Tropical Ecology **58**(4): 731-739, 2017 ISSN 0564-3295

www.tropecol.com

An investigation on rattan taxonomic diversity in four selected forest reserves of northern Peninsular Malaysia

WAN NUR FASIHAH ZARIFAH BINTI WAN ROZALI[1], KAZI MOHAMMAD MASUM[2], AMIRRUDIN BIN AHMAD[3], RAHMAD ZAKARIA[1], ASYRAF MANSOR[1,4] & AHMAD SOFIMAN OTHMAN[1,4]

[1]*School of Biological Sciences, Universiti Sains Malaysia, Pulau Pinang-11800, Malaysia*

[2]*Department of Forestry and Environmental Science, Shahjalal University of Science and Technology, Sylhet-3114, Bangladesh*

[3]*School of Marine and Environmental Sciences, Universiti Malaysia Terengganu, 21030 Kuala Terengganu, Terengganu, Malaysia*

[4]*Centre for Marine and Coastal Studies (CEMACS), Universiti Sains Malaysia, Pulau Pinang-11800, Malaysia*

Abstract: Besides extraction stresses, rattans (climbing palms) are harshly undermined by human- induced forest fragmentation and their habitat loss. However, there is lack of data on rattan distribution patterns, species abundance and species composition from Malaysian forests. To reduce the gap of information and documentation, specifically on rattan ecology and diversity, we assessed the diversity and abundance of rattans using the taxonomic diversity and distinctness analysis in both island and mainland of northern Peninsular Malaysia. A total of 5482 individuals representing five genera and 21 species of rattans were recorded from 40 randomly selected sample plots covering an area of 3.6 ha. Higher species richness was recorded on the mainland (Margalefs (R1) and Menhiniks value (R2) - R1=1.91, R2=0.3151). In contrast, Penang island recorded a higher value of dominance (D=0.40101). The species evenness is moderately high in all forest reserves. The highest number of rattans (11 species) was recorded in Bukit Panchor. Penang hill forest reserve had the highest taxonomic diversity and distinctness (Δ=1.406, Δ*=1.8000). The lowest taxonomic diversity (Δ=1.260) and taxonomic distinctness (Δ*=1.636) was obtained for Bukit Panchor. The other locations featured the average diversity line of the funnel analysis. Implications for rattan abundance and species composition for proper management of depleting resources are discussed.

Key words: Dominance, Forest reserve, Malaysia, Rattans, Species richness, Taxonomic diversity.

Handling Editor: N. Parthasarathy

Introduction

Rattans (Family – Arecaceae; subfamily – Calamoideae), constitute one of the most important non-wood forest products after timber, supporting the livelihood especially for forest-based communities (Meitram & Sharma 2005). Moreover they became one of the world's most expensive non-

*Corresponding Author; e-mail: kmmasum-for@sust.edu; kmmasum@gmail.com

timber forest products in the last century (Ros-Tonen 2000). In Malaysia, rattans play an important role in the physiognomy of the tropical rainforest (Richards 1996). There are about 600 rattan species in 13 genera, of which almost all of them are used locally, but only about 50 species are used regularly and commercially (Dransfield & Manokaran 1994). According to Dransfield (1992) Peninsular Malaysia recorded 106 species under eight genera, in Sarawak there were 105 species and Sabah recorded 79 species. They have widespread range of habitat, but mostly prevalent in tropical hill rainforests, tropical evergreen monsoon forests or secondary forests.

Species diversity and abundance are among the most important features in ecology and conservation (Watanabe & Suzuki 2008). Diversity of rattan species is known in tropical forests and the diversity in Southeast Asia varies among different forest types (Hamid & Suratman 2010). The highest distribution of rattans is found in the lowland forest, where there is little or no seasonal water shortage and where the climate is continuously warm and humid (Hamid & Suratman 2010; Lapis *et al.* 2004; Nagabhatla *et al.* 2007).

Much of the lowland dipterocarp forests in Malaysia have been logged (Latiff 2011; Masum *et al.* 2017a) due to rapid industrial and economic growth (Masum *et al.* 2017b). According to Mansor & Zakaria (2012), woody species of the coastal forest of Penang Island have received substantial attention in terms of their diversity, composition and spatial distribution. In comparison, comprehensive data on the non-woody plant species, specifically on palms are relatively deficient. Furthermore, there is lack of data on rattan species composition in the Malaysian national parks (Hamid & Suratman 2010) and limited data exist on their distribution patterns and species abundance; particularly lacking from the Penang offshore forest reserves. Rattan inventory is a way of assessing the status of rattan resources in the forest and it is very important for management of this declining resource. Also, the inventory of available rattan resources is very important in order to understand their location and distribution since Malaysia is particularly abundant in rattan resources (Hamid & Suratman 2010). Therefore, the objectives of this study are to determine the species composition and distribution of rattans in selected forest reserves in Penang island and mainland.

Methodology

Study Area

Penang State is located in the north-west coast of Peninsular Malaysia which comprises of island and mainland. To provide overall status of rattan taxonomic diversity in Penang State, two forest reserves one each in island and mainland were selected. From island, Penang National Park and Penang Hill reserved forest and from mainland Bukit Panchor and Cherok To'kun reserved forest were chosen. Penang Island has a land area of about 29,500 hectares while Penang Mainland covers 75,300 hectares on the Peninsular Malaysia (Masum *et al.* 2017b; Samat *et al.* 2011; Wan Rozali *et al.* 2014). Penang National Park located in the northwest corner of Penang Island (longitude 100˚18′95E and latitude 5˚47′03"N). Penang Hill (latitude of 5°25'60"N and a longitude of 100°16'00"E) is mainly hilly granitic mass (also known as Bukit Bendera). Bukit Panchor State Park is a tract of protected forest in Nibong Tebal, Penang which is located at the southern part of Penang mainland. It covers an area of 445 hectares and reaches a height at highest elevation at 416 metres (Quah *et al.* 2013). Coordinates of the park are 5°09'38"N and 100°32'53"E. Cherok To'kun is situated in coordinated 5°21'28"N and 100°29'33"E (Fig. 1).

Sampling

To assess the species composition, 40 random enumeration plots (30 m × 30 m) of 900 m^2 each were established with the total of 3.6 hectares at different locations to identify rattans to the species level. The altitude and position of the forest were recorded using the Global Positioning System (PS map 76 CSX Versatile Navigator (Garmin®). The location of four studied sites are shown in Fig. 1. Selection of study plots were based on different topography and locations. All studied sites were characterized by dipterocarp forest and contain diverse tree species. For rattan assessment, the number of rattan clumps and number of rattan individuals inside the study plots were recorded as per Hamid & Suratman (2010). Number of leaves (including spear leaves when they were at least as long as the petiole of fully expanded leaves) was counted as per Bagh (1996) and Watanabe & Suzuki (2008). The rattan habit in parameter of interest was also recorded to identify rattan species (Hamid & Suratman 2010). Identification process was based on plant morphology such as colour, shape of leaves, flowers, stems, roots, habitat, local name, and the

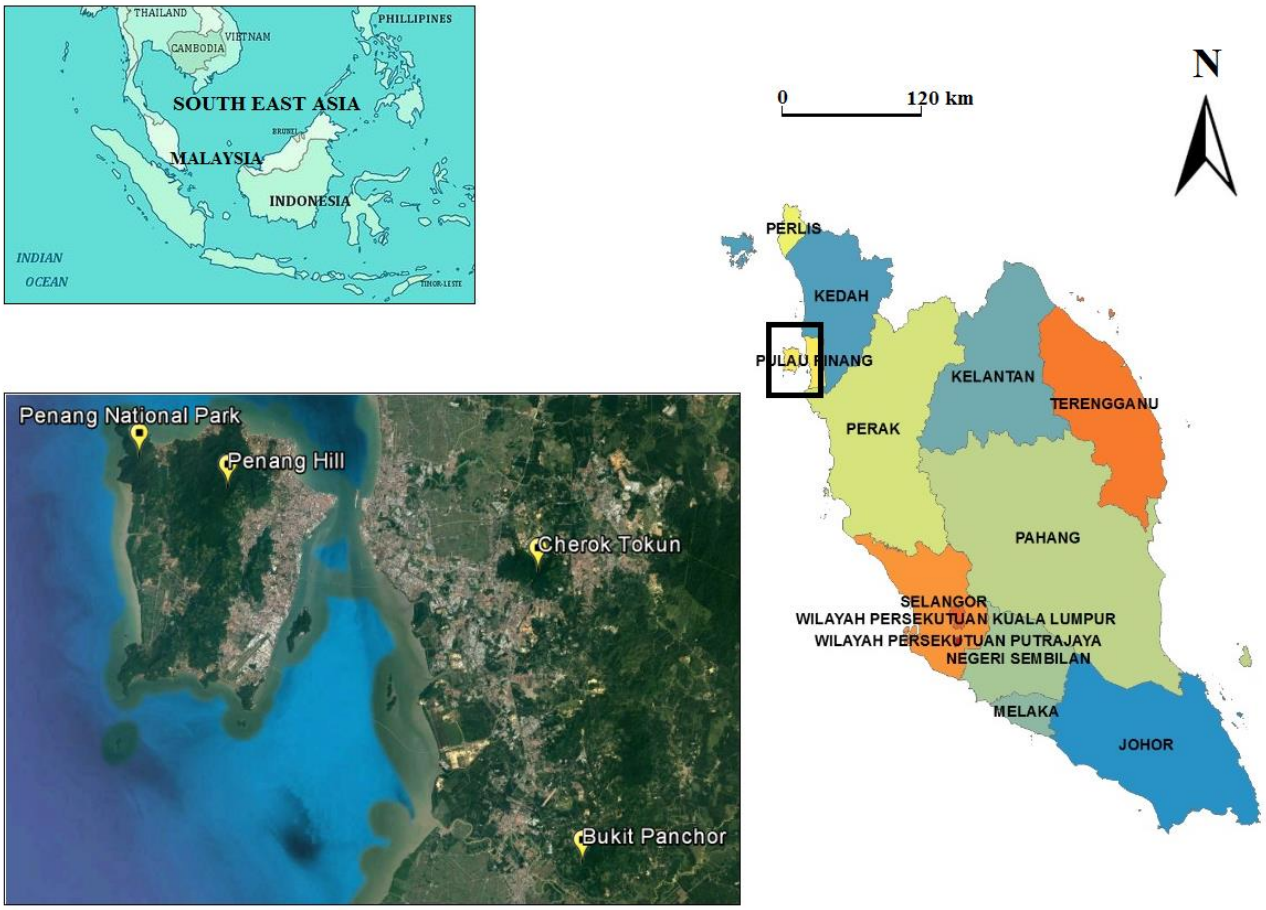

Fig.1. Map showing the location of the study area.

distribution and composition of rattan species. In general, the rattan species recognition was based on Dransfield (1979). Rattan species samples in the studied locations were collected, labelled and photographed. Some rattan species were identified in the field and others were identified with the assistance from the personnel from the Forestry Training Unit, Kepong. All collected rattan species samples were made into herbarium specimens and deposited in Biodiversity Centre in Universiti Sains Malaysia.

Data Analysis

Data analysis of ecological indices (Shannon-Wiener, Simpson, Margalef and Menhinicks and Evenness) was carried out using PAST software. Taxonomic diversity and distinctness were computed using PAST Software ver. 2.17 and (funnel-Primer 6) software. Computations were made using the following formula as in Ludwig & Reynolds (1988):

Shannon-Weiner index:

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

Pi = *Pi* is the proportion of each species in the sample

ln = is the base of the logarithm

Margalefs index: R1 $= \frac{(S-1)}{\ln N}$

S = Number of species in a community

ln = is the base of the logarithm

N = total number of individuals in the sample

Menhinicks index: R2 $= \frac{S}{\sqrt{N}}$

S = Number of species in a community

N = total number of individuals in the sample

Dominance (Simpsons) Index: D $= \sum \frac{ni-(ni-1)}{N-(N-1)}$

N = total number of individuals in the sample

ni= Number of individuals of the species

Table 1. The total of 5482 individuals of rattans belonging to 21 species recorded in all four selected forests.

Genera	Species	Local name	Penang Island		Penang Mainland	
			Penang National Park	Penang Hill	Bukit Panchor	Cherok To'kun
Calamus	*Calamus castaneus*	Rotancucor	6 (0.51%)	60 (3.49%)	98 (7.67%)	155 (11.91%)
	Calamus densiflorus	Rotankerai	–	–	15 (1.17%)	–
	Calamus diepenhorstii	Rotankerai	386 (32.63%)	225 (13.07%)	158 (12.37%)	219 (16.83%)
	Calamus javensis	Rotanbatu	–	18 (1.05%)	–	–
	Calamus ornatus	Rotandok	–	–	139 (10.88%)	–
	Calamus pennisilatus	Rotanbatu	48 (4.06%)	121 (7.03%)	–	–
	Calamus radulosus	Rotankerai	–	–	442 (34.61%)	–
	Calamus calospathus	Rotandemuk	–	31 (1.8%)	–	–
Daemonorops	*Daemonorops brachystachys*	Rotanjernang	–	–	–	6 (0.46%)
	Daemonorops callicarpa	Rotanlumpit	50 (4.23%)	56 (3.25%)	37 (2.9%)	292 (22.44%)
	Daemonorops geniculata	Rotanjahaca	–	213 (12.38%)	218 (17.07%)	499 (38.36%)
	Daemonorops grandis	Rotansendang	–	–	30 (2.35%)	–
	Daemonorops hystrix	Rotan tai landak	–	–	7 (0.55%)	–
	Daemonorops lewisiana	Rotanlumpitkecil	312 (26.37%)	180 (10.46%)	–	25 (1.92%)
	Daemonorops sepal	Rotangetahgunung	–	–	119 (9.32%)	–
Korthalsia	*Kortahlsia hispida*	Rotansemut	–	–	14 (1.1%)	–
	Korthalsia rigida	Rotandahan	–	–	–	34 (2.61%)
	Korthalsia scaphigera	Rotansemut, rotanudang	–	34 (1.98%)	–	–
	Korthalsia scortechinii	Rotandahan, rotansemut	–	–	–	23 (1.77%)
Myrialepis	*Myrialepis scortechinii*	Rotankertong	–	–	–	48 (3.69%)
Plectocomia	*Plectocomia griffithii*	Rotanmantang	381 (32.21%)	783 (45.5%)	–	–

Results

Rattan species abundance and composition

A total number of 5482 individuals representing five genera of rattan species and 21 species were recorded from all four sampling sites. *Calamus dieppenhorstii* is dominant species in Penang National Park with 386 individuals (32.63%) of rattan, followed by *Plectocomia griffithii* (381, 32.21%) and *Daemonorops lewisiana* (312, 26.37%) (Table 1). While other species with lower abundance in Penang National Park were *Daemonorops*

calicarpa, *Calamus penicillatus*, and *Calamus castaneus*. In Penang Hill ten species occurred and *Plectocomia griffithii* scored the highest abundance (783, 45.5%). *Calamus diepenhorstii*, *Daemonorops geniculata* occurred in moderately high abundance with 225 (13.07%) and 213 (12.38%) respectively, followed by *Daemonorops lewisiana* (180, 10.46%) and *Calamus penicillatus* (121, 7.03%) which were also characteristic of Penang Hill. Five rattan species *Calamus castaneus* (60, 3.49%), *Daemonorops calicarpa* (56, 3.25%), *Korthalsia scaphigera* (34, 1.98%), *Calamus calospathus* (31, 1.80%) and *Calamus javensis* (18, 1.05%) were recorded in lower abundance in Penang Hill.

Bukit Panchor was dominated by *Calamus radulosus* with 442 individuals (34. 61%), followed by *Daemonorops geniculata* (218, 17.07%), *Calamus diepenhorstii* (158, 12.37%), *Calamus ornatus* (139, 10.88%), *Daemonorops sepal* (119, 9.32%) and *Calamus castaneus* (98, 7.67%). Very few individuals from species *Daemonorops calicarpa*, *Daemonorops grandis*, *Calamus densiflorus*, *Korthalsia hispida* and *Daemonrops hystrix* were found in Bukit Panchor. *Daemonorops geniculata* was dominant in Cherok To'kun with an abundance of 499 (38.36%) followed by *Daemonorops calicarpa* (292, 22.44%), *Calamus diepenhorstii* (219, 16.83%) and *Calamus castaneus* (155, 11.91%). While the other rattan species that were found in lower abundance include *Myrialepis scortechinii* (48, 3.69%) followed by *Korthalsia rigida* (34, 2.61%), *Daemonorops lewisiana* (25, 1.92%), *Korthalsia scortechinii* (23, 1.77%) and *Daemonorops brachystachys* (6, 0.46%).

The dominant genera varied between the study sites. *Calamus* was dominant in Bukit Panchor with 852 rattan individuals, followed by Penang Hill with 455 individuals; 440 individuals were recorded from Penang National Park and Cherok To'kun was recorded with least number (374) of rattan individuals (Fig. 2). Cherok To'kun was recorded with the highest number of rattan individuals from *Daemonorops* with total of 822 individuals, followed by Penang Hill with 449 individuals, 411 individuals were recorded in Bukit Panchor, while 362 individuals were recorded from Penang National Park. For *Plectocomia*, that occurs only in Penang Island, and limited to Penang Hill and Penang National Park. Penang Hill was recorded the highest number of *Plectocomia* with 783 rattan individuals, while Penang National park was recorded 381 individuals. *Myrialepis* was recorded only in Cherok To'kun with 48 individuals.

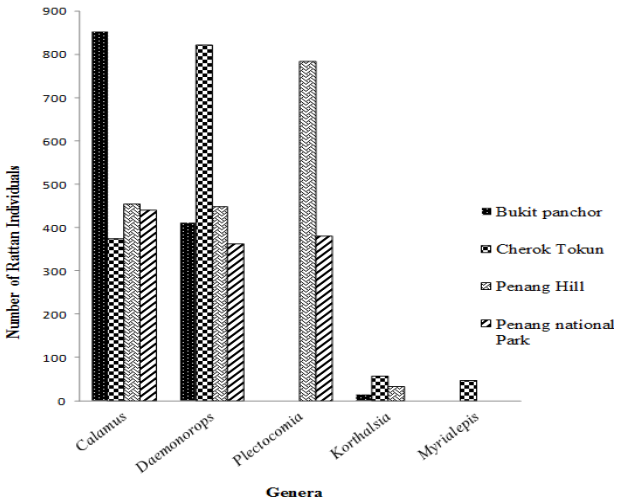

Fig. 2. Number of rattan individuals according to genera in all studied locations.

Ecological indices in four study sites

High diversity of rattan species was observed in Bukit Panchor as indicated by the high values of Shannon (H'=1.908) followed by Penang Hill (H'=1.732) and Cherok Tokun (H'=1.645). Penang National Park had the lowest diversity (H'=1.372) and recorded the highest dominance (D=0.2832) (Table 2). Dominance index for Bukit Panchor was D=0.1924 which is lower compared to all other forests. There was high species richness in Bukit Panchor as indicated by the high values of Margalef, R1=1.398 and Menhinicks, R2=0.3078. In contrast, Penang National Park recorded lowest Margalef, R1=0.7066 and Menhiniks, R2=0.1744. The species evenness is moderately high in all locations as the value is greater than 0.5.

Taxonomic diversity and taxonomic distinctness in four sites

Penang Hill had the highest taxonomic diversity and distinctness (Δ=1.406, Δ*=1.8000) (Table 3). The lowest taxonomic diversity (Δ=1.260) was observed in Bukit Panchor, while Bukit Panchor also had the lowest taxonomic distinctness (Δ*=1.636). Rattan species in all sites approached the average diversity line of the funnel (Fig. 3). Rattan community in Penang National Park, Penang Hill and Cherok To'kun were close to the average. However, Bukit Panchor recorded the lowest delta value of taxonomic diversity and taxonomic distinctness. Bukit Panchor had significantly lower delta value in term of species population and species richness.

Table 2. Ecological Indices (diversity, richness and evenness) in four investigated forests.

	Penang Island		Penang Mainland	
	Penang National Park	Penang Hill	Bukit Panchor	CherokTo'kun
Taxa (S)	6	10	11	9
Individuals	1183	1721	1277	1301
Dominance (D)	0.2832	0.2584	0.1924	0.2428
Shannon (H')	1.372	1.732	1.908	1.645
Evenness (e^H/S)	0.6575	0.565	0.6127	0.5759
Menhinick	0.1744	0.2411	0.3078	0.2495
Margalef	0.7066	1.208	1.398	1.116

Table 3. Descriptive statistics of Taxonomic diversity and Taxonomic distinctness in all four locations.

Location sites		Taxonomic diversity Δ			Taxonomic distinctness Δ*		
		calculated	lower limit	upper limit	calculated	lower limit	upper limit
Penang Island	Penang National Park	1.382	1.524	1.548	1.733	1.357	2
	Penang Hill	1.406	1.529	1.544	1.8	1.512	1.886
Penang Mainland	Bukit Panchor	1.26	1.527	1.545	1.636	1.549	1.865
	Cherok Tokun	1.273	1.527	1.547	1.778	1.545	1.871

Discussion

Rattans occur with varied overstorey vegetation of different structure and physiognomy and they can be found in almost all forest types, but their abundance varies with the quality of the site (Noor *et al.* 1999). The species richness and Shannon diversity is greatest in Bukit Panchor and the lowest in Penang National Park. Penang National Park is always under anthropogenic disturbance due to support ecotourism, infrastructure development and solid waste pollution inside the park (Wern & Weng 2010). On the other hand, Bukit Panchor is a home to many dipterocarps; while tree community in Bukit Panchor is made up of various strata which allow the rattan species growth by climbing over various forest canopies with less human disturbances. Mixed dipterocarp forest supports high diversity of rattan species in this area. Bukit Panchor comprised of dense canopy of multi-strata forest allowing minimal light penetration and some part of Bukit Panchor is comprised of partly open and some other part with highly dense canopy.

More rattan species were found in areas of high light intensity, as they must also be able to adapt to wide ranging light levels. Some rattans are pioneer species, while others require shade to mature (especially forest-floor and understorey rattans) (Dransfield 1979). Different species had varying maximum stem heights, and rattans occupy all strata within the forest from floor to canopy (Watanabe & Suzuki 2008). Besides, there are patches of gap opening at certain place that provide good light penetration and provide sufficient light intensities for rattans, especially light demanding species (Bagh 1996); higher light intensities generally promote higher growth rates. In addition, good water supply in this forest area contributes to various species of rattans as most of them prefer habitats with good drainage. In previous study, Watanabe & Suzuki (2008) stated that poor drainage inhibited the growth of rattans as well as many plants. Greatest species evenness indicated that rattan species in this area is evenly distributed. However, this area was recorded with low dominance and low rattan individuals.

In contrast, Penang National Park recorded the lowest rattan species richness and diversity. This area is partly an open area and exposed to high light intensity which limit the growth of som plants. Its sandy substrate and dry soil condition support only

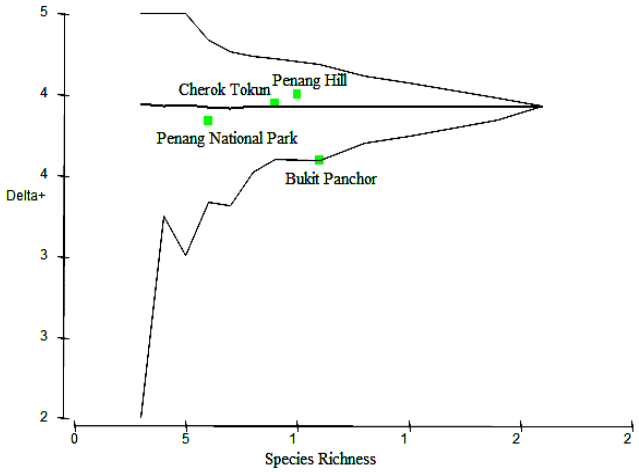

Fig. 3. Average taxonomic distinctness of rattan species in all four studied locations.

a few species. Situated near the beaches along the coastal lines of seashore, exposes this forest to high wind velocity. Wind plays an important role in the movement of the rattan crown. Through wind movement the cirrus/flagella comes in contact with tree branches nearby (ITTO 2007). Strong winds however break tree branches where the rattan is hanging and result in damage of rattan shoots, and fallen branches can also damage young seedlings. In addition, high abundance of well-grown timbers and other plants limits the growth and establishment of rattan species. According to Bacilieri (1999) there is a significant negative correlation between rattan growth and the competition with surrounding trees especially from Dipterocarpaceae family. Rattan occupied the forest floor (Bui 2009) and high abundance of *Eugeissona tristis* in the forest floor suppressed the growth of rattan species. Penang National Park also faced the pressure from natural disturbance, but also accelerated by human activities. Therefore, it is not surprising that this area has the least rattan species compared to the other studied forests.

The dominance in Penang Hill is higher compared to the other forests. However, species evenness of this particular area was lower compared to Bukit Panchor and Cherok To'kun. Penang Hill comprised of rocks, mainly hilly granitic mass and it stands out prominently from the lowlands as a hill forest area. Rattan palms can be found on most types of rock and soils within their natural distribution area (Dransfield & Manokaran 1994; Stiegel *et al.* 2011). Thus the rattan species composition increases with increasing elevation and this feature is corroborative with previous study by Kharuk *et al.* (2010) who stated that the dense forest area also increased with increasing elevation. Rattans exhibited the greatest species diversity at higher elevations (Siebert 2005). Higher elevation in Cherok To'kun is less threatened by human activities because this uphill area is not accessible to public and visitors. Lowland part of Cherok To'kun forest was exposed to the public and human activities such as trekking, recreational event, and road embankment which are currently under construction lead to disturbed natural forest community. In addition the lowland forest of Cherok To'kun is overgrown by *Eugeissona tristis*, ferns and bushes. The overgrowth of this vegetation suppressed the establishment and growth of rattan species on the forest floor because of the competition of essentials and spaces. The environment of these areas might suppress the growth of non-climbing rattans on the forest floor but have relatively small effects on climbing rattans once the rattans are established and have escaped from the forest floor (Watanabe & Suzuki 2008).

The lowest taxonomic diversity (Δ=1.260) was observed in Bukit Panchor which also had the lowest taxonomic distinctness (Δ^*=1.636). The rattan species in Bukit Panchor would have been expected to be highly affected by the taxonomic diversity and distinctness of rattan species community in selected study area in Penang forest. Depletion of forest community in Bukit Panchor area may affect the rattan species community in Penang. This condition is reinforced by evidence based on the funnel from Fig. 3, as rattan species in all sites approach the average diversity line of the funnel. Rattan community in Penang National Park, Penang Hill and Cherok To'kun were close to the average. However, Bukit Panchor seems to be apart from the average diversity and recorded the lowest delta value of taxonomic diversity and taxonomic distinctness. Bukit Panchor had significantly lower delta value in term of species population and species richness. This claim that the similarity of rattan species in this area was lower compared to the rest of other forest and Bukit Panchor has distinct rattan species compared to the other studied sites.

Conclusions

The rattan species were most abundant in Penang hill and lowest in Penang National Park. Bukit Panchor is a stable lowland forest and supported by most diverse rattan species compared to other three forests and became distinct. In

contrast, Penang National Park recorded least diversity of rattans mainly due to its coastal location which exposes it to high biotic and abiotic interferences and only certain rattan species can withstand the extreme conditions. Human activities are still going on pressurizing forests which also indirectly affect the rattan species composition and abundance. However, further intensive ecological and conservational research as well as biodiversity surveys on rattan species is necessary as the distribution patterns and composition of most rattan species is still not clear**.** A systematic comparison study should be made between different localities. Future study should cover a larger extent of sample plots using tools such as GIS (geographic Information System) and remote sensing. An integral approach to research on rattan taxonomy, conservation, genetic improvement and silviculture would help to contribute rational management in future.

Acknowledgements

We acknowledge the all out help of USM and the logistic support of Penang State Government. The study was partially funded by the FRGS-KPT research grant and funded by Fundamental Research Grant KPT-USM (1001/PBIO/815076). We also acknowledge the constant help, advice and encouragement received from the research team members, academic staff, especially Dr. Amirudin Bin Ahmad, UMT and non-academic staff. We would like to thank Mrs. Farah Sharmin for her cordial proof reading service.

References

Bacilieri, R. & S. Appanah. 1999. Rattan cultivation: achievements, problems and prospects. *In*: An International Consultation of Experts for the Project:conservation, genetic improvement and silviculture of rattan species in south-east asia, Kuala Lumpur, Malaysia.

Bagh, A. 1996. Abundance and growth of rattans in Khao Chong National Park, Thailand. *Forest Ecology and Management* **84**: 71–80.

Bui, B. M. 2009. *Rattans of Vietnam: Ecology, Demography and Harvesting*. Ph. D. Thesis, Utrecht University, The Netherlands.

Dransfield, J. 1979. *A Manual of the Rattans of the Malay Peninsula*. Malayan forest records No. 29. Forest Department, Ministry of Primary Industries, Malaysia.

Dransfield, J. 1992. Traditional uses of rattan. pp. 47–50. *In*: M. W. Razali, J. Dransfiled & N. Manokaran. (eds.) *A Guide to the Cultivation of Rattan, Malayan Forest Records*. FRIM, Kepong, Malaysia.

Dransfield, J. & N. Manokaran. 1994. *PROSEA: Plant Resources of South-East Asia no 6. Rattans*. Prosea Foundation, Indonesia.

ITTO. 2007. *Establishment of Commercial Rattans Cultivation to Ensure Sustainable and Continuous of Raw Material for Rattan Industry in Indonesia*. Technical report. Ministry of Forestry, Indonesia.

Hamid, N. H. A. & M. N. Suratman. 2010. Assessment of Rattan Abundance and Species Composition at Kuala Keniam, Taman Negara Pahang. pp. 1041–1046. *In*: International Conference on Science and Social Research, Kuala Lumpur, Malaysia.

Kharuk, V. I., K. J. Ranson, S. T. Im & A. S. Vdovin. 2010. Spatial distribution and temporal dynamics of high-elevation forest stands in southern Siberia. *Global Ecology and Biogeography* **19**: 822–830.

Lapis, A. B., A. A. Faraon, K. G. Bueser, N. R. Pablo. 2004. Rattan reborn? *Ecosystems Research and Development Bureau* **14**: 12–13.

Latiff, A. 2011. Rehabilitation of tropical rainforest ecosystems, Kuala Lumpur. pp. 137–144. *In*: A. Latiff. (ed.) *Rehabilitation of Tropical Rainforest Ecosystems*. Kuala Lumpur.

Ludwig, J. A. & J. F. Reynolds. 1988. *Statistical Ecology*. John Wiley, New York.

Mansor, A. & R. Zakaria. 2012. The distribution of palms and *Pandans* in Teluk Bahang permanent forest reserves, Penang. *Pertanika Journal of Tropical Agricultural Science* **35**: 85–91.

Masum, K. M., A. Mansor, S. A. M. Sah & H. S. Lim. 2017a. Effect of differential forest management on land-use change (LUC) in a tropical hill forest of Malaysia. *Journal of Environmental Management* **200**: 468-474.

Masum, K. M., A. Mansor, S. A. M. Sah, H. S. Lim & M. K. Hossain. 2017b. Effect of differential forest management on biodiversity in a tropical hill forest of Malaysia and implications for conservation. *Biodiversity and Conservation* **26**: 1569–1586.

Meitram, B. & G. J. Sharma. 2005. Rattan resources of Manipur : species diversity. *Journal of Bamboo and Rattan* **4**: 399–419.

Nagabhatla, N., P. S. Roy & R. Jagdale. 2007. Monitoring spatial distribution of commercial rattans and palms in the tropical forest of Baratang Islands (Andaman and Nicobar Islands). *Indian Journal of Traditional Knowledge* **6:** 630–635.

Noor, N. S., K. A. Hamzah & W. R. Mohd. 1999. *Considerations in Rattan Inventory Practices in the Tropics*. Forest Research Institute, Kuala Lumpur, Malaysia.

Quah, E. S. F., S. A. M. Sah, M. A. Muin, N. A. A. Rahman & F. S. Mustafa. 2013. Species diversity of Herpetofauna of Bukit Panchor State Park, Penang, Peninsular Malaysia. *Malayan Nature Journal* **64**:193–211.

Richards, P. W. 1996. *The Tropical Rain Forest*. 2nd edition. Cambridge University Press, Cambridge.

Ros-Tonen, M. A. F. 2000. The role of non-timber forest products in sustainable tropical forest management, *Holz als Roh-und Werkstoff* **58**: 196–201.

Samat, N., R. Hasni & Y. A. E. Elhadary. 2011. Modelling land use changes at the peri-urban areas using geographic information systems and cellular automata model. *Journal of Sustainable Development* **4**: 72–84.

Siebert, S. F. 2005. The abundance and distribution of rattan over an elevation gradient in Sulawesi, Indonesia. *Forest Ecology and Management* **210**: 143–158.

Stiegel, S., M. Kessler, D. Getto, J. Thonhofer & S. F. Siebert. 2011. Elevational patterns of species richness and density of rattan palms (Arecaceae: Calamoideae) in Central Sulawesi, Indonesia. *Biodiversity and Conservation* **20**: 1987–2005.

Wan Rozali, N. F. Z. B., K. M. Masum, R. Zakaria, A. Mansor & A. S. Othman. 2014. Species diversity and abundance of rattan in offshore hill reserve forest of peninsular Malaysia along the elevation gradient. *Journal of Bamboo and Rattan* **13**: 1–11.

Watanabe, N. & E. Suzuki. 2008. Species diversity, abundance, and vertical size structure of rattans in Borneo and Java. *Biodiversity and Conservation* **17**: 523–538.

Wern, H. C. & C. N. Weng. 2010. The potentials, threats and challenges in sustainable development of Penang National Park. *Malaysian Journal of Environmental Management* **11**: 95–109.

(Received on 31.05.2017 and accepted after revisions, on 23.10.2017)