POPULATION DYNAMICS OF *Calamus castaneus* GRIFF. IN SELECTED FOREST RESERVE IN NORTHERN REGION OF PENINSULAR MALAYSIA

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2019

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by

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Thesis submitted in fulfilment of the requirements

for the degree of

Master of Science

July 2019

ACKNOWLEDGEMENT

Alhamdulillah, I am very grateful to Allah for the ease He granted and blessing me mentally and physically until I completed my studies. I would like to express my deepest gratitude to my supervisor, Assoc. Prof. Dr. Asyraf bin Mansor for his excellent supervision and support throughout this project. I thanked USM research university grant project number 1001/PBIOLOGI/8011031 and School of Biological Sciences under Graduate Assistant Scheme (GA) for supporting me financially throughout my studies.

Special thanks to drivers and lab assistants from the School of Biological Sciences; Mr. Sukor Harun, Mr. Hanizam, Mr. Muthu, Mr. Yusoff, Mr. Nazri, Mr. Shunmugam, Mr. Hilmi, Mr. Syed Ezham and Mr. Nizam who always provides excellent services when I am in need. Not to forget Peninsular Malaysia Forestry Department for issuing respective permits.

My deepest appreciation to all my lab mates and friends; Noorazila, Syafiq, Zhafarina, Fasihah, Nora, Azim, Festus, Fatinizzati, Muzalifah and Izzuddin who helped me conducting lab works and statistical analysis. Not to mention, a thousand thanks to all my helpers; Anis, Ashraf, Husna, Hazni, Izazi, Syahida, Tengku, Amalia, Afiqah, Kunpeng, Kaz, Khairul, Anas, Murni, Shaida and Khodijah which without them I could not be able to finish my super challenging samplings.

To my parents; Mohd Rusdi bin Yaacob and Salmiah bt Shaari I shared my heartiest gratitude for their endless support, encouragement and prayers. Thanks to my siblings for their unlimited love and motivational guidance. Lastly, I thanked those who were involved whether directly or indirectly from beginning until the end of this research.

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LIST OF ABBREVIATIONS

TBFR	Teluk Bahang Forest Reserve
SMFR	Segari Melintang Forest Reserve
BMFEP	Bukit Mertajam Forest Eco Park
GPS	Global Positioning System
ha	Hectare
RH	Relative Humidity
Air Temp	Air Temperature
Soil Temp	Soil temperature
SMC	Soil Moisture Content
SBD	Soil Bulk Density
DI	Disturbance Index
pH	Power of Hydrogen
p	Significant value
CCA	Canonical Correspondence Analysis
SPSS	Statistical Package for Social Science

DINAMIK POPULASI *Calamus castaneus* GRIFF. DI HUTAN SIMPAN TERPILIH DI BAHAGIAN UTARA SEMENANJUNG MALAYSIA

ABSTRAK

Dinamik populasi pokok rotan di dalam hutan di Malaysia masih belum didokumentasikan sepenuhnya lagi. Sehubungan dengan itu, tujuan utama kajian ini adalah untuk mengenal pasti corak dinamik populasi pokok rotan yang tidak memanjat iaitu *Calamus castaneus*. Kajian ini dijalankan di hutan simpan terpilih di bahagian utara Semenanjung Malaysia antaranya ialah Hutan Simpan Segari Melintang di Perak, Hutan Simpan Teluk Bahang dan Hutan Eko Rimba Bukit Mertajam di Pulau Pinang bermula bulan pada Mac 2017 sehingga Mac 2018. Objektif kajian ini adalah; 1) untuk menilai status penjanaan semula dan tumbesaran *C. castaneus*, 2) untuk mengkaji tempoh pembungaan dan buah, dan 3) untuk menganalisis korelasi iklim mikro dan faktor tanah ke atas populasi dinamika *C. castaneus*. Lima plot berukuran 10 m x 10 m (100 m^2) telah didirikan di setiap kawasan kajian. Keseluruhan pokok *C. castaneus* di dalam plot telah ditanda menggunakan tag plastik bernombor. Sebanyak 180 pokok telah dinilai di semua kawasan kajian iaitu; 52 pokok di HS Teluk Bahang, 86 pokok di HS Segari Melintang, dan 42 pokok di HER Bukit Mertajam. Analisis kajian ini menunjukkan status pertumbuhan semula, pertumbuhan, tempoh pembungaan dan buah serta perbezaan persekitaran mempunyai pengaruh ke atas corak dinamik populasi *C. castaneus*. Dapatan kajian menjelaskan bahawa tiada perbezaan signifikan ($p < 0.05$) menggunakan ujian Kruskal- Wallis antara kadar pertumbuhan semula *C. castaneus* di setiap kawasan kajian yang bermakna status pertumbuhan semula di setiap lokasi kajian adalah hampir sama. Kadar pertumbuhan dibahagikan kepada tiga bahagian iaitu bilangan penghasilan pelepah daun setiap individu, panjang tangkai dan panjang rakis.

HS Segari Melintang menunjukkan kadar pertumbuhan tertinggi bagi setiap bahagian yang telah di senaraikan manakala kadar pertumbuhan paling rendah adalah di HS Teluk Bahang. Selain itu, ketinggian anak pokok di HS Segari Melintang adalah yang tertinggi (11.6 cm setiap bulan). Kematian yang tertinggi sepanjang tempoh penyampelan dicatatkan di HS Teluk Bahang (30 individu mati). Kepadatan populasi di HS Segari Melintang adalah yang tertinggi dengan jumlah 0.172 pokok setiap m^2. Sementara itu, HS Segari Melintang mencatatkan tempoh pembungaan dan buah yang paling panjang berbanding dua lagi kawasan kajian. HS Segari Melintang mengeluarkan bunga jantan dan buah yang berterusan sepanjang tahun manakala bunga betina dianggarkan berkembang hanya untuk sebulan dua sahaja. Di HS Teluk Bahang, hanya pokok jantan sahaja dijumpai, menyebabkan ia hanya berbunga buat seketika iaitu sebulan hingga dua bulan sahaja. Pokok jantan dan betina di HER Bukit Mertajam berbunga selama dua hingga tiga bulan manakala tempoh berbuah boleh mencapai sehingga enam bulan. Kajian ini juga mendapati bahawa terdapat korelasi yang kuat antara iklim ikro dan faktor tanah ke atas corak populasi dinamika. Kesemua parameter yang telah disenaraikan iaitu kelembapan relatif, suhu udara, keamatan cahaya, suhu tanah, kandungan kelembapan tanah, pH tanah, ketumpatan pukal tanah, keterbukaan ruang kanopi dan indeks gangguan berkorelasi positif dengan kadar pertumbuhan *C. castaneus* di HER Bukit Mertajam dan HS Teluk Bahang. Namun begitu, kandungan kelembapan tanah, pH tanah, ketumpatan pukal tanah, keterbukaan ruang kanopi, dan indeks gangguan berkorelasi negatif di HS Segari Melintang. Kajian ini membuktikan bahawa, *C. castaneus* tidak mempunyai taburan yang khusus. Secara amnya, kajian ini penting dalam memberikan kefahaman yang lebih mendalam mengenai biologi dan dinamik populasi spesis rotan yang kurang dikenali di Malaysia.

POPULATION DYNAMICS OF *Calamus castaneus* GRIFF. IN SELECTED FOREST RESERVE IN NORTHERN REGION OF PENINSULAR MALAYSIA

ABSTRACT

The population dynamics of rattan in Malaysian forests was not fully documented. Hence, the major aim of this study was to investigate the population dynamics pattern of *Calamus castaneus*; a non-climbing rattan. This study was conducted in selected forest reserve in the northern region of Peninsular Malaysia namely Segari Melintang Forest Reserve in Perak, Teluk Bahang Forest Reserve and Bukit Mertajam Forest Eco Park in Pulau Pinang from March 2017 until March 2018. The objectives of this study were; 1) to evaluate the regeneration status and growth of *C. castaneus*. 2) to investigate flowering and fruiting duration, and 3) to correlate the microclimate parameters and soil properties on the population dynamics of *C. castaneus*. In each study site, five plots with the size of 10 m x 10 m (100 m^2) each were established. All *C. castaneus* individuals inside the plot were marked with numbered plastic tags. A total of 180 individuals was evaluated in all study sites; Teluk Bahang FR (52 individuals), Segari Melintang FR (86 individuals) and Bukit Mertajam FEP (42 individuals). Present analysis showed that the regeneration status, growth, duration of flowering and fruiting, as well as different environmental would influence the population dynamics pattern of *C. castaneus*. The findings of this study revealed that the regeneration rate of *C. castaneus* had no significant difference ($p < 0.05$) using Kruskal-Wallis test between each site which means the regeneration status is all study locations is nearly the same. The growth was divided into three parts; number of leaf sheath per individuals, petiole length and rachis length. Segari Melintang FR displayed the fastest growth rate in all parts listed meanwhile Teluk Bahang FR was the slowest. Besides that, the height in seedlings of Segari Melintang FR (11.6 cm per month) was also recorded the highest. The death of individuals throughout the sampling period were recorded in Teluk Bahang FR (30 individuals died). It was found that the population density of *C. castaneus* was the largest in Segari Melintang FR (0.172 individual per m^2). Meanwhile, Segari Melintang FR recorded the longest flowering and fruiting duration compared with other two sites. Segari Melintang FR produced male inflorescences and fruits continuously throughout the year while female inflorescences bloomed approximately one to two months only. In Teluk Bahang FR, only male plants were present in the plot and hence it only flowers in a short period from one to two months. Male and female inflorescences in Bukit Mertajam FEP flowers for two to three months while the duration of fruiting can reach to six months. This study also discovered that there was strong correlation between microclimate parameters and soil properties on the population dynamics pattern. All of parameter listed particularly relative humidity, air temperature, light intensity, soil temperature, soil moisture content, soil pH, soil bulk density, canopy gap opening, and disturbance index were positively correlated with growth of *C. castaneus* in Bukit Mertajam FEP and Teluk Bahang FR. However, soil moisture content, soil pH, soil bulk density, canopy gap opening and disturbance index correlates negatively in Segari Melintang FR. This study revealed that *C. castaneus* shows no specific distribution. Generally, this study is important in providing a better understanding of the biology and the population dynamics of lesser known rattan species in Malaysia.

CHAPTER 1

INTRODUCTION

1.1 Definition of Population Dynamics

According to Turchin (2003), population dynamics is the study of how and why number of individuals in a population change in size and structure over time. It includes the rate of reproduction, growth, mortality, morbidity and migration (UNDESA & UNFPA, 2012). Example of scenario are population growth, population density, ageing population, birth rate or death rate. Therefore, population dynamicist document the changes in population pattern and attempt to find out the mechanisms to define the observed patterns (Turchin, 2003).

1.2 Introduction to Rattans

Rattans are from the family Arecaceae or Palmae under the subfamily of Calamoideae. Rattan in Malay words are “rotan” which means spiny climbing palms (Dransfield, 2001). In addition, Dransfield (1981) stated that rattan are one of the least protected groups of flowering plants. Meanwhile, rattan can be clustered or solitary. It consists of 600 species from 13 genera where majority of them are climbers and mostly have spines. *Calamus*, *Daemonorops*, *Ceratolobus*, *Korthalsia*, *Plectocomia*, *Plectocomiopsis*, *Myrialepis*, *Calospatha*, *Pogonotium* and *Retispatha* can be found in South East Asia while the genera *Laccosperma*, *Eremospatha* and *Oncocalamus* are endemic to Africa (Dransfield, 1979). The largest rattan genus is *Calamus* with 370 species. A total of 194 rattan species are present in Malaysia where 107 rattan species can be found in Peninsula Malaysia, 85 species in Sabah and 105 species in Sarawak (Aminuddin, 2000; Dransfield, 1979, 1992, 2001).

Furniture is the most popular rattan product (Sastry, 2001). Apart of that, rattan is also used to make carpet, beaters, walking stick, umbrella handles, sporting goods, hats, ropes, cordage, birdcages, matting, shopping and laundry baskets, panelling, serving trays, hoops, raft making, thatching material, house construction and fish traps (Dransfield, 2001; Oteng-Amoako & Obiri-Darko, 2001; Renuka, 2001; Sastry, 2001; Sunderland & Dransfield, 2002). In Peninsular Malaysia , rattan collection is usually done by aborigines, for example in the northern state of Kedah in Peninsular Malaysia (The International Development Research Centre, 1979). Out of 106 species of rattan in Peninsular Malaysia which consists of 8 genera, approximately 30 species are collected and utilized by the country's rattan industry. Most commercial canes come from the genus *Calamus*. The top five most important species in term of utilization are; *Calamus manan* (Rotan manau), *Calamus tumidus* (Rotan manau tikus), *Calamus scipionum* (Rotan semambu), *Calamus caesius* (Rotan sega), and *Calamus trachycoleus* (Rotan irit) (Ali & Barizan, 2002; Dransfield, 1979).

1.3 An Overview of *Calamus castaneus* Griff.

Calamus castaneus Griff. is a non-climbing rattan as shown in Figure 1.1 (Dransfield, 1979; Kidyoo & McKey, 2012; Ruppert *et al*., 2016). It shows no tendency to climb due to the lack of climbing organ which were flagellum and cirrus. Their scaly chestnut brown coloured fruit as shown in Figure 1.2 where sweet and acidic taste were favoured by primates especially macaques (Dransfield, 1979; Ruppert *et al*., 2016).

Figure 1.1: Non-climbing rattan *C. castaneus*

Figure 1.2: *C. castaneus* fruits were scaly and chestnut brown coloured

One of the characteristics to identify *C. castaneus* or “rotan cucor” are the presence of glaucous or dull dirty grey indumentose under the leaflet (Figure 1.3). The leaflets were armed with scattered black bristle on lower 3 nerves on margin and sometimes on upper surface. Besides that, “cucor” was easily recognised by the grey spines with yellowish bases as shown in Figure 1.4 (Dransfield, 1979; Ruppert *et al*., 2012). The cane is too short to be used hence the leaves were used for “atap” and the immature fruit were used as cough medicine by “Orang Temuan” (Dransfield, 1979; Sunderland & Dransfield, 2002).

Figure 1.3: Leaf sheath with grey indumentose below

Figure 1.4: Yellow-based spines can be seen clearly from the image

The selection of *C. castaneus* as preferred studied rattan species was due to three reasons. First of all, this species is the most common rattan in Malaysia (Dransfield, 1979) hence, it is easy to find it and it is also fruits all year round. Secondly, *C. castaneus* is a suitable model although its non-climbing nature could lead to some ecological differences from the rest of rattans. Moreover, this rattan is little exploited by human due to its inability to produce long cane or large stem diameter. Hence, its natural populations are thus relatively preserved (Kidyoo & McKey, 2012).

1.4 Research Questions

To provide a better understanding of this research, the following research question were addressed accordingly:

1) What is the regeneration status and growth of *C. castaneus* in all studied locations?
2) Does flowering and fruiting duration of *C. castaneus* vary in relation to different study sites?
3) Which environmental factors influence the population dynamics of *C. castaneus* in the three study sites?

1.5 Aim and Objectives of Research Study

The aim of this research is to study the population dynamics pattern of *C. castaneus* in selected forest reserve in Northern Region of Peninsular Malaysia.

The objectives of this study are:

1) To evaluate the regeneration status and growth of *C. castaneus* in all studied locations.
2) To investigate flowering and fruiting duration of *C. castaneus* in relation to different study sites.
3) To correlate microclimate parameter and soil properties on the population dynamics of *C. castaneus* in the three study sites.

1.6 General Hypothesis

It is hypothesised that the site or locality, regeneration status, growth, flowering and fruiting duration as well as microclimate parameters and soil properties does affect the overall population dynamics of *C. castaneus*.

CHAPTER 2

LITERATURE REVIEW

2.1 Population Dynamics in Palms

Johnson (1998) has stated that all palms belong to family Arecaceae (or previously called Palmae) which consists of 2200 species. All palm are monocots and shares characteristics with plants such as grasses, lilies, arums and orchids (Kricher, 1999). Palms are usually armed with sharp spines along the trunks and leaves. Palms are often abundant in the forest understorey (Kricher, 1999). Three plant families that stands out in term of economy and have been utilized for wide range of products are from grass family (Graminae), legume family (Leguminosae) and palm family (Arecaceae). These plant families are utilised to produce beverages, building materials, cosmetics and hygiene, feeds, fertilizers, food, fuel, handicrafts, medicine and rituals, ornamental plants, structure and shelter (Anderson *et. al*., 1991; Balick & Beck, 1990; Henderson *et. al*., 1995; Johnson, 1998; Kahn, 1991; Kahn & de Granville, 1992). Indeed, many palm species have multiple uses and thus among the most important plant species for human.

As stated by Tomlinson (1979), palms are ideal subjects for demographic study since they are easy to be identified at all stages of growth and their fruits are readily visible. For instance, *Rhopalostylis sapida* (nikau palm) is the only palm native to New Zealand (Moore & Edgar, 1970). Preliminary studies by Enright (1985) and Esler (1969) stated that *R. sapida* could not be aged precisely according to their frond scar counts. Reproductive maturity of palms in forested areas is normally attained only once stem height exceeds 2 m, and size might a better indicator of reproductive behaviour than age as estimated from frond scars (Enright, 1985, 1992; Enright & Watson, 1992).

Most of plant species tend to display has clumped spatial distribution rather than random or overdispersed distribution (Hubbell, 1979).

Another example is *Mauritia flexuosa* which is a long-lived, dioecious, canopy dominant palm found in tropical, flooded, swamps throughout Amazonia basin (Cardoso *et. al*., 2002; Henderson *et al*., 1995; Kahn & Meija, 1990; Kalliola *et. al*., 1991). *M. flexuosa* act as non-timber forest resource and their fruit are only produced by female palm. The fruits are economically useful to extract oil (Holm *et. al*., 2008). Study has shown that palms also can be a source of food for wild animals and pollinators. Palms are often one of the most crucial sources of food for a few species along dry seasons (Duran & Franco, 1992). *M. flexuosa* could be considered as a keystone species because a large number of other species feed on the fruit and seed, including agouties, spider monkeys, red and green macaws, lowland tapirs, red and gray brocket deer,white-lipped and collared peccaries and fish (Bodmer, 1990, 1991; Fragoso, 1999; Goulding, 1989; Henderson et al., 1995).

However, population studies on rattan are very few (see review by Anto, 2005; Pederson, 1995). Renuka & Rugmini (2007) have conducted studies on endangered rattan species in Western Ghats. This literature stated that population dynamics and population structure differ based on habitat confines.

2.2 Genus *Calamus*

Calamus L. (370 to 400 sp.) are predominantly an Asian genus and ranges from Tropical Africa, India and Sri Lanka, China, South and East to Fiji, Vanuatu and Eastern Australia. Most of the best commercial species of rattan are members from this genus (Dransfield, 1992; Uhl & Dransfield, 1987). In 1979, Dransfield has stated that *Calamus* could be clustered or solitary, acaulescent to high-climbing pleonanthic dioecious; that is, there are separate male and female plants and the species are thus obligatory out-crossing (Dransfield, 2002). The spines are highly organized and the sheaths usually heavily armed with spines with either cirrus or flagella present. Very rarely both of them present and in some species neither present. The knee is frequently present meanwhile the leaves are with petiole or without petiole. In addition, the leaflet of *Calamus* spp. are variously arranged. Meanwhile, the inflorescence of male and female are superficially similar. Their fruits are covered in reflexed scales with various shape and the seeds covered with thin or thick sarcotesta (Dransfield, 1979).

According to Dransfield (2001), the most important product of rattan palm is the cane (rattan stem stripped of its leaf sheaths) which are solid in contrasts to bamboo poles which are almost always hollow (Johnson, 1998). Furniture is the most popular rattan product (Sastry, 2001). From Table 2.1, Sunderland & Dransfield (2002) listed the examples usage of rattan from genus *Calamus* spp. besides canes are; *C. conirostris* and *C. longisetus* fruit are could be consumed, *C. deeratus* and *C. javensis* palm heart eaten, *C. castaneus* and *C. longispathus* fruit are used in traditional medicine, *C. andamanicus* and *C. castaneus* leaves used for thatching and *C. longispathus* leaf is used as cigarette paper. Since genus *Calamus* are widely used, now some of them are threatened for instance *C. manan* (Peninsular Malaysia & Sumatra), *C. merrillii* (Philippine) and *C. ovideus* (Western Sri Lanka) are harvested for their cane (Dransfield & Manokaran, 1994; Tuley, 1995; Sunderland, 1999).

Majority of rattan trade is dominated by countries of Southeast Asia such as Indonesia, Philipphine, Thailand and Malaysia (Sunderland & Nkefor, 1999). Among the producing countries, Indonesia dominates the world rattan trade with the most bountiful supply of wild and cultivated rattan (Sastry, 2001).

Table 2.1 Some traditional uses of rattan, excluding cane (Sunderland & Dransfield, 2002)

Product / Use	Species
Fruit eaten	*Calamus conirostris; C. longisetus; C. manillensis; C. merrillii; C. ornatus; C. paspalanthus; C. subinermis; C. viminalis; Calospatha scortechinii; Daemonorops ingens; D. periacantha; D. ruptilis;*
Palm heart eaten	*Calamus deeratus; C. egregius; C. javensis; C. muricatus; C. paspalanthus; C.siamensis; C. simplicifolius; C. subinermis; C. tenui; C. viminalis; Daemonorops fiss; D. longispatha; D. margaritae; D. melanochaetes; D. periacantha; D. scapigera; D. schmidtiana; D. sparsiflora; Laccosperma secundiflorum; Plectocomiopsis geminiflora*
Fruit used in traditional medicine	*Calamus castaneus; C. longispathus; Daemonorops didymophylla*
Palm heart in traditional medicine	*Calamus exilis; C. javensis; C. ornatus; Daemonorops grandis; Korthalsia rigida*
Fruit as source of red resin exuded between scales, used medicinally and as a dye (one source of "dragon's blood")	*Daemonorops didymophylla; D. draco; D. maculata; D. micrantha; D. propinqua; D. rubra*
Leaves for thatching	*Calamus andamanicus; C. castaneus; C. longisetus; Daemonorops calicarpa; D.elongata; D. grandis; D. ingens; D. manii*
Leaflet as cigarette paper	*Calamus longispathus; Daemonorops leptopus*
Leaves chewed as vermifuge	*Laccosperma secundiflorum*
Roots used as treatment for syphilis	*Eremospatha macrocarpa*
Leaf sheath used as toothbrush	*Eremospatha wendlandiana; Oncocalamus sp.*
Leaf sheath/petiole as grater	*Calamus sp. (undescribed, from Bali)*
Rachis for fishing pole	*Daemonorops grandis; Laccosperma secundiflorum*

2.3 Non-climbing Rattan

Non-climbing rattan are rattans with lack of whip-like organ; cirrus and flagella that are used as hook to grab other large trees. Most non-climbing rattan are acaulescent, having no discernible stem at all (Sunderland & Dransfield, 2002). *Calamus castaneus* is one of a non-climbing rattan species along with *C. sedens*, *C. whitmorei*, *C. minutus*, *C. cockburnii*, *C. lobbianus* and *C. concinnus* present in Malaysia (Dransfield, 1979). Meanwhile *C. acanthophyllus*, *C. sedens*, *C. erectus*, *C. cillaris*, *C. acaulis*, *C. dianbalensis*, *C. dongnalensis*, *C. harmandii*, *C. kampucheaensis*, *C. modestus*, *C. salicifolius*, *C. thysanolepis*, *C. yentuensis*, *D. brevicaulis*, *D. nulchuaensis* can be found in Cambodia, Laos and Vietnam (Peters & Henderson, 2014).

Non-climbing rattans mostly considered as low in economic value due to inability to produce long canes or large stem diameter.However, this kind of rattan have other commodity value such as medicinal value, the fruit or the palm heart can be eaten meanwhile the leaves are great for thatching (Sunderland & Dransfield, 2002; Watanabe & Suzuki, 2008). Despite the low commercial values as cane, most produce inflorescences continually and would provide food for animals, birds and insects as reward for pollination or seed dispersal (Watanabe & Suzuki, 2008).

2.4 Taxonomy and Morphology of *Calamus castaneus* (Griff.)

Family:	Arecaceae
Subfamily:	Calamoideae
Tribe:	Calameae
Subtribe:	Calaminae
Genus:	*Calamus*
Species:	*castaneus*
Local name:	rotan cucor

According to Dransfield (1992), *Calamus* is the largest rattan genus with 370 species. One of them is *Calamus castaneus* or "rotan cucor" which is a clustering rattan and one of the commonest palms in Malaysia growing throughout the Peninsular except for Perlis, South Thailand and North Sumatra. The stems rarely grow more than 1.5 m tall, by up to 8 cm in diameter without sheaths, with very crowded nodes (Appendix A). The distinct features of *C. castaneus* that it has yellow-based spines and grey-brown indumentum; spines arranged in groups. The leaflets about 30-40 on each side of the rachis with dull dirty indumentose below, armed with scattered black bristles on lower 3 nerves on margins and sometimes on upper surface (Dransfield, 1979). It usually produced inflorescences up to about 45 cm long that are borne low on the abaxial surface of the leaf sheath immediately above the subtending axil, the origin obscured by other leaf sheath.

"Rotan cucor" is a pleonanthic species of which its axillary inflorescence was produced continually which flowering or fruiting does not affect the death of the stem (Sunderland & Dransfield, 2002). It is a dioecious rattan; male and female reproductive system occur on separate plants which features a striking system of mimicry. On female plants, the pistillate flower is accompanied by a sterile staminate flower that appears to contribute to insect attraction (Kidyoo & McKey, 2012). *C. castaneus* are known to produce shoots from its stem (Ruppert *et al*., 2012). Pursuant to Watanabe & Suzuki (2008), many rattans can produced clonal shoot at the base of the stem and build up clumps as well as reproduce by seed. However, formation of new shoots from the inflorescence apex by Ruppert *et al*. (2012) proved that the reproductive behaviour of *C. castaneus* and the specific ecological role of the shoot proliferation is still unclear. These unique flowering and recruitment methods in rattans should complicate the growth and reproduction strategies relative to tropical tree and may promote coexistence (Watanabe & Suzuki, 2008).

C. castaneus produces chestnut coloured fruits non-seasonally throughout the year and one individual would exhibit different fruiting stages (ripe, unripe, budding, and flowering) all at the same time (Ruppert *et al*., 2014). Rattan fruits are usually eaten by animals such as primates, birds and insects as a compensation for pollination or seed dispersal (Watanabe & Suzuki, 2008). Aside from hornbill, primates are considered as the main dispersers of rattan seeds in both South East Asia and Africa (Corlett & Lucas, 1990; Dransfield, 2001; Sunderland, 2001).

C. castaneus is a non-climbing rattan species due to the absence of cirrus and flagellum. According to Ali & Barizan (2002), the most important commercial cane is from genus *Calamus*. However, cane from *C. castaneus* is too short to be used hence the leaves are commonly used for roofing material. In addition, the immature fruits are used as cough medicine by “Orang Temuan” (Dransfield, 1979).

2.5 Environmental Factors Influencing Population Dynamics of *Calamus castaneus*

2.5.1 Microclimate

Studies from different ecosystems and habitats variations has established that microclimate has significant influence of plant species (Godefroid *et al*., 2007). These microclimate properties would include forest structure, soil and its attributes as well as light intensity, temperature and humidity would influence plant species composition (Godefroid, 2001; Godefroid *et al*., 2007; Siebert, 2005). Russell (1932) listed the soil factors that affect the growth of plants are water supply, air supply, temperature, supply in plant nutrients, various injurious factors, and depth of soil. The plant may be affected in many ways such as in the rate of growth, in the character or habit of growth, in its composition at different stages and in the amount of yield.

2.5.1 (a) Relative humidity

Relative humidity is generally high in the tropics especially in lowland rainforests where humidities are ranging from 90% to 95% at ground level. Meanwhile, humidity is less in rainforest canopy and usually is no higher than 70% (Kricher, 1999). Powling (2004) discussed that high relative humidity in the air were probably due to low percentage of gap opening in the forest. In addition, high humidity will help in rattan growth and establishment (Vongkaluang, 1985).

2.5.1 (b) Air temperature

Godefroid *et al*., (2007) stated that the presence of some plant species was influenced by air temperature and humidity. It has been suggested that the regional and habitat distributions of species are limited by temperature extremes (Suggitt *et al*., 2011). Temperature is important as it affects rate growth of plants and thus determines what plant can be grown and what cannot be grown at a given area (Godefroid *et al*., 2007; Russell, 1932). In addition, length of the period of vegetative growth and maturation were also affected by temperature. (Godefroid *et al*., 2007; Russell, 1932). A rise in temperature would accelerate the setting in the reproductive phase in such a way reduce the vegetative period and so decreased the yield (Godefroid *et al*., 2007; Russell, 1932).

Besides, temperature may affect the height growth of rattan. Around the canopy, crowns are exposed to wind, and during the night the temperature should be cooler than that inside the forest (Whitmore, 1984). The cool environment might suppress the height growth of rattans to the canopy. This indicated that rattan have low tolerance towards low temperature (Watanabe & Suzuki, 2008). As reported by Russell (1932), the temperature at the time of ripening greatly affect the gemination capacity of the seeds. Moreover, root flourish better at lower temperature than the shoot and increase in temperature might injured the roots.

2.5.1 (c) Light intensity and canopy gap

As reported by Appanah & Nor (1991), rattan are known to establish and grow rapidly in large gap. Nonetheless, not all rattan species exhibit strong light-demanding, gap-regenerating growth preferences (Siebert, 1993). Throughout their natural range, rattan species are found in wide range of forest and soil type. Despite of wide range of ecological condition, certain rattan species need good light penetration for their development (Sunderland & Dransfield, 2002). In addition, Russell (1932) documented that light largely determines nature and amount of organic matter of the soil. As stated by Kricher (1999), low light intensity is a chronic feature of rainforest interior and is an important potential limiting factor for plant growth.

Dransfield (1979) has described two extreme growth situations of rattans: 1) non-climbing rattans and some climbing rattans slowly go through maturity in deep shade in the forest undergrowth, 2) others required light gap to develop into mature plants. Some rattan species rely on good light penetration for their growth hence some of them could be found in gap vegetation (Sunderland & Dransfield, 2002). Increase in forest disturbance such as through selective logging activity, lightning strike, hurricane and isolated tree fall would permit large penetration of light thus encourage the regeneration of rattan (Kricher, 1999; Sunderland, 2002). Sunderland & Dransfield (2002) indicated that seed would germinate under wide range of light conditions. The seedling would remain dormant until there is sufficient light for them to develop, such as tree fall (Sunderland, 2002). In addition, stem elongation is also affected by light (Sunderland & Dransfield, 2002). Sunderland & Dransfield (2002) also have reported that in clustering species, some clump could be harvested many times if the light condition is conducive for the remaining suckers to develop and elongate.

Renuka *et al*., (2007) have stated that light intensity has effects on growth, survival percentage and number of shoots produced. The effects of light intensity on rattan growth also vary according to species. Generally, higher light intensity results in higher growth rate of rattan (BØgh, 1996). Besides, BØgh (1996) also state that the dependence on the light regime seem equally strong in clustering species. Moreover, light intensity had considerable effect on height growth of rattan. Rattans tend to produce greater number of shoots under 50% light in all species while under 100% light, minimum number of shoot is produced (Renuka *et al*., 2007).

2.5.2 Altitude, elevation and forest type

Changes in habitat elevation also affect plants' composition. Increasing in altitude would affect the physiognomy, structure and floristic composition of tropical vegetation. Soil physical and chemical properties change with increasing elevation as well. In general, soils at higher elevation in ever-wet mountains (e.g., in montane forests) tend to be more acidic and have higher organic matter levels and more extreme nutrient deficiencies (e.g., N, P, K, Ca) than soils in adjacent lowlands (Burnham, 1975).

Rattan is more confined to equatorial tropical rainforest (Dransfield, 1992) with the highest distribution of rattan could be seen in lowland forest. The altitudinal distribution range indicates that rattans have low tolerance to low temperatures; the decrease of temperature with increase of altitude would limit the distribution of rattans along the altitudinal gradient (Watanabe & Suzuki, 2008). Rattan is highly abundant in lowland tropics but tend to decline in higher elevation (Gentry, 1991; Schnitzer & Bongers, 2002). In contrary, research by Appanah *et al*. (1993) stated that the diversity and abundance of rattan are the greatest in hill dipterocarp forest of Peninsular

Malaysia. Later, Siebert (2005) proved that rattans are found to be abundant at all elevation and showed a great species diversity at higher elevation. Most of rattans are distributed in lowlands but several grow in montane region (Dransfield, 1992;1979).

Rattan stem density and vertical structure are affected by changes in altitude and associated environment (Watanabe & Suzuki, 2008). This literature also stated that stem density of rattan is smaller in lowland forests rather than lower montane forest. In addition, small rattans are predominant and made dense colonies. High climbing rattan are dominant in peripheral swampy forest (Watanabe & Suzuki, 2008). Swamp forest has poor rattan flora meanwhile dipterocarp forest has richer flora than alluvial forest. This is due to alluvial forests habitat that are intermediate between dipterocarp forest and swamp forest (Watanabe & Suzuki, 2008). On the other hand, mixed dipterocarp forest had a variety of growth forms of rattan, dominated by species remaining on the forest floor or understorey (Watanabe & Suzuki, 2008). Hence, it is important to preserve mixed dipterocarp forest as non-climbing rattan require deep shade to grow in maturity.

2.5.3 Soil properties

2.5.3 (a) Soil temperature

It is difficult to separate soil temperature effects from temperature effects in general since temperature of the air is largely determined by temperature of soil (Russell, 1932). Pursuant to Russell (1932), any soil would nourish any plant if the temperature and water supply are regulated properly. Soil temperature and moisture could affect plant and root growth. Ripening of fruit also is influenced by water supply and soil temperature (Russell, 1932). Furthermore, soil temperature and air supply to the roots are intimately bound up with the water content in the soil but this case are less studied by the soil experts. Rise of soil temperature also lowers the solubility of oxygen in the water thus alters the aeration conditions (Russell, 1932). Haskell et al., (2012) state that soil temperatures are lower under canopy coverage compared to soils with no canopy coverage.

2.5.3 (b) Soil moisture content

The amount of water that a soil could hold is determined by the volume and size of soil pores and the total surface are of the particles (Anon, 2010). The increasing percentage of micropores in the soils would result in increasing its water-holding capacity. In contrary, soils with a greater amount of macropore space than micropore space has a lower water-holding capacity. For example, sandy soils has low water holding capacity due to its low micropore space meanwhile in clay soils, the pore space is dominated by micropores resulting the high water-holding capacity (Anon, 2010).

Tropical forest has received more precipitation than temperate forest, but the rainfall and soil moisture are distributed irregularly throughout the year (Reid *et al*., 2015). Besides that, tropical forest also suffered from longer and more intense dry season which prompted a greater competition for water availability (Reid *et al*., 2015). High decomposition of rate of the organic matter results in low organic matter content in the soil of tropical rainforests (Longman & Jenik, 1974). Meanwhile, microorganisms are enable to decompose organic residue at high rate due to high temperature and moisture in the tropics (Longman & Jenik, 1974). A study on composition of rattan communities in Forest Reserve Penang by Wan-Rozali (2014) indicate that less water supply and dried soil would suppressed rattan growth to the canopy.

2.5.3 (c) Soil bulk density

Bulk density is the mass (weight) of dried soil per unit of bulk volume, including the air space. The bulk density is determined before drying to constant weight at 105 °C (Brady & Weil, 2014; Anon, 2010). Soil with a high proportion of a pore space to solids have lower bulk densities than those that are more compact and have less pore space (Brady & Weil, 2014).

Bulk density could be used to assess whether adequate pore space exists only if soil texture is known. The suitability of bulk densities depends on soil texture (Anon, 2010). However, increase of bulk density and decrease in total pore space would make the soil more compact. Compacted soils restrict root growth, limit the movement of oxygen as well as carbon dioxide in the root zone, and undesirable changes in hydrologic function, such as reduced water infiltration (Brady & Weil, 2014; Anon, 2010).

2.5.3 (d) Soil texture

Soil texture refers to the relative fineness or coarseness of the inorganic, mineral soil particles specifically the relative proportions of sand, silt and clay. Sand particles are relatively large, silt particles are intermediate in size meanwhile clay is the smallest soil particles. Loam is considered as an ideal soil texture because of the favourable characteristics for plant growth. However, loam is not an equal mix of sand, silt and clay. It actually contains relatively less clay (Anon, 2010).

Soil structure and texture are crucial for water holding capacity and providing oxygen to the roots. It also has a profound influence on the chemical and biological properties of the soil. Besides that, soil texture plays a major role in water infiltration and percolation. Hence, texture were an important role in determining which tree species would grow well in a given site (Anon, 2010; Troeh & Thompson, 2005).

2.5.3 (e) Soil pH

Soil pH is the measure of the acidity or alkalinity of soil. The pH scale ranges from 0 to 14. Soils with pH less than 7 are acidic, and those with a pH greater than 7 are alkaline. Although quite variable for different species, has varied pH, the number would usually fall in the range of 6.0 to 6.5 for most trees (Anon, 2010). However, tropical rainforest of Peninsular Malaysia commonly comprises soil pH between 3.5 to 5.5 of which is high in acidity (Nurfarfazliza *et al*., 2012).

Soil pH has many effects on the chemistry and ecology of the soil. Soil pH may affect which species will grow and which soil organisms are present (John *et al*., 2007).

Some essential elements are available for uptake within a relatively narrow pH range (Anon, 2010). Essential element form chemical compound at certain pH range that are insoluble in water, which are hard to absorb by plant since roots could only take up minerals dissolved in water (Anon, 2010). One of the effects of pH on tree growth is the availability of mineral nutrients. Low pH values may reduce the availability of Ca, Mg, K and P (John *et al.*, 2007). For instance, phosphorus may be unavailable with soil pH of 5.5 or below due to high acidity. On the other hand, in alkaline soils, iron, zinc and manganese may be unavailable (Anon, 2010).

CHAPTER 3

METHODOLOGY

3.1 Description of Study Sites

The study was conducted in two forest reserves and one forest eco-park which were Teluk Bahang Forest Reserve in Penang Island, Segari Melintang Forest Reserve in Manjung, Perak and Bukit Mertajam Forest Eco-Park in Penang mainland (Figure 3.1). The study sites were chosen according to two major criteria; elevation and forest type. Teluk Bahang FR (125 m above sea level) is a lowland dipterocarp forest, Segari Melintang FR (30 m above sea level) is a coastal dipterocarp forest and lastly Bukit Mertajam FEP (557 m above sea level) is a hill dipterocarp forest.