POPULATION DYNAMICS OF RATTANS (ARECACEAE, SUBFAMILY CALAMOIDEAE) THROUGH FRUIT UTILIZATION AND SEED DISTRIBUTION BY FRUGIVOROUS MAMMALS

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by

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LIST OF ABBREVIATIONS

AGB	- aboveground biomass
am	- before noon (*lat*.: ante meridiem)
app.	- approximately
c.	- circa
cm	- centimetre
DBH	- diameter at breast height
e.g.	- for example (*lat.:* exempli gratia)
et al.	- and others (*lat.:* et alii)
g	- gram
ha	- hectare
HB	- head to body length (without tail)
HF	- hind foot length
hr	- hour
HxWxL	- height x width x length
i.e.	- that is (*lat*.: id est)
in litt.	- unpublished (*lat*.: in litteris)
in prep.	- in preparation
in press	- publication still being printed, not yet available for distribution
kg	- kilogram
km	- kilometre
m	- metre
mm	- millimetre
min	- minute
MHz	- Mega Hertz
pers. comm.	- personal communication
pers. obs.	- personal observation
PFR	- Permanent Forest Reserve
pm	- after noon (*lat*.: post meridiem)
SMFR	- Segari Melintang Forest Reserve
T	- ton
T	- tail length (anus to tail tip)
VJR	- Virgin Jungle Reserve
W	- weight

KEDINAMIKAN POPULASI ROTAN (ARECACEAE, SUBFAMILI CALAMOIDEAE) MELALUI PEMAKAN BUAH DAN PENYEBARAN BIJI BENIH OLEH MAMALIA PEMAKAN BUAH

ABSTRAK

Banyak spesies rotan mempunyai nilai ekonomi yang tinggi dan ini menyebabkan spesies tersebut terancam oleh kerana eksploitasi berlebihan dalam habitat liarnya. Kajian ini menilai kepelbagaian rotan, kelimpahan dan perubahan biomasanya serta mengenalpasti mamalia pemakan buah utama yang menyebarkan benih rotan dalam satu hutan hujan tanah pamah di Semenanjung Malaysia dalam masa tiga tahun. Kajian ini juga membincangkan berkenaan corak taburan dan penyebaran anak benih, serta fasa pembungaan dan penghasilan buah yang melibatkan penelitian lanjut terhadap satu spesies, *Calamus castaneus*. Kesemua rumpun rotan dalam kawsan kajian (12.2 ha) ditanda dengan GPS dan bilangan batang dikira. Dengan menggunakan rakaman video, mamalia pemakan buah dan biji benih utama rotan telah dikenal pasti. Saiz populasi, kawasan rayau (home range), corak pergerakan dan keupayaan maksimum menggerakkan biji benih oleh haiwan-haiwan ini telah di dikaji dengan kaedah tangkap-tanda lepas dan tangkap semula dan juga dengan kaedah jejak radio (radio-tracking) bagi primat, *Macaca nemestrina*. Sejumlah duabelas spesies rotan dari lima genera yang meliputi 2000 batang rotan dengan purata biomasa ialah 3 t ha^{-1} telah ditinjau dalam kawasan kajian. Lima spesies rotan yang paling banyak ialah *Daemonorops angustifolia* (39.0 batang ha^{-1}), *Calamus castaneus* (31.5 batang ha^{-1}), *D. micracantha* (29.3 batang ha^{-1}), *D. calicarpa* (17.9 batang ha^{-1}), dan *Ceratolobus*

subangulatus (10.3 batang ha^{-1}). Didapati bahawa secara keseluruhan populasi rotan dalam kawasan kajian telah merosot 9% (298 batang ha^{-1} pada tahun 2011 ke 27 batang ha^{-1} pada tahun 2013) dan 21% (3.4 t ha^{-1} pada 2011 ke 2.7 t ha^{-1} pada 2013) pengurangan biomasa dalam jangka masa dua tahun. Komposisi spesies antara kelima-lima plot dalam dua tahun adalah berbeza secara signifikan (Chi-Square Test χ^2_{2011}=2108, χ^2_{2013}=1554, d.f.= 40, $p_{2011,\ 2013} < 0.01$). Jarak antara anak benih ke tumbuhan betina (dianggap sebagai tumbuhan yang berpotensi sebagai induk) juga berbeza secara signifikan (One-way ANOVA, F=24.2, d.f.=4, $p<0.01$) antara spesies, dengan *Daemonorops calicarpa* menunjukkan minimum jarak paling pendek antara anak benih dan tumbuhan induk (md=22 m, σ 3.9 m) dan *Daemonorops geniculata* menunjukkan min jarak paling jauh (md=105 m, σ 24.3 m).

Hanya dua spesies Muridae (keluarga tikus) yang boleh dikaitkan dengan penggunaan biji rotan (*Leopoldamys sabanus* dan *Maxomys spp.)* secara pengumpulan biji benih. Kelimpahan spesies-spesies ini ($N_{L.s.}$ 8.2 ind ha^{-1}, $N_{M.spp.}$ <1 ind ha^{-1}) serta biomassanya ($BM_{L.s.}$ 2149 g ha^{-1}, $BM_{M.spp.}$ 110 g ha^{-1}) dan kawasan rayauan ($MCP_{L.s.}$ 640 m^2, $MCP_{M.spp.}$ 604 m^2) adalah terlalu kecil untuk memberi sebarang kesan terhadap keberkesanan corak penyebaran biji rotan. Satu spesies primat, beruk (*Macaca nemestrina*) didapati merupakan spesies utama dalam pengambilan biji rotan dan berkemungkinan menyebarkan biji benih jauh dari pokok induk. Jarak penyebaran biji yang maksimum didapati tidak lebih dari 3.5 km dan dua kumpulan beruk yang berbeza mempunyai kawasan rayau seluas lebih-kurang 1 km^2 yang mana dua kawasan ini tidak bertindih. Haiwan-haiwan lain di kawasan kajian, termasuklah burung, didapati tidak memakan buah rotan. *Macaca nemestrina* dan kesemua spesies rotan dalam kawasan kajian telah disenaraikan sebagai spesies terancam dan dengan kadar kehilangan habitat di kawasan ini akan menambahkan tekanan pada ekosistem yang mempunyai jaringan sedia ada yang kompleks dan sensitif. Oleh itu, usaha pemeliharaan perlu dilaksanakan dengan undang-undang yang lebih ketat di masa hadapan untuk memelihara habitat-habitat di hutan primer Malaysia yang mengandungi tumbuhan bukan balak dengan nilai tinggi seperti rotan.

POPULATION DYNAMICS OF RATTANS (ARECACEAE, SUBFAMILY CALAMOIDEAE) THROUGH FRUIT UITILIZATION AND SEED DISTRIBUTION BY FRUGIVOROUS MAMMALS

ABSTRACT

Many rattan species have a high economic value and thus became threatened by overexploitation in the wild. This study assesses rattan diversity, abundance and biomass change and identifies main mammal seed dispersers of rattans in a lowland Dipterocarp rain forest of West-Malaysia during a three-years study period. It also adresses seedling development and general flowering and fruiting events whereof a more detailed look on one species, namely *Calamus castaneus*, is taken. All rattan clusters within the study plots (12.2 ha) were GPS-tagged and their stems counted. By means of video-traps at rattan frutescenses and seed stations their main mammal fruit and seed utilizers were identified. Population sizes, home ranges, moving patterns, and maximum seed dispersal ability were analysed by executing a mark and recapture study of small mammals and by means of radio-tracking of the primate species *Macaca nemestrina*. In total twelve rattan species of five genera comprising almost 2000 stems with a mean biomass of 3.1 t ha^{-1} were surveyed. The five most abundant species were *Daemonorops angustifolia* (39.0 stems ha^{-1}), *Calamus castneus* (31.5 stems ha^{-1}), *D. micracantha* (29.3 stems ha^{-1}), *D. calicarpa* (17.9 stems ha^{-1}), and *Cerotolobus subangulatus* (10.3 stems ha^{-1}). The overall rattan population at the study site declined by 9% (298 stems ha^{-1} in 2011, 27 stems ha^{-1} in 2013) and suffered a biomass loss of 21% (3.4 t ha^{-1} in 2011, 2.7 t ha^{-1} in 2013). The species composition amongst the five plots differed significantly in both years (Chi-Square Test χ^2_{2011}=2108, χ^2_{2013}=1554, d.f.= 40, $p_{2011, 2013} < 0.01$). Distances of

seedlings to the closest female plant (considered as potential mother plant) also varied significantly (One-way ANOVA, F=24.2, d.f.=4, p<0.01) amongst species, with *Daemonorops calicarpa* showing the shortest mean distance between seedling and mother plant (md=22 m, σ 3.9 m) and *Daemonorops geniculata* exhibiting the longest mean distance (md=105 m, σ 24.3 m). Only two small mammals species, *i.e.* *Leopoldamys sabanus* and *Maxomys spp*. could be associated to rattan seed utilization through scatter-hoarding. Their abundances ($N_{L.s.}$ 8.2 ind ha^{-1}, $N_{M.spp.}$<1 ind ha^{-1}), biomasses ($BM_{L.s.}$ 2149 g ha^{-1}, $BM_{M.spp.}$ 110 g ha^{-1}), and home ranges ($MCP_{L.s.}$ 640 m^2, $MCP_{M.spp.}$ 604 m^2) were presumably too small to have a considerable impact on the efficiency of rattans' seed dispersal. Solely found responsible for rattan fruit removal and possible long-distance dispersal of seeds was *Macaca nemestrina*. Maximum daily walking distance in this species was 3.5 km and two different groups occupied home range areas of around 1 km^2, respectively; whereas home ranges did not overlap. Other animal species at the study site, including birds, could not be observed consuming local rattan fruits. *Macaca nemstrina* and all rattan species at the study site are already listed as "vulnerable" species. Because of the ongoing habitat loss in the region conservation efforts must be enhanced and stricter laws imposed in order to protect Malaysia's remaining primary forest habitats that host commercially valuable non-timber species like rattans.

CHAPTER 1

INTRODUCTION

1.1 General

Rattans (subfamily Calamoideae, Arecaceae), which are climbing palms that are used for the global furniture industry are an important component of the rain forest ecosystem of the Malay Peninsula. Many species that are used for commercial purposes have been overexploited in the wild and are threatened with extinction. Still, there is a major gap in the knowledge of some basic principles of rattan ecology and their function in the complex jigsaw of the rain forest ecosystem. Thus, it is important to study rattans' contribution to the overall biomass of a forest and their population dynamics that is facilitated by seed dispersal processes; and furthermore to study the ecology of animal species that utilize rattan fruits and seeds as a food source. Elsewhere primates have been found to contribute to rattan seed dispersal. Also, small scatter-hoarding mammals were found responsible for seed dispersal in some plant species. A detailed review on rattans and seed dispersal is given in Chapter 2. The role of certain primates and scatter-hoarding rodents and their impact on rattan seed dispersal on the Malay Peninsula has not been studied, yet.

Here, it was assumed that certain species of both orders influence rattan population dynamics by contributing to the seed dispersal of these palms.

1.2 Scope of research

The scope of this study was to survey the changes in abundance, diversity and biomass of a rattan community in an undisturbed rain forest over 3 years. Distribution of rattan clusters and seedlings and distances to closest potential parents were analyzed. Mammal rattan seed dispersers were identified and their abundances, home ranges and foraging behaviour were studied in order to assess their influence on rattan seed dispersal.

1.3 Objectives

In particular, the objectives of this study were:

- to determine rattan diversity abundances, biomass and their changes from 2011-2013 in a coastal lowland Dipterocarp forest site at the Segari Melintang Forest Reserve, Peninsular Malaysia.
- to observe general flowering and fruiting patterns and calculate sex ratios of rattans.
- to assess habitat structures in the study plots that were occupied by rattans.
- to identify key rattan fruit and seed removers of three rattan species at the study site.
- to analyze rattan fruit and seed utilization by frugivorous mammals and their foraging behaviour, home ranges, movement patterns and population sizes.

1.4 Proximate study aims

The study aims of this multi-disciplinary study were addressed by following assessments and experiments:

- In order to determine the forest's rattan diversity, abundance and biomass five 1 ha-sized permanent study plots (A-E) near the forest edge and four 900 x 20 m transect strips were sampled for rattans. Long-term rattan observation and a small mammal mark and recapture program were run in those plots. Transect strips reached from the forest edge into the forest centre (0-900 m) and rattans here were sampled once in 2012 in order to test for a possible edge effect of rattan diversity or abundance. For statistical analysis it was assumed (null-hypothesis: H_0) that rattan diversity or abundance does not differ between forest edge and center.
- Habitat structures of the five study plots (A-E) were assessed by examining light regime, soil drainage and competition from understory vegetation around rattan clusters, and seedling fate was examined. Also, distances between two clusters of the same species, distances of seedlings to potential mother plants and to closest seedlings of the same species were measured to test species related differences in dispersal patterns. For statistical analysis H_0 stated that there was no difference in the dispersal patterns between different rattan species.
- Fruiting and flowering events during regular survey walks in plots A-E were recorded. A more detailed study of the flowering and fruiting phenology of one species, namely *Calamus castaneus* was conducted.

- Fruiting individuals of *Calamus castaneus*, *Daemonorops angustifolia* and *Daemonorops calicarpa* were long-term video-monitored in order to identify rattan fruit consumers. Artificial seed stations were video-monitored in order to identify rattan seed removers.
- An extensive mark and recapture study of small mammals was conducted in the five plots A-E in order to assess abundances and home ranges of candidate rattan seed removers. Spool and line tracking of rodents was used as a means of finding rattan seed caches.
- Radio-tracking and observation of the feeding behaviour of the primate species *Macaca nemestrina* was done to learn more about this species' foraging patterns and estimate possible rattan seed dispersal distances.

CHAPTER 2

LITERATURE REVIEW

2.1 Rattans (Calamoideae)

Rattans (Arecaceae: subfamily Calamoideae) are usually spiny climbing palms; some species, however, do not climb but are linked to the other rattans by sharing common flower and fruit characteristics, *e.g*. overlapping reflexed scales on the fruits (Dransfield 1992b, Dransfield and Manokaran 1994). They comprise approximately 600 species of 13 genera and occur throughout the Old World tropics and subtropics of Asia and Africa (Dransfield *et al.* 2008). Their greatest diversity can be found in the Western part of Malesia (Dransfield and Manokaran 1994).

In Peninsular Malaysia alone, 106 species of eight genera grow in the wild (Dransfield 1979a, a detailed description of these local species can be found in there). A total of 105 species with eight genera can be found in Sarawak (Dransfield 1992a); and Sabah accounts for 82 species of seven genera (Dransfield 1984) of “rotan”, as they are called locally. During the Fourth National Forest Inventory around 2 billion rattan clumps were surveyed in forests of the Malay Peninsula (FDPM 2013). Rattans display a high degree of endemism (Dransfield 1992c) and about half of the species that occur on Peninsular Malaysia have not yet been found elsewhere (Dransfield 1979a).

Rattans are distributed from sea-level up to 3,000 m altitude, however, at higher elevations rattan flora becomes less diverse (Dransfield 1979a, Dransfield 1992c). They inhabit almost all forest types, except for mangrove forests (Dransfield 1992c). They also occur on most soil types from swamp lands to dry ridge tops, and on all rock types. Nevertheless, some species are restricted to forests on certain rock or soil types (Dransfield 1992c, Watanabe and Suzuki 2008). Their high ecological diversity derives from the large number of rattan species and their wide geographic range that allowed adaption to various habitat types (Dransfield 1992c).

2.2 Rattans' role in the forest ecosystem

Rattans are an important component of the primary and secondary forest vegetation of Malaysia as they "bind" the forest vegetation together (Putz 1991). Rattans play an important role in the rain forest ecosystem: they can act as shelter (*e.g.* for ants) (Sunderland 2004), or as food source, *e.g.* for various insects groups that feed on their pollen (Henderson 1986, Lee 1995, Kidyoo and McKey 2010) and mammals or birds that feed on fruits, seeds, or fresh shoots (Sunderland and Dransfield 2002). Not much has been studied on the biomass of rattans in their wild habitat. Biomass calculations that do exist in literature derive from assessments executed on farmed rattan stems and on few species of *Calamus* (Lee 1994, Shim 1989, Supardi & Wan Razali 1989). No published references for wild rattans or for other genera are available.

Rattans need an intact forest stand in order to strive properly. Supardi (1999) suggests that the species composition of rattans and their abundances are highly affected by logging because climbing rattan species depend on other trees to grow on. Disturbed forests sites, such as logged forests, support less rattan stems as they are brought down together with their host trees during logging. The elongation of palms is at the apical meristem and this is likely to be damaged during logging. The regeneration of clustering species can be facilitated by the production of suckers, while solitary species solely depend on the survival of dispersed seeds and seedlings. However, seeds of some species only germinate under certain light and temperature regimes that cannot be provided by logged forests (Supardi 1999, Stockdale 1994).

Loss of rattan species and decline in abundances poses an overall threat, both to the balance of the ecosystem, but also to local communities that depend on rattan as an income source (Avé 1988, WWF Global 2011, also see 2.3).

2.3 Threats to rattans

Of the approximately 600 rattan species that can be found worldwide 117 are now being regarded as threatened to some degree (Walter and Gillet 1998). The threats are manifolds but habitat loss due to land conversion must be considered the most hazardous one to any forest species. Between 1956 and 1990 most of the lowland Dipterocarp forests of Peninsular Malaysia were converted to agricultural or industrial/ urban land (Aiken and Leigh 1992) and this process is still ongoing (Mongabay 2011). Other threats, specifically to rattans, are the overexploitation of their stems for the furniture industry or handicrafts, harvesting for palm hearts, and biotic factors, such as an increasing population of wild pigs that are responsible for seed and seedling removal of rattans in Malaysian forests (Supardi *et al.* 1998).

Rattans have been used by humans for multiple purposes for centuries, for example binding, basketry, home-building material, medicine, or food (DeBeer and McDermott 1989). They have been used extensively as a commercial commodity, for local purposes and on a global scale, and therefore became the most important non-timber forest product in Southeast Asia (Ros-Tonen 2000). A detailed survey on the global status of rattan resources is given in Dransfield *et al.* (2002). The global commercial value of rattan and its products is estimated at over US$ 7.0 billion per year (Sastry 2002). Around 30 rattan species are used for commercial purposes. Twenty of the 106 species found in Peninsular Malaysia were identified to have market value; amongst them are *Calamus manan, C. ornatus, C. turnidus, C. scipionium, and C. caesius* (FDPM 2013), of which *C. manan* and *C. caesius* were listed as "priority species" for future research (Rao *et al.* 1998). In general, the most important commercial species are from the genus *Calamus,* which is the largest genus in the subfamily Calamoideae (Dransfield *et al.* 2008) and comprises about 370 species that predominantly occur in Asia (Dransfield 1992bc, Dransfield and Manokaran 1993).

There have been some attempts to establish commercial rattan plantations in the region during the last decades. By the end of 1997 a total of 15,000 ha had been planted with rattan, mainly *C. manan* throughout the Malay Peninsula (Harnarinder and Chin 1999). Despite the efforts to establish plantations, rattan is still overexploited by the use of unsustainable harvesting methods (Sunderland and Dransfield 2002) and stems are collected mainly illegally from the wild (Siebert 2001).

A detailed description on rattan ecology, history of rattan cultivation, plantations and commercial use and value of rattans can be found in Dransfield *et al.* (2000), Wan Razali *et al.* (1992) and Abdul Razak and Raja Barizan (2011).

2.4 Seed dispersal of rattan palms

Seed dispersal is the last step in the reproduction cycle of most vascular plants. By means of seeds, plants produce genetically diverse offspring that can colonize new habitats and allows the species to survive in a variable and changing environment. Seeds can be dispersed by means of abiotic factors such as wind and water, or by biotic factors, *e.g.* by animals. Environmental factors, both abiotic and biotic, that affect seeds are crucial for plant evolution and population dynamics (Vander Wall *et al*. 2005a, Wang and Smith 2002). Seed ecology and seed dispersal is a broad field in biology and extensive literature on this topic does exist (*e.g.* Black *et al.* 2000, Dennis *et al.* 2007, Fenner and Thompson 2005, Forget *et al.* 2005, Levey *et al.* 2002).

Long-distance seed dispersal away from the parent plant is crucial to the survival of a plant population. There seems to be a density- or distance-dependent relation in the mortality or recruitment of seedlings due to host-specific predators and pathogens that accumulate in proximity to the mother plant. According to the Janzen–Connell hypothesis, seeds dispersed farthest away from their parent have a competitive advantage as they do not suffer from the species-specific predators that are found more commonly around the parent (Connell 1970, Janzen 1970).

In all tropical forest habitats, seed dispersal by vertebrates is of significant importance. Here, as many as 75% of all tree species produce fruits that are assumed to be adapted for bird or mammal dispersal (Frankie *et al.* 1974, Howe and Smallwood 1982, Lambert *et al.* 2005) and more than 95% of tropical seeds are moved by animals (Terborgh *et al.* 2002). They can transport seeds in many ways, *e.g.* within their guts, attached to their outer surface (*e.g.* fur), or inside their cheek poaches (primates); other animals, such as scatter-hoarding rodents, contribute to seed dispersal by storing seeds (Vander Wall *et al.* 2005ab). Forget (1996) found that 25–48% of seed removed by rodents were scatter-hoarded and only 9–43% were eaten. Scatter-hoarding by rodents is not well studied, but it is suspected that many of the medium-to-larger sized seeds would be attractive to scatter-hoarding animals (Vander Wall and Longland 2004). Moreover, some tropical palms seem to depend on a single small mammal species for seed dispersal and seedling recruitment (Klinger and Rejmánek 2010).

Of the 205 mammal species of the Malay Peninsula (Khan 1992), small mammals (less than 300g) are an important component of the rain forest community. Although they are rather cryptic and only hard to discover in the dense forest vegetation, they are vital for the forest communities: they contribute to key biotic processes like seed dispersal (Emmons 1991, Miura *et al.* 2007, Shanahan and Compton 2000, van der Meer *et al.* 2008, Yasuda *et al.* 2005) and pollination (Carthew and Goldingay 1997), prey on insect pests (Elkington *et al.* 1996), or act as valuable energy sources when being preyed upon by larger carnivores (Eisenberg 1980, Wilting *et al.* 2006). Despite being very diverse and abundant in Malaysian forests those species, like squirrels, tree shrews, and rats are only very little studied (Meijaard and Sheil 2008) and have not received much public or conservational attention, yet (Wells *et al.* 2004). Most of them, either terrestrial or arboreal, were found to be mainly frugivorous and/ or granivorous (Francis 2008) and contribute to seed dispersal, either by ingesting and defecating seeds (Wells *et al.* 2009) or by scatter-hoarding their food (van der Meer *et al.* 2008, Wells and Bagchi 2005, Yasuda *et al*. 2000)**.**

Primates as well seem to be of particular importance to primary seed dispersal. They comprise an average of 20 to 40% of the frugivore biomass in tropical forests (Eisenberg and Thorington 1973, Chapman 1995) and consume large quantities of fruits and defecate or spit high numbers of diverse seeds (Lambert 1999).

Primates, besides hornbills, are considered to be the main dispersers of rattan seeds in both Southeast Asia and Africa as they are attracted to rattans' often brightly coloured fruits (Corlett and Lucas 1990, Dransfield 2001, Sunderland 2001). There are two commonly observed phenomena: either fruits are ingested as a whole and pass through the intestinal tract with the seed intact, or are sucked and spat out (Corlett and Lucas 1990, Pritchard & Davies, 1999).

Only a few studies address the potential role of primates in rattan seed dispersal (*e.g.* Corlett and Lucas 1990, Lucas and Corlett 1998, Sunderland 2001, Tutin *et al.* 1994, White and Abernethy 1997) and none were conducted on Peninsular Malaysia. Most rattan species that were found at the study site have relatively big seeds (< 1 cm length). Primates belong to the most important dispersers of larger seeded plant species (Howe and Smallwood 1982, Chapman and Chapman 1995, Chapman and Russo 2006) and play a major role in the regeneration of tropical forest ecosystems (Chapman and

Onderdonk 1998). They carry seeds away from the mother plant (Herrera 2002) and add positive effects on seed germination that are caused by the passage of seeds through their digestive system (Samuels and Levey 2005, Robertson *et al.* 2006, González-Di Pierro *et al*. 2011).

In studies on African primates, rattan fruits were found to be consumed. Here, gorillas, chimpanzees, bonobos, drills and mandrills were found to use rattan fruits as a food source (Sunderland 2001, Tutin *et al.* 1994, White and Abernethy 1997). Their feeding habit, however, seems to lead to the destruction of the seeds. Those larger primate species often chew before they swallow their food and this might be benign for seeds as it inhibits their germination ability (Martin 1990, Kingdon 1997). Feeding experiments with African rattan seeds represented to those primate species showed that only fruits of the genus *Laccosperma*, which has small seeds (1 cm x 0.6 cm), were swallowed as a whole and thus, stood the chance of being dispersed intact away from the parent plant. Bigger seeds (diameter >1.5 cm) of the genera *Eremospatha* and *Oncocalamus* were either chewed and destroyed or spit out at site (Sunderland 2001).

Also in Southeast Asia, primates have been found to contribute to rattan seed dispersal (Dransfield 2001). In Singapore, long-tailed macaques (*Macaca fascicularis*) have been observed to feed on seeds of the genera *Calamus, Daemonorops* and *Korthalsia* in the wild. They were found to spit out or clean and drop the majority (up to 69 %) of seeds of the ripe fruits they consume. This alternative “seed spitting behaviour” might be regarded as a means of dispersing viable seeds (Corlett and Lucas 1990, Lucas and Corlett 1998).

2.5 Conclusion

Although rattan usage is widespread and several commercial species are amongst the threatened ones, not much is yet known about many aspects of the natural history of these palms (Dransfield and Manokaran 1993). A problem researchers often face when studying wild rattans is in finding study areas that are free from illegal harvesting. Thus, there have been only few studies in the wild that addressed ecologically important aspects like rattan population structure, seed and seedling fate (Dransfield 1992c), sex ratios in wild populations, flower and fruiting phenology, pollination, seed dispersal processes (Dransfield 1979a) and mammals (*e.g.* primates) that contribute to seed dispersal (Sunderland and Dransfield 2002).

CHAPTER 3

MATERIAL AND METHODS

3.1 Study site

3.1.1 Segari Melintang Forest Reserve

The study site was located at the Western edge of the Segari Melintang Forest Reserve (SMFR), Manjung District, Perak, Peninsular Malaysia (4°19-20'N, 100°34-36'E) (Figure 3.1).

The SMFR originally comprised of 4566 ha (1960's) but in 2010 only about 2720 ha remained. 408 ha of the SMFR are strictly protected Virgin Jungle Reserve (VJR). The rest is logged-over, regenerated Permanent Forest Reserve (PFR) (Perak Forestry Department, pers. comm.). No obvious differences in the vegetation structure of the VJR and PFR are visible as the vegetation has mainly recovered. Parts of the SMFR are declared High Conservational Value Forests as they host the critically endangered endemic Dipterocarp species *Shorea lumutensis* (Ashton 1998). Vegetation within the SMFR consists of coastal lowland mixed Dipterocarp forest and areas with alluvial freshwater swamp forest, which is temporarily flooded (water level *app.* 20 cm) for 6-8 months (except for the dry season). The maximum height of the closed canopy is about 40 m with few exceptions (Wiens and Zitzmann 2003). The SMFR extends from 20 m to 250 m above sea level.

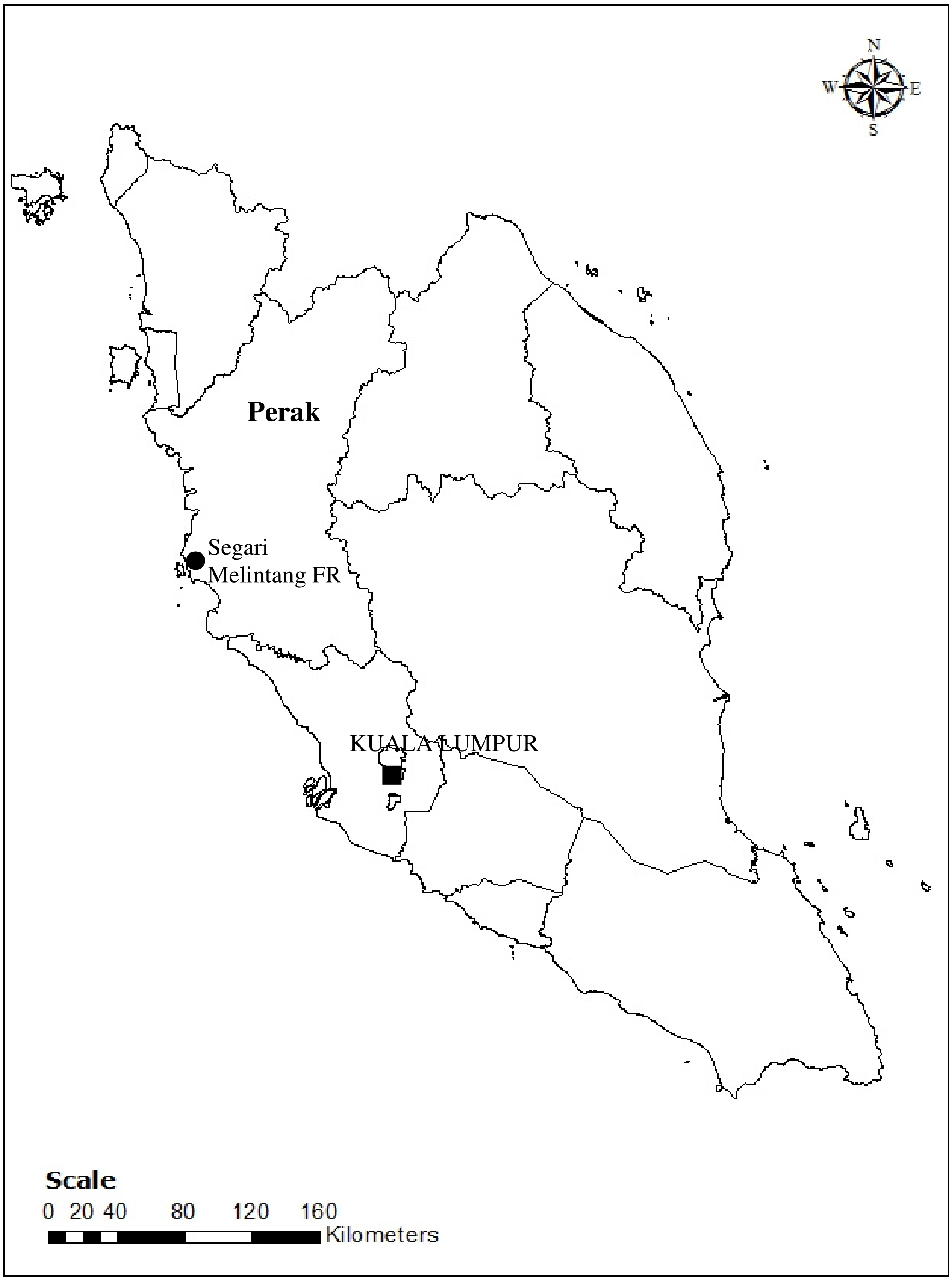

Figure 3.1: Location of the Segari Melintang Forest Reserve, Manjung District, Perak, Peninsular Malaysia.

3.1.2 Description of the study plots and transect strips

Five permanent study plots near the forest edge (see 3.1.2.1) were chosen for the long-term rattan survey and a small mammal mark and recapture study in order to cover the different vegetation types (swamp and Dipterocarp forest) as the swamp was only located near the forest edge but not near the forest center. In addition, four transect strips reaching into the forest (see 3.1.2.2) were sampled once in 2012 in order to test for differences in rattan abundance and diversity between the forest edge and center.

3.1.2.1 Study plots

Five 1 ha sized square-shaped (100 m x 100 m) study plots were established along the Western edge of the study site, near Telok Senangin. They were termed Plot A, B, C, D and E, and located within the VJR and PFR, equally covering both vegetation types (alluvial freshwater swamp and Dipterocarp forest) of the SMFR. They were set near the forest edge that borders on vast oil palm plantations (*Elaeis guineensis*). Plot centres were at least 150 m apart from each other. The distance between the outermost plots (A to E) was around 1.5 km (Table 3.1, Figure 3.2).

3.1.2.2 Transect strips

Four transect strips, each 900 m x 20 m long, parallel to each other and reaching from the forest edge towards the forest centre (*app.* 900 m from forest edge) were sampled for rattans once in 2012 where species and number of stems per cluster were counted. This part of the study area (see Figure 2.2) is *app.* 2 km wide, meaning the ends of the transects (after 900 m at the ridge top) represent the forest centre. Transects were demarcated towards the hill (up to 250 m above sea level) east of the study plots (Figure 3.2).

3.1.3 Climate

The climate of the study site (weather station Sitiawan, N4° 22', E100° 70') is characterized by the northeast monsoon with highest precipitation from October to December (209 mm to 251 mm) and a short drier season that typically lasts from June to July (84 mm to 90 mm). Annual average rainfall is 1,881 mm. Annual average temperature is 26.8°C with minimum and maximum annual averages of 22.6°C and 31.6°C, respectively (GHCN 2008).

During 2010-2012 the climate was influenced by La Niña which normally has notable impact on the weather in East Malaysia during the northeast and southwest monsoon but results in only slightly lower than average rainfalls over Peninsular Malaysia, and only during the southwest monsoon (June to August) (JMM 2013).

3.2 Study period

Field data for this thesis was collected from July 2010 until March 2013.

Table 3.1: Description of the five 1 ha study plots A-E.

study plot	distance to forest edge	distance to next plot	dominant vegetation type	elevation (a.s.l.)	reserve type
A	5-105 m	350 m	Dipterocarp	10-40 m	PFR
B	5-105 m	500 m	swamp	3-10 m	VJR
C	20-120 m	150 m	swamp	3-10 m	VJR
D	60-160 m	350 m	Dipterocarp	20-60 m	VJR
E	90-190 m	350 m	mix swamp/ Dipt.	3-5 m	PFR

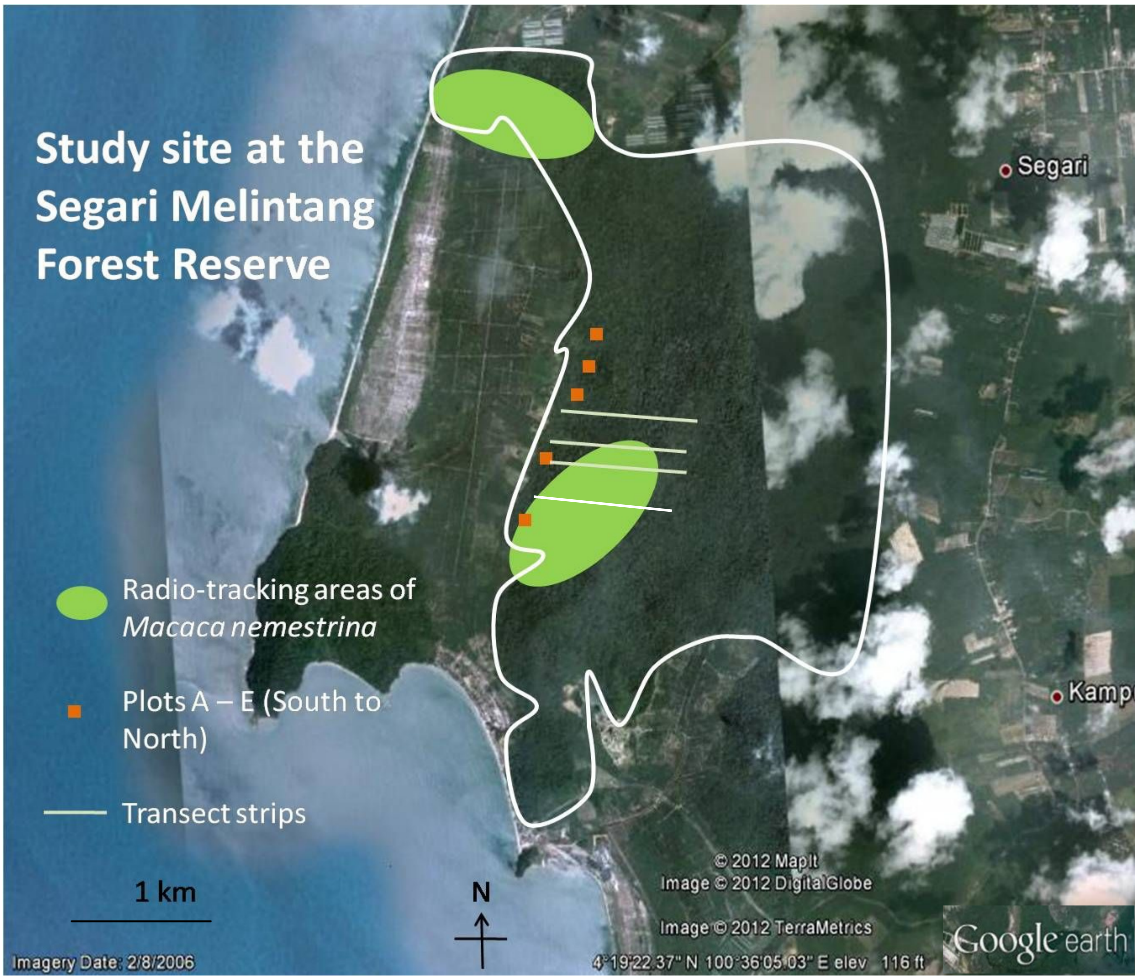

Figure 3.2: Location of the plots A-E, transect strips and radio-tracking areas within the study site at the Segari Melintang Forest Reserve.

3.3 Rattan assessment

3.3.1 Cluster tagging

Some rattan species can produce multiple stems (ramets) by basal suckering (clustering), whereas other species are single-stemmed (solitary). An individual was defined as any plant with its own root system, unless it was in a clump, in which case all individuals were considered the same plant clone (cluster or genet) (Putz and Chai 1987, Siebert 1993ab).

Each rattan genet within the five study plots (A-E) was given a unique identification number using a 5-digit coded red plastic tree tag. Tags were nailed to the closest timber tree and all genets within a 5 m radius were labelled according to this tree tag number. Species name, number of stems in each cluster, and flowering or fruiting status was noted. The GPS position (accuracy ± 3 m) of each tree tag was taken for permanent relocation purposes (Appendix B).

All rattan clusters (genets) and their aerial stems that were longer than 50 cm, and all sessile rattans in rosette form that were higher than 50 cm, were counted at least four times, starting from July 2010 until March 2013. The relapse between two counts was *app.* 6 months. During more frequent survey walks (at least every 3 months per plot) flowering and fruiting events of each cluster were noted.

3.3.2 Rattan species determination

Rattan species within the study site were determined with the help of "The manual of the rattans of the Malay Peninsula" by Dr John Dransfield (Dransfield 1979a). Additionally, sufficient picture material was sent to Dr Dransfield who personally assisted with the species verification.

3.3.3 Sampled rattan species

A brief description of the sampled rattan species can be found in the Appendix A. All descriptions of the rattans of the study area were adapted from "The manual of the rattans of the Malay Peninsula" (Dransfield 1979a), if not referred to as otherwise. More detailed descriptions of all species – except for *Korthalsia laciniosa* - can be found in there. The two *Korthalsia* species found at the study site, *K. laciniosa* and *K. rigida,* appeared in rather low abundances and some clusters could not finally be determined to species level. Thus, in the following, all sampled clusters are put together under "*Korthalsia spp*.".

3.3.4 Seedlings assessment

Seedlings of five rattan species that could be determined to species level (*i.e. Calamus castaneus, Calamus densiflorus, Daemonorops angustifolia, Daemonorops calicarpa,* and *Daemonorops geniculata*).

Twenty-five seedlings were GPS-tagged for long term observation in January 2011. They were classified into nine size (height) categories: I: 5-10 cm; II: 10.5-20 cm; III: 20.5-30 cm; IV: 30.5-40 cm; V: 40.5-50 cm, VI: 50.5-60 cm, VII: 60.5-70 cm; VIII: 70.5-80 cm; IX: 80.5-90 cm. The seedlings were counted again in March 2013 and their fate (growth rate, extinction, aerial establishment) was noted.

Additionally, GPS positions of all seedlings smaller than 20 cm tall growing in Plot C, which hosted the highest amount of seedlings, were taken once in May 2012 in order to calculate the minimum distances to neighbouring seedlings of the same species and to their potential mother plants. Distance calculations were performed in Map Source 6.13.7 (Trip and Waypoint Manager Version 5.00, Garmin Ltd. 1995-2008).

3.3.5 Habitat assessment

A rough habitat assessment around each rattan cluster was conducted to evaluate species dependent preferences for certain light regimes, densities of understory vegetation, and hydrologic substrate feature. The surrounding environment of each cluster was visually evaluated by the same observer during a 2 day survey in May 2012. As of importance for the assessment of light regime, the weather condition on both days was clear sunny sky and the assessment was done from 10 am until 4 pm. Methods were adapted from Siebert 1993a (also see De Stevens 1989):

- The predominant light regime of each rattan genet followed a qualitatively score on a scale from I to IV. The category (I-IV) was applied if the majority (> 60%) of a cluster's stems was found in it:

I: cluster in full sunlight in canopy gaps (non- or low climbing plants or acaulescent species);

II: in full sunlight in the upper canopy (high climbing plants); here, I+II can represent the same light regime quality for either climbing or non-climbing species.

III: in intermitted sunlight at subcanopy/ ground level (non- or low climbing plants);

IV: in complete shade at subcanopy/ ground level (non- or low climbing plant).

- Soil drainage at the root of each cluster was scaled from I to IV:

  I: swamp, soil waterlogged;

  II: well drained but not in swamp, *e.g*. at swamp edge or near stream;

  III: poorly drained soils, *e.g.* flat area away from swamp or streams;

  IV: dry soils, *e.g.* at steep hill slope or on rocks.

- Possible competition from understory vegetation referred to the amount of vegetation in a *ca.* 2 m radius around the root. It was qualified from I to IV:

  I: little understory vegetation;

  II: scattered understory vegetation of little apparent competitive significance;

  III: dense understory growth of moderate competitive significance;

  IV: complete cover of understory growth of potentially severe competitive significance.

  An illustration of the qualitative assessment of the understory vegetation is given in Appendix F.

3.3.6 Aboveground biomass estimations

Aboveground biomass (AGB) of trees and rattans at the study site were calculated in order to correlate the AGB of rattans at the study site to the AGB of trees, and to assess the general AGB (of rattans and trees) of all five study plots of the SMFR.

3.3.6.1 AGB of trees

AGB of trees is strongly correlated with bole diameter, which makes it possible to convert tree bole measurement into biomass estimations by making use of regression models (Brown 1997). In each of the five study plots a 100 m x 20 m subplot was established for tree biomass assessment. Inside each subplot the diameter (D) of each tree stem ≥ 10 cm DBH was measured. Aboveground biomass calculations (AGB in kg) of trees in Asian moist forests can follow different formulas, of which two are described in Brown (1997):

(1) $AGB_1 = 42.69 - 12.80\ D + 1.242\ D^2$

(2) $AGB_2 = e^{(-2.134 + 2.530\ \ln D)}$

Both formulas (which create slightly different results), their means and standard deviations were calculated in order to estimate the biomass of timber trees at the SMFR. Palm species (others than rattans, see 3.3.6.2) were not sampled.

3.3.6.2 AGB of rattans

Due to the VJR status of the study site it was not possible to apply destructive methods in order to measure the weight of local rattan species. Therefore, two separate non-invasive methods were applied for either climbing or acaulescent species.

- Acaulescent species: in the two non-climbing, stemless species *Calamus castaneus* and *Daemonorops calicarpa* the leaves shafts protrude from the root close to the ground. The fresh weight of each sampled individual (own root system) was estimated by cutting and weighing three leaves of each individual. Only individuals with a total of more than ten leaves were taken for sampling to ensure that the cutting process would not harm the survival of the clump. Leaf cutting was performed as close as possible to the ground, including the leaf shafts. The total number of leaves of each sampled individual was counted. Above ground biomass (in kg) of these two species follows the formula:

$$AGB = N[(w_1+w_2+w_3) / 3]$$

w: fresh weight of leaf
N: total number of leaves of the individual

- Climbing species: methods to measure the aboveground biomass of climbing species were adapted from Lee (1994). Cane lengths were measured as follows: Each stem was pulled out of the canopy as far as possible until its apex was visible. The beginning of each stem (l) that was absent of leaves, was measured with measuring tape from the root until the first green leaf. From there onwards the lengths (i) of a minimum of five to eight leaf internodes (from knee to knee)