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Article · December 2014

DOI: 10.14203/reinwardtia.v14i1.396

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REINWARDTIA
Vol 14, No 1, pp: 67 − 71

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Received December 9, 2013; accepted May 27, 2014

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ABSTRACT
LATIFF, N. A., SUKRI, R. S., & METALI, F. *Nepenthes* diversity and abundance in five habitats in Brunei Darussalam. *Reinwardtia* 14(1): 67 – 71. — The genus *Nepenthes* is known to be diverse in Bornean forests and has been recorded in Brunei Darussalam in various forest types. We aim to investigate variation in *Nepenthes* species richness and abundance at five forest types throughout Brunei Darussalam: open secondary, heath, peat swamp, white sand and mixed dipterocarp forests. A total of thirty-nine 5 × 5 m^2 plots were set up in these forest types. Within each plot, *Nepenthes* species abundance was quantified, with *Nepenthes* voucher specimens collected and identified to determine species richness. No significant differences were detected either for *Nepenthes* species richness or abundance between the five forest types, despite records of *Nepenthes* in Brunei showing preferences for particular habitat types. We suggest that average species richness and abundance remained constant regardless of forest types in this study, but that these results would likely change if sampling intensity is increased in future studies.

Keywords: Borneo, pitcher plants, habitat, tropical forest.

ABSTRAK
LATIFF, N. A., SUKRI, R. S., & METALI, F. Keanekaragaman dan kelimpahan *Nepenthes* di lima habitat di Brunei Darussalam. *Reinwardtia* 14(1): 67 – 71. — Marga *Nepenthes* dikenal beragam di hutan Borneo dan dilaporkan terdapat di Brunei Darussalam pada berbagai tipe hutan. Tujuan dari penelitian ini adalah untuk mengetahui variasi kelimpahan dan kekayaan jenis *Nepenthes* pada lima tipe hutan di Brunei Darussalam: hutan sekunder terbuka, kerangas, rawa gambut, pasir putih serta hutan campuran dipterokarpa. Sebanyak 39 plot berukuran 5 × 5 m^2 digunakan pada tiap tipe hutan. Pada tiap plot dihitung kelimpahan jenis *Nepenthes*, serta koleksi contohnya diidentifikasi untuk menentukan kelimpahan jenisnya. Tidak ada perbedaan nyata antara kelimpahan dan kekayaan jenis *Nepenthes* diantara kelima tipe hutan tersebut, kecuali catatan bahwa *Nepenthes* di Brunei menunjukkan ketertarikan pada tipe habitat tertentu. Hasil penelitian menunjukkan bahwa rata-rata kelimpahan dan kekayaan jenis tetap tidak memandang tipe hutannya. Namun demikian hasil studi ini akan berubah jika intensitas pencuplikan lebih ditingkatkan.

Kata kunci: Borneo, tumbuhan pemangsa, habitat, hutan tropis.

INTRODUCTION

Nepenthes (Family Nepenthaceae) is the largest genus of pitcher plants with a distribution ranging from northern Australia throughout South-east Asia to southern China (Clarke, 2006). *Nepenthes* are carnivorous plants that have evolved leaf extensions into jug shaped structures which contain a pool of digestive enzymes to attract, trap and digest animals for its nutritional values (Clarke, 2006). Moran (2010) listed more than 100 recognised species of *Nepenthes*, with the vast majority occurring in the Indonesian archipelago, Philippines, Borneo and Sumatra. At present, there are 24 *Nepenthes* species which are endemic to Borneo (Clarke, 2006). Thirteen *Nepenthes* species have been recorded in the Checklist of Flowering Plants and Gymnosperms of Brunei Darussalam (Coode & Dransfield, 1996): *N. albomarginata, N. ampullaria, N. bicalcarata, N. fusca, N. gracilis, N. hirsuta, N. lowii, N. mirabilis, N. rafflesiana, N. reinwardtiana, N. stenophylla, N. tentaculata,*

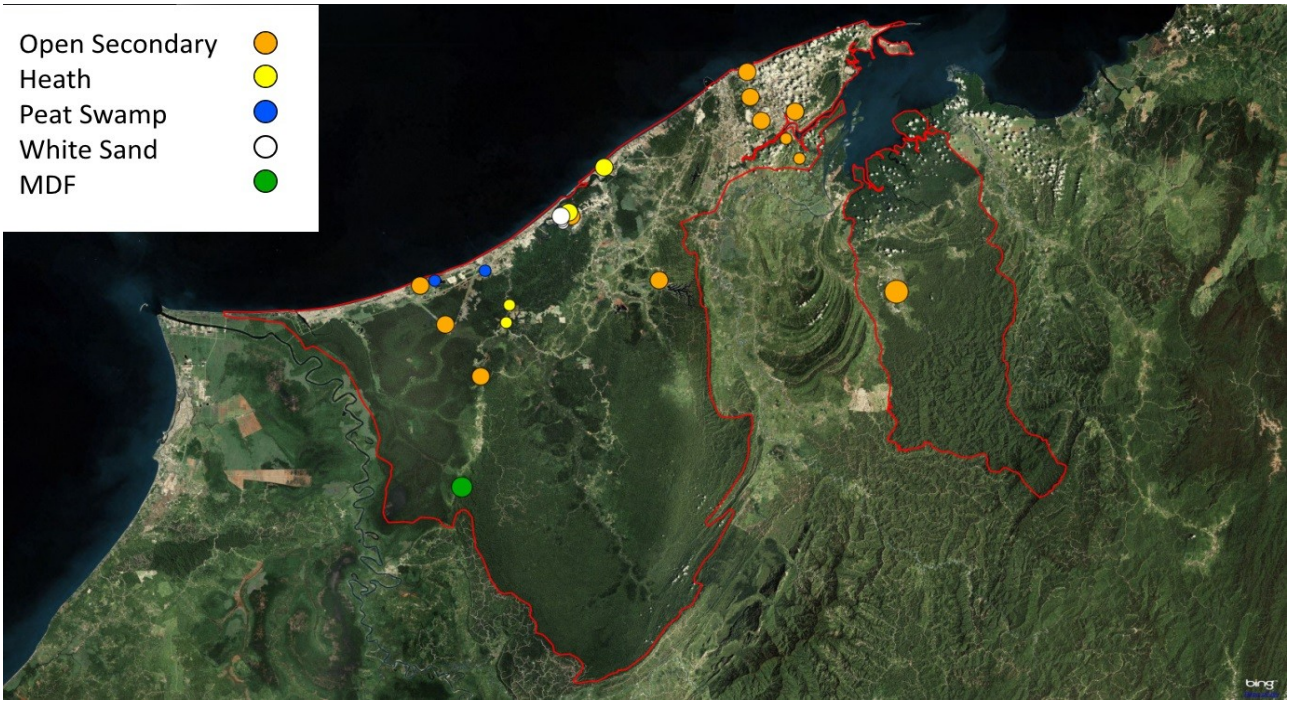

Fig. 1. The map of Brunei Darussalam showing 19 locations of the study sites. The size of the circle in the map is proportional to the number of plots at that location. A total of 39 plots were located, each of size 5 × 5 m.

N. veitchii and *Nepenthes* sp. (unidentified species).

Nepenthes is often characterized as to be able to colonize habitat which lack nutrient (Juniper *et al.*, 1989; Ellison & Gotelli, 2001). *Nepenthes* can be found in six major habitat types: tropical lowland evergreen rain forest, heath forest, peat swamp forest, montane forest and limestone forest (Clarke, 2006). Lowland mixed dipterocarp forests are typically not very favourable as a habitat for *Nepenthes* although epiphytic species of *Nepenthes (N. reinwardtiana* and *N. veitchii)* have been recorded (Clarke, 2006). In contrast, heath forest or *Kerangas* forest has generally siliceous and acidic soil, higher temperature and lower humidity, all of which are preferred by *Nepenthes*. The main aim of this study is to investigate the species diversity, richness and abundance of *Nepenthes* in five forest types throughout Brunei Darussalam.

METHODOLOGY

A total of nineteen locations within the five forest types (open secondary forest, heath forest, peat swamp forest, white sand and mixed dipterocarp forest) were chosen as study sites throughout Brunei Darussalam (Fig. 1). At each site, two 5 × 5 m^2 plots were set up with the exception of the mixed dipterocarp forest site where three plots were set up, giving a total of 39 (Table 1). To ensure the presence of *Nepenthes*, sites were surveyed and selected in localities with *Nepenthes* presence, but plots were set up randomly at these selected localities.

Nepenthes plants were counted as one individual plant if the stems or runners grew from the same root (Clarke, 2006). In this study, only terrestrial *Nepenthes* species were recorded but not epiphytic *Nepenthes* species due to limited access. Voucher specimens of all *Nepenthes* species, including possible hybrids, were collected and prepared as herbarium specimens following the guidelines of Clarke & Moran (2011). Representative samples of the intact pitcher of each species collected was also preserved in ethanol and high quality photographs were taken of the upper and lower pitchers to record details of pitcher geometry for identification purposes (Clarke & Moran, 2011). All specimens were taken to the Brunei Forestry Department Herbarium (BRUN) at Sungai Liang for identification with the assistance of BRUN staff.

Between plot differences in *Nepenthes* species richness and abundance from the five forest types was determined by using one-way ANOVA. Species richness and abundance were expressed as the number of *Nepenthes* species, and the number of individuals, respectively within a plot. Assumptions of normality and equal variances were

Table 1. The sites or localities, number of plots and altitudinal ranges of the five forest types sampled.

Forest Types	Sites	Number of plots	Altitudinal range (asl m)
Open Secondary Forest	Beribi, Putat, Lumapas, Katok, Jerudong, Tasek Lama, Bukit Sulang/Kg.Menengah, Bukit Bendera, Lumut, Bukit Lumut, Labi, Amo	24	15 - 70
Heath Forest	Sawat	2	29 - 39
Peat Swamp Forest	Anduki, Badas	4	11 - 31
White Sand	Telisai Satellite, Pasir Putih, Teli-sai-Lumut	6	21 - 32
Mixed Dipterocarp Forest	Bukit Teraja	3	296 - 312

checked during one-way ANOVA and were not violated. *Nepenthes* species diversity for each plot was calculated using Shannon's index of diversity. All statistical analyses were conducted in R 2.15.2 (R Development Core Team, 2012).

RESULTS

A total of five *Nepenthes* species were recorded within the 39 plots: *N. ampullaria, N. bicalcarata, N. gracilis, N. mirabilis* and *N. rafflesiana*. In addition, there were two unidentified hybrids (Hybrid sp.1 and sp.2) recorded. The most abundant species was *N. gracilis* (n = 3067) while the two hybrid species were the least abundant (Hybrid 1 = 2; Hybrid 2 = 5) (Table 2). *N. gracilis* and *N. ampullaria* were recorded in all five forest types. However, some *Nepenthes* species were restricted to certain forest types: *N. bicalcarata* was only found in the peat swamp forest, *N. rafflesiana* was found in all forest types except in the heath forests and both hybrids were only found in the open secondary forests (Table 2). An individual of *N. hemsleyana* was also recorded in close proximity to one of the peat swamp forest plots in Badas, but was not censused as it was found outside the plots.

The highest mean *Nepenthes* species richness was recorded in the white sands plots (2.2 ± 0.2 species, Table 3), while the highest mean abundance was recorded in the peat swamp forest plots (135.5 ± 58.4 individuals, Table 3). However, these differences were not significant when tested using one-way ANOVA (Table 3). The highest species richness of 4 species was recorded in plot 30, located in open secondary forest. The plot with the highest abundance was the plot located in the peat swamp forest (n = 273), and the plot with the least abundance was the plot located in open secondary forest (n = 17).

DISCUSSIONS

The present study recorded highest mean species richness of *Nepenthes* in the white sands plots but the highest mean species abundance was recorded in the peat swamp forest plots. Despite this, species richness and abundance of *Nepenthes* were not significantly different between the five forest types. A possible reason for the lack of significant difference may be inadequate and unequal sample sizes in terms of replication of the plots for each forest type. Attempt to record as many sites as possible was done but there was an obstacle of limited access to the different forest types especially high altitude forest. Our study also focussed only on terrestrial species, thus there may be an underestimate of species richness due to the omission of epiphytic species.

Nepenthes gracilis showed the highest abundance and was found in almost all of the plots especially in open secondary forest plots. *N. gracilis* is known to be the most common *Nepenthes* species in Borneo regardless of soil

Table 2. The *Nepenthes* species abundance for each *Nepenthes* species recorded and five forest types (A – Open Secondary forest, B – Heath forest, C – Peat Swamp Forest, D – White sands forest, E – Mixed Dipterocarp forest).

***Nepenthes* species**	**Forest type**					
	A	**B**	**C**	**D**	**E**	**Total *Nepenthes* species abundance per species**
N. ampullaria	9	23	37	20	68	157
N. bicalcarata	0	0	23	0	0	23
N. gracilis	2238	89	481	226	33	3067
N. mirabilis	60	0	0	0	0	60
N. rafflesiana	321	0	1	89	17	428
Hybrid sp.1	2	0	0	0	0	2
Hybrid sp.2	5	0	0	0	0	5
Total *Nepenthes* species abundance per forest types	2635	112	542	335	118	

types, light, water content and can be found in almost all vegetation types (Clarke, 2006). *N. rafflesiana* was found in open secondary forest, lowland MDF and white sands plots, but not in the heath forest and only one individual was found in the peat swamp forest plot. Adam (2011) found that *N. rafflesiana* grew in acidic soil with high clay content and water retention, such as the clay soils of the lowland MDF. He further stated that *N. rafflesiana* is commonly found in cleared areas such as the open secondary forest plots and white sands area. However, Clarke (2006) stated that lowland MDF is not very favourable as a habitat for *Nepenthes* due to its very poor soil where the nutrients are recycled in the detritus layer on top of the soil – only epiphytic types of *Nepenthes* (*N. reinwardtiana* and *N. veitchii)* have been recorded in such habitat. In this study, three *Nepenthes* species (*N. rafflesiana, N. ampullaria* and *N. gracilis)* were found at the ridge of the MDF. As reported by Clarke (2006) that certain lithophytic *Nepenthes* species such as *N. hirsuta* has been recorded growing near vegetation boundaries of MDF. *Nepenthes ampullaria* was found in all of the forest types except in the open secondary forest. Adam (2011) noted that *N. ampullaria* can grow in acidic soils with high clay content.

Almost all of the *Nepenthes* species recorded in this study were found in the open secondary forest except for *N. bicalcarata* which was exclusive to the peat swamp forest plots. One of the distinctive characteristics of the peat swamp forest is its forest floor which is waterlogged and permanently wet compared to other forest types. It is possible that *N. bicalcarata* is specialised to the waterlogged and highly acidic condition of the peat swamp forest (Clarke, 2006). Anderson (1963) also recorded the presence of *N. bicalcarata* in open canopy areas of peat swamp forests. Moreover, *N. bicalcarata* has evolved mutualistic relationship with the ant *Camponotus schmitzi* which are only found in peat swamp forests (Moran & Clarke, 2010; Bonhomme *et al*., 2011). It is therefore possible that this mutualistic association further contributes to the specialisation of *N. bicalcarata* to peat swamp forests, by encouraging co-evolution between the ants and *N. bicalcarata*. Hence, these combine characteristics of peat swamp forests seem to be the most favourable for *N. bicalcarata* to grow.

CONCLUSION

Our study has detected no significant difference in *Nepenthes* species richness and abundance between the five habitat types in Brunei Darussalam. We argue that this was likely due to limited replication of plots representing the different forest types and that a higher sample size and replication would enable a significant difference to be detected. One interesting finding from our study was the presence of *Nepenthes* species at the lowland MDF site in Teraja. We suggest that future studies should quantify both edaphic and environmental variables that may be influential upon *Nepenthes* species diversity and abundance in Brunei Darussalam.

Table 3. The mean values (± SE) of species richness, species abundance and Shannon's Index (species diversity) of *Nepenthes* recorded in each forest type: A = Open Secondary, B= Heath, C= Peat Swamp, D= White Sand, E= Mixed Dipterocarp. Level of significance of the differences between these values was statistically quantified at $P < 0.05$ using one-way ANOVA.

	Forest type					
Species diversity measures	**A**	**B**	**C**	**D**	**E**	**P value**
Species richness	1.79 ± 0.15	1[†]	1.5 ± 0.28	2.16 ± 0.16	1.66 ± 0.33	0.300
Species abundance	109.8 ± 12.6	56 ± 33.0	135.5 ± 58.4	55.8 ± 10.7	39.3 ± 7.8	0.100
Shannon's Index	0.46 ± 0.08	0[†]	0.35 ± 0.20	0.77 ± 0.07	0.69	0.070

[†] Only one *Nepenthes* species was recorded in heath forest plots, giving no variation and no value for Shannon's index.

ACKNOWLEDGEMENTS

This study was conducted as part of an honours dissertation at Universiti Brunei Darussalam. We would like to thank the Brunei Forestry Department for permission to conduct research and sample *Nepenthes* in the plots. We are grateful to botany staff of the Brunei National Herbarium (BRUN), particularly Awg. Joffre Hj Ali Ahmad (Head of BRUN) and Awg. Muhammad Ariffin Kalat, Awg. Watu Awok and Awg. Azlan Pandai for their assistance with identification of *Nepenthes* specimens. Dr Martin Dancak (Palacky University, the Czech Republic) kindly verified the identification of *Nepenthes*, both in the field and by examining voucher specimens. We also thank the technical staff of the Environmental and Life Sciences Programme, Faculty of Science, UBD for assistance with laboratory work.

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