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Distribution, Diversity and Abundance of Ferns in A Tropical University Campus

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ABSTRACT

This study assessed the diversity and abundance of ferns species in ten 10 m × 10 m plots which were established each, in less disturbed forest, most-disturbed forest and urbanized areas within the main campus of Universiti Sains Malaysia. Distance of at least 50 m was maintained between plots in each study site. The life forms of the fern species were documented together with their relative abundances. Also, diversity indices of the study sites such as Shannon index, Simpson index, Margalef index and Fisher's alpha were determined. Non-asymptotic rarefaction-extrapolation analysis was carried out to determine the significance differences between the species richness of each study site. One way anova using pairwise permutation test was done to determine the significance differences between the diversity indices in the sites. A total of twenty-three fern species belonging to 14 families were identified. The most abundant ferns are *Lindsaea napaea* (63.4% in less-disturbed forest), *Pyrrosia lanceolata* (36.0% in most-disturbed forest and 47.0% in urbanized area). Urbanized area was observed to have more epiphytic ferns while less-disturbed forest was more popupated by terrestrial ferns. The most accommodating host tree with the highest number of epiphytic fern species is *Samanea saman.* The result of rarefaction-extrapolation analysis showed that less-disturbed forest is significantly richer in species than the other sites while the diversity indices of more-disturbed forest and urbanized area are significantly higher than less-disturbed forest. This was attributed to the common fern species which were found almost in all plots sampled in the more-disturbed sites. The Shannon index in all the sites was less than 2. Therefore,

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Universiti Sains Malaysia campus having a low diversity of ferns could be regarded as a disturbed environment due to the high level of developments in it.

Keywords: Diversity, ferns, Malaysia, *Pyrrosia lanceolata*, *Samanea saman*

INTRODUCTION

Ferns and fern-allies are known as seedless vascular plants in the plant kingdom Pteridophyta. Their body structures are differentiated into roots, stems, fronds and pinnae similar to other vascular plants. These groups of plants are cryptogamic in that they do not produce flowers, seeds and fruits and this differentiate them from higher plants. They are also similar to bryophytes and algae in their mode of reproduction by spores, but differ from them by possessing vascular tissues (Yusuf, 2010). Most ferns are found to occupy lower altitudes of tropical forests whereas they may also colonize the understories of some temperate forests (Rost, Barbour, Stockinga, & Murphy, 2006). About 4400 ferns species have been recorded in South East Asia out of which 1165 species were found from the Malaysian tropical rain forest (Parris & Latiff, 1997; Roos, 1996).

Malaysia, especially some parts of Penang State is well endowed with a wide diversity of ferns because the vegetation lies within tropical rain forests. An activity such as logging which has dominated Malaysia forests has constituted a great threat to the survival of these ferns (Saw & Chung, 2007). This coupled with insufficient information on plant species composition, distribution and their conservation in Malaysia made their study highly imperative. One other aspect that has been neglected in most researches is the economic uses of ferns (Yusuf, 2010). Beside their invaluable impact on the global plant diversity, ferns have been discovered to be good sources of medicine, food, aesthetics and fuel (Akomolafe & Sulaimon, 2018; Benjamin & Manickam, 2007; Jaman & Yusuf, 2010). Ferns also have the ability to clean the environment polluted with various heavy metals through a process called phytoremediation (Akomolafe, Dedeke, & Sirajo, 2013; Oloyede, Akomolafe, & Odiwe, 2013). Over the years, studies have also focused on their taxonomy and mere inventory while researches on using quantitative methods to determine their distributions and diversities are rare in Malaysia probably because of their cryptogamic nature.

In South East Asia, where Malaysia belongs, very few studies have been recorded on using quantitative methods to determine the diversity of ferns (Yusuf, Tan, & Turner, 2003). However, Johnson (1969) was the first recognized to carry out survey on herbaceous plants including ferns using quadrant method. Sato, Saw and Furukawa (2000) also made use of cubic quadrant methods to investigate the diversity of ferns in some man-made and natural forests in Malaysia. The documentation of distribution patterns of Pteridophytes diversities in Malaysia and some other parts of the world is regarded as very deficient compared to angiosperms and other higher plants.

Also, the recent work done by Rahmad, Mansor, Fadzly, Rosely and Mansor (2009) on the status of some forest reserves in Penang, Malaysia also focused more on the diversity of Angiosperms and Gymnosperms with no emphasis on Pteridophytes. The unrealistically low figure of ferns and mosses in most countries reveals the lack of adequate available information on these groups of plants (Mutke & Barthlott, 2005).

Quantitative knowledge of their spread in Penang State using Universiti Sains Malaysia (USM) campus as a case study could provide vital information on conservation threats and ecology which are unsatisfactory at the moment. Therefore, there is a need for greater investment in their taxonomic, geographical distribution and ecological studies in order to broaden the base of plant diversity in Malaysia using USM campus as a case study, hence this study. Conservation plans are needed to be put in place for these neglected and under-utilized plants of Penang, Malaysia.

MATERIALS AND METHODS

Study Area

The study area is the main campus of USM which is the second oldest university in Malaysia established in the year 1969. It is in the tropical belt region of Penang island of Malaysia. This peninsular is described as the floristically richest region of Indomalesian sub-kingdom. The main campus covers an area of 252.7 hectares comprising large canopy trees, lakes and a valley. Extensive land developments have taken place in the campus over the years since inception which has led to loss of some of the native plant species (Asma, Manshhor, Khairun, Mohammed, & Lee, 2009).

Sampling Techniques

Reconnaissance survey was initially conducted in the study area to ascertain the different vegetation types present (Oloyede, Odiwe, & Olujiyan, 2014). The study area was divided into three main sites comprising; the less-disturbed forest, most-disturbed forest and urbanized area based on visual observation of the rate of land developments and human encroachments. The less-disturbed forest is a reserved forest within a valley in the campus with very little human encroachment. The urbanized area is the totality of the areas developed into roads, lecture halls, office and residential complexes whereas most-disturbed forest is the forest occupying an intermediate position between less-disturbed forest and urbanized area. The sampling plots in each site was separated by a minimum distance of 50 m. Ten $10 \times 10\ m^2$ plots were demarcated in each site, giving a total of 30 plots for the entire study area. This plot area has been stated as the suitable area for diversity study of Pteridophytes in natural and man-made forests (Yusuf et al., 2003). The non-random selective method was adopted where plots were preferentially located to ensure that at least one individual fern is present in each plot (Akinsoji et al., 2016). The geographic coordinates of each study sites were taken using a GPS Garmin eTrex 10 device.

Sample Collection and Identification

In all the plots, the fern species present were recorded and classified as aquatic, terrestrial, epiphytes and lithophytes. Each fern stipe (i.e. the entire frond emanating from the rhizome) is counted as an individual fern as most of the individual fern species usually emerge from a common inseparable underground rhizome thereby forming clumps. Fern specimens were subsequently identified using a taxonomic flora (Piggott, 1988) and the herbarium of USM. The voucher specimens were deposited in the herbarium of USM for references. For the epiphytic ferns, the host trees were also identified.

Statistical Analyses

The fern diversity indices such as Shannon index, Simpson index and Margalef index were quantified for each forest type using PAST software. The relative frequency of each fern species was calculated. A non-asymptotic species richness evaluator called rarefaction-extrapolation analysis using abundance data was carried out for species richness. Significant difference in fern species richness between the forest types was determined by means of confidence intervals, constructed using 50 bootstrap replicates (Addo-Fordhour, Rahmad, & Burham, 2016). This was done using software iNEXT (online version) (Chao, Ma, & Hsieh, 2016). Significant differences in the diversity indices between the forest types were determined using One-way ANOVA in PAST software.

RESULTS AND DISCUSSION

The geographical coordinates of all the study plots and map of the study area are presented in Table 1 and Figure 1. A total of twenty-three (23) ferns species belonging to 14 families were observed in all the sampled sites in USM. Thelipteridaceae and Polypodiaceae had the highest number of ferns species with 5 and 4 species respectively. More ferns species were observed in less-disturbed forests (15 species) than more-disturbed forest (11 sspecies) and urbanized area (11 species). The most abundant fern species in less-disturbed forest, most-disturbed forest and urbanized site are *Lindsaea napaea* (63.4%), *Pyrrosia lanceolata* (36.0%) and *Pyrrosia lanceolata* (47.0%) respectively (Table 2). Ferns have been reported to play very important roles in the ecology of tropical regions as they form a prominent portion of the species composition (Watkins, 2011). It is evident from our study that the study site has a considerable number of fern species. Similar studies carried out in some university campuses in Nigeria, a tropical country have recorded far less number of ferns compared to USM (Akinsoji et al., 2016; Akomolafe & Sulaimon, 2018; Oloyede et al., 2014). In addition, an inventory of ferns carried out in some natural and man-made forests in Johor and Singapore documented not more than eighteen (18) fern species in each forest (Yusuf et al., 2003). The less-disturbed forest is richer in ferns than more-disturbed forest and urbanized area. This is similar to Corbett, Bannister, Bell and Richards (2002) who observed lesser number of

Table 1
Geographical coordinates of study plots at Universiti Sains Malaysia main campus

S/N	LATITUDE (N)	LONGITUDE (E)	ELEVATION (m)
URBANIZED SITE			
1	5° 21' 17.784"	100° 17' 36.816"	21
2	5° 21' 18"	100° 17' 46.176"	11
3	5° 21' 17.892"	100° 17' 48.408"	13
4	5° 21' 18.36"	100° 17' 50.964"	13
5	5° 21' 12.6"	100° 17' 50.388"	18
6	5° 21' 14.688"	100° 18' 1.26"	13
7	5° 21' 18.648"	100° 18' 1.368"	41
8	5° 21' 19.512"	100° 18' 0.684"	10
9	5° 21' 32.796"	100° 18' 8.496"	22
10	5° 21' 29.556"	100° 18' 10.692"	15
MOST-DISTURBED FOREST			
1	5° 21' 15.336"	100° 17' 53.412"	46
2	5° 21' 12.996"	100° 17' 59.064"	14
3	5° 21' 10.188"	100° 18' 2.736"	16
4	5° 21' 17.604"	100° 18' 8.64"	22
5	5° 21' 18.612"	100° 18' 9.144"	10
6	5° 21' 20.988"	100° 18' 9.72"	14
7	5° 21' 21.456"	100° 18' 2.448"	23
8	5° 21' 21.708"	100° 18' 2.772"	17
9	5° 21' 18.468"	100° 18' 12.168"	18
10	5° 21' 16.524"	100° 18' 17.64"	25
LESS-DISTURBED FOREST			
1	5° 21' 37.764"	100° 18' 21.996"	18
2	5° 21' 36.252"	100° 18' 20.592"	16
3	5° 21' 36.612"	100° 18' 20.34"	19
4	5° 21' 37.26"	100° 18' 19.692"	24
5	5° 21' 38.16"	100° 18' 17.82"	16
6	5° 21' 38.592"	100° 18' 17.964"	23
7	5° 21' 38.52"	100° 18' 18"	19
8	5° 21' 38.808"	100° 18' 19.656"	20
9	5° 21' 36.684"	100° 18' 21.348"	15
10	5° 21' 36.72"	100° 18' 21.456"	16

fern species in the highly disturbed forest than less-disturbed one in some parts of Oklahoma USA. However, in terms of abundance, urbanized area seemed to have a larger number of individuals of ferns in each plot, followed by the more-disturbed forest. This is normal as it is expected for less-disturbed forest to have a lesser

Table 2
Distribution of ferns observed in the study area

S/N	Name of fern	Family	Study sites: Less-disturbed forest Presence/ absence	Less-disturbed forest Relative abundance (%)	Most-disturbed forest Presence/ absence	Most-disturbed forest Relative abundance (%)	Urbanized area Presence/ absence	Urbanized area Relative abundance (%)
1	*Adiantum latifolium* Lam.	Adiantaceae	X	0	X	0	√	0.2
2	*Angiopteris evecta* (Forst.) Hoffm.	Marattiaceae	√	0.4	X	0	X	0
3	*Asplenium nidus* L.	Aspleniaceae	√	2.2	√	1.4	√	2.8
4	*Bolbitis virens* (Wall. Ex Hook. & Grev.) Schott	Lomariopsidaceae	X	0	X	0	√	0.4
5	*Cyathea contaminans* (Hook.) Copel.	Cyatheaceae	X	0	X	0	√	0.3
6	*Cyclosorus ecallosa* Holtt.	Thelipteridaceae	√	1.5	√	0.1	X	0
7	*Davallia denticulata* (Burm.) Mett.	Davalliaceae	√	1.0	√	2.3	√	8.5
8	*Drymoglossum piloselloides* (L.) Presl	Polypodiaceae	√	6.1	√	9.2	√	0.9
9	*Drynaria quercifolia* (L.) J.Sm.	Polypodiaceae	√	0.7	√	32.9	√	35.9
10	*Elaphoglossum callifolium* (Bl.) Moore	Lomariopsidaceae	X	0	√	0.3	X	0
11	*Lindsaea napaea* v.A.v.R.	Lindsaeaceae	√	63.4	X	0	X	0
12	*Lygodium circinnatum* (Burm.) Sw.	Schizaeaceae	√	0.6	X	0	X	0
13	*Merinthosorus drynarioides* (Hook.) Copel.	Polypodiaceae	X	0	√	1.4	X	0
14	*Nephrolepis biserrata* (Sw.) Schott	Nephrolepidaceae	√	3.9	√	2.4	√	1.6
15	*Pronephrium asperum* (Presl) Holtt.	Thelipteridaceae	√	1.1	X	0	X	0
16	*Pronephrium menisciicarpon* (Bl.) Holtt.	Thelipteridaceae	√	4.3	X	0	X	0
17	*Pronephrium salicifolium* (Hook.) Holtt.	Thelipteridaceae	√	2.4	X	0	X	0
18	*Pronephrium triphyllum* (Sw.) Holtt.	Thelipteridaceae	√	3.6	X	0	X	0
19	*Pteris venulosa* Bl.	Pteridaceae	√	0.7	X	0	X	0
20	*Pteris vittata* L.	Pteridaceae	X		X	0	√	0.8
21	*Pyrrosia lanceolata* (L.) Farwell	Polypodiaceae	√	7.7	√	36.0	√	47.0
22	*Salvinia molesta* D.S. Mitchell	Salviniaceae	X	0	√	6.8	X	0
23	*Scleroglossum minus* (Fee) C.Chr.	Grammitidaceae	X	0	√	7.3	√	1.6

KEY: √ means present, X means absent

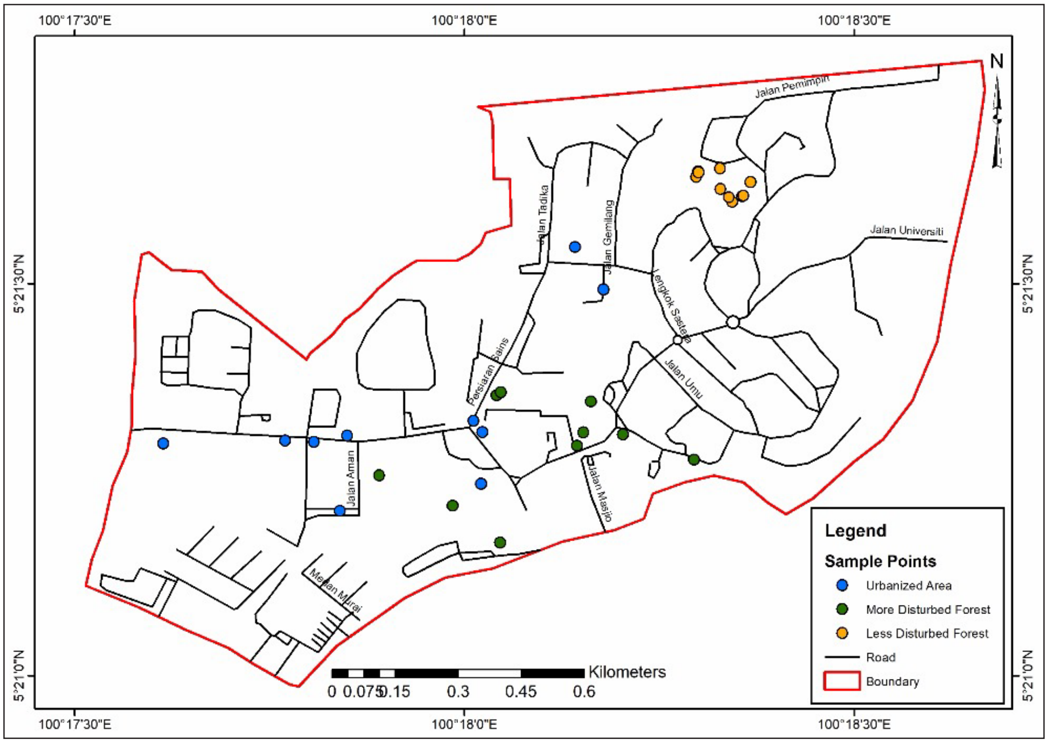

Figure 1. Study area map of Universiti Sains Malaysia main campus

abundance of individual ferns than other study sites. A similar trend was observed in Thailand, where highly disturbed sites had the lowest number of species, but the highest number of individual ferns in each plot than the less-disturbed ones (Sathapattayanon & Boonkerd, 2006).

Most-disturbed forest and urbanized site were discovered to have more epiphytic ferns than the other life forms (Table 3). Some of the species such as *Asplenium nidus, Davalia denticulata* and *Nephrolepis biserrata* were observed to be growing as epiphytes and terrestrial ferns. However, in

Table 3
Life forms of ferns in the study area

S/N	LIFE FORM	NUMBER OF SPECIES		
		Less-disturbed forest	Most-disturbed forest	Urbanized area
1	Aquatic	0	1	0
2	Epiphytic	3	6	7
3	Terrestrial	12	5	3
4	Lithophytic	0	0	3

less-disturbed forest, more terrestrial ferns were observed to be growing there than other life forms. The fact that urbanized area comprises more of epiphytic ferns could be an explanation for the higher abundance of individual ferns observed. Invariably, this is an indication of the suitability of the microenvironment to the growth and abundance of the epiphytic ferns. This also imply that despite the high rate of developments inside the campus over the years, there has been a high level of conservation of tree plants which hosted these ferns. These trees could have been deliberately conserved by the university in order to provide shade and purify the environment. This has a positive impact on the vascular plant diversity and sustainance of diverse animal communities such as birds and reptiles within the campus (Cruz-Angón & Greenberg, 2005; Magrach, Rodríguez-Pérez, Campbell, & Laurance, 2014). *Samanea saman* is the host tree that had the highest number of epiphytic ferns species in both urbanized site and most-disturbed forest (Table 4). These epiphytic ferns could be described as not host specific as they were found growing on more than

Table 4
Hosts of epiphytic ferns in the study area

S/N	Host plant	Epiphytic fern hosted
URBANIZED AREA		
1	Pinus nigra	Davallia denticulata, Pyrrosia lanceolata, Drynaria quercifolia
2	*Cassia fistula*	Asplenium nidus, Davallia denticulata, Drynaria quercifolia, Pyrrosia lanceolata
3	Samanea saman	Drynaria quercifolia, Davallia denticulata, Pyrrosia lanceolata, Drymoglossum piloselloides, Scleroglossum minus
4	*Ficus benjamina*	Davallia denticulata, Drynaria quercifolia, Nephrolepis biserrata, Bolbitis virens
5	*Azadiractha indica*	*Davallia denticulata, Scleroglossum minus*
6	*Tamarindus indica*	*Pyrrosia lanceolata*
7	*Milletia pinnata*	*Pyrrosia lanceolata*
8	*Delonix regia*	*Pyrrosia lanceolata*
9	*Adenanthera pavonina*	*Pyrrosia lanceolata, Drymoglossum piloselloides*
10	*Mimusops elengi*	*Pyrrosia lanceolata*
11	*Peltophorum petrocarpum*	*Pyrrosia lanceolata*
MOST-DISTURBED FOREST		
1	*Samanea saman*	*Drynaria quercifolia, Davallia denticulata, Pyrrosia lanceolata, Drymoglossum piloselloides, Scleroglossum minus*
2	*Azadiractha indica*	*Davallia denticulata, Scleroglossum minus, Pyrrosia lanceolata, Drynaria quercifolia*
3	*Bambusa vulgaris*	*Drynaria quercifolia*
LESS-DISTURBED FOREST		
1	Samanea saman	Drymoglossum piloselloides, Pyrrosia lanceolata, Drynaria quercifolia

one type of host trees. Their predominance in the more-disturbed forest and urbanized area is further supported by Oloyede et al. (2014) who observed similar occurrence of epiphytes in Obafemi Awolowo University campus, Nigeria. Also, the occurrence of *Asplenium nidus* as an epiphyte in this study area agrees with the report of Cummings, Martin and Rogers (2006) that the fern usually creates a special microclimatic conditions in disturbed forests where it is found thereby serving as habitat to various animals.

Contrariwise, the fewer number of terrestrial ferns observed in urbanized and more-disturbed forests could serve as justification to the reason why they are disturbed compared with the less-disturbed forest which had a higher number of terrestrial ferns. This agrees with the work of Sathapattayanon and Boonkerd (2006) who investigated the diversity of ferns along a gradient of disturbance in Thailand. They also observed that terrestrial ferns were more in less-disturbed forest than more-disturbed one. It could be assumed that terrestrial ferns are more susceptible to human threats than epiphytic and aquatic ferns in that they can be easily removed alongside with other herbaceous plants. Aquatic fern, *Salvinia molesta* was only found in the most-disturbed forest site, while lithophytic ferns were only observed at the urbanized site.

As shown in Table 5, urbanized area was observed to have the highest total number of individual ferns (3409), followed by more-disturbed forest (3257) and less-disturbed forest (1434). The species richness value of the rarefaction and extrapolation curve for less-disturbed forests was significantly higher than those of more-disturbed forest and urbanized area (Table 5 and Figure 2). There was overlap in the confidence interval of rarefied-extrapolated species richness of more-disturbed forest and urbanized area. The rarefied-extrapolated curves for diversity indices of all the sampled sites

Table 5
Diversity indices of sampled sites in the study area

Diversity indices	Urbanized area	More-disturbed forest	Less-disturbed forest
Observed species richness	11	11	15
Rarefaction and extrapolation species richness*	11[a]	11[a]	15[b]
Number of Individuals	3409	3257	1434
Simpson Index**	0.641[a]	0.743[b]	0.582[c]
Shannon Index**	1.294[a]	1.644[b]	1.504[c]
Species evenness**	0.332[a]	0.471[b]	0.299[c]
Margalef index**	1.229[a]	1.236[a]	1.926[b]
Fisher's alpha**	1.412[a]	1.422[a]	2.336[b]

*Significant difference was determined using confidence interval (95%)
**Significant difference was determined using pairwise permutation test in PAST

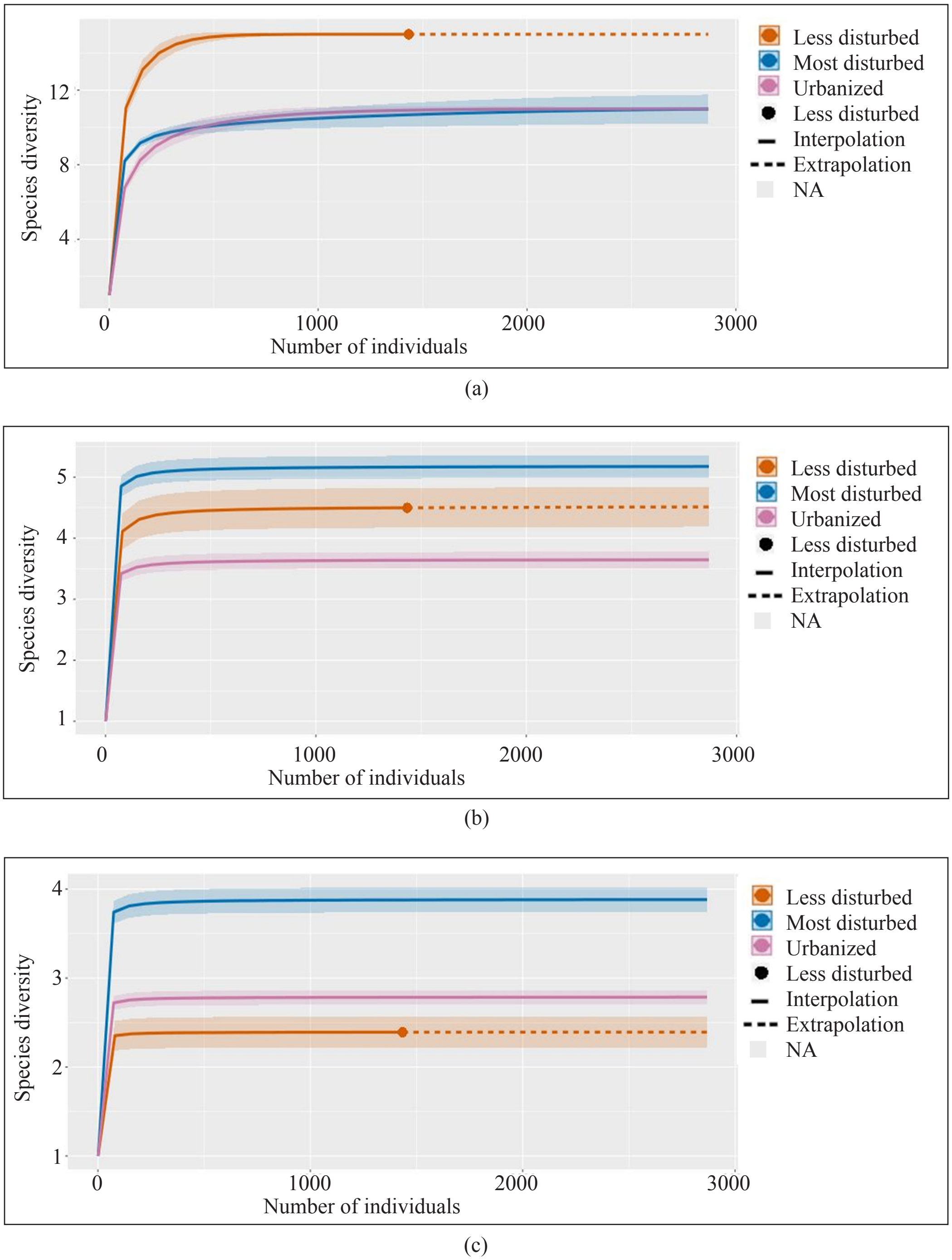

Figure 2. Individual based rarefaction and extrapolation curves for: (a) Species richness; (b) Shannon index; and (c) Simpson index. Solid lines represent rarefaction curves while dashed lines represent extrapolation curves. Each dot stands for the observed number of individuals

approached asymptote thereby showing the adequacy of sampling of ferns in the study area. The diversity indices such as Simpson index, Shannon index and Species evenness of more-disturbed forest are significantly higher than less-disturbed forest and urbanized area (Table 5). This could be because the common species were found in each plot. The common species observed in these sites are *Davalia enticulata, Drynaria quercifolia* and *Pyrrosia lanceolata.* These species could be regarded as pioneer fern species in most-disturbed areas (Boonkerd, 1996). The lower species evenness index recorded in less-disturbed forest could be attributed to the low number of individual ferns observed and the same species are not found in more than 2 or 3 plots. However, Fisher's alpha and Margalef indices for less-disturbed forests are significantly higher than those of less-disturbed forest and urbanized area ($P \leq 0.05$). According to Barbour, Burk, Pitts, Gillians and Schwartz (1999), a community with Shannon index greater than 2 is regarded as more diverse. It could then be said that all the sampled sites are less diverse in fern species since their Shannon index values are less than 2. This could have a long term negative effect in determining the stability and functionality of this ecosystem. Ecosystems with higher species diversity tend to be more stable and do have higher level of productivity due to the dynamic nature of the species driving them (Seabloom, 2007; Tilman, 1996).

CONCLUSION

Conclusively, the main campus of Universiti Sains Malaysia is a typical example of a disturbed ecosystem. It is obvious that the rate of developments over the years has reduced the diversity and richness of ferns particularly terrestrial ones in the disturbed areas. Efforts should therefore be made in restricting further developments into the less-disturbed forest which had the highest number of terrestrial fern species. This forest has been described as the only green space left in the campus which has been habitat to many native plants and birds (Asma et al., 2009). Therefore, it is recommended for other institutions across the world to maintain a greener environment by conserving the natural tree species within the university campuses. These trees will not only serve as shades and purifiers of the environment, but will also host varieties of birds and epiphytes.

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