

Species diversity and abundance of rattan in offshore hill reserve forest of peninsular Malaysia along the elevation gradient

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Abstract: Elevation act as determinant of variation in species diversity, especially for the rattan palms which have become one of the most important non-wood forest produce. This study examines the species abundance, composition and species diversity of rattan along an altitudinal gradient in the offshore Penang Hill Reserve Forest of peninsular Malaysia. A total number of 1721 individuals under 10 species representing 4 genera of rattan were recorded in Penang Hill Reserve. High elevation recorded the highest abundance of individuals (966) comprising all ten species with the highest Margalef index value ($R1=1.309$) and least evenness ($e^H/S=0.4919$). High diversity of rattan species (value of Shannon, $H'=1.749$), greater species evenness ($e^H/S=0.7184$) and the highest Menhinicks index value ($R2=0.3694$) was observed in middle elevation. Low elevation recorded the lowest species richness ($R1=0.5304$, $R2=0.2365$) but the highest dominance value ($D=0.4306$). Anthropogenic disturbances hamper the habitat of rattan in the lower elevation, near the periphery of this reserve on a continuous basis.

Key words: Elevation, Penang Hill Reserve, dominance, evenness, richness

INTRODUCTION

Rattans are the principal lianas in Asian tropical rain forests (Gentry, 1991). No rattans are found growing naturally in other tropical and sub-tropical areas, or in the temperate regions (Pantarella, 2005). Rattan belongs to Arecaceae/Palmae and subfamily Calamoideae is one of the most important non-wood forest produce after timber, support the livelihood especially of local people who depend on forest resources (Meitram and Sharma, 2005; Ros-Tonen, 2000; Sastry, 2002). According to Dransfield and Manokaran (1994), there are about 600 rattan species belonging to 13 genera of which virtually all are being used by the locals although only about 50 are used commercially. They are found in peat swamp, evergreen, dry evergreen and mixed deciduous forests at elevations up to 1,000 masl (Hinsui *et al.*, 2008). Rattan canes are mostly collected from primary forests (Siebert, 2001). In Malaysia, rattans play an important role in the physiognomy of the tropical rain forest (Richards, 1996). But most important commercial rattan species are already in threat in Malaysia,

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Sumatra and the Philippines (Dransfield and Sunderland, 2002). Diminishing forest cover and uncontrolled exploitation has threatened both wild rattan populations and rattan industry (Sastri, 2002). Rattan populations in tropical rain forests require urgent measures for conservation.

Elevation is well known to determine vegetation characteristics (Sundqvist *et al.*, 2011). And also the most important variable in terms of variations in species diversity (Zhang and Zhang, 2007) as richness of organismic taxa declines with elevation (Rawat, 2011). The most common patterns seem to be either decreasing richness with increasing elevation or a humpshaped pattern, in which diversity peaks at mid-elevations (Rahbek, 2005; McCain, 2009). Thus the inventory of available rattan resources is very important in order to understand their potential location and distribution in different elevations. The main objective of rattan inventory is to contribute baseline information on rattan composition and distribution in different elevations. Malaysia is known to have abundant resources of rattan (Hamid and Suratman, 2010). However, there is a limited data on their distribution patterns, species abundance and species composition of rattans in relation to altitude elsewhere in the country. Therefore, the first objective of this study was to determine the species abundance and composition of rattan with different altitude. Secondly, to determine its distribution and diversity according to elevation.

METHODOLOGY

Study sites

Penang Hill, with a latitude of 5° 25' 60 N and a longitude of 100° 16' 0 E is mainly hilly granitic mass, is also known as Bukit Bendera comprising a group of peaks in Penang, Malaysia with elevation of about 833 m.

Field data collection

The altitude range for this study ranged from 0 - 800 m which was classified into three elevations intervals viz. 0-300 m (low elevation), 300 m-600 m (middle elevation) and above 600 m (high elevation). Elevation for each plot was recorded using Global Positioning System (PS map 76 CSX Versatile Navigator Garmin®). The elevation reading (the mean of several altimeter readings) in each plot had been recorded (Siebert, 2005).

To assess the species composition, 30 randomly enumeration plots (30 m x 30 m) of 900m² each had been established with the total of 0.9 hectares at different elevations to identify rattans to the species level (Figure 1). In addition, there were some limitations on plot establishment due to steepness of hill which was the main cause that make impossible to establish 100 m of transects lines across elevations.

The sample plots were placed randomly at one elevation within the surveyed forest area. The position of each rattan in the transect (using x and y coordinates) were

recorded (as described by Bagh, 1996; Watanabe and Suzuki, 2008) in graph paper. Identification process is based on plant morphology such as colour, shape of leaves, flowers, stems, roots, habitat, local name, and the distribution and composition of rattan species. In general, the rattan species recognition was based on Dransfield (1979). Rattan species sample in the studied locations were collected, labelled and photographed. Some rattan species had been identified in the field and the rest were identified with the assistance from the personnel from the Forestry Training Unit, Kepong. All collected rattan species samples were made into herbarium specimens deposited in Biodiversity Centre in Universiti Sains Malaysia.

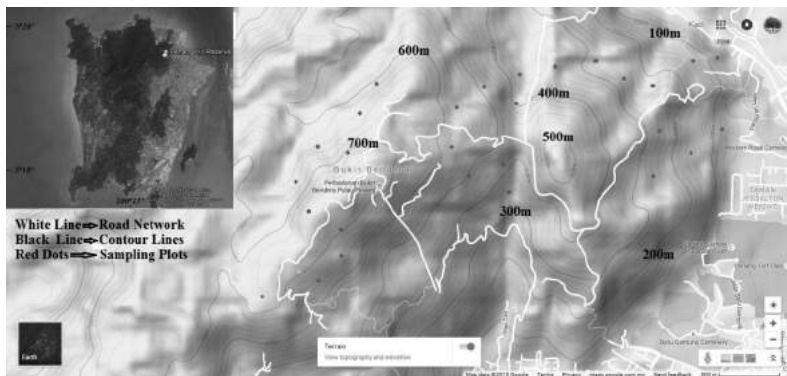


Figure 1: Study area showing the sampling plots and road network in and around the contour lines (Source: www.google.com/maps/@5.4231894,100.2710427,15z/data=!5m1!1e4)

DATA ANALYSIS

Composition of Rattans

Taxonomic diversity and distinctness was computed using PAST Software ver. 2.17 and (funnel-Primer 6) software. Data analysis on four ecological indices (Shannon-Wiener, Simpson, Margalef and Menhinicks and Evenness) was calculated using the following formula (Ludwig and Reynolds, 1988):

$$\text{Shannon-Weiner index: } H' = - \sum_{i=1}^S p_i \ln p_i$$

$$\text{Margalef's index: } R1 = \frac{(S-1)}{\ln N}$$

$$\text{Menhinick's index: } R2 = \frac{S}{\sqrt{N}}$$

$$\text{Dominance (Simpson's)} \quad D = \sum \frac{n_i(n_i-1)}{N(N-1)}$$

S = number of species in a community

pi = is the proportion of each species in the sample

\ln = is the base of the logarithm

N = total number of individuals obtained

n_i = number of individuals of i th species

RESULTS

Composition and abundance of rattan in Penang Hill along Elevation gradient

A total number of 1721 individuals under 10 species representing four genera of rattan were recorded from all three elevations of sampling sites in Penang Hill Reserve. High elevation recorded highest abundance of individuals (966) followed by middle elevation (469) and low elevation (286) (Figure 2).

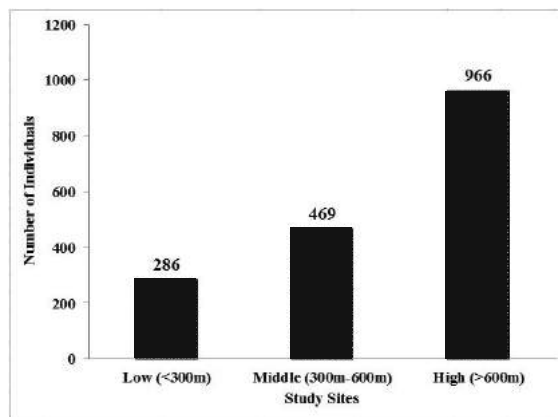


Figure 2: Abundance of rattan in relation to elevation

Four species (*Calamus diepenhorstii*, *Daemonorops lewisiana*, *Korthalsia scaphigera* and *Plectocomia griffithii*) were found to be the most common species which occurs in all three study sites of different elevation in Penang Hill Reserve. Another four species of rattan (*Calamus javensis*, *Calamus penicillatus*, *Daemonorops calicarpa*, and *Daemonorops geniculata*) were found to occur in both middle and high elevation while the rest of the two species (*Calamus castaneus* and *Calamus calospathus*) were found in high elevation only (Table 1).

Plectocomia griffithii was found with the highest number of individuals (144) and become dominant species in low elevation with percentage of 50.35% followed by *Daemonorops lewisiana* (119, 41.61%), *Calamus diepenhorstii* (17, 5.94%) and *Korthalsia scaphigera* (6, 2.10%). In middle elevation, *Plectocomia griffithii* also have the highest abundance with 144 individuals (30.70%) followed by *Calamus diepenhorstii* (117, 24.95%), *Calamus penicillatus* (76, 16.20%), *Daemonorops geniculata* (49, 10.45%), *Daemonorops calicarpa* (38, 8.10%) and *Korthalsia scaphigera* (24, 5.12%). *Daemonorops lewisiana* and *Calamus javensis* were found

Table 1: List of rattan species according to elevation

Genera	Species	Local Name	Low (<300m)	Middle (300m-600m)	High (>600m)
<i>Calamus</i>	<i>Calamus castaneus</i>	Rotan cucor	-	-	v
	<i>Calamus diepenhorstii</i>	Rotan kerai	v	v	v
	<i>Calamus javensis</i>	Rotan batu	-	v	v
	<i>Calamus penicillatus</i>	Rotan batu	-	v	v
	<i>Calamus calospathus</i>	Rotan demuk	-	-	v
<i>Daemonorops</i>	<i>Daemonorops callicarpa</i>	Rotan lumpit	-	v	v
	<i>Daemonorops geniculata</i>	Rotan jahaca	-	v	v
	<i>Daemonorops lewisiana</i>	Rotan lumpitkecil	v	v	v
<i>Korthalsia</i>	<i>Korthalsia scaphigera</i>	Rotan semut, rotan udang	v	v	v
<i>Plectocomia</i>	<i>Plectocomia griffithii</i>	Rotan mantang	v	v	v
<i>Frequency</i>			4	8	10

Table 2: Abundance and l/c Percentage of Rattan Species in low, middle and high elevation in Penang Hill Reserve.

Species	Low (<300m)	Middle (300m-600m)	High (>600m)
<i>Calamus castaneus</i>	-	-	60 (6.21%)
<i>Calamus diepenhorstii</i>	17 (5.94%)	117 (24.95%)	91 (9.42%)
<i>Calamus javensis</i>	-	2 (0.43%)	16 (1.66%)
<i>Calamus penicillatus</i>	-	76 (16.20%)	45 (4.66%)
<i>Calamus calospathus</i>	-	-	31 (3.21%)
<i>Daemonorops callicarpa</i>	-	38 (8.10%)	18 (1.86%)
<i>Daemonorops geniculata</i>	-	49 (10.45%)	164 (16.98%)
<i>Daemonorops lewisiana</i>	119 (41.61%)	19 (4.05%)	42 (4.35%)
<i>Korthalsia scaphigera</i>	6 (2.10%)	24 (5.12%)	4 (0.41%)
<i>Plectocomia griffithii</i>	144 (50.35%)	144 (30.70%)	495 (51.24%)

lower in abundance in middle elevation. All species of rattan (10 species) were recorded in high elevation. *Plectocomia griffithii* recorded the highest abundance (495, 51.24%) in high elevation also as in low and middle elevation. *Daemonorops geniculata* have moderately high abundance (164, 16.98%) followed by *Calamus diepenhorstii* (91, 9.42%), *Calamus castaneus* (60, 6.21%), *Calamus penicillatus* (45,

4.66%), *Daemonorops lewisiana* (42, 4.35%) and *Calamus calospathus* (31, 3.21%) in high elevation (Table 2).

Table 3 : Diversity table of Rattan in relation to to elevation in Penang Hill

	Low	Middle	High
Taxa_S	4	8	10
Individuals	286	469	966
Dominance_D	0.4306	0.2045	0.3099
Shannon_H	0.9592	1.749	1.593
Evenness_e^H/S	0.6524	0.7184	0.4919
Menhinick	0.2365	0.3694	0.3217
Margalef	0.5304	1.138	1.309

Table 3 depicts the high diversity of rattan species observed in middle elevation as indicated by the high value of Shannon, $H'=1.749$. Dominance in low elevation ($D=0.4306$) was the highest compared to other elevation (middle and high). High elevation recorded the highest Margalef index value (with $R1= 1.309$) while middle elevation recorded the highest Menhinicks index value (with $R2= 0.3694$). Low elevation recorded the lowest species richness as indicated by the lowest value ($R1=0.5304$, $R2= 0.2365$). Species evenness was greater in middle elevation and lower in high elevation.

DISCUSSION

Ecological indices revealed that species richness and species diversity in low altitude of Penang Hill was significantly lower compared to middle and high altitude. All the plots faced disturbances from human population because of the construction of roads and infrastructure development inside the Hill Reserved Forest. Lower altitude facing more disturbances compared to higher altitude. Figure 1 showed the presence of maximum road networks in the lower altitude. Moreover there were lot of hiking trails across the road networks to facilitate the visitors inside the reserved forest. Forest Department still continuing lots of construction work for recreational activities and extension of road networks in the study area. Thus increasing activities in lowland area of Penang Hill influenced the composition of rattan community in lower altitude.. In addition, natural disturbances (landslides, hurricanes, wind storm and drought) have accelerated the loss of some rattan species by uprooting and damaging them and eventually affect their diversity and species richness. Both species structure and

composition of rattan were found sensitive to environmental impacts (pressure) thus they can be used as indicators for destruction of forests (Isango and Varmola, 2007). According to Masykur (2005) low elevation recorded relatively high density of rattan in dipterocarp forest. Rattan and dipterocarps in Southeast Asia share the same area of natural distribution, but generally not the same site preferences. While most dipterocarp species are concentrated on ridges and upper slopes, most rattan species seem to prefer lower slopes and valley bottoms. Between there is a wide area of overlap and transition (Weidelt, 1996). High competition from surrounding trees in low elevation limit retards the establishment of rattan growth. Bacilieri and Appanah (1999) documented the relationship among environmental variability and the growth of rattan species showed a significant correlation between rattan growth and the competition with the surrounding trees.

Dominance recorded in low altitude of rattan is higher than both middle and high altitude. Low variability in forests canopy and forests strata facilitates the establishment of climbing rattan species in this particular altitude. Only a certain rattan species can withstand high light intensities under thin forest canopy in low elevation area. However, extreme and direct light penetration can retard the development of rattan (Belcher, 1999). Thus, only four rattan species were found to occur in low elevation which can withstand higher understory light levels (Figure 3).

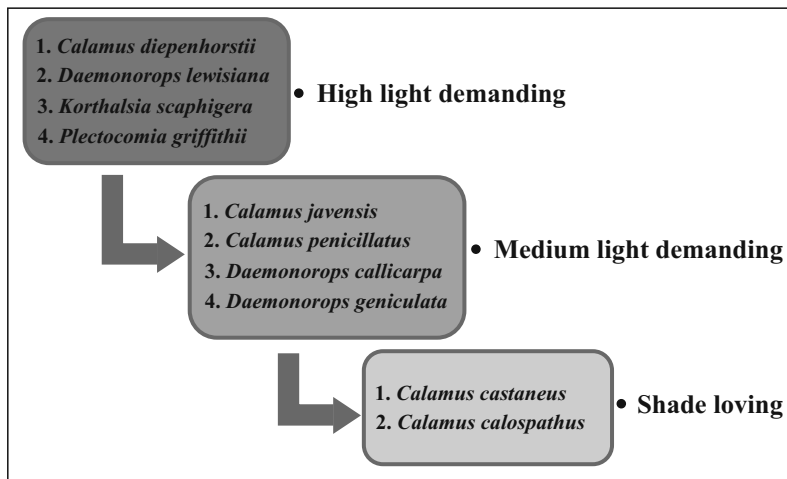


Figure 3: Habitat preference of available rattan species in the context of light requirement (Based on field observation)

The palm prefers the low elevation in humid tropical areas and can withstand with little damage and prolonged seasonal flooding (Pantanella, 2005). Gap openings and more bushes found in lowland area did not affect the establishment for some rattan species however there were some species which do not survive in that condition. Seedlings grow well in forest canopy gaps where sunlight can penetrate to the ground (Hourt, 2008). However, different species grow well under different sunlight and soil conditions and therefore certain species have adapted to different forest types (Hourt,

2008). Most species occur naturally in closed tropical forests and are early gap colonizers. Many require extremely high levels of light and respond well to a limited reduction in the forest canopy (Sunderland, 2001). Thus, natural tree fall gaps likely influence the general distribution and density (i.e., clumpiness) of rattan populations (Siebert, 2005). However, it should be noted that the gap partitioning is influential purely in terms of abundance and not in terms of diversity and the number of species (Sunderland, 2001).

Middle elevation recorded higher value in species richness and species diversity. This finding was very interesting because according to the general pattern of plant diversity and abundance in relation to altitude they usually decrease in diversity, species richness and abundance with the increasing elevation (McCain, 2009). After reaching at certain elevation, the rattan species diversity decline with increasing elevation and substitute with other plant community which indicates that species diversity in Penang Hill according to elevations followed the general pattern of humped-shaped. The elevation patterns for species richness and density were humped-shaped with maxima around 1000 m (Stiegel *et al.*, 2011). From the perspective of population ecology, such hump-shaped patterns may result because of the dispersal of species from lower and higher elevations, resulting in the highest overlap of such dispersing populations at mid-elevations (Kessler, 2009; Fischer *et al.*, 2011). Middle altitude had stable forest ecosystem which can support variety of rattan species. This intermediate condition contributes too many type of flora and provides variation in forests canopy. This variation was very important for this type of climbing palm to establish and grow well. Presence of small stream, steep area, flat area lowland area and upland area support different rattan species to establish in different kind of favorable surroundings. Moreover, species that prefer fertile soil normally occur in mid-elevation plots (Zhang and Zhang, 2007).

With increasing elevation, less rattan species are found (Bui, 2009). Rattans occur with varied over storey vegetation of different structure and physiognomy. They can be found in almost all forest types, but their abundance varies with the quality of the site and one of the factors are the accessibility of human population and the level of protection from biotic interference (Noor *et al.*, 1999). High elevation of Penang Hill was less exposed to human disturbance that destroys the habitats of various living organisms is changing the ecology and increasing the extinction of species (FAO, 2009). Adaptability in marginal lands, and its minimal disturbance to the environment or existing forest with limited amount of tree felling for canopy openings (Pantarella, 2005) contribute to high species richness and dominance in this particular area. Diversification of flora in high elevation contributes to variety of forest canopy and strata which support high diversity of rattan. Most species require soil with good moisture and relatively bright light (Powling, 2004). Rattans mostly grow in forest, where they climb up on other plants to reach the sunlight using specially adapted flagella covered with recurved hooks (Hourt, 2008). Seedlings grow well in forest canopy gaps where sunlight can penetrate to the ground (Hourt, 2008).

Rattans grow slowly when they are still in the seedling stage, but mature plants grow faster (Hourt, 2008). Depending on the species, rattan growing naturally in areas where light intensity is varying at wide range (Ban *et al.*, 2005). Light and support affect rattans life continuously as their light needs bring them to grow on their crown above the forest canopy and the lack of branched trees make them susceptible to fall onto the ground at the increase of stem weight and height (Pantanella, 2005). The lowest species evenness recorded in high altitude in Penang Hill indicates that rattan species was poorly distributed and only a few species can grow and establish well in this particular altitude since not all species contribute equally to the functioning of ecosystems. This indicates that a relatively unequal abundance of each rattan species was present in the mixed low elevation forest. It has been stated by McGill *et al.* (2007) that less evenness, suggesting a mechanism of competitive and high competition between rattan species and surrounding trees affected the distribution of rattan species which occurred unequally in the area.

CONCLUSIONS

Generally, rattan species and abundance increases with increasing elevation. Less disturbance of human activities in higher elevation contribute to high rattan community compared to lower altitude. Middle elevation supported highest diversity of rattan which composed of diverse and high canopy cover which provides favourable condition for many rattan species to grow and establish well. It is highly recommended that other variables should be considered including different canopy types, precipitation, and other soils properties since these factors could influence the growth and distribution of rattans. Scientific collaboration between private, government and academic institutions should be organized in the theme of conserving and protecting the natural biodiversity of the forests ecosystems in Malaysia including forests reserves in Penang provide recommendations for sustainable management.

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