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Ecological Characteristics of a *Gonystylus bancanus*-rich Area in Pekan Forest Reserve, Pahang, Malaysia

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Abstrak: Hutan paya gambut (HPG) tropika merupakan satu ekosistem tanah lembap yang unik dengan pelbagai jenis tumbuhan. Oleh kerana secara umum persekitarannya merupakan air yang bertakung menyebabkan sifat-sifat dirian di sini berbeza dari dirian hutan darat yang lain. Kertas kerja ini menerangkan ciri-ciri dirian HPG berdasarkan kajian di petak 1 ha yang ditubuhkan di kawasan Hutan Simpanan Hutan Dara di Kompatmen 100, Hutan Simpan Pekan, Pahang, Malaysia. Kawasan ini dikategorikan sebagai kaya dengan spesies *Gonystylus bancanus*. Hasil dari inventori, kami merekodkan sejumlah 49 spesies dari 38 genera dan 25 famili bagi semua pokok ≥10 cm pada perepang paras dada. *Calophyllum ferrugineum* var. *ferrugineum* merupakan spesies paling dominan diikuti oleh *G. bancanus*. Kawasan hutan berkenaan boleh dikatakan sebagai sihat memandangkan semua ciri pokok (bentuk silara, gred balak dan gangguan pepanjat) secara umumnya pada Kelas 1 dan 2 (baik dan sederhana), kecuali pencahayaan silara yang mana majoriti pokok adalah pada Kelas 3 (terima kurang cahaya). Keadaan tersebut menunjukkan kebanyakan pokok di bawah naungan menerima cahaya matahari yang minimal. Dari segi biomass pokok, kami menganggarkan sebanyak 414.6 ton di dalam petak 1 ha ini yang menunjukkan biomass pokok di sini adalah lebih tinggi berbanding dengan beberapa kawasan HPG di Sumatra, Indonesia.

Kata kunci: Kajian Ekologi, Hutan Paya Gambut, Hutan Simpanan Dara, Diversiti, Biomas Pokok

Abstract: Tropical peat swamp forest (PSF) is a unique wetland ecosystem with distinct vegetation types. Due to the waterlogged environment, the stand characteristics in this ecosystem are different from those of other inland forests. This paper highlights stand characteristics of a PSF based on our investigation of a 1 ha ecological plot established in a Virgin Jungle Reserve (VJR) at Compartment 100, Pekan Forest Reserve, Pahang, Malaysia. This site is considered a *Gonystylus bancanus*-rich area. From the inventory, we recorded a total of 49 tree species from 38 genera and 25 families among all trees of ≥ 10 cm in diameter at breast height. *Calophyllum ferrugineum* var. *ferrugineum* was the most abundant species, followed by *G. bancanus*. The forest appeared healthy, as all tree characteristics (crown shape, log grade and climber infestation) generally fell within Classes 1 and 2 (good and moderate categories), with the exception of crown illumination which majority of the trees were rated as class 3 (received less sunlight). The latter finding indicates that most of the trees living under the canopy received minimal illumination. In terms of total tree biomass, we estimated that about 414.6 tonnes exist in this 1 ha area; this tree biomass is higher than in some PSF areas of Sumatra, Indonesia.

Keywords: Ecological Studies, Peat Swamp Forest, Virgin Jungle Reserve, Diversity, Tree Biomass

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INTRODUCTION

Peat swamp forest (PSF) is one of the characteristic wetland forest types of Malaysia. Ecologically, PSF is a unique forest formation, occupying and thriving in waterlogged, poorly drained lands. The vegetation of this ecosystem possesses unique characteristics and is adapted to harsh environmental conditions. PSF is generally not as diverse as are dry inland forests. Wyatt-Smith (1963) reported 232 tree species of ≥ 10 cm in diameter at breast height (dbh) in a coastal lowland dipterocarp forest at Sungai Menyala Forest Reserve (FR), while Appanah *et al.* (1989) found only 84 species of ≥ 10 cm dbh trees in the PSF at Sungai Bebar, Pahang. In fact, even the greatest number of species recorded in PSF that is 113, (Nizam *et al.* 2005), is still far lower than the number of species typically recorded in dry inland forests. Species richness of the PSF may be influenced by soil nutrient status and rainfall. Anderson (1961) found that the flora of the Rejang Delta, including Maludam National Park (NP), was richer and denser than that of swamps elsewhere in Sarawak and Brunei. Stand structure in Maludam NP also varies significantly and there is evidence that variation in stand structure and floristic composition may be related to environmental gradient and soil water availability (Tan 2005).

Here, we highlight ecological characteristics of a PSF based on a 1 ha ecological plot established in a Virgin Jungle Reserve (VJR) at Compartment 100, Pekan FR, Pahang, Malaysia, an area considered to be rich in *G. bancanus* (Ramin melawis) as reported by Blackett and Wollesen (2005). As stated by JPSM (1999), the main objective of establishing an ecological plot is to acquire information and examine changes in forest structure and species composition through time, and to examine changes in stand density and basal area as a function of taxon and tree type. Therefore, the long-term objective of this study is to characterise the dynamics of *G. bancanus*-rich areas of the PSF.

MATERIALS AND METHODS

Study Site

The study area is located at Compartment 100, Pekan FR, in the southeast of Pahang, Malaysia (Fig. 1). The area has been classified as a Ramin-Bintangor forest subtype by Blackett and Wollesen (2005) due to the predominance of *G. bancanus* (Ramin melawis) and *C. ferrugineum* var. *ferrugineum* (Bintangor gambut), which together represent more than 20% of the stand basal area for trees ≥ 30 cm dbh.

Ecological Plot Establishment

We established the ecological plot using the standard growth plot design prepared by Forestry Department Peninsular Malaysia (JPSM 1999). The plot size is 1 ha, with dimensions of 100 x 100 m, and it is divided into 25 quadrats of 20 x 20 m.

Data Collection and Analysis

For all trees enumerated in the plots, we assessed overall taxonomic composition and several metrics of abundance. These included basal area, as well as density and frequency of occurrence of each species.

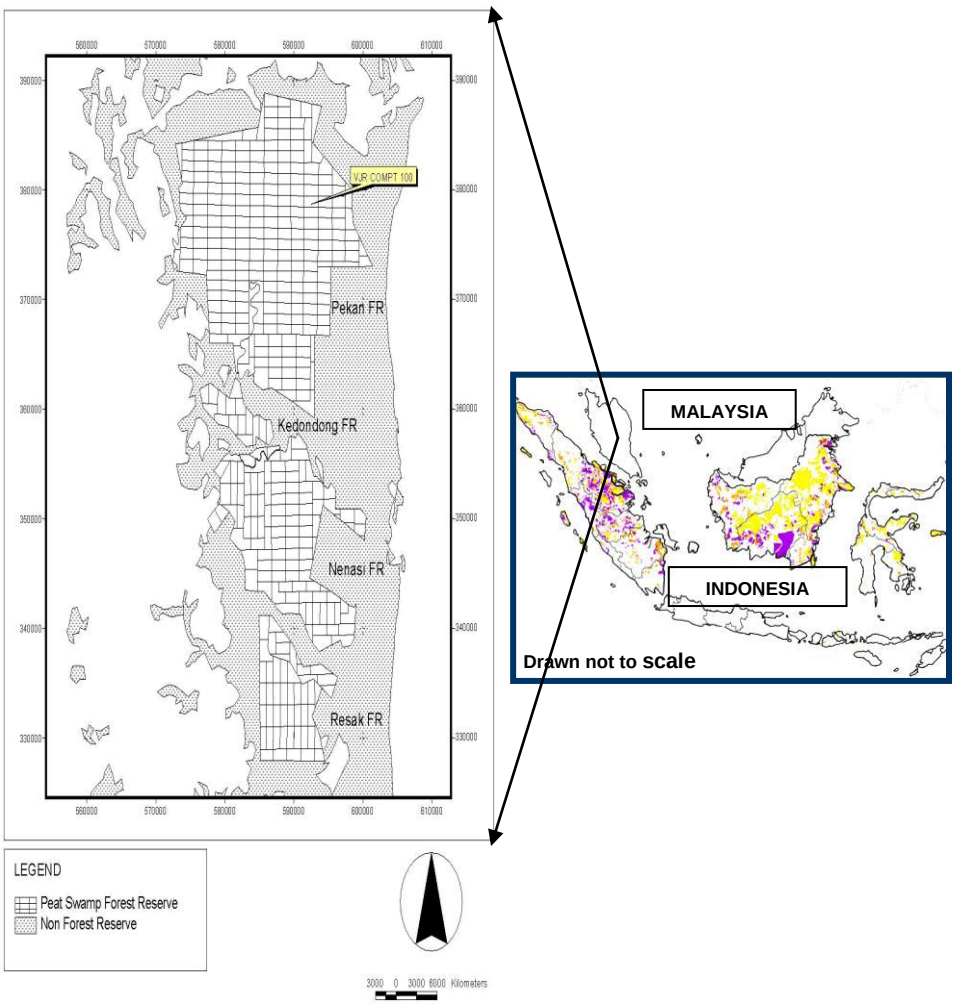

Figure 1: Ecological plot location in Compartment 100, Pekan FR.

Tree basal area was calculated as follows: ba = [π x (dbh^2)/40,000] (units = m^2). Tree volume was calculated as follows: vol = ba x mht x 0.65 (units = m^3), where mht is the merchantable bole height in meters. The 0.65 value is a presumed form factor that applies to all trees (JPSM 1997). In this paper, only trees with ≥ 10 cm dbh were analysed.

Several indices, including the Importance Value Index (IV_i) and Shannon-Wiener Diversity Index (*H'*), were calculated to determine species importance and species diversity in the study area. The IV_i was calculated by summing the values of relative density (*RD*), relative dominance (based on basal area; *RB*), and relative frequency (*RF*) of each species or family; the Shannon-Wiener Diversity Index (*H'*) was calculated using the following formula:

$$H' = -\sum_{i=1}^{s} p_i \ln p_i \quad ,$$

where

s = the number of species
p_i = the proportion of individuals or the abundance of the *i*th species expressed as a proportion of total abundance
ln = log base *e*

Forest Health

Forest health for dbh classes of 10–30 cm, 30–45 cm and ≥ 45 cm was determined by assessing crown illumination, crown shape, log grade and climber infestation. The classification system for forest health is based on a standard code developed by JPSM (1999).

Tree Biomass

We define tree biomass as the total amount of living organic matter in trees and express it as oven-dry biomass per unit area, usually in tonnes ha^{-1} (Brown 1997). Common equations used for estimating tropical tree biomass in Malaysia were developed by Kato *et al.* (1978), but these equations are more suitable for dry inland forests, as their study was conducted in a dry lowland forest at Pasoh FR. For PSF, Istomo (2006) has developed equations for biomass estimations from a study of PSFs in Sumatra; his equations are more suitable for use in this study than those of Kato *et al.* (1978), because they are based on a more similar forest type. The equations developed by Istomo (2006) and used in this study are as follows:

Biomass (above-ground) = 0.0145 (dbh^3) – 0.4659 (dbh^2) + 30.64 (dbh) – 263.32 (note: dbh in cm)

Biomass (below-ground) = 20.1% of biomass (above-ground)

Total plant biomass = biomass (above-ground) + biomass (below-ground)

RESULTS

Taxonomic Composition

A total of 376 trees were enumerated in the plot, encompassing 49 species in 38 genera and 25 families (Table 1). The most common family was Guttiferae with five genera and the most common genus was *Syzygium* with four species. In comparison, Grippin (2005) reported 67 species in 2156 ha from his post-felling inventories in Pekan FR, while Nizam *et al.* (2005) reported 113 species in PSF at Bebar of Pekan, Pahang.

Table 1: Species compositions (dbh ≥ 10 cm) in the plot at Compartment 100, Pekan FR.

No.	Species	Vernacular name	Family
1	*Aglaia rubiginosa* (Hiern) Pannell	Bekak	Meliaceae
2	*Beilschmiedia glabra* Kosterm.	Medang	Lauraceae
3	*Blumeodendron tokbrai* (Blume) J.J.Sm.	Gaham badak	Euphorbiaceae
4	*Brackenridgea palustris* Bartell.	Mata ketam	Ochnaceae
5	*Calophyllum ferrugineum* var. *ferrugineum* Ridl.	Bintangor gambut	Guttiferae
6	*Calophyllum sclerophyllum* Vesque	Bintangor jangkang	Guttiferae
7	*Campnosperma auriculatum* (Blume) Hook.f.	Terentang simpoh	Anacardiaceae
8	*Cratoxylum arborescens* (Vahl) Blume	Geronggang	Guttiferae
9	*Ctenolophon parvifolius* Oliv.	Mertas	Linaceae
10	*Dialium indum* var. *Indum* L.	Keranji paya	Leguminosae
11	*Diospyros lanceifolia* Roxb.	Kayu arang	Ebenaceae
12	*Diospyros maingayi* (Hiern) Bakh.	Kayu arang	Ebenaceae
13	*Durio carinatus* Mast	Durian paya	Bombacaceae
14	*Endiandra holttumii* M.R. Hend.	Medang	Lauraceae
15	*Ficus obscura* Blume	Ara	Moraceae
16	*Garcinia bancana* var. *Bancana* (Miq.) Miq.	Kandis	Guttiferae
17	*Garcinia nigrolineata* Planch. ex T. Anderson	Kandis	Guttiferae
18	*Gonystylus bancanus* (Miq.) Kurz	Ramin melawis	Thymelaeceae
19	*Gymnacranthera farquhariana var. eugeniifolia* (Hook.f. & Thomson) Warb.	Penarahan	Myristicaceae
20	*Horsfieldia crassifolia* (Hook.f. & Thomson) Warb.	Penarahan	Myristicaceae
21	*Ilex cymosa* Blume	Timah timah bulan	Aquifoliaceae
22	*Ilex macrophylla* Hook.f.	Timah timah bulan	Aquifoliaceae
23	*Koompassia malaccensis* Maing. ex Benth.	Kempas	Leguminosae
24	*Licania splendens* (Korth.) Prance	Kungkur	Leguminosae
25	*Litsea teysmannii* Gamble	Medang	Lauraceae
26	*Lophopetalum multinervium* Ridl.	Perupuk	Celastraceae

(continued on next page)

Table 1: *(continued)*

No.	Species	Vernacular name	Family
27	*Maclurodendron porteri* (Hook.f.) T.G. Hartley	Limau hutan	Rutaceae
28	*Myristica lowiana* King	Penarahan arang	Myristicaceae
29	*Nephelium maingayi* Hiern	Redan	Sapindaceae
30	*Palaquium ridleyi* King & Gamble	Nyatoh paya	Sapotaceae
31	*Parastemom urophyllus* (Wall. ex A. DC.) A. DC.	Nyalas	Rosaceae
32	*Polyalthia glauca* (Hassk.) F. Muell.	Mempisang	Annonaceae
33	*Polyalthia hypoleuca* Hook.f. & Thomson	Mempisang	Annonaceae
34	*Pometia pinnata* J.R. Forst. & G. Forst	Kasai	Sapindaceae
35	*Pouteria maingayi* (C.B. Clarke) Baehni	Nyatoh nangka merah	Sapotaceae
36	*Sandoricum beccarianum* Baill.	Sentul	Meliaceae
37	*Santiria laevigata* Blume	Kedondong kerantai licin	Burseraceae
38	*Santiria rubiginosa* Blume	Kedondong kerantai	Burseraceae
39	*Santiria tomentosa* Blume	Kedondong	Burseraceae
40	*Scutinanthe brunnea* Thwaites	Kedondong sengkuang	Burseraceae
41	*Shorea platycarpa* F. Heim	Meranti paya	Dipterocarpaceae
42	*Stemonurus secundiflorus* Blume	Sampul keris	Icacinaceae
43	*Syzygium inophyllum* (DC.) Roxb.	Kelat	Myrtaceae
44	*Syzygium kiahii* var. *kiahii* (M.R. Hend.) I.M. Turner	Kelat	Myrtaceae
45	*Syzygium lineatum* (DC.) Merr. & L.M. Perry	Kelat	Myrtaceae
46	*Syzygium napiforme* (Koord. & Valeton) Merr. & L.M. Perry	Kelat	Myrtaceae
47	*Tetramerista glabra* Miq.	Punah	Tetramaristicaceae
48	*Xylopia fusca* Maingay ex Hook.f. & Thomson	Banit kijang	Annonaceae
49	*Xylopia malayana* Hook.f. & Thomson	Jangkang	Annonaceae

Tree Distribution and Abundance

Table 2 shows data on the structure of trees ≥ 10 cm dbh in the plot. There were 376 stems with total basal area and volume of 35.04 m^2 and 325.83 m^3, respectively. Stocking density was highest in the dbh class of 10.0–24.9 cm, represented by 182 stems (48.4%). Basal area and volume were largest in the dbh class of 40.0–54.9 cm with 13.11 m^2 (37.4%) and 136.49 m^3 (41.9%), respectively. Generally, basal area and volume were also high in the dbh class of 55.0–69.9 cm, even though the stocking density was relatively low at only about 9.1% (34 stems) out of the total. Distribution of trees with dbh ≥ 10 cm in the 1 ha ecological plot at Compartment 100 are shown in Figure 2.

Table 2: Stand structure of trees by dbh classes in Compartment 100, Pekan FR.

Dbh class (cm)	Stem (stems ha^{-1})	Basal area (m^2 ha^{-1})	Volume (m^3 ha^{-1})
10.0 – 24.9	182 (48.4%)	3.93 (11.2%)	20.44 (6.3%)
25.0 – 39.9	84 (22.3%)	6.94 (19.8%)	65.17 (20.0%)
40.0 – 54.9	73 (19.4%)	13.11 (37.4%)	136.49 (41.9%)
55.0 – 69.9	34 (9.1%)	9.83 (28.1%)	92.97 (28.5%)
≥ 70.0	3 (0.8%)	1.23 (3.5%)	10.76 (3.3%)
Total	376 (100%)	35.04 (100%)	325.83 (100%)

Note: Number in parentheses denotes the percentage value.

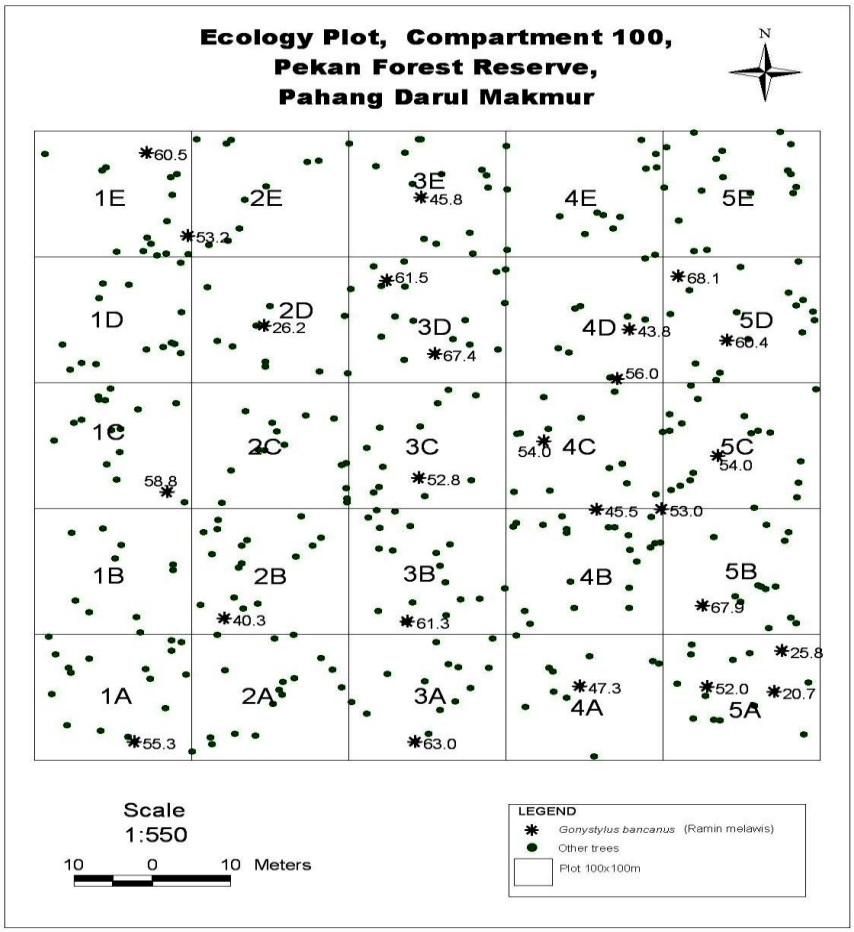

Figure 2: Distribution of all trees and *G. bancanus* of dbh ≥ 10 cm in the ecological plot at Compartment 100, Pekan FR.

The stand structure of all trees differed slightly from the typical reverse J-shape curve normally found in multi-aged and multi-species stands in the tropics (Fig. 3). Only few stems existed in the larger dbh classes (≥ 70 cm dbh). This pattern confirms that trees in the PSF are generally smaller than trees in the hill forests.

The Importance Value Index (IV_i) of the ten most abundant species of trees having dbh ≥ 10 cm is listed in Table 3. The three most abundant species were *C. ferrugineum* var. *ferrugineum* with IV_i of 22.23%, followed by *G. bancanus* with IV_i of 9.88% and *K. malaccensis* with IV_i of 5.87%. The IV_i of the top species, *C. ferrugineum* var. *ferrugineum*, was large compared to the other species, and was greater than that of *G. bancanus* (the second species in the list) by 12.35%.

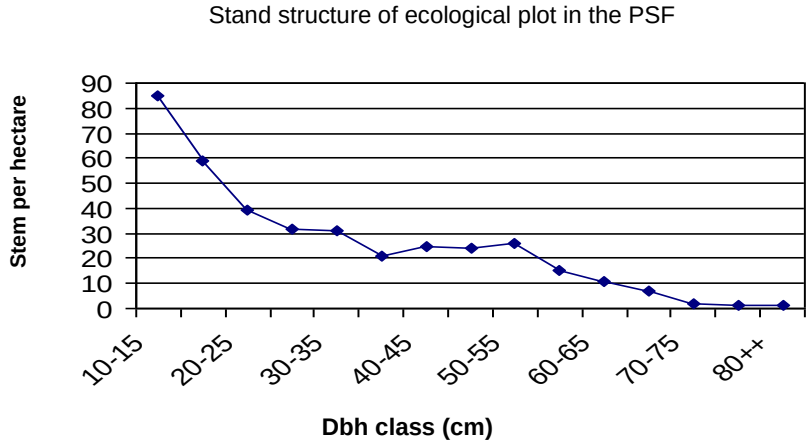

Figure 3: The stand size structure of the ecological plot in the PSF.

Table 3: Abundance of all species with dbh ≥ 10 cm in the plot based on the Importance Value Index (IV_i).

No.	Species	No. of individuals	Presence in each subplot	Basal area (m^2)	Volume (m^3)	IV_i (%)
1	*C. ferrugineum* var. *ferrugineum*	84	25	12.08	115.55	22.23
2	*G. bancanus*	25	18	5.57	72.40	9.88
3	*K. malaccensis*	19	15	2.33	25.02	5.87
4	*T. glabra*	19	8	3.05	16.59	5.64
5	*S. inophyllum*	28	17	0.76	3.19	5.44
6	*C. coriaceum*	18	11	2.17	19.62	5.11
7	*S. platycarpa*	13	10	1.08	10.42	3.50
8	*M. porteri*	14	11	0.55	3.33	3.21
9	*D. lanceifolia*	16	11	0.24	0.80	3.09
10	*S. rubiginosa*	12	11	0.39	2.21	2.88

Species Diversity

The Shannon-Wiener Diversity Index (*H'*) was 3.15 (H'_{max} = 3.89), as shown in Table 4. Nizam *et al.* (2005) reported a Shannon-Wiener Diversity Index value of 4.23 (H'_{max} = 4.73) in their study at Bebar PSF, Pekan FR. This confirms that the plot at Compartment 100 is less diverse than certain areas in the Pekan FR (Grippin 2005; Nizam *et al.* 2005).

Table 4: Diversity of the ecological plot.

Shannon-Wiener Diversity Index (*H'*)	3.15
Evenness	0.81
H'_{max}	3.89

Forest Health

Results in Table 5 demonstrate that all stand characteristics generally fall in Classes 1 and 2 (good and moderate categories), with the exception of crown illumination. For crown illumination, trees in the lowest dbh class has the highest percentage in Class 3 (85.6%), while the trees with dbh of 30–45 cm and ≥ 45 cm had the highest percentage in Class 1 (63.6% and 79.1%, respectively). The distribution of crown illumination by class showed some similarities to the relationship between dbh and class; where the area was densely populated, most of the trees received less illumination and grew under canopy. This also indicates that there is distinct vegetation structure in this ecosystem, comprised of the emergent layer with spreading crowns above the main canopy, the main canopy with continuous crowns under the emergent layer and the understory, which is made up of young poles, saplings and shrub. In terms of crown shape, more than 90% of the trees fell in the Class 1 category (complete crown) for all dbh classes. A similar result was found for log grade, where all size classes were most

strongly represented in Class 1. In this class, trees exhibit no stem defects and a straight bole to the first log length. In the climber infestation classification, most of the trees in all dbh classes (more than 77%) fell into Class 2, in which the presence of climbers is not a nuisance to the tree growth.

Table 5: Stand characteristics based on crown illumination, crown shape, log grade and climber infestation on trees by dbh class.

Parameters	Dbh class (cm)	Classification of tree characteristics					
		Class			Percentage (%)		
		1	2	3	1	2	3
Crown illumination*	10 – 30	19	12	184	8.8	5.6	85.6
	30 – 45	49	13	15	63.6	16.9	19.5
	≥ 45	68	8	10	79.1	9.3	11.6
Crown shape**	10 – 30	200	13	2	93.0	6.0	0.9
	30 – 45	77	0	0	100.0	0.0	0.0
	≥ 45	84	2	0	97.7	2.3	0.0
Log grade***	10 – 30	193	19	3	89.8	8.8	1.4
	30 – 45	76	1	0	98.7	1.3	0.0
	≥ 45	83	2	1	96.5	2.3	1.2
Climber infestation****	10 – 30	26	189	0	12.1	87.9	0.0
	30 – 45	16	60	1	20.8	77.9	1.3
	≥ 45	14	72	0	16.3	83.7	0.0

Note: *Crown illumination class, 1: receives full sunlight, 2: receives half partial sunlight, 3: receives light on the top of the crown only. **Crown shape class, 1: complete round, 2: incomplete round, 3: half round. ***Log grade class, 1: complete log with crown, 2: log broken 4.5 m from surface, 3: log broken below 4.5 m from surface. ****Climber infestation class, 1: no climber, 2: climber present with no impact to the tree, 3: climber present with some impact to the tree.

Tree Biomass

Biomass of trees with dbh ≥ 10 cm for the 1 ha plot in the Compartment 100 is shown in Table 6. The plot had a total tree biomass value of 414.57 tonnes ha^{-1}. The dbh class in the plot with the greatest total plant biomass was 40.0–54.9 cm with 153.22 tonnes ha^{-1}; the smallest was ≥ 70.0 cm with 18.26 tonnes ha^{-1}. Istomo (2006) has estimated of 280.12 tonnes ha^{-1} of total tree biomass in the PSF of Sumatra. Therefore, it can be concluded that, in general, the area has a relatively high amount of tree biomass.

Table 6: Tree biomass for all species in the plot at Compartment 100, Pekan FR.

Diameter class (cm)	Above-ground biomass (tonnes ha^{-1})	Below-ground biomass (tonnes ha^{-1})	Total tree biomass (tonnes ha^{-1})	Percentage (%)
10.0 – 24.9	32.11	6.74	38.85	9.4
25.0 – 39.9	62.21	13.06	75.27	18.2
40.0 – 54.9	126.63	26.59	153.22	37.0
55.0 – 69.9	106.58	22.38	128.96	31.1
≥ 70.0	15.09	3.17	18.26	4.4
Total	342.62	71.95	414.57	100.0

DISCUSSION

In comparison with data presented here, Grippin (2005) reported that 67 species were found in 2156 ha during his post-felling inventories at Pekan FR, while Nizam *et al.* (2005) reported 113 species in PSF at Bebar of Pekan, Pahang. Our survey showed the stand structure of all trees differs slightly from the typical reverse J-shape curve normally found in multi-aged and multi-species stand in the tropics (Fig. 3). Only a few stems of the larger dbh classes (≥ 70 cm dbh) were found during this study. The pattern confirms that trees in the PSF are generally smaller than trees in the hill forests. The IV_i of the top species, *C. ferrugineum* var. *ferrugineum*, was large compared to other species, and was greater than that of *G. bancanus* (the second species in the list) by 12.35%. Nizam *et al.* (2005) reported a Shannon-Wiener Diversity Index value of 4.23 (H'_{max} = 4.73) in his study at Bebar PSF, Pekan FR. This confirms that the plot at Compartment 100 is less diverse than certain areas in the Pekan FR (Grippin 2005; Nizam *et al.* 2005).

The distribution of crown illumination class showed some relationship with dbh class; where the area was densely populated, most of the trees received less illumination and grew under canopy. This also indicates that there is distinct vegetation structure in this ecosystem, comprised of the emergent layer with spreading crowns above the main canopy, the main canopy with continuous crowns under the emergent layer and the understory, which is made up of young poles, saplings and shrub. In terms of crown shape, more than 90% of the trees fall into the Class 1 category (complete crown) in all dbh classes. A similar result was also found for log grade, where all size classes were most strongly represented in Class 1. In this class, trees exhibit no stem defects and a straight bole to the first log length. In the climber infestation classification, most of the trees in all dbh classes (more than 77%) fell into Class 2, in which the presence of climbers is not a nuisance to tree growth. Istomo (2006) has estimated 280.12 tonnes ha^{-1} of total tree biomass in PSF of Sumatra. Therefore, it can be concluded that, in general, the area has a relatively high amount of tree biomass; about 414.6 tonnes ha^{-1}.

CONCLUSION

We recorded 49 tree species of dbh ≥ 10 cm, representing 38 genera and 25 families from a 1 ha ecological plot rich in *G. bancanus*. In general, the area is less diverse than other areas in the PSF. The three most abundant species in terms of the Importance Value Index (IV_i) were *C. ferrugineum* var. *ferrugineum*, *G. bancanus* and *K. malaccensis.* We found the forest to be generally healthy, as all stand characteristics (crown shape, log grade and climber infestation) fell mainly in Classes 1 and 2 (good and moderate categories), with the exception of crown illumination. The latter finding demonstrates that most of the trees living under the canopy received minimal illumination. We estimate a tree biomass of about 414.6 tonnes for this 1 ha area.

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