in tropical area varies greatly due to variation in biogeography, habitat and disturbance (Whitmore, 1988).

According to Mishra *et al.* (2004), species evenness measures how equally the species abundance at that area. It measures the relative abundance of the different species making up the richness of an area or can be referred to how even the species distribution in the study area. In this study, the Shannon's equitability (EH) value was 0.93 in wet condition and 0.92 in dry condition sites. There was no significant difference in the means of evenness between both study sites ($p \geq 0.05$). A community dominated by several different species that have a similar abundance is considered to be more diverse, thus as species richness and evenness increase, diversity increases. In this study, wet and dry conditions had a uniform trend of high species evenness value which indicates a close number of tree species in the study area. This finding may also suggest that the numbers of species are evenly distributed in both study sites. Generally, the findings of species diversity suggest that both study sites are uniform in both factors of species richness and evenness.

B. Community Similarity

The similarity analysis (i.e., Sörensen's Similarity Index, Ss) on the species composition of both sites revealed that the similarity between the sites was moderate with a value of 48.5 %, whilst at the family level, a high similarity was observed with Sorensen Index of 89.2 %. This could be due to wet condition site contains higher species richness as compared to dry condition, and the majority of species occurred only at the wet condition. In addition, the similarity of family or species in an area is probably due to the ecological behaviour of the family or species. Furthermore, species compositions that differ significantly among habitats could be due to the influence of the edaphic factors. Moreover, study by Newbery and Proctor (1984), who surveyed swamp forest, alluvium soil forest, limestone hill forest and dipterocarp forest at Gunung Mulu National Park, Sarawak, reported that differences in species composition between the forest habitats could be due to differences in soil chemical properties of the different study sites.

1. Family-Wise Distribution

Data for tree families were pooled for both study sites. A total of 41 tree families were encountered in the study sites. The highest number of tree species belonged to the family of Euphorbiaceae which accounted for 11.7% of the total individuals encountered in the study sites. This was followed by Sapotaceae, Guttiferae and Myrtaceae which accounted for 8.9%, 7.8% and 5.6%, respectively. Quite numbers of families had lowest percentages of the total individual encountered in the study sites with 0.6 % (i.e., Anisophylleaceae, Aquifoliaceae, Celastraceae, Icacinaceae, Lecythidaceae, Olacaceae, Opiliaceae, Passifloraceae, Polygalaceae, Rosaceae, Sterculiaceae and Verbenaceae) (Figure 4).

In this study, the most specious and well represented family was the Euphorbiaceae. This is not surprising because Euphorbiaceae had been reported as the second largest plant family (after Rubiaceae) in Peninsular Malaysia which represented 70 genera and 364 species that included trees, shrubs and lianas (Turner, 1995). Furthermore, Whitmore (1984) also claimed that Euphorbiaceae was the most common family in the lowland dipterocarp, hill primary and secondary forest. Euphorbiaceae usually occupies the lower layer of rainforest canopy, thus possess high tolerance to shade. This might be the reason of the frequent distribution of Euphorbiaceae in the study area.

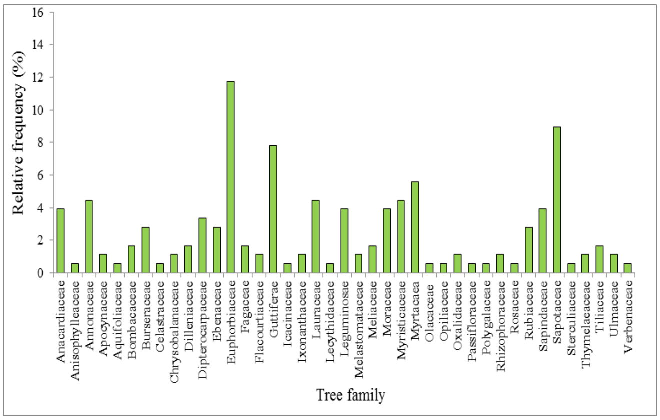

Figure 4. Family-wise distribution of trees in the study sites

A study by Khairil *et al.* (2014) on the Chini watershed forest in Peninsular Malaysia found that Euphorbiaceae was a dominant family in the study sites of inland forest (372 number of individuals) and riverine forest (138 number of individuals). Other study on tree species diversity and forest stand structure of Kuala Keniam by Suratman (2014) at Pahang National Park, Malaysia reported that Euphorbiaceae was also the dominant family with 23.9 % of the total individuals was encountered in the study area. The study area presented high family richness as commonly found in swamp forest. In total, 53.7 % of tree families in this area were similar to previous studies conducted at evergreen swamp forest in Cambodia by Theilade *et al.* (2011) and at freshwater swamp forest in south eastern Brazil by Magalhaes and Maimoni-Rodella (2012). Based on the present and previous studies, freshwater swamp forests consist of common families such as Euphorbiaceae, Guttiferae, Myrtacaea, Lauraceae and Moraceae.

2. Important Value Index (IVI)

Important Value Index was calculated in order to determine the important of a species in a particular area which indicates the species dominance of the area. Table 3 presents the *IVI* of five leading species at wet and dry conditions of freshwater swamp forest of Parit Forest Reserve. The top five species of each site contributed to 27.3 % and 37.0 % of *IVI* at wet and dry conditions, respectively. In wet condition, *A. scortechinii* was the dominant species with the highest value of *IVI* at 28.44 %, followed by *Nephelium lappaceum* as co-dominant species (26.99 %). However, in dry condition, *M. hypolueca* was the dominant species with an *IVI* of 24.73 %. The co-dominant species in dry condition was *Ficus microcarpa* with an *IVI* of 19.61 %.

Table 3. Species importance value for the ten most dominant species in wet and dry locations

Species	**Family**	***IVI***
Wet Condition		
Artocarpus scortechinii	Moraceae	28.44
Nephelium lappaceum	Sapindaceae	26.99
Syzygium papillosum	Myrtacaea	20.15
Palaquium spp.	Sapotaceae	12.57
Shorea macrantha	Dipterocarpaceae	11.85
Total (percentage for top 10 species)		100.00 (27.3%)
Dry Condition		
Macaranga hypolueca	Euphorbiaceae	24.73
Ficus microcarpa	Moraceae	19.61
Syzygium spp.	Myrtacaea	16.4
Artocarpus integer	Moraceae	14.95
Nephelium lappaceum	Sapindaceae	10.69
Total (percentage for top 10 species)		86.38 (37.0%)

In wet condition, the dominant and co-dominant species might be influenced by highest value of density and basal area, which both are dominated by *A. scortechinii* and *N. lappaceum*. The *IVI* value indicated by *M. hypolueca*, as the most important species, was expected since this species recorded the highest density than other species in dry condition. According to Curtis and McIntosh (1951), species with *IVI* of more than 10% can be assumed to have absolute dominance in a particular community. Therefore, from these values, *M. hypolueca* can be considered as the most dominant species in dry condition in the study area. In addition, the high *IVI* value recorded for *F. microcarpa* also was expected based on the highest basal area recorded compared to other species in dry condition. In comparison with other studies on freshwater swamp forest, Theilade *et al.* (2011) recorded *M. triloba* being dominant in swamp forest of Cambodia, and Infante *et al.* (2011) found that *Pachira aquatic* was the dominant species in Chira forested wetland, Mexico.

3. Tree Species of Special Interest

From the field observation, some of critically endangered species were encountered in the study sites. Based on the IUCN Red List data list, six species of Dipterocarpaceae (i.e., *Dipterocarpus semivestitus, Hopea apiculata, Shorea hemsleyana, S. macrantha, S. platycarpa* and *Vatica flavida*) are listed in the category (Saw *et al.*, 2010). All these species are restricted to freshwater swamp forest in Peninsular Malaysia except for *H. apiculata* that can be found in lowland to hill dipterocarp forests up to 610 m altitude (Saw *et al.*, 2010).

C. Stand Structure

1. Density

Density refers to the amount of tree per unit area or space. In this study, the analysis showed that the dry condition site recorded higher tree density of 663 individuals ha^{-1} as compared to 484 individuals ha^{-1} in the wet condition study site. From the t-test, it was found that there was a significant difference in mean of tree density between the both study sites ($p \leq 0.05$). When compared to other findings, the result of this study for density was lower in both study sites. This is in agreement with Whitmore (1984) who reported freshwater swamp forest seemed to have lower tree density compared to other forest types of tropical rainforest. It is apparent that density of trees in freshwater swamp forests shows high variation due on various factors. The effects of natural and anthropogenic disturbances could be the factors that influence tree density.

2. Basal Area

In terms of stand basal area, wet condition recorded 23.9 $m^2 ha^{-1}$ and dry condition was 29.2 $m^2 ha^{-1}$. However, there was no significant difference in the mean of basal area between both locations ($p \geq 0.05$). *F. microcarpa* in dry condition was the largest tree for both locations, thus it may contribute to an overall basal area. From the field collection it was found that *F. microcarpa* had a diameter of more than 90 cm. In this study, despite the density of this species was not in the top ten lists, the tree was of large diameter size, thus occupying a large area on the dry condition study site.

3. Diameter Class Distribution

The stand structure of freshwater swamp forest of Parit Forest Reserve was studied based on the number of trees present for each diameter class. This study area is considered as an uneven-aged stand that is common for tropical forest. Figure 5 shows that 39.5 % of trees fell within 10 – 14.9 cm, 22.7 % fell within 15 – 19.9 cm, 12.8 % fell within 20 – 24.9 cm, 8.5 % fell within 25 – 29.9 cm and 5.3 % fell within 30 – 34.9 cm in wet condition study site. In addition, it shows a less or an absent number of stems in diameter classes from 70 – 79.9 cm onwards.

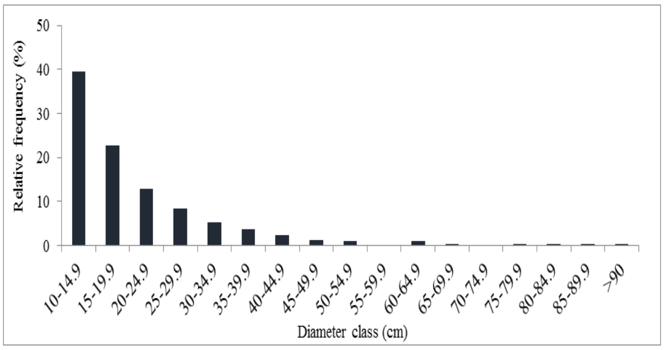

Figure 5. Diameter class distribution of wet condition study site

From Figure 5, it is apparent that stand structure of wet condition showed an inversely J curve characteristic as the number of individuals decrease with the increase of tree diameter. Majority of trees in the wet condition were classed in diameter 10.0 – 14.9 cm with 39.5 % of the total number of individuals. Trees with DBH of more than 90 cm represented 0.33 % from the total number of individuals in wet condition.

When compared to dry condition study site as presented in Figure 6, the smaller trees (10 – 14.9 cm) made up a greater portion with percentage of 45.2 % However, trees in diameter classes from 60 – 64.9 cm until 85 – 89.9 cm appear to be absent (Figure 6).

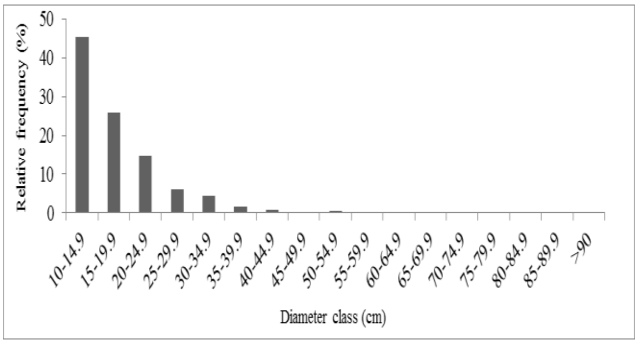

Figure 6. Diameter class distribution of dry condition study site

The same result occurred in dry condition where an inversely J curve distribution is apparent (see Figure 6). Dry condition recorded a higher number of individuals compared to wet condition. Most of the trees in dry condition were found within diameter class of 10.0 cm – 14.9 cm with the number of individuals of 300 trees (i.e., 45.2 %). Unlike wet condition, there was only one tree in dry condition that reached a diameter of more than 90 cm which was belonged to the family of Moraceae. The stand structure in the present study showed that both study sites clearly displayed the characteristic of De iocourt's factor procedure (inverse J-distribution) where stem frequencies decrease with the increase in DBH. This indicates that the stands at both study sites are developing and regeneration in the forest is present. The inversely J curve characteristic for diameter distribution for both study sites showed that the study site had good recruitment pattern of saplings (Zhang *et al.*, 2012). However, when these two study sites were compared, the dry condition was better than the wet condition study site. The reason is that there are higher numbers of trees in dry condition and the distribution of trees was in wide range of diameter compared to wet condition. Regeneration in natural forest is dependent on the availability of mother trees, fruiting pattern and favourable condition (Suratman *et al.,* 2010). The presence of growth of the forest in both study sites are indicated by the movement of trees in various diameter classes. The findings showed that dry condition had higher regeneration due to high percentage of small trees compared to wet condition.

IV. CONCLUSION

The freshwater swamp forest of Parit Forest Reserve comprises of natural vegetation and is dictated by microhabitat conditions. A comparison of the mean of species diversity between the two site conditions (i.e., wet condition and dry condition) indicated that there were no significan*t* differences between them except for Simpson's. The similar value of H' (2. 39) suggests that both study sites are uniform in terms of species diversity. The Shannon's equitability suggested that numbers of species were evenly distributed in both study sites. The most dominant families in the study area were Euphorbiaceae, Sapotaceae, Guttiferae and Myrtaceae. The sites were represented by different combinations of the dominant and co-dominant species where *A. scortechinii* (*IVI*: 28.44) was the dominant species followed by *N. lappaceum* as co-dominant in wet condition (*IVI*: 26.99), whilst in dry condition the dominant and co-dominant species were *M. hypolueca* (*IVI*: 24.73) and *F. microcarpa* (*IVI*: 19.61), respectively.

In this study, the analysis showed that the dry condition recorded higher tree density compared to the wet condition study site. The lower stand density in wet condition might be due to hydroperiod which may disturb the growth of seedlings or saplings or even destroy some of the small trees. The higher tree density in dry condition also might contribute to the higher basal area in the study site compared to wet condition. The findings showed that dry condition had higher regeneration compared to wet condition. However, both study sites follow the characteristic of De iocourt's factor procedure (inverse J-distribution) that indicate the stands are developing and regeneration in the forest is present. The result of stand structure of both study sites indicate regenerations occurrence in the forest stand and the stand is developing well. More comprehensive information is required to identify conservation efforts towards the protection of freshwater swamp forests.

V. ACKNOWLEDGEMENT

The authors would like to thank to the Ministry of Education (MoE), Malaysia for providing research grants through the Fundamental Research Grant Scheme (FRGS) 600-RMI/FRGS 5/3 (41/2014) and Universiti Teknologi MARA (UiTM) for providing support and logistic related services.

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