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Diversity and ecology of ferns on Mount Alab, Crocker Range Park, Sabah, Malaysia

L. MAJUAKIM* and F. ANTHONY

Abstract: This study was conducted to investigate the fern diversity in tropical montane forest of Mount Alab, Crocker Range Park, Sabah. A total of eight quadrats of 400 m^2 were set up in a line transect at an elevation of 1,800 m to 1,900 m above sea level. The quadrats were positioned at an interval of 100 m along a transect line that parallels a nature trail. The diversity index represented by Shannon Index, H', is 2.946, whereas the computed evenness index is 0.84. A total of 35 taxa belonging to 12 families of ferns were observed, representing 4.1% of the currently recorded 804 species of ferns in Sabah. Polypodiaceae and Hymenophyllaceae contributed the highest richness of species and were commonly found within the environment of the study area. Most of the species in these two families are epiphytes and thrive in cool moist habitats such as fallen logs and stumps, which provide suitable substrate and niches for epiphytic ferns. Polypodiaceae and Hymenophyllaceae were also dominantly abundant. *Selliguea taenita* (Polypodiaceae) was frequently observed and dominated most habitats as epiphytes and terrestrial ferns. Hymenophyllaceae is a potential indicator for climate change as species of this family are sensitive to desiccation caused by increased temperature. Fluctuation in abundance and species diversity of Hymenophyllaceae may provide a warning signs in the event of climate change such as global warming.

Key words: Species composition, tropical, montane, ferns and lycophyte.

INTRODUCTION

The ferns are distinctively of tropical origin (Mehltreter et al. 2010), and later spread all over the world. However, ferns can be found in abundance in tropical rainforest compared to the other areas. Ferns occur over a wide range of habitats, surviving in environments ranging from isolated mountainous areas to desert-like rock faces. Some species of ferns have narrow ecological niches, while others survive in an array of various habitats. Several fern species depend on moisture, temperature and shaded environment for growth. Such species are inadaptable to the changes in temperature, moisture and light exposure. Hence, ferns can be used as an indicator of their ecological niche. Moreover, ferns can be a good indicator of overall species diversity and richness of biodiversity as ferns provide the food resources to many herbivores. Ferns are also indicators for the quality of natural forest (Beukema and Noordwijk, 2004), because different species of ferns occupy different habitats. Some species that can adapt to environmental changes belong to the fern groups that usually dominate disturbed areas.

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Good quality forests defined by its pristine and undisturbed nature are usually associated with ferns which exhibit low tolerance level towards disturbance. A good quality of the forest should contain high individual of species of fern that are intolerant with the environmental changes. Fern can be used as an indicator to anthropogenic disturbance level of a forest. Therefore, the depletion of biodiversity can be revealed through continuous observation and monitoring of the status of the fern species.

Ferns are conspicuously found in moist cool environments, its abundance and richness peak at approximately 1,000–2,600 m above sea level in tropical regions (Kessler et al. 2001; Hemp 2002; Watkins et al. 2006). High humidity and annual precipitation in tropical forests are the contributing factors of fern richness and composition. In tropical Malaysia, with a range of varying altitude encompassing various forest types, 1,165 taxa of fern were recorded (Parris and Latiff, 1997; Maideen et al. 2011). Out of this number, a total of 647 taxa occur in Peninsular Malaysia. Said (2005) listed 804 species of fern for Sabah, of which the majority of the species amounting to 613 species were found in Kinabalu Park (Kessler et al. 2001). Montane areas in the tropics are haven for fern diversity study due to its various microclimates and distinct ecological niches. Over the past decades, ferns have gained much attention due to its potential as ecological indicators for forest health and disturbance, but limited explorations to inaccessible areas and expertise in the fern systematics render a slow progress in the documentation of the fern flora in Sabah. A historical account on the documentation and scientific collection of the biodiversity of the fern flora in Sabah was provided by Said (2005). In brief, fern studies evidently have been extensive for the past decades in Sabah. However, these studies covered only a substantial part of Sabah's natural forested areas through random collections and expeditions. Furthermore, the richness and composition of ferns have been studied extensively in certain areas only such as in Kinabalu Park (Parris et al. 1992; 1997b; Parris 1997c; Jaman and Latiff 1998; Beaman and Edward 2007).

Fewer studies on the fern flora have been conducted in Crocker Range Park, whilst it was almost non-existent for Mount Alab area. Parris et al. (1992) reported 157 species (derived from field observations and herbarium records) were found at an altitude of 300–1,800 m above sea level in the Crocker Range. Another documentation of fern flora in Crocker Range Park reported 174 taxa from 24 families which were based on collections and sight records at sites in elevational range of 400–1,800 m above sea level (Parris 1997a). The lower slopes of Mount Alab were included in the survey. The objective of our research is to determine the species diversity, composition and abundance of epiphytic and terrestrial ferns in Mount Alab using plot method. This study also endeavoured to provide information on the potential indicator species for forest microhabitats as well as forest quality.

MATERIALS AND METHODS

Study site

The study was conducted in Crocker Range Park, the site specifically located in the Mount Alab substation area. Crocker Range Park is located in the interior west coast of Sabah (5' 07' to 5' 56' N; 115' 50' to 116'28' E) (Figure 1). Crocker Range Park covers an area of 139,919 ha and consists of lowland forests at the lower elevation, while montane forests are prominent at higher elevation. Crocker Range Park is the largest terrestrial protected area in Sabah. The topography of this area is undulating with different elevation ranging 100 m– , 076 m above sea level. The highest peak is 2, 076 m above sea level on Mount Minduk Sirung, whereas Mount Alab area receives the highest annual precipitation (4,000 mm) in Crocker Range Park (Suleiman et al. 2007). This area has the highest humidity, making it a suitable habitat for many species of ferns to thrive. The vegetation in Mount Alab area is characterised as upper montane forest, however the ever presence of fogs is

reminiscent of a cloud forest feature. Mean annual temperature was 14.5ºC for the duration of April 2013–June 2014 for Mount Alab. The highest monthly temperature recorded was 22.3ºC in April 2014 and the lowest was 12.8 ºC recorded in January 2014.

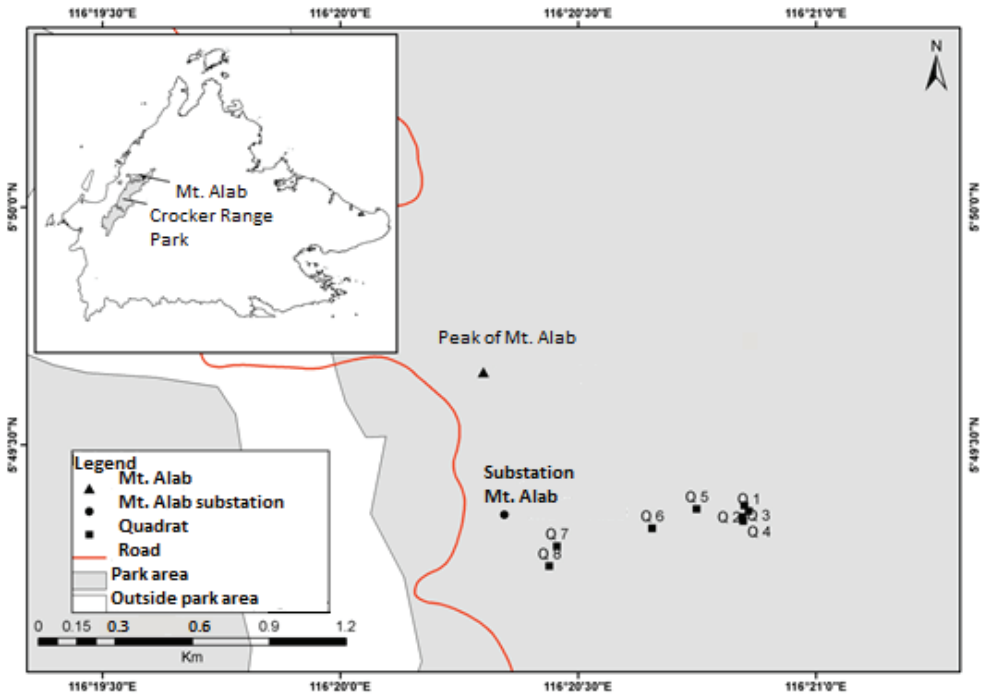

Figure 1. The location of the quadrats (Q1-Q8) undertaken in the study site. Inset map shows the location of Mount Alab and Crocker Range Park in Sabah.

Sampling methods and data analysis

Fieldwork was carried out between November 2012 and February 2013 in two consecutive periods of about two weeks. Eight quadrats of 20 x 20 m were established at an interval of 100 m along a transect line that runs alongside a nature trail, along an elevation gradient of 1,800–1,900 m above sea level. The 100 m elevation difference posed minimal elevational effects to the fern communities of the sampled area and maintained environmental factors and forest structure homogeneous within the quadrats. Each quadrat measured 400m^2 for a total of 3,200 m^2 for the eight quadrats, equivalent to 0.32 ha. The quadrats were subdivided into 16 subplots of 5m × 5m each. Edge effects were avoided by locating the plots at least >5 m away from forest edges and nature trails. A 400m^2 quadrat size is employed in many ecological and diversity studies of small vascular plants such as ferns (Kessler et al. 2001; Kluge et al. 2006; Krömer and Kessler 2006; Mandl et al. 2010; Kludge and Kessler 2010). The quadrat size also corresponds to the minimum requirement that is needed to compare species richness in a neotropical montane forest (Kessler and Bach 1999) and is applicable to tropical regions with similar environment.

All terrestrial individuals rooted to the ground were enumerated, whereas only the presence of low-trunk epiphytes occurring less than 1 m above ground level was recorded. Species, altitude, substrates and habit of the fern individuals were recorded. Two complete and fertile specimens were collected as voucher specimens. Voucher specimens were deposited in the Sabah Park Herbarium (SNP) located at Kinabalu Park, and in the University Malaysia Sabah Herbarium (BORH).

The cumulative number of fern species recorded in the study site was plotted as a function of sampling effort. Species richness estimates and completeness were computed based on three species richness estimators (Chao 1, Jacknife- 1st Order, and ACE). Species diversity was quantified using the Shannon Diversity Index (H'), an index which is commonly used to characterize species diversity in a community. Evenness or equitability was also calculated. Indices were computed using the software program Species Diversity Richness version 4.0 (Seaby and Henderson 2006). Classification for family of ferns followed Christenhusz et al. (2011) and Rothfels et al. (2012). Species name and authority of ferns followed the nomenclature in the Checklist of Ferns and Lycophytes of the World Version 5.61 (https://worldplants.webarchiv.kit.edu/ferns/).

RESULTS

A total of 1,452 individuals of fern were sampled in eight quadrats which cover ca. 0.32 ha. We also carried out random collections of ferns outside the quadrats, around the vicinity of Mount Alab substation. This resulted in an addition of two taxa represented by *Cyathea cf. lurida* and *Cyathea sp*. The ferns collected belong to 12 families, 20 genera, 35 taxa of ferns (Table 1). The species composition of fern in Mount Alab area represents 4.1% of all fern taxa in Sabah, and 20% of the current fern flora of Crocker Range Park. *Selliguea taeniata*, *Diplazium sp.*, *Hymenophyllum emarginatum* and *Calymmodon gracilis* were found in abundance among the top ten dominant species, whereas the least abundant species (< 5 individual) were *Elaphoglossum heterolepium, Selliguea albidosquamata and Xiphopterella hieronymusii* (Figure 2). The fern families Hymenophyllaceae and Polypodiaceae were the most speciose groups contributing about 52% of the recorded species. Hymenophyllaceae and Polypodiaceae were represented by nine species and eight species respectively (Figure 3). Each family comprised three genera and five genera respectively. The least speciose families were Aspleniaceae, Tectariaceae, Pteridaceae, Plagiogyriaceae and Thelypteridaceae, each represented by a single species.

Table 1. The checklist of fern species in Mount Alab, Crocker Range Park. (*E: epiphytes*; *T: Terrestrial*; * species observed outside the sampling plots).

FAMILY	SPECIES	LIFEFORM
Aspleniaceae	*Asplenium normale* D. Don	T
Athyriaceae	*Diplazium cordifolium* Blume	T
	Diplazium sp.	T
Cyatheaceae	*Cyathea cf. lurida* (Blume) Copel.	T
	Cyathea sp.	T
Davalliaceae	*Davallia denticulata var. denticulata* (Burm. f.) Mett. ex Kuhn	T
	Davallia hymenophylloides (Blume) Kuhn	T
	Davallia repens (L.f.) Kuhn	E
Dryopteridaceae	*Dryopteris nodosa* (C.Presl) Li Bing Zhang	T
	Elaphoglossum heterolepium Alderw.	E
	Elaphoglossum stenolepis Bell ex.Holtt.	T
Hymenophyllaceae	*Abrodictyum obscurum* (Blume) Ebihara & K. Iwats.	T
	Abrodictyum pluma (Hook.) Ebihara & K. Iwats.	T
	Crepidomanes bipunctatum (Poir.) Copel.	E
	Hymenophyllum pallidum (Blume) Ebihara & K. Iwats.	E
	*Hymenophyllum carduncul*us C. Chr.	E
	Hymenophyllum denticulatum Sw.	E

	Hymenophyllum emarginatum Sw.	E
	Hymenophyllum holochilum (Bosch) C. Chr.	E
	Hymenophyllum microchilum (Bak.) C. Chr.	E
Lindsaeaceae	*Lindsaea doryphora* Kramer	T
	Lindsaea rigida J. Sm.	T/E
	Osmolindsaea odorata (Roxb.) Lehtonen & Christenh.	T
Plagiogyriaceae	*Plagiogyria adnata* (Blume) Bedd.	T
Polypodiaceae	*Calymmodon gracilis* (Fée) Copel.	E
	Oreogrammitis reinwardtioides (Copel.) Parris	E
	Prosaptia obliquata (Blume) Mett.	E
	Prosaptia venulosa (Blume) M. G. Price	E
	Selliguea albidosquamata (Blume) Parris	E
	Selliguea murudensis (C. Chr.) Parris	E
	Selliguea taeniata (Sw.) Parris.	T/E
	Xiphopterella hieronymusii (C. Chr.) Parris	E
Pteridaceae	*Antrophyum callifolium* Blume	E
Tectariaceae	*Tectaria wigmanii* (Racib.) S. Y. Dong	T
Thelypteridaceae	*Coryphopteris gymnopoda* (Bak.) Holtt.	T

In terms of family dominance based on abundance (number of individuals), in descending order, Polypodiaceae, Hymenophyllaceae, Athyriaceae and Lindsaeaceae were observed to contribute the greatest abundance in the study area (Figure 4). Concurrently, species rich Polypodiaceae and Hymenophyllaceae were abundant and widespread throughout the area. On the other hand, less diverse family Athyriaceae with only two species were also found to be relatively abundant in the study area. Pteridaceae and Thelyteridaceae, each represented by a single species, were less abundant.

More than half of the species encountered were epiphytic ferns, whereas 14 species were dominantly terrestrial. Two species were both epiphytic and terrestrial ferns, namely, *Lindsaea rigida* and *Selliguea taeniata*. Most of the species observed in the families Hymenophyllaceae and Polypodiaceae were obligate epiphytic ferns which conspicously covered tree trunks and branches.

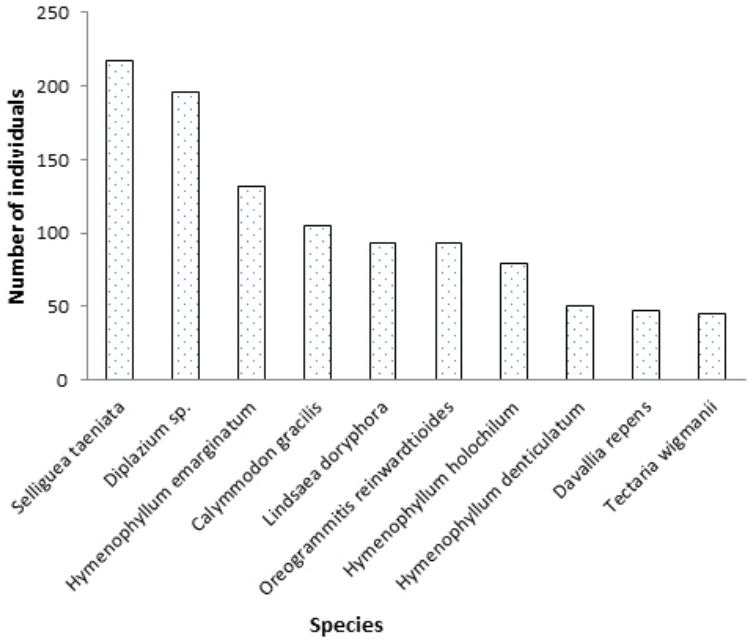

Figure 2. The top ten dominant species of ferns in terms of abundance.

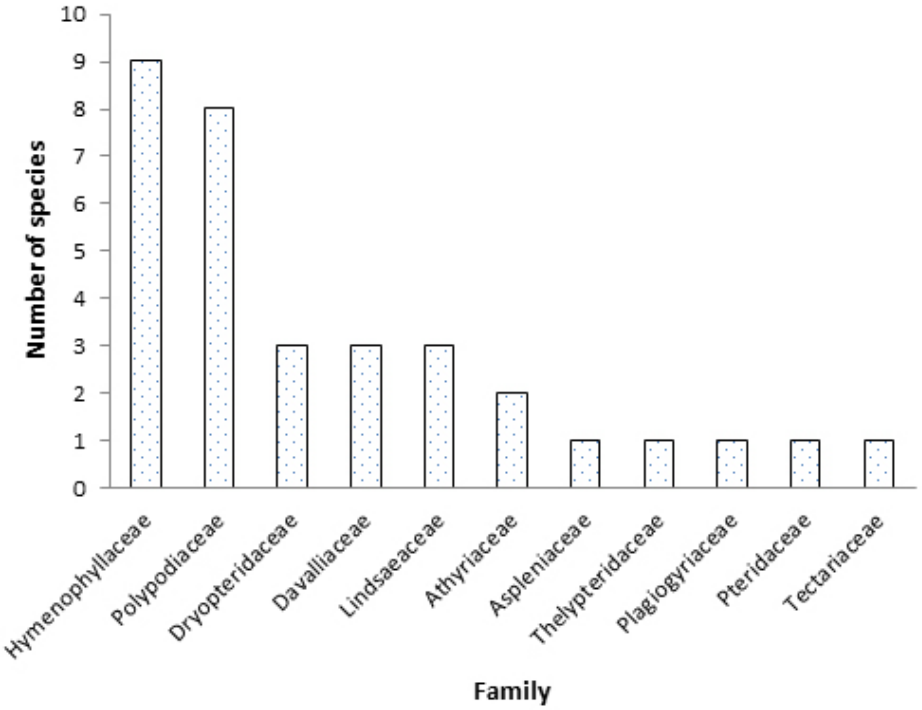

Figure 3. Species richness of fern families.

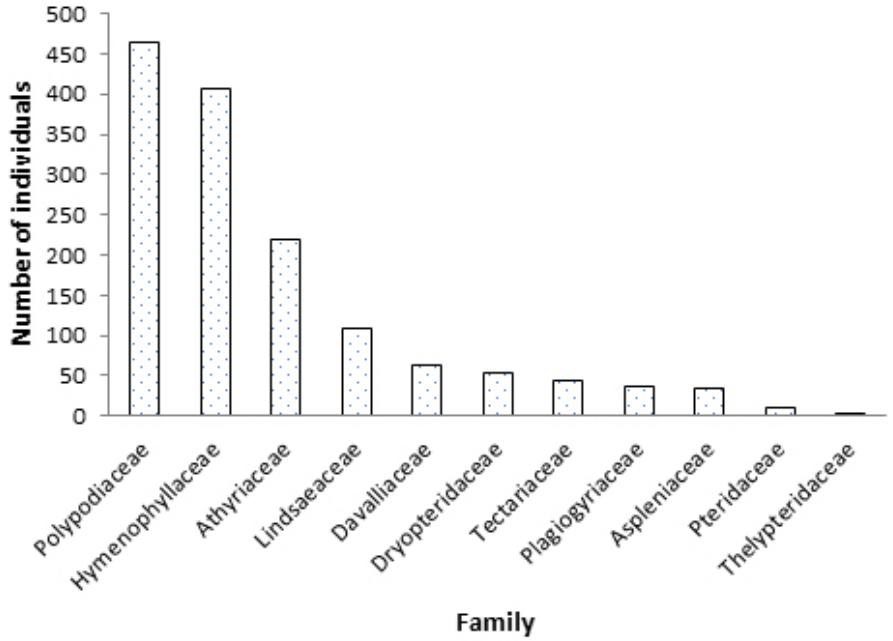

Figure 4. Family dominance in terms of abundance.

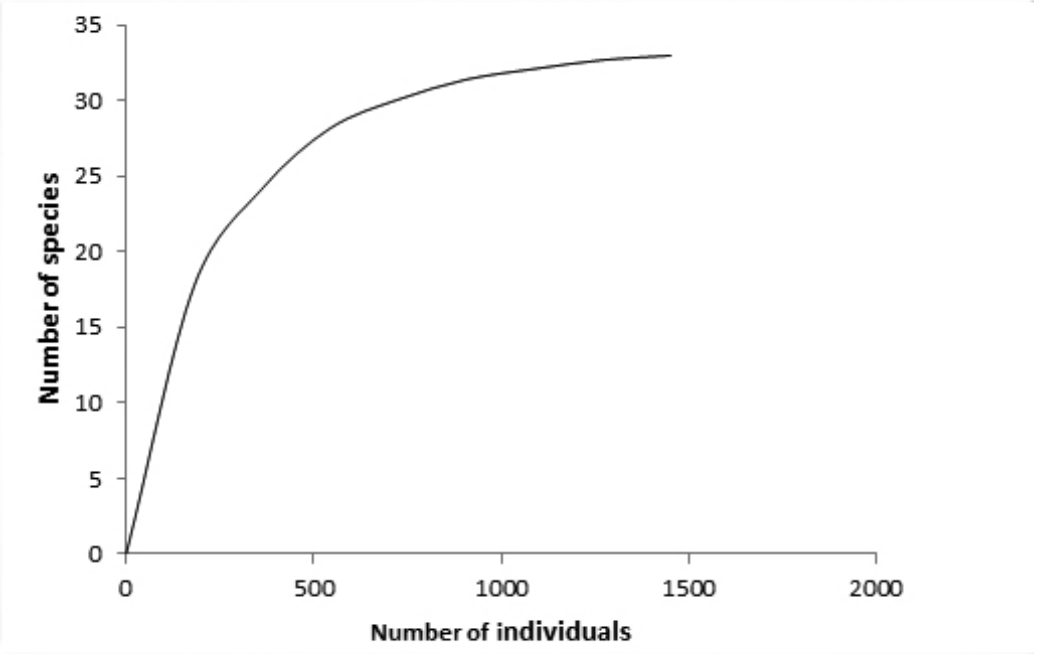

Figure 5. Species accumulation curve based on sampling of ferns in eight 400m^2 quadrats at Mount Alab

Shannon's diversity index (H') was 2.946 whereas the Shannon's evenness index (H_E) was 0.84. The species accumulation curve as a measure of sampling effort showed a curve arriving at a plateau as the cumulative abundance reached the maximum total sampled individuals (Figure 5). The actual abundance of sampled individuals in this study was 1,452 belonging to 33 taxa of ferns (the total inventoried taxa were 35 of which two taxa were collected outside the sampling plots). Three species richness estimates (Chao 1, Jacknife- 1st Order, and ACE) were calculated and this resulted in an estimate of 33-35 expected numbers of species to be found for the study site, whilst sample completeness was above 90% for the three estimators (Table 2).

Table 2. Species richness estimates and completeness based on three species richness estimators (Chao 1, Jacknife- 1st Order, and ACE) for Mount Alab.

Number of species observed	33.00
	Estimated species richness
Chao 1	33.00
Jacknife (1st Order)	35.63
ACE	33.00
	Sample completeness (%)
Chao 1	100.00
Jacknife (1st Order)	92.6
ACE	100.00

DISCUSSION

Most of the fern species found in Mount Alab are primarily montane forest inhabitants with several rare species utilizing specific ecological niches. The montane forest is well known as the centre of fern diversity in many tropical regions, however, the zone of high fern diversity depends on the geographical location of the region in the tropics and the highest mountain peak for a particular site (Parris et al. 1992; Kessler et al. 2001; Hemp 2002; Watkins et al. 2006). According to Parris et al. (1992) and Kessler et al. (2001), a more pronounced peak of species richness occurred at 1,500 m above sea level on Mount Kinabalu, which is the highest mountain peak in the Crocker Range. The study site at Mount Alab is located about 300 – 400 m above the 'hotspot' zone of fern diversity which explains the moderate diversity of fern community as implicated by the Shannon's diversity index. Although, increase in elevation contributes to increase in species richness, composition and dominance of fern communities, the fern diversity levels off after reaching a saturated diversity zone (Kludge and Kessler 2010; Watkins et al. 2006). Hence, a concomitant decrease in species richness is expected at elevation higher than 1,500 m above sea level in the Crocker Range Park. A plateau or even a decrease of species richness may have occurred at Mount Alab area.

The occurrence of epiphytic ferns is generally more pronounced in montane tropical forests compared to the lowlands, and in this regards, Watkins et al. (2006) found that species richness of epiphytic ferns peaked at 1,000 m above sea level whilst terrestrial ferns were evenly distributed along increasing elevational gradient. In contrast, species richness of both epiphytic and terrestrial ferns peaks at 1,500 m above sea level and decreases with increasing elevation on Mount Kinabalu (Parris et al. 1992). The majority of epiphytic ferns, tree ferns and filmy ferns were distributed in a zone that coincided with the maximum rainfall on Mount Kilimanjaro in tropical Tanzania (Hemp 2002). On Mount Alab, ferns consisted of epiphytic and terrestrial life forms, the filmy ferns (Hymenophyllaceae) being the dominant group. We did not observe any tree ferns in our sampling plots, nonetheless, several tree ferns were found in opened areas near the roadside of the Mount Alab substation. The forests on Mount Alab display an environment similar to tropical cloud forests with limited duration of sunlight and prevalent fog throughout the day. These factors coupled with high rainfall promote the existence and growth of filmy ferns and other epiphytic ferns. In addition, a habitat filled with fallen logs and stumps provide suitable substrate for epiphytes (Watkins et al. 2006), a condition which was observed within the study site.

Epiphytic species of the Hymenophyllaceae have developed certain strategies to compensate for their lack of dominance on the forest floor. These species display a reduction of the root system and frond size resulting in dwarfism, an extreme hygrophilous epiphytic strategy (Dubuisson et al. 2003; Dubuisson et al. 2009). Even some species, especially in the genus *Hymenophyllum*, are poikilohydric and able to withstand short periods of desiccation (Benzing 1990; Iwatsuki 1990). The membranous fronds of the filmy ferns show little decay or damage indicating their high disease resistance despite suitable conditions for microbial growth (Page 2002).

The species *Calymmodon gracilis* and *Oreogrammitis reinwardtioides* of the family Polypodiaceae (previously grammitids were classified in Grammitidaceae) were also found in abundance at the study site. The success of grammitids and filmy ferns species to conquer the many niches in the study site was facilitated by long distance dispersal of their spores. Species with long living gametophytes are favoured in the context of living as epiphytes (Dubuisson et al. 2009). This also holds true for Hymenophyllaceae because long-living gametophyte increases the probability of cross-fertilization by gametes from distinct gametophytes (Dassler and Farrar 2001), and thus increase the fitness of the related organism. The most abundant species was *Selliguea taeniata* (Polypodiaceae) due to the fact that this particular species existed as epiphyte and terrestrial lifeform. Both terrestrial and epiphytic ferns use wind as the main dispersal agent. But species having both lifeforms, as epiphytic and terrestrial fern, possess an advantage over others with a single life form. *Selliguea taeniata* has the potential to disperse at a wider range and distance, which provides a competitive advantage for the species in colonizing new niches.

Different species of ferns have different range of distribution along the elevational gradient, depending on their ecological requirements. Some species can survive shaded and humid environment whilst others thrive in the open area with unlimited abundance of sunlight. Hence certain species may not adapt to extreme environmental changes. Because of this factor, ferns can

be used as an indicator for montane forest zonation and change in abiotic parameters (Banaticla and Buot 2005). For instance Hymenophyllaceae is a prominent feature of montane cloud forests at mid elevation in the tropical regions. Forests at higher altitude are particularly susceptible to climate change. Effective management of these forests therefore needs an efficient early warning detection system that signals changes in forest condition. Using ecological indicators especially epiphytic ferns of Hymenophyllaceae to monitor climate change is a low-cost alternative. Since *Hymenophyllum emarginatum* is a common constituent of the forest on Mount Alab and due to its limited tolerance to low humidity, this species can be regarded as an ecological indicator for climate change for this area. Monitoring abundance of this species may provide information about the climate condition of the forest.

The plateau in the species accumulation curve indicated that sampling of ferns was sufficient in the study site. This was supported by the three species richness and sample completeness estimates. However, adding several more quadrats may capture a few more species and result in a slightly increase species richness. Nevertheless, we believe that our results for the diversity of ferns are representative of the fern community on Mount Alab. Further studies are necessary to identify specific fern species or groups that can be potentially used as ecological indicators for climate change, disturbance and forest zones.

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REFERENCES

Banaticla, M.C.N. and Buot Jr, I.E. 2005. Altitudinal zonation of pteridophytes on Mt.Banahaw de Lucban, Luzon Island, Philippines. *Plant Ecology* 180: 135-151.

Beaman, J.H. and Edward, P.S. 2007. *Ferns of Kinabalu: An Introduction*. Kota Kinabalu: Natural History Publication (Borneo).

Benzing, D.H. 1990. *Vascular epiphytes. General biology and related biota*. Cambridge: Cambridge University Press.

Beukema, H. and 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.

Christenhusz, M.J.M., Zhang, X-C. and Schneider, H. 2011. A linear sequence of extant families and genera of lycophytes and ferns. *Phytotaxa* 19: 7-54.

Dassler, C.L. and Farrar, D.R. 2001. Significance of gametophyte form in long-distance colonization by tropical epiphytic ferns. *Brittonia* 53: 352–369.

Dubuisson, J.Y., Hennequin, S., Rakotondrainibe, F. and Schneider, H. 2003. Ecological diversity and adaptive tendencies in the tropical fern Trichomanes L. (Hymenophyllaceae) with special reference to epiphytic and climbing habits. *Botanical Journal of the Linnean Society* 142: 41-63.

Dubuisson, J-Y., Schneider, H. and Hennequin, S. 2009. Epiphytism in ferns: diversity and history. *Comptes Rendus Biologies* 332: 120-128.

Hemp, A. 2002. Ecology of the pteridophytes on the southern slopes of Mt. Kilimanjaro. *Plant Ecology* 159: 211-239.

Said, I. M. 2005. A preliminary checklist of the pteridophytes of Sabah. *Journal of Tropical Biology and Conservation 1: 47-69.*

Iwatsuki, K. 1990. Hymenophyllaceae. In Kubitzki. K. (ed.). *The families and genera of vascular plants, Vol. I. Pteridophytes and gymnosperms*. pp. 157-163, Berlin: Springer-Verlag.

Jaman, R. and Latiff, A. 1995. On some pteridophytes from Sayap-Kinabalu Park, Sabah. In Ismail, G. and Din, L.B.(eds.). *Scientific journey through Borneo*: Sayap-Kinabalu Park Sabah. pp. 67-104, Subang Jaya: Pelanduk Publications.

Kessler, M. 2001. Pteridophytes species richness in Andean forest in Bolivia. *Biodiversity and Conservation* 10: 1473-1495.

Kessler, M. and Bach, K. 1999. Using indicator groups for vegetation classification in species rich Neotropical forests. *Phytocoenologia 29*: 485-502.

Kessler, M., Parris, B.S. and Kessler, E. 2001. A comparison of the tropical montane Pteridophytes flora of Mount Kinabalu, Borneo and Parane National Carrasco, Bolivia. *Journal of Biogeography 28*: 611-622.

Kludge, J. and Kessler, M. 2010. Influence of niche characteristics and forest type on fern species richness, abundance and plant size along an elevational gradient in Costa Rica. *Plant Ecology* 212: 1109-1121.

Kludge, J., Kessler, M. and Dunn, R. 2006. What drives elevational patterns of diversity? A test of geometric constraints, climate, and species pool effects for pteridophytes on an elevational gradient in Costa Rica. *Global Ecology and Biogeography* 15: 358-371.

Krömer, T. and Kessler, M. 2006. Filmy ferns (Hymenophyllaceae) as high-canopy epiphytes. *Ecotropica* 12: 57-63.

Maideen, H., Zuraidah, A., Damanhuri, A., Latiff, A. and Rusea, G. 2011. Diversity and habitat of pteridophytes in Gunung Angsi Forest Reserve, Negeri Sembilan. *Sains Malaysiana* 40: 1341-1344.

Mandl, N., Lehnert, M., Kessler, M. and Gradstein, S.R. 2010. A comparison of alpha and beta diversity patterns of ferns, bryophytes and macrolichens in tropical montane forests of southern Ecuador. *Biodiversity and Conservation* 19: 2359-2369.

Mehltreter, K., Walker, L.R. and Sharpe, J.M. 2010. *Fern Ecology*. New York: Cambridge University Press.

Page, C. N. 2002. Ecological strategies in fern evolution: A neopteridological overview. *Review of Palaeobotany and Palynology* 119(1): 1-33.

Parris, B.S. 1997a. A provisional checklist of pteridophytes from the Crocker Range National Park, Sabah. *Sandakania* 9: 103-111.

Parris, B.S. 1997b. New pteridophyte records from Mount Kinabalu. *Sandakania* 9: 87-88.

Parris, B.S. 1997c. The ecology and phytogeography of Mount Kinabalu pteridophytes. *Sandakania* 9: 89-102.

Parris, B. S. and A. Latiff. 1997. Towards a pteridophyte flora of Malaysia : A provisional checklist of taxa. *Malayan Nature Jounal* 50 : 235-280

Parris, B.S., Beaman, R S. and Beaman, J.H. 1992. *The Plant of Mount Kinabalu*. Kew: Royal Botanic Garden.

Rothfels, C.J., Michael, A., Sundue, L-Y. K., Larsson, A, Kato, M., Schuettpelz, E. and Pryer, K.M. 2012. A revised family-level classification for eupolypod II ferns (Polypodiidae: Polypodiales). *Taxon 61* (3): 515-533.

Seaby R. M. and Henderson, P.A. 2006. *Species Diversity and Richness Version 4*. Lymington: Pisces Conservation Ltd.

Suleiman, M., Ishida, H., Spait, M., Said, I.M., Sugawara, A. and Repin, R. 2007. *The Introduction to the Crocker Range Park Permanent Research Plot Project*. Kota Kinabalu: Institute for Tropical Biology and Conservation (ITBC), Universiti Malaysia Sabah.

Watkins Jr., J.E., Cardelus, C., Colwell, R.K. and Moran, R.C. 2006. Species richness and distribution of ferns along an elevation gradient in Costa Rica. *American Journal of Botany* 93: 73-83.