TRANSACTIONS ON SCIENCE AND TECHNOLOGY

Fern Diversity in Primary and Secondary Forests of Danum Valley and Ulu Segama Forest Complex, Lahad Datu, Sabah

Florina Anthony*, Luiza Majuakim & Monica Suleiman
Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah, Jalan UMS, 88400 Kota Kinabalu, Sabah, MALAYSIA.
*Corresponding author. E-Mail: florina23@ymail.com; Tel: +6013-5532996; Fax: +60-88 320291.

Received: *28 March 2016*
Revised: *4 April 2016*
Accepted: *27 April 2016*
In press: *10 May 2016*
Online: *30 June 2016*

Keywords:
Selective logging; Diversity; Composition; Biomass

Abstract
Due to the depletion of primary forests, secondary forests are becoming important to sustain biodiversity. Ferns are good indicators for forest quality as many species have specific ecological preferences. The aim of this study is to compare the diversity and composition of fern species between lowland primary and secondary forests. Secondary forests caused by logging activities are classified into secondary forest of high biomass and low biomass. Eight plots of 20 m × 20 m (400 m^2) were established in each forest type totaling to 24 plots. Twenty-six species of ferns belonging to 11 families were identified. Out of this, one species is new to Danum Valley which is *Leptochilus* cf. *decurrens*. Shannon-Wiener Index showed that secondary forest of high biomass (H'=2.49) have high species richness than primary forest (H'=2.03) and secondary forest of low biomass (H'= 2.07). Similarity Index was used to compare the diversity of three forest types and cluster analysis was used to show the grouping of the different forest types by using PAST (Paleontological Statistics) version 2.17. Secondary forest of high and low biomass showed high similarities. Higher species richness of ferns in the secondary forest of high biomass is due to the presence of many light demanding fern species. Thus, canopy opening may have influence the species diversity of ferns in secondary forests.

Introduction

Primary and secondary forests are two types of forest that differ in terms of species composition, vegetation structure, light condition, humidity and shaded area. Primary forests refer to largely old growth forests that have experienced little to no recent human disturbance (Gibson *et al.*, 2011). Most primary forests in tropical areas have high humidity, shaded area, low light condition and higher species composition than secondary forests. On the other hand, the state of secondary forest is not permanent because forest may recover from disturbance, depending on disturbance types, the time elapsed since disturbance and local site conditions. The opening of canopy in secondary forest has an adverse effect on the micro climate of the forest; temperature increases, humidity decreases, and more sunlight reach the forest floor. The forest composition changes as the more aggressive and light-demanding plants invade these open areas. Shade plants, including shade ferns, are phased out as climatic conditions become unsuitable for their survival.

Ferns can be specific to certain areas, thus the presence or absence of ferns is a good indicator to define primary or secondary forests. Previous study suggest that species richness of fern group may indicate forest habitat quality because this group of plants contain enough species that differ in habitat requirement with respect to the range of environmental factor that change when a forest is disturbed by human activities (Beukema & Nordwjck, 2007). In addition, species information of ferns is able to show the compositional patterns of other vascular plant species (Duque *et al*., 2005; Ruokolainen *et al*., 1997). Thus, ferns can be used to detect and forecast changes in the forest composition of an area. However, only a few studies on the impacts of forest disturbances on ferns communities have been conducted, and most of the studies were focused on edge effects or forest fragmentation towards fern communities.

Previous studies on ferns in Sabah focused mainly on distribution patterns and species inventories. Thus, this study aims to compare the diversity and composition of fern species between primary and secondary forests in Danum Valley and Ulu Segama forest complex.

Methodology

Study sites

Danum Valley and Ulu Segama forest complex is located at the South eastern part of Sabah. Danum Valley is classified as Class 1 (Protection) Forest Reserve, covering approximately 428km^2 of undisturbed forest and surrounded by the Ulu Segama Commercial Forest Reserves (203, 808 ha). It is situated approximately 80 km west of Lahad Datu, at 5'01'N; 117' E.

The study was carried out in two different forest types, primary and secondary forests; the secondary forest is classified into high biomass (selectively logged) and low biomass (cleared logged forest). Characteristics of the two study areas are similar in topographic features, with elevation ranging from 150 m to 230 m a.s.l (Marsh & Greer, 1992). The logged forest was selectively logged within 1988 to 1989. However, the logging activities in Ulu Segama Forest Reserve began in 1950s. All the logging activities had ceased completely in 2007.

Sampling design

There were three blocks of forest in the study site, whereby two blocks were in secondary forest and one in primary forest. The two blocks in secondary forest were selected based on forest biomass information of old secondary forest (high biomass) and highly degraded forest (low biomass). Each block contains eight plots, totaling to 24 plots. In each of the 24 sampling sites, one plot of 0.04 ha (20 × 20 m) was established and all the ferns species up to 2 m above the ground, including the epiphytes, were taken into consideration. Veining species and species with interwoven rhizomes were treated as one individual on a single tree or branch. Shannon-Wiener Index was used to estimate species diversity which incorporates richness while Similarity Index was calculated to determine the similarity between any two sites. Cluster analysis was used to classify the similarities of each samples of different forest types by using PAST (Paleontological Statistics) version 2.17 and the computer program "Species Richness and Diversity" (Henderson & Seaby, 1998) for the species richness analysis.

Results

A total of 476 individuals belonging to 26 species of ferns were recorded in all the 24 plots, of which 10 species were terrestrials and 16 were epiphytes (Table 1). There were 15 species of ferns in the primary forest (PF), 18 species in the secondary forest (SF) of high biomass, and 11 species in secondary forest of low biomass (Figure 1). Altogether there were 11 families of fern and the Polypodiaceae had the most species (7), while family Tectariaceae, Aspleniaceae and Dryopteridaceae only consisted of one species each. Shannon-Wiener diversity indices (H') also showed that the secondary forest of high biomass was more diverse (H'= 2.496) as compared to the secondary forest of low biomass (H' = 2.0797) and the primary forest (H' = 2.0297). Based on family classification, Tectariaceae had the highest number of individual count (103) followed by Pteridaceae (95) and Polypodiaceae (75) (Table 1).

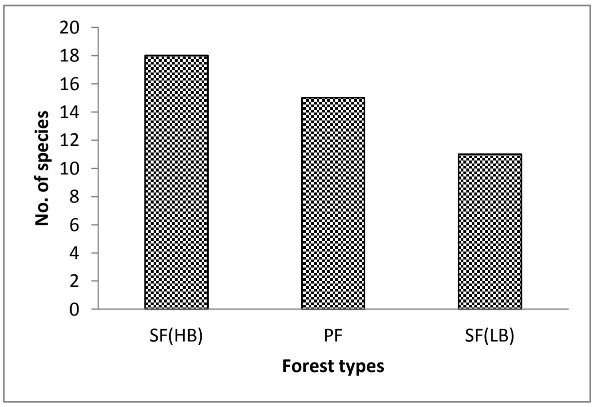

Figure 1. Number of species in each of forest types. PF – Primary forest, SF (HB) – Secondary forest (High biomass), SF (LB) – Secondary forest (Low biomass)

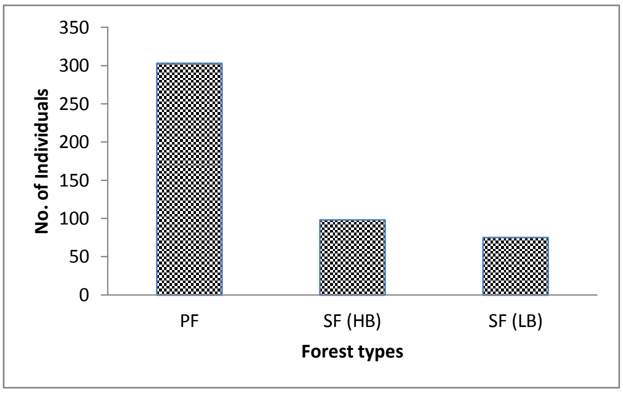

Figure 2. Total abundance of ferns in different forest types. PF – Primary forest, SF (HB) – Secondary forest (High biomass), SF (LB) – Secondary forest (Low biomass)

TRANSACTIONS ON SCIENCE AND TECHNOLOGY

The abundance of species showed a pattern of highly uneven distribution among the fern species. *Tectaria griffithii* (Tectariaceae) had the highest number with 103 individuals, followed by *Anthrophyum callifolium* (Pteridaceae) with 85 individuals and *Leptochilus* cf. *decurrens* with 62 individuals (Table 1). Interestingly, *Leptochilus* cf. *decurrens* is new to Danum Valley (Parris, 1997). The primary forest had the highest abundance totaling to 303 (63.66%) individuals, followed by the secondary forest with high biomass with 98 (20.59%) individuals and the secondary forest with low biomass with 75 (15.76%) individuals (Figure 2). This was supported by the rank abundance curve (Figure 3). High biomass secondary forest exhibited the longest tail of the curve which indicated that it was more diverse than primary forest and low biomass secondary forest in terms of species richness (Figure 3). The shortest tail was observed in low biomass secondary forest suggesting low species diversity as compared to the other two forest types. Primary forest had a steeper abundance curve compared to both categories of secondary forest (Figure 3). This indicated that primary forest was dominated by several species with high abundance. In contrast, the species dominance in each categories of secondary forest was more evenly distributed. Species accumulation curve showed the greatest number of species diversity in terms of abundance in primary forest. The species accumulation curve of primary forest had leveled higher compared to the secondary forest types (Figure 4). The curve of each forest type nearly reached an asymptote indicating that the sampling efforts are adequate to represent ferns communities in each forest types.

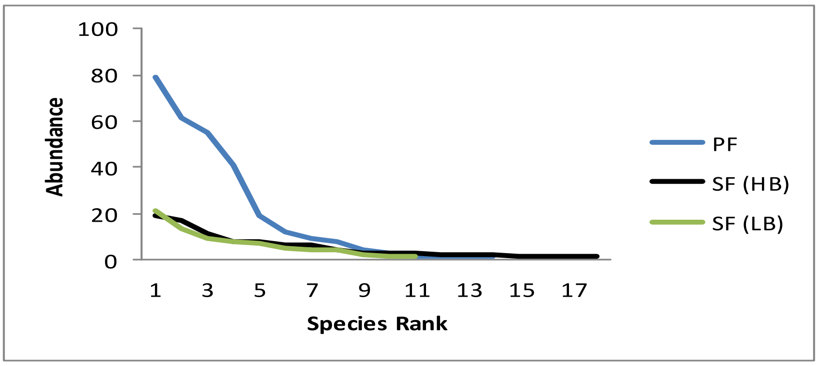

Figure 3. Rank abundance distribution of ferns in three forest types. The species was ranked in order from the most to the least abundant. PF – Primary forest, SF (HB) – Secondary forest (High biomass), SF (LB) – Secondary forest (Low biomass)

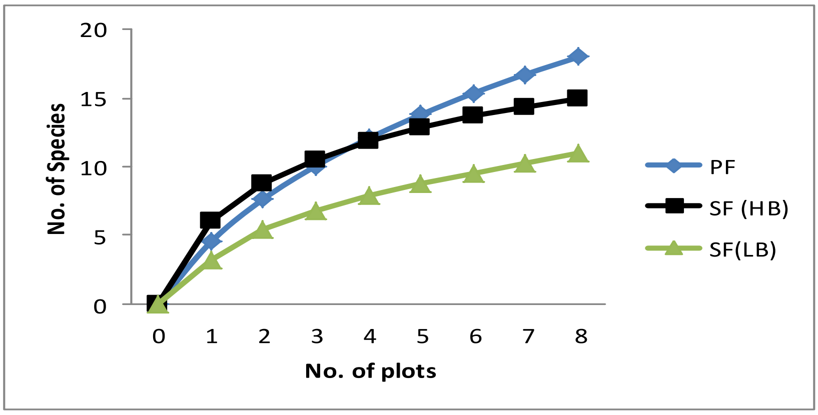

Figure 4. Species accumulation curve for three forest types. PF – Primary forest, SF (HB) – Secondary forest (High biomass), SF (LB) – Secondary forest (Low biomass)

ISSN 2289-8786. http://transectscience.org/

Table 1. Checklist and abundance of ferns species recorded in all forest types at Danum Valley/Ulu Segama forest complex

Species	Forest types			Total	Percentage (%)	
	PF	SF(HB)	SF(LB)			
Tectariaceae						**21.64**
Tectaria griffithii	79	11	13	103	21.64	
Pteridaceae						**19.96**
Antrophyum callifolium	61	17	7	85	17.86	
Adiantum latifolium	0	8	0	8	1.68	
Haplopteris elongata	0	0	2	2	0.42	
Polypodiaceae						**15.76**
Leptochilus cf. *decurrens*	55	6	1	62	13.03	
Christella quadrangularis	0	0	5	5	1.05	
Pyrrosia christii	0	3	0	3	0.63	
Phymatosorus membranifolius	0	2	0	2	0.42	
Lepisorus mucronatus	1	0	0	1	0.21	
Pyrrosia lanceolata	1	0	0	1	0.21	
Lepisorus longifolius	1	0	0	1	0.21	
Aspleniaceae						**12.39**
Asplenium phyllitidis	19	19	21	59	12.39	
Dryopteridaceae						**11.13**
Teratophyllum aculeatum	41	8	4	53	11.13	
Thelypteridaceae						**7.35**
Sphaerostephanos penniger	3	6	19	18	3.78	
Mesophlebion dulitense	12	1	0	13	2.73	
Sphaerostephanos heterocarpus	0	3	0	3	0.63	
Pronephrium menisciicarpon	0	1	0	1	0.21	
Davalliaceae						**3.15**
Davallia denticulata	8	4	0	12	2.52	
Davallia triphylla	0	3	0	3	0.63	
Athyriaceae						**3.15**
Diplazium cordifolium	9	0	4	13	2.73	
Diplazium crenatoserratum	0	2	0	2	0.42	
Hymenophyllaceae						**2.94**
Crepidomanes bipunctatum	8	1	0	9	1.89	
Didymoglossum mindorense	4	1	0	5	1.05	
Lygodiaceae						**1.89**
Lygodium longifolium	0	0	8	8	1.68	
Lygodium circinnatum	1	0	0	1	0.21	
Nephrolepidaceae						**0.63**
Nephrolepis falcata	0	2	1	3	0.63	
Total of individuals	**303**	**98**	**75**	**476**	**100**	

Similarity indices showed that the similarity between primary and secondary forests of high biomass was higher (0.734) than with the secondary forest of low biomass (0.584). On the other hand, the similarity between the secondary forest of high biomass and secondary forest of low biomass was high (0.786) compared to the primary forest (0.734). Cluster analysis was used to classify the similarities between species types and the 24 plots in Danum Valley and Ulu Segama forest complex (Figure 5). The dendogram showed 24 chains with three large groups. The first group consisted mainly of plots from low biomass secondary forest and plots from high biomass secondary forest. The second group included plots from primary forest and high biomass secondary forest whilst, the third group was formed mainly by primary forest plots.

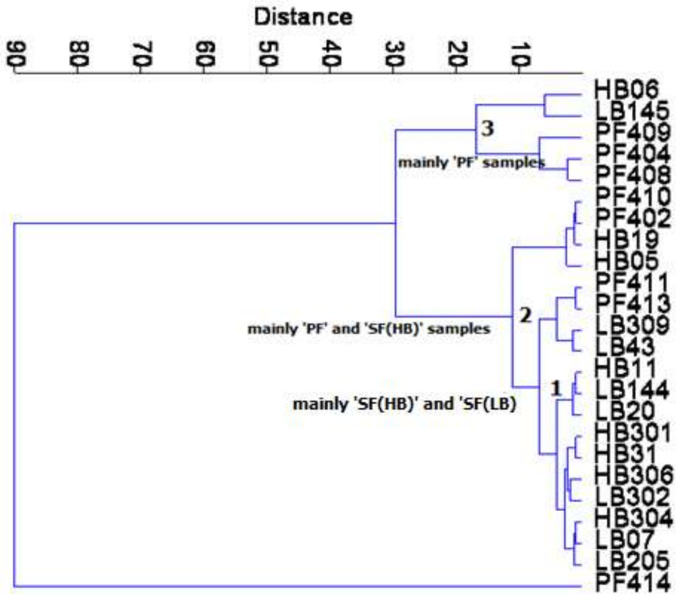

Figure 5. A dendrogram from the cluster analysis using species parameters data. PF – Primary forest, SF (HB) – Secondary forest (High biomass), SF (LB) – Secondary forest (Low biomass)

Discussion

Species diversity

Secondary forest of high biomass had shown higher species richness than other forest types in Danum Valley and Ulu Segama Forest Complex. This trend is similar to previous studies on plants in secondary forests due to logging activities. Cannon *et al*. (1994) reported that there was an increase in tree diversity eight years after selective logging in West Kalimantan, Indonesia. Similarly, Roberts & Gilliam (1995) found that herbs layer species diversity increased after disturbance on mesic sites, but shade-tolerant tree species decreased. They suggested that increase in resource availability, particularly light, in disturbed stand have influenced the species composition in disturb areas. In the present study, ecological factors such as canopy opening may have influenced the species diversity of ferns in the secondary forest. Nonetheless, primary forest has the highest abundance of fern communities as compared to the other types of forests. The abundance of the fern communities are influenced by water availability (Barrington, 1993) and most of the plots in the primary forest are located near water sources. The high abundance of ferns in the primary forest was due to the number of individuals of *Tectaria griffithii*, *Antrophyum callifolium* and *Leptochilus* cf. *deccurens*. These three species were present in all of the forest types but were found to be the most abundant in the primary forest. Thus, the lower species diversity in the primary forest could be due to these dominant species. The alteration of the canopy structure in the secondary forests may stimulate the growth of different fern species that is light demanding but not the abundance of fern communities. As a result, both of the secondary forests in the study site are low in species abundance. Thus, it is suggested that further study on the correlation between ecological factors and fern diversity should be conducted to clarify the high diversity in secondary forests.

Species composition

In the present study, secondary forest of high biomass had higher similarity to the secondary forest of low biomass than the primary forest. Both categories of secondary forests share similar environmental condition. Most of the fern species in the secondary forests are light demanding species. Logging had changed the canopy structure and altered the composition of the stand, reducing the number of shade tolerant species and stimulating light demanding species (Silva *et al.*, 1995). However, high biomass secondary forest harboured higher species richness than the secondary forest of low biomass. This is related to the age of the secondary forest and the logging technique used. The secondary forest of high biomass has regenerated for more than 25 years and was selectively logged. In comparison, the secondary forest of low biomass is still heavily degraded and has only regenerated for eight years as logging activities ceased only in 2007.

Classification of the plots based on species showed that the plots of the primary forest were clustered separately from plots of both categories of the secondary forest. This implies that most plots in primary forest have similar species of ferns. Nevertheless, a few plots from primary forest and secondary forest of high biomass were grouped together which indicated that these plots have similar species of ferns. A few plots in secondary forest of high biomass have similar environmental condition with primary forest in terms of canopy coverage and this has resulted in the grouping of these plots. Therefore, micro-level site differences pertaining to environmental conditions greatly influence the species diversity of regenerating forests whereby certain species prefer specific forest types whilst the more robust and adaptive fern species thrive in all forest types.

Conclusion

Old growth secondary forests caused by logging activities harbour more species of ferns than primary forest in Danum Valley and Ulu Segama Forest Complex. However, most of the species found are light demanding species. Ecological factors, such as humidity, temperature and canopy coverage may influence the species diversity of ferns. Thus, it is suggested that further study on the correlation between ecological factors and fern diversity should be conducted to clarify the high diversity in secondary forests.

Acknowledgements

We are thankful to the Sabah Foundation (Danum Valley Conservation Area) and Danum Valley Management Committee for the research permit and support in this study. We are also grateful for the help we received from the Royal Society who provided expertise and assistance in the field. We appreciate Mr. Markus Gubilil of Sabah Forest Research, Sabah Forestry Department, for his kind assistance in species verification. This research was supported by the Transdiciplinary Research Grant Scheme TRGS FTD0001-SWN-1/2013 from the Malaysian Ministry of Higher Education.

References

[1] Barrington, D. S. (1993). Ecological and historical factors in fern biogeography. *Journal of Biogeograph,* **20**, 275–80.

[2] Beukema, H. & Noordwick, M. V. (2004). Terrestrial pteridophytes as indicator of a forest-like environment in rubber production system in the lowlands of Jambi, Sumatra. *Agriculture, Ecosystem and Environment*, **104**, 63-73.

[3] Cannon, H. C., Peart, D. R., Leighton, M. & Kuswata, K. (1994). The structure of lowland rainforest after selective logging in West Kalimantan, Indonesia. *Forest Ecology and Management*, **67**, 49-68.

[4] Duque, A. J., Duivenvoorden, J. F., Cavelier, J., Sánchez, M., Polania, C. & León, A. (2005). Ferns and Melastomataceae as indicators of vascular plant composition in rain forests of Colombian Amazonia**.** *Plant Ecology*, **178**, 1–13.

[5] Gibson., Tien, M.L.,Lian, P.K.,Barry, W.B., Toby, A.G., Jos, B., Carlos A. P., Corey, J.A.B., William, F.L., Thomas, E.L., & Navjot, S.S. (2011). Primary forests are irreplaceable for sustaining tropical biodiversity. *Nature*, **478,** 378-381.

[6] Marsh, C.W. & Greer, A. G. (1992). Forest land-use in Sabah, Malaysia: An introduction to Danum Valley. *Philosophical Transactions of the Royal Society of London, Series B,* **335,** 331-339.

[7] Parris, B.S. (1997). A provisional check-list of pteridophytes from the Danum Valley, Sabah. *Sandakania*, **9**, 77-85.

[8] Roberts, M. R. & Gilliam, F.S. (1995). Disturbance effects on herbaceous layer vegetation and soil nutrients in *Populus* forests of northern lower Michigan. *Journal of Vegetation Science*, **6**, 903-912.

[9] Ruokolainen, K., Linna, A. & Tuomisto, H. (1997). Use of Melastomataceae and pteridophytes for revealing phytogeographical patterns in Amazonian rain forests. *Journal of Tropical Ecology*, **3** (2), 243-256.

[10] Seaby, R. M. & Henderson, P.A. (2006). *Species Diversity and Richness Version 4*. Lymington: Pisces Conservation Ltd.

[11] Silva, J. N. M, de Carvalho, J. O.P., Lopes, J do CA, de Almeida, BF, Costa, DHM, de Oliveira, LC, Vanclay, J. K & Skovsgaard, J. P. (1995). 'Growth and yield of a tropical rain forest in the Brazilian Amazon 13 years after logging'. *Forest Ecology and Management*, **71** (3), 267-274.