Seed Dispersal of Three Framework Tree Species and Seed Predation of *Manglietia garrettii* Craib

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Abstract

Deforestation is a serious problem in northern Thailand. Framework tree species are native forest trees that help to accelerate natural forest regeneration. Planting them can, therefore, rapidly restore forest ecosystems in degraded areas. Understanding seed dispersal and predation mechanisms can help to select framework tree species and generate useful information to improve restoration techniques. The study site of this research was evergreen forest (1000-1600 m above from sea level) in Doi Suthep-Pui National Park, Muang, Chiang Mai. Direct observations of animals visiting three framework tree species (*Prunus cerasoides* D. Don, *Balakata baccata* (Roxb.) Ess. and *Manglietia garrettii* Craib) were made with binoculars. The animals were identified and their role in seed dispersal or seed predation were recorded. The observation for each tree species totaled 50 hours. Various bird and squirrel species were observed to be the main seed dispersers of these tree species. Five bird species fed on *P. cerasoides* fruits; one squirrel species and 5 bird species fed on the fruits of *B. baccata* and one squirrel species and 6 bird species fed on *M. garrettii* fruits. The most common seed disperser of all 3 framework tree species was *Pycnonotus jocosus*, a very common resident bird. The species of squirrel that fed on both *B. baccata* and *M. garrettii* fruits was *Callosciurus erythraeus*. Animals dispersed the seeds by

swallowing seeds or whole fresh fruits, bringing them far from the parent trees or deliberately or accidentally dropping fresh fruits or seeds beneath the parent trees.

Seed predation in natural habitats and the effects of seed proximity to the parent tree on seed survival levels were determined for *M. garrettii*. The seeds were placed on ground in circular sampling units, established along two line transects beneath each of 3 parent trees. Seven days after seeds were placed, percent removal was 100 in the first and second tree sampled, and for the third tree sampled was 92.8. Average percent removal of *M. garrettii* seeds was 97.6. Seed removal of *M. garrettii* was density- and distance-independent. Seed removal animals observed from sand trap were *Sus scrofa*, pheasants and ants. Ants were secondary dispersers that induced seed germination by consuming the aril of the seeds.

Seed germination tests were conducted at the Forest Restoration Research Unit (FORRU) nursery. Percent germination of seeds with aril (65.67±4.72) was significantly higher than that of seeds that retained the aril (10.67±2.08). Median length of dormancy (MLD) of seeds with aril was significantly shorter that of seeds that retained the aril. In natural conditions, aril is related to seed dormancy, removing the aril can increase seed germination. *Manglietia garrettii* is rare tree species with regeneration problem in natural conditions. It needs nursery production of seedlings and reintroduction to the natural habitat, direct seeding is not suitable.

หัวข้อปัญหาพิเศษ	การกระจายเมล็ดพันธุ์ของพรรณไม้โครงสร้าง 3 ชนิด และการล่าเมล็ดมณฑาแดง (*Manglietia garrettii* Craib)
ชื่อผู้เขียน	นางสาวพิมลรัตน์ เทียนสวัสดิ์
วิทยาศาสตรบัณฑิต	สาขาวิชาชีววิทยา

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บทคัดย่อ

การตัดไม้ทำลายป่าเป็นปัญหาที่สำคัญปัญหาหนึ่งของประเทศไทย พรรณไม้โครงสร้างเป็นพรรณไม้ท้องถิ่นที่ช่วยเร่งการกลับมาของสภาพป่า การปลูกพรรณไม้โครงสร้างสามารถฟื้นฟูระบบนิเวศป่าในพื้นที่ที่ถูกทำลายได้ ความเข้าใจในกลไกการกระจายเมล็ดพันธุ์ และการล่าเมล็ดมีส่วนช่วยในการคัดเลือกพรรณไม้ และเป็นข้อมูลเพื่อพัฒนาวิธีการฟื้นฟูระบบนิเวศป่า งานวิจัยนี้ศึกษาการแพร่กระจายเมล็ดพันธุ์ของพรรณไม้โครงสร้าง 3 ชนิดในป่าไม่ผลัดใบ (ความสูง 1000-1600 เมตร จากระดับน้ำทะเล) ของอุทยานแห่งชาติดอยสุเทพ-ปุย จังหวัดเชียงใหม่ คือ นางพญาเสือโคร่ง (*Prunus cerasoides* D. Don) สลีนก (*Balakata baccata* (Roxb.) Ess.) และ มณฑาแดง (*Manglietia garrettii* Craib) สังเกตและบันทึกสัตว์ที่มีปฏิสัมพันธ์กับพรรณไม้ที่กำหนด เป็นเวลาชนิดละ 50 ชั่วโมง ด้วยกล้องส่องทางไกล ผลการสังเกตพบว่าพรรณไม้ทั้ง 3 ชนิดมีการกระจายเมล็ดพันธุ์โดยสัตว์ ที่สำคัญคือ นก และกระรอก โดยพบนก 5 ชนิดเข้ามากินผลนางพญาเสือโคร่ง พบกระรอก 1 ชนิด และนก 5 ชนิดเข้ามากินผลสลีนก ในมณฑาแดง พบกระรอก 1 ชนิด และนก 6 ชนิด นกที่เข้ามากินผลของพรรณไม้ทั้ง 3 ชนิด คือ ปรอดหัวโขน (*Pycnonotus jocosus*) ซึ่งเป็นนกประจำถิ่นที่พบได้ทั่วไป กระรอกที่เข้ามากินผลสลีนก และมณฑาแดง คือ กระรอกท้องแดง (*Callosciurus erythraeus*) กลไกการกระจายเมล็ดพันธุ์เกิดจากการที่สัตว์กลืนเมล็ด หรือผลเข้าไป และนำออกไปจากต้นแม่ รวมทั้งทิ้ง หรือทำให้ผล และเมล็ดตกจากต้นแม่โดยไม่ตั้งใจ

ศึกษาการล่าเมล็ดในสภาพธรรมชาติและผลของระยะห่างจากต้นแม่ต่อการอยู่รอดของเมล็ดมณฑาแดง โดยทดลองวางเมล็ดใต้ต้นแม่ 3 ต้นในพื้นที่ตัวอย่างวงกลมที่กำหนดขึ้นบนแนวเส้นสำรวจ 2 เส้น ที่ลากจากต้นแม่แต่ละต้น ผลการทดลอง พบว่าในระยะเวลา 7 วัน ต้นแม่ลำดับที่ 1 และ 2 มีเปอร์เซ็นต์การเคลื่อนย้ายเมล็ด 100 เปอร์เซนต์ ส่วนต้นแม่ลำดับที่ 3 เปอร์เซ็นต์การเคลื่อนย้ายเมล็ดมีค่า 92.8 เปอร์เซนต์ เปอร์เซนต์การเคลื่อนย้ายเฉลี่ย 97.6 การเคลื่อนย้ายเมล็ดมณฑาแดง ไม่ขึ้นอยู่กับความหนาแน่นของเมล็ด และระยะห่างจากต้นแม่ พบร่องรอยสัตว์เข้ามาเคลื่อนย้ายเมล็ด คือ หมูป่า (*Sus scrofa*), ไก่ป่า (pheasant) บทบาทของสัตว์ทั้ง 2 กลุ่มนี้ยังไม่เป็นที่แน่ชัดว่า เป็นการล่าเมล็ด หรือกระจายเมล็ดพันธุ์ สัตว์ที่พบอีกชนิด คือ มด ซึ่งการเคลื่อนย้าย

เมล็ดที่เกิดจากมด ถือว่าเป็นการกระจายเมล็ดพันธุ์ และมดยังช่วยเร่งการงอกของเมล็ด โดยการกินส่วนเนื้อหุ้มเมล็ด

ผลการศึกษาการงอกของเมล็ดในเรือนเพาะชำของหน่วยวิจัยการฟื้นฟูป่า (FORRU) พบว่า เมล็ดมณฑาแดงที่ขัดเอาเนื้อหุ้มเมล็ดออกก่อนเพาะ มีเปอร์เซนต์การงอกสูงกว่า และมีค่ากลางของระยะพักตัว (median length of dormancy) สั้นกว่าเมล็ดที่ไม่ขัดเนื้อหุ้มเมล็ดออก อย่างมีนัยสำคัญทางสถิติ แสดงว่าเนื้อหุ้มเมล็ดมีบทบาทชะลอการงอกตามธรรมชาติ ทำให้เมล็ดเกิดการพักตัว ดังนั้น หากต้องการเร่งการงอกของเมล็ด ควรกำจัดส่วนเนื้อหุ้มเมล็ดก่อนการเพาะ มณฑาแดงเป็นพืชหายากที่ประสบปัญหาการเพิ่มจำนวนตามธรรมชาติ แนวทางในการอนุรักษ์จำเป็นต้องอาศัยเรือนเพาะชำ ช่วยขยายพันธุ์ ผลิตกล้าไม้ และนำไปปลูกในธรรมชาติ การปลูกด้วยเมล็ดโดยตรงไม่เหมาะสมกับพืชชนิดนี้

Table of contents

List of Tables

List of Figures

Chapter 1
Introduction

Forests are complex ecosystems and play many essential roles for humans, animals and global stability. The list of forest goods and services is long and varied. Tropical and subtropical forests comprise 56 percent of the world's forest (FAO, 2001a). Thailand is known for the high biodiversity of its forests. However, Thailand is now facing major losses of forests often from illegal cuttings. In 2000, natural forests covered 19.26 percent of the country area. Between 1990 and 2000, the annual rate of deforestation was 0.7 percent (FAO, 2001b). If forests are destroyed, many big problems will arise - loss of biodiversity, climatic change, depletion of natural resources, flooding, etc.

Thailand's northern forests provide important natural resources. There are many kinds of forest ecosystems, such as bamboo - deciduous, deciduous dipterocarp-oak, mixed evergreen-deciduous, evergreen and evergreen with pine forests. Although there are many protected areas, forests are still destroyed especially upland forests. Focusing on Doi Suthep-Pui National Park, deforestation has been caused by growing demand for land and resources for agriculture and living, which follows from increasing human population.

Establishing tree plantations is one way to restore tree cover but does little for biodiversity recovery because only a few kinds of common, economic tree species are planted. Plantations cannot be considered as true forests. Alternatively, the framework species method of forest restoration involves planting up to 30 native tree species, which have high seed germination rates in the nursery, high growth rates when planted out in deforested sites and are attractive to seed-dispersing animals, which help restore biodiversity. Tree species with such properties are called "framework tree species". This idea was first pioneered in Queensland, Australia, in the 1980's to restore Queensland's Wet Tropics World Heritage Site (Goosem and Tucker, 1995 referred to by Forest Restoration Research Unit, 2000).

Framework tree species for restoration of northern Thailand's forest were selected from many species of native trees in the natural forest. A great deal of research has been done to determine how to select the species and develop techniques to plant and reintroduce them to deforested areas (Forest Restoration Research Unit, 1998).

In the forest, tree-animal relationships create balance within ecosystems. Two interesting mechanisms involving both trees and animals are seed dispersal and predation. Seed dispersal is the active process of transportation seeds to other places (van der Pijl, 1972). Seed predation is an important factor affecting recruitment of forest trees (Romo *et al.*, 2004). Understanding of these two mechanisms can help to select framework tree species and generate more information to improve restoration techniques. Moreover, it can help to conserve some endangered tree species. However, little is known about seed dispersal and predation in framework tree species.

In this special project, seed-dispersal of three framework tree species by animals was studied. If seed dispersal by animals occurs, it shows that animals are attracted by the trees and there is a chance that planting such species will encourage deposition of seeds in planted sites. In addition, seed predation was studied in *Manglietia garrettii* Craib, a framework tree species with few seedlings found in natural conditions. I attempted to determine if seed predation might be responsible for the lack of natural regeneration of this species and therefore to what extent planting it might be required as a conservation measure.

Objective

To determine seed dispersal mechanisms of three framework tree species: *Prunus cerasoides* D. Don, *Balakata baccata* (Roxb.) Ess. and *Manglietia gerrettii* Craib.

To determine levels of seed predation and germination amongst *Manglietia garrettii* Craib seeds in forest.

To determine effects of proximity of seeds to the parent tree on seed predation levels of *Manglietia garrettii* Craib.

Chapter 2
Literature review

Framework tree species

In 1995, Goosem and Tucker (referred to by Forest Restoration Research Unit, 1998) stated that the framework species method, developed in Queensland, Australia in the late 1980's, is one effective approaches for forest restoration. The Forest Restoration Research Unit (FORRU) of Chiang Mai University was established in 1994 (Forest Restoration Research Unit, 2000) and initiated research to examine more than 400 native tree species of northern Thailand and selected some of them as framework tree species for forest restoration. FORRU compiled a list of criteria for the selection of framework species in tropical forest of northern Thailand (Blakeley *et al*., 2000). There were

1. Ease of propagation in the nursery
2. Seedling survival in the rehabilitation plots
3. Seedling growth rate in the rehabilitation plots
4. Crown architecture and the ability to shade out weeds in the rehabilitation plots
5. Ease of natural dispersal
6. Attractiveness to frugivores
7. Age of fruiting
8. Rarity

From several research projects conducted at FORRU, many tree species were selected for testing as framework species. There are 4 main groups of framework species (Forest Restoration Research Unit, 1998) – *Ficus* spp. (Moraceae), Legumes (Leguminosae), Oaks and Chestnuts (Fagaceae) and other individual framework species.

Tree species in this research

1. *Prunus cerasoides* D. Don (Rosaceae)

P. cerasoides is an excellent framework species (Elliott *et al*., 2003). Its Thai common name is Nang Phraya Seu Krong. It is a common, medium sized, fast-growing, deciduous tree. The characteristics of tree species were described by Forest Restoration Research Unit in 2000, there were

Bark: medium to dark grey or dark brown, thick, densely roughened with pustular-lenticels, the outer layer thin, crack and peeling horizontally with age.

Leaves: simple, spirally arranged; oblong to ovate-oblong, 9-12 x 3-5 cm, apex acuminate, base acute, margin finely serrate; above shiny dark green, below light green with sparse, short, white hairs on veins on both sides; midrib with 9-11 ascending secondary veins on each side, finer venation scalariform, finest venation reticulate; petiole 14-16 mm long with 1-2 dorsal, dark red, circular glands at the tip; young leaves, glossy dark maroon above and below.

Flowers: appearing mostly on leafless trees, racemes, each 4-5 cm long; axes hairless, light green to red; pedicels 7-9 mm long; flower numerous, 2 cm long; calyx dark red, bract dark maroon; petal pink; anther yellow turning tan; filament pink; style light green; stigma green (Figure 1).

Fruit/seed: an ellipsoid drupe, hairless, pericarp juicy, light green when unripe, bright red when ripe, mean dimension 10.6 x 8.7 x 7.9 mm, pyrene contains one seed, mean dimension 9.7 x 7.5 x 6.1 mm (Figure 1), dispersed by animals. However, there have been no data about their seed dispersers.

Habitat: evergreen + deciduous, evergreen and evergreen + pine forest in disturbed areas, often planted as an ornamental; elevation 1040-1700 m.

Distribution: northern Thailand, Himalayas, Yunnan, Myanmar, northern Indo-China

Although, there has been research carried out on this species in the past, *P. cerasoides* (Elliott *et al*., 2003, Pakkad *et al*., 2004), seed dispersal has received little attention.

Figure 1 *Prunus cerasoides* flowers (left) and fruits (right) (FORRU, 2000)

2. *Balakata baccata* (Roxb.) Ess. (Euphorbiaceae)

B. baccata is an acceptable framework species (Elliott *et al*., 2003). Its synonym is *Sapium baccata* Roxb. And its common English name is Mousedeer's Rubber Tree. The characteristics of tree species were described by Forest Restoration Research Unit in 2000. there were

Bark: dark grey to blackish, thick, roughly vertically cracked and sometimes flaking.

Leaves: simple, spirally arranged; blades elliptic to oblong, apex acuminate, base acute or obtuse; margin entirely; hairless 13-19 x 6-9 cm; above dark green, below light green; midrib prominent with c.10 sub-opposite to alternate pair of arching secondary veins; finer venation reticulate; petioles reddish, 4-9 cm long

Flowers: numerous, tiny, unisexual, in a terminal panicle of often bisexual spikes; axes light green; calyx and filaments light yellow-green; anther locules reddish and turning blackish.

Fruit/seed: fleshy drupes with white sap, green when unripe, glaucous, dark red-purple to black when ripe, dimension 14.9 x 14.3 x 12.1 cm, each containing two black seeds, 5.3 x 4.2 x 4.1 mm (Figure 2), dispersed by animals. However, there have been no data about their seed dispersal agents.

Habitat: mixed evergreen + deciduous, and evergreen forests, particularly along streams; elevation 475-1300 m.

Distribution: throughout Thailand, east Himalayas and north India to Indo-China, southern China, Myanmar, peninsular Malaysia and Sumatra

Figure 2 *Balakata baccata* tree (left) and fruits (right) (FORRU, 2000)

3. *Manglietia garrettii* Craib (Magnoliaceae)

Common name is Garrett's Champaka. It is an uncommon, medium-sized, deciduous tree. The characteristics of tree species were described by Forest Restoration Research Unit in 2000.

Bark: grey, thin, smooth, becoming markedly pustular-lenticellate.

Leaves: blades simple, spirally arranged; leather, elliptic to oblong, 22-30 x 6-11 cm; apex and base acute, margin entire, hairless; above dull dark green, below light green; midrib with 20-24 thin secondary veins on each side; finer venation reticulate; petiole hairless, 3-4 cm long.

Flowers: inflorescences terminal with a solitary, bisexual flower 5.5-6.5 cm long; pedicels 2-3 cm long; stamens and carpel numerous.

Fruit/seed: aggregate follicle, light yellow-green when unripe, maroon to brown when ripe, 95 x 60 mm, containing one black seed within a red aril per follicle, 10 x 4 mm (Figure 3); dispersed by birds. However, there have been no data about bird species.

Habitat: evergreen forests; elevation 1050-1500 m.

Distribution: northern Thailand

Although, *M. garrettii* fruits contain many seeds, *M. garrettii* seedlings are rarely seen in the natural habitat (Kuarak, 2004 pers. comm.) In addition, no research has been carried on seed dispersal and germination of this species.

Figure 3 *Manglietia garrettii* fruits and seeds

In natural ecosystems, the life cycle of flowering plants is intimately related with that of animals. Hence, animals have a strong influence on the genetic fitness and reproductive success of plants.

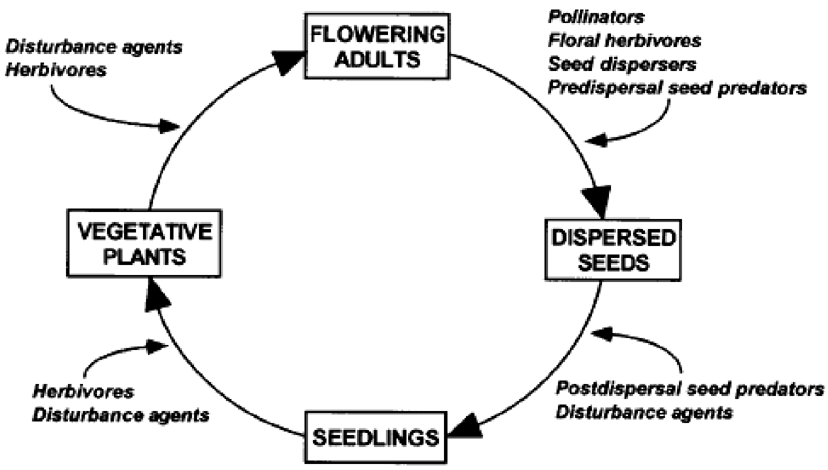

Figure 4 A simplified general life cycle for a flowering plant, showing major classes of animals that influence different life cycle transitions and thus have the potential to affect individual plant fitness and plant population dynamics (Waser and Price, 1998)

Seed Dispersal

Trees and other plants produce offspring by making seeds. If seeds drop to the ground near their parent trees, it is difficult for seedlings to grow to adulthood due to competition with the parent tree. Therefore, the trees need the way to disperse their seeds to a suitable place (Wolfe, 2002). This process is known as seed dispersal. There are many forms of seed dispersal – wind, animal, water, fire (Parkin, 2004). The form of the seed determines its dispersal mechanism, in terms of morphology and physiology. Sharp (1995) studied seed dispersal using seed traps in primary forest and in a gap on Doi Suthep. She reported that small, flat, light weight and usually winged fruits/seeds can disperse farther into the gap, while bigger ones can disperse only a few meters from the parent trees. However, small, flat, light weight and usually winged fruits/seeds are suitable for wind dispersal. The big fruits/seeds may be better dispersed in other form.

Animals can help spread seed in several ways (Wolfe, 2002). Frugivorous animals, for example birds, bats, squirrels, deers, elephants which feed on fruits and seeds can help to disperse the seeds to other places (Howe, 1981; Corlett, 1992; Wenny *et al.*, 1998; Kitamura *et al.*, 2002; Myers *et al.*, 2004).

Corlett (1992) studied seed dispersal by birds in Hong Kong shrubland by netting birds and collecting faecal samples. He reported that 20 species of birds are found to eat at least some fruit. Crested Bulbul (*Pycnonotus jocosus*) has highest total number of fruit species identified in the faeces with 93 percent with fruit species remains. Pulp of fruit or aril of seeds eaten by frugivores are removed through frugivores' ingestion but the seeds are not digested (Yagihashi *et al.*, 1998). Therefore, seeds are expelled from animal's digestive system and germinate.

Myers *et al.* (2004) studied seed dispersal by collecting dung of white-tailed deer (*Odocoileus virginiaus*) that contained seeds and they provided conditions likely to promote germination of seeds. They found that more than 70 plant species germinated from deer faeces collected over a 1-year period. Viable seeds include native and alien herbs, shrubs and trees. It is likely that white-tailed deer contribute an important long-distance component to the seed shadows of 100 of plant species.

The characters of fruits are significant in determining which animals disperse them (Jordano, 1995; Corlett, 1996 referred to by Kitamura *et al.*, 2002). Colour, size, chemistry of fruits and seeds influence consumption and dispersal by frugivores. The number of frugivores that serve plant species declines with increasing seed size (Kitamura *et al.*, 2002). Small fruits and large soft fruits consumed by wide range of seed dispersal agents. Larger, bigger-seeded fruits are consumed by fewer dispersers (Corlett, 1998).

In the Oriental region, patterns of fruiting phenology are varied and complex. Fruiting periods of difference trees species are distinct and seasonal. There is a more or less regular annual cycle of fruit availability (Corlett, 1998). Many animals rely on fruits as essential food resources, most fruit species are eaten by various kinds of frugivore. No close relationship between a particular fruit and a frugivore is found (Kitamura *et al*., 2002).

Seed dispersal is one of the processes potentially accelerated by tree plantation on degraded site (Wunderle, 1997). Seed dispersal agents help to spread seeds to plantation sites

<u>Seed predation</u>

Seed predation is one of the plant-animal interactions that affect recruitment of forest trees (Romo *et al*., 2004). A well-known model of spatial patterns of recruitment is the Janzen-Connell model (Janzen, 1970; Connell, 1971 referred to by Notman, 1996), which predicts that seed density decreases with increased parental distance, in contrast to seed survival that increases. Under the model, recruitment only occurs in a center zone at some distances from parent trees where seeds are available for germination and predation pressure is not too high, allowing some seeds to survive and germinate (Hyatt *et al*, 2003).

When seeds are harvested by granivorous animals, seed fate depends on how the animals handle and process the seeds. Seeds may be killed (seed predation) or deposited in a suitable location to germinate.

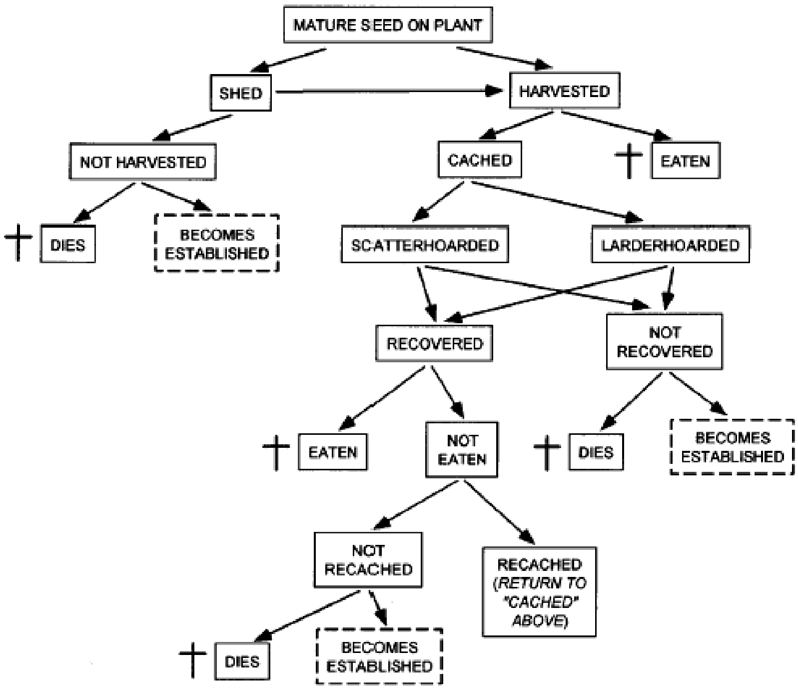

Figure 5 A fate diagram of seeds subject to harvest by granivorous animals. Boxes indicate possible events in the life of seeds, arrows indicate possible transitions between events and seed death indicate by a cross (Waser and Price, 1998).

Hulme (1997) studied post dispersal seed predation and the establishment of 3 vertebrate-dispersed plants: *Crataegus monogyna*, *Prunus mahaleb* and *Taxus baccata* in Mediteranean scrubland. He reported that the percentage of diaspores removed, ranges from 5% for *C. monogyna* to 87% for *T. baccata*. Rodents (*Apodemus sylvaticus*) are the main vertebrate removers of seed and fruit. Ants are the only invertebrate removers of *P. mahaleb* fruits. While removal of seed by rodents is equivalent to predation, ants are responsible for secondary dispersal. Ants and rodents respond differently to an increase in diaspore density of *P. mahaleb* but not in *T. baccata* or *C. monogyna*. Seed removal by rodents occurs most frequently where vegetation cover is highest and is intense beneath parent plants whereas ants favour open sites and rarely forage beneath parent plants. However, Hulme (1997) did not determine about the effects of distance from the parent trees on seed removal.

Hong and Zhi (2003) used a new method of labeling seeds with small pieces of code tin-tags to investigate the effects of rodents on the seed fate of Liodong oak (*Quercus liaotungensis*) in a mountainous area of Beijing, China. They found that the acorns are dispersed by rodents over distances of up to 20 m from original plots. There are three fates of acorn dispersed i) eaten seeds ii) intact seeds iii) buried seeds. In this study, only one buried seed became a seedling which did not survive the second year. Most acorns were eaten, demonstrating that seed predation is quite high. It indicated that seeds face high predation risk both *in situ* and post-dispersal. However, there were no data of seed fate of other tree species.

Chapter 3
Methodology

Field observations of seed dispersal and experiments on seed predation were carried out in evergreen forest in Doi Suthep-Pui National Park (18˚ 48’ 10’’ N, 98˚ 55’ 30’’ E) at an elevation of 1000-1600 m above from sea level in Chiang Mai Province. The forest near the headquarters of Doi Suthep-Pui National Park and the Chiang Mai Herb Garden was surveyed to locate the individual trees used to study. The trees were identified to species by collecting specimens and comparing them with herbarium specimens at the herbarium of Biology Department, Chiang Mai University. In case of that had been tagged by Forest Restoration Research Unit (FORRU), the trees were identified to species by comparing with FORRU database.

Seed dispersal

Seed dispersal was observed for three tree species, recognized as framework tree species which accelerate natural forest regeneration. Three fruiting trees of *Prunus cerasoides* in front of the Chiang Mai Herb Garden (elevation 1090 m above sea level) were selected and observations of seed dispersal carried out between 14th and 16th April 2004. Five trees of *Balakata baccata*, were also observed for seed dispersal between 21st August and 4th September 2004 during the peak of that species’ fruiting season. Four of the trees were located at the headquarters of Doi Suthep-Pui National Park (elevation 1080 m above sea level) and one at the edge of evergreen forest and the Chiang Mai Herb Garden area (elevation 1090 m above sea level). Two trees of *Manglietia garrettii*, were observed at the edge between evergreen forest and Chiang Mai Herb Garden and another 3 trees were located in evergreen forest at elevations of 1090, 1150 and 1600 m above from sea level. Observations were carried out from 18th October to 3rd December 2004. Descriptive data of the trees and their surrounding habitat (height, girth, etc.) were recorded, as well as the phenological condition of the trees (Table 1).

Any animals visiting the trees were observed with binoculars and identified with a guide to the birds of Thailand book (Lekagul and Round, 1991), Mammals of Thailand book (Lekagul and McNeely, 1988) and a guide to the Large mammals of Thailand books (Parr, 2003) (Figure 6). Observations were made for a total of 50 hours (10 hours for each tree), rotating among the trees every hour. Observation times were for 5 hours in the morning (5 AM – 10 AM) and 5 hours in the evening (2 PM – 7 PM).

Table 1 Description of observed three framework tree species in seed dispersal observation

Tree species	Tree number	Elevation (m above from sea level)	Girth (m)	Height (m)	Fruiting score*
Prunus cerasoides	1	1090	1.15	13.11	3
	2	1090	0.70	12.21	1
	3	1090	0.69	7.92	2
Balakata baccata	1	1080	2.90	26.77	2.5
	2	1080	2.29	36.48	1
	3	1080	3.13	23.44	4
	4	1080	2.28	31.62	2
	5	1090	2.45	34.46	3
Manglietia garrettii	1	1090	1.77	35.22	2
	2	1090	3.25	39.08	2.5
	3	1090	1.46	21.84	4
	4	1150	2.28	36.54	1
	5	1600	2.43	37.01	3

Note * Phenological stage of fruit available in observed period. The score indicate quantity of fruits available in the tree (score ‘0’ = none and ‘4’ = maximum fruiting score).

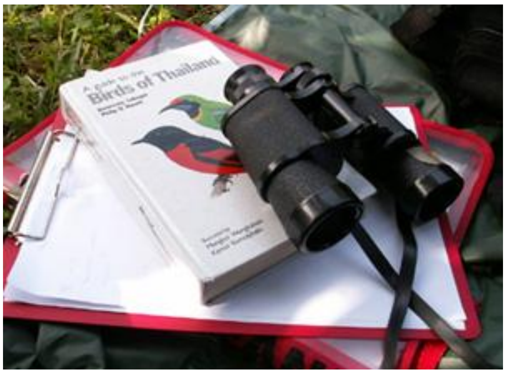

Figure 6 Equipments for seed dispersal observation

Seed predation experiment

Five hundred and forty *Manglietia garrettii* seeds were collected from mature fruiting trees. Good quality seeds were selected by putting them in water and discarding any which floated. Three trees of *Manglietia garrettii* in the forest were selected to establish temporary plots. The ground beneath each tree was cleared, by removing all fallen *Manglietia garrettii* fruits. Two radial line transects were measured from each tree base. Total line transect was 15 m long. One-m-diameter, circular, sampling units (SU's) made from wire were placed along each radial line transect, spaced 2 metres apart. The first circular SU was at the bases of the parent trees. Seeds were placed directly on the ground in each SU and the position of each seed marked with a small skewer. In each SU, the following number of seeds were placed: 50, 30 and 10 seeds (Figure 7).

The number of seeds removed, condition of seeds, animals' tracks (possibly of seed predators) and number of germinating seeds were monitored. Data were recorded every day for 2 weeks and there after every week until germination and predation stopped. Percent germination and seed removal were calculated.

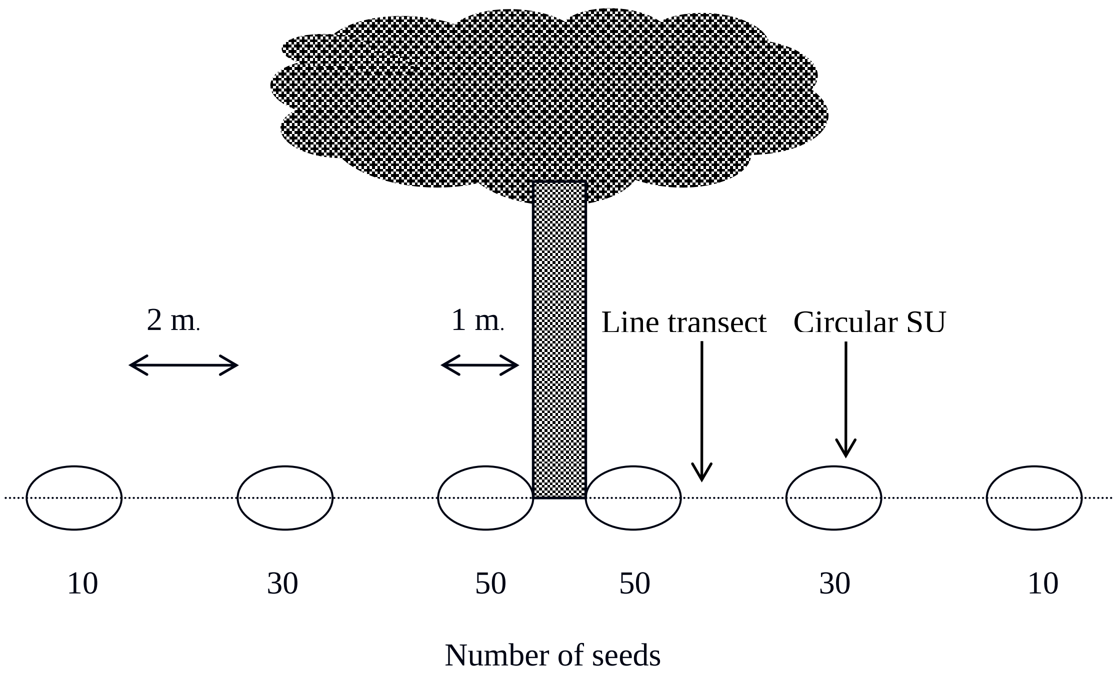

Figure 7 Seed predation experiment in the natural habitat

Figure 8 A sampling unit of seed predation experiment in the forest

After the seed predation experiment had been finished, sand traps were established to record the tracks of potential seed removers. Five hundred and forty *Manglietia garrettii* seeds were collected again and the experiment was repeated with fine sand covering the ground around each SU before the seeds were placed. Animals' tracks were recorded.

Seed germination in the nursery

Seed germination experiments were conducted at the Forest Restoration Research Unit (FORRU) tree nursery, located at the headquarters of Doi Suthep-Pui National Park (18˚ 50' N, 98˚ 50' E) at 1000 m elevation. Experiments were used to compare survival and germination of *Manglietia garrettii* seeds in the natural habitat compared with their maximum viability under the controlled conditions in the nursery. In addition, I tested the effects of aril removal on seed germination.

Manglietia garrettii fruits were collected. Seeds were removed and then cleaned with water and dried. Good quality seeds were selected by putting them in water and discarding any which floated. One hundred seeds that retained their aril were sown in seed germination trays. In addition, the red aril of another 100 seeds was removed before sowing the seeds (Figure 10). There were 3 replications of sowing seed that retained arils and the seed with removed arils, so 600 seeds were used in all. The numbers of germinated seeds were recorded once a week until germination was complete and percent germination was calculated.

Figure 9 *Manglietia garrettii* seeds

Figure 10 Seeds of *M.garrettii* that retained arils and removed arils, used in seed germination experiment in the nursery

Figure 11 Seed germination of *M. garrettii* in the nursery

Chapter 4
Results

Seed dispersal

Prunus cerasoides D. Don

Many birds and squirrels visited the trees. Some of them fed on the fruits but some did not. I did not observe squirrels eating the fruits. Birds that fed on the fruits included Blue-winged Leafbird (*Chloropsis cochinchinensis*), Red-whiskered Bulbul (*Pycnonotus jocosus*), Ashy Bulbul (*Hypsipetes flavala*), and Yuhina (*Yuhina* sp.). The average time spent feed in the tree was 10 seconds. *P. cerasoides* fruits are juicy, drupes containing a single-seeded pyrene.

Table 2 Animals' species and their activities to *P. cerasoides*

Animal name	activities
Chloropsis cochinchinensis	P, D
Chloropsis sp.	P, S
Hypsipetes flavala	P, H, S
Pycnonotus jocosus	P
Yuhina sp.	P
Pericrocotus flammeus	V
Phylloscopus sp.	V
Squirrels	V

Note: P = pecking the pulp with the beak

H = holding the fruit in the beak and flying away

S = swallowing the whole fruit

D = pecking and drop the fruits

V = visiting without feeding

The different bird species varied in their feeding behaviour and processing of *P. cerasoides* fruits (Table 2). Some of the birds pecked at the fruit pulp with their beaks and sometimes dropped the fruits on the ground, whilst some birds held the fruits in their beaks and flew away to consume them in another tree. Other birds swallowed the whole fruits.

Birds observed only visiting the trees without feeding on the fruits were Scarlet Minivet (*Pericrocotus flammeus*) and various Leaf Warblers (*Phylloscopus* sp.), as well as squirrels.

Balakata baccata (Roxb.) Ess.

Squirrels were the most common visitor to this tree species including the Pallas's Squirrel (*Callosciurus erythraeus*) and the Burmese Striped Tree Squirrel (*Tamiops mcclellandi*). They jumped from surrounding tree crowns into the *B. baccata* trees. A few of them did not feed on the fruits (passing through the tree crowns to reach other trees), but most squirrels foraged on the fruits with several patterns, these were:

- They held the tree branch with their hind legs, while picking the fruits with their forefeet. Mostly the pulp was eaten and the seeds dropped, but sometimes they swallowed the seeds (Figure 12).

Figure 12 *Callosciurus erythraeus* feeding on *Balakata baccata* fruits

- They carried many fruits in their forelimbs, jumped into other trees, swallowed whole fruits and/or ate only the pulp and dropped the seeds. The seeds were dropped either deliberately or accidentally (Figure 13).

Figure 13 *Callosciurus erythraeus* feeding on *Balakata baccata* fruits

Birds which only visited the tree without feeding were Green-billed Malkoha (*Phaenicophaeus tristis*), Puff-throated Bulbul (*Criniger pallidus*), Black-crested Bulbul (*Pycnonotus melanicterus*) and a species in Genus *Rhipidura*. Red-whiskered Bulbul (*Pycnonotus jocosus*), Sooty-headed Bulbul (*Pycnonotus aurigaster*) and a Leaf Warbler (*Phylloscopus* sp.) fed on the fruits by pecking the pulp and dropping them. Swallowing of whole fruits was not observed in this 3 species. The Blue-throated Barbet (*Megalaima asiatica*) lived in a cavity in the observed tree. *M. asiatica* birds held fruit in their beaks and carried them to the cavity. It was not clear that they brought to feed their chicks or buried the fruits.

Birds and squirrels sometimes visited and foraged in the tree at the same time. The total time spent feeding in the whole tree on many fruits of squirrels was longer than birds.

Manglietia garrettii Craib

Many bird species fed on *M. garrettii* seeds. These were the Red-whiskered Bulbul (*Pycnonotus jocosus*), Oriental White-eye (*Zosterops palpebrosus*), Chestnutflanked White-eye (*Zosterops erythropleurus*), Grey-eyed Bulbul (*Hypsipetes propinquus*), Puff-throated Bulbul (*Cringer pallidus*) and a species of Leaf Warbler (*Phylloscopus* sp.). The fruit type was an aggregate follicle, split when ripe with red arilloid seeds. The feeding pattern of birds was pecking the seeds out from the cracks of the fruits and swallowing them whole (Figure 15). Sometimes the seeds were dropped accidentally. Scarlet Minivet (*Pericrocotus flammeus*) and Burmese Striped Tree Squirrel (*Tamiops mcclellandi*) visited the tree but did not eat the fruits.

The Pallas's Squirrel (*Callosciurus erythraeus*) was the only squirrel species that foraged on *M. garrettii* fruits. They gnawed on the woody seed case and ate seeds in the cracks of the fruits (Figure 14). Ripe fruits and/or seeds were dropped by squirrels.

Figure 14 *Manglietia garrettii* fruit and *Callosciurus erythraeus*

Figure 15 *Manglietia garrettii* fruit and *Pycnonotus jocosus*

Table 3 List of animal species found that fed on fruits/seeds of the observed tree species

Family name	Animal name	Tree species		
		Prunus cerasoides	*Balakata baccata*	*Manglietia garrettii*
Birds				
Pycnonotidae	*Pycnonotus jocosus*	/	/	/
	Pycnonotus aurigaster		/	
	Hypsipetes flavala	/		
	Hypsipetes propinquus			/
	Crininger pallidus			/
Chloropseidae	*Chloropsis cochinchinensis*	/		
	Chloropsis sp.	/		
Zosteropidae	*Zosterops erythropleurus*			/
	Zosterops palpebrosus			/
Megalaimidae	*Megalaima asiatica*		/	
Sylviidae	*Phylloscopus* sp.		/	/
Timaliidae	*Yuhina* sp.	/		
Squirrels				
Sciuridae	*Callosciurus erythraeus*		/	/
	Tamiops mcclellandi		/	

Seed removal from the ground

All seeds in every sampling unit (SU) of the first and second parent trees were removed within 7 days after the seeds were placed (100 % removed). For the third tree sampled, only 13 seeds remained after 7 days, with 167 removed (92.8% removed). Remaining seeds became infected with a blue-coloured fungus, which darkened the red aril of the seeds and made them difficult to see on the dark brown soil. No seed germination was recorded in any of the SU's (0 % germination).

Figure 16 Remaining intact seeds of *M. garrettii* with fungi infestation

Ants were the only animals seen in the SU's. In addition, the tracks of pheasants (Phasianidae) was observed in 3 SU's, trails appeared and some skewers (marks) were removed. It could be assumed that animals removed the seeds, but it was difficult to identify the animals' tracks on the coarse particle soil surface.

Data were recorded only once using the sand trap. After the sand traps had been established for 1 day, it rained and the sand traps were damaged. The sand traps showed the footprints of Common Wild Pig (*Sus scrofa*) (Figure 19). Evidence from the sand traps also supported that pheasants (Phasianidae) (Figure 18) removed the seeds. In addition, ants were recorded again (Figure 17).

Figure 17 *M. garrettii* seeds were removed to the entrance of ants' nest

Figure 18 Pheasants’ tracks on the sand trap

Figure 19 Common Wild Pig’s (*Sus scrofa*) footprints on the sand trap

Seed germination

Although seed germination in the nursery had not stopped completely, the data were analyzed at the end of 14 weeks due to limitation of time in semester. Percent germination of seeds with removed arils was 65.67±4.72 (197/300) and percent germination of seeds with retained arils was 10.67±2.08 (32/300) (Figure 20), while percent germination in the natural conditions was zero, due to seed removal.

The statistical significance of the results of percent seed germination and median length of dormancy (MLD) in the nursery were determined by using t-Test (two-sample assuming equal variances). The percent germination of seeds with the red aril removed was significantly higher (t value = 18.45, P<0.05) than that of seeds that retained the aril. MLD of seeds with removed arils was significantly shorter (t value = -3.44, P<0.05) from that of seeds with retained the arils (Figure 22)

Mean of 3 replicates germination rates in the nursery

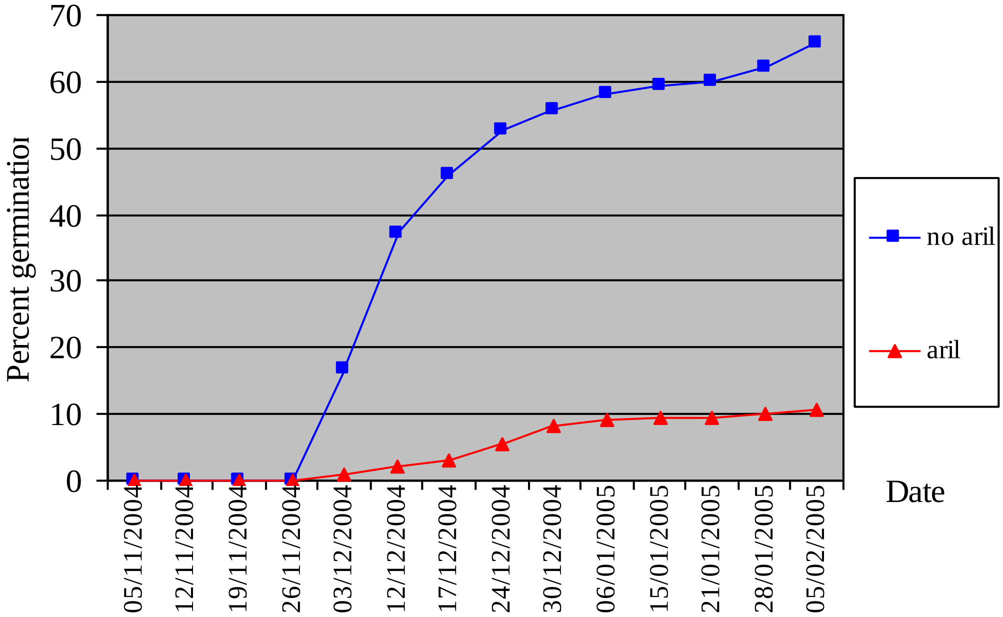

Figure 20 Mean of 3 replicates germination rates of *Manglietia garrettii* seeds in the nursery

Figure 21 Seedling of *M. garrettii* in the nursery

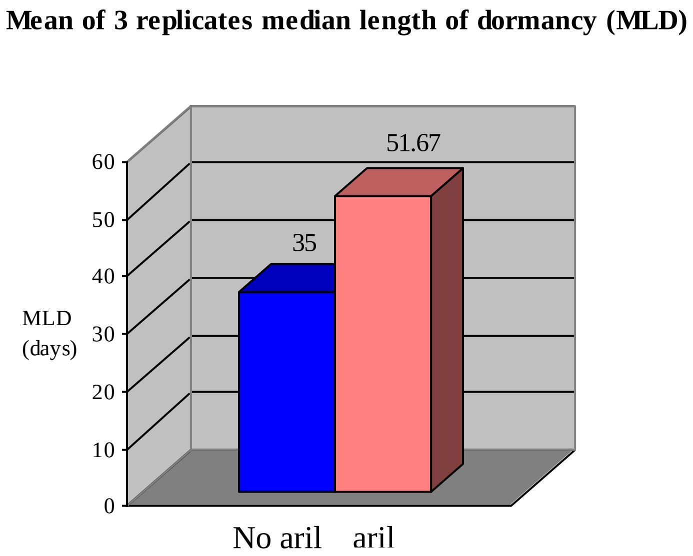

Figure 22 Mean of 3 replicates median length of dormancy of *Manglietia garrettii* seed in the nursery

Figure 23 Showing the number of fourteen-week-old seedlings of *M. garrettii* in the nursery, sown with seeds with removed the arils (left) and seeds with retained the arils (right)

Chapter 5
Discussion

Seed dispersal

Many animal species visited the observed trees. Observations of their behaviour were the basic technique used to identify seed dispersal mechanisms. If the animals only dropped the fruits or seeds beneath the parent tree, primary dispersal is said to have occurred. The seeds or fruits beneath the tree would then need other mechanisms to move them far away from parent tree canopy to sites free of competition which are suitable for them to germinate and survive. This is called secondary dispersal.

Seed dispersal of *Prunus cerasoides*

Important seed dispersal agents of *Prunus cerasoides* fruits were birds. *P. cerasoides* fruits are small with an average size of 10.6 x 8.7 x 7.9 mm. It was easy for birds with bigger gapes than the fruit size to swallow and disperse them to other places. This is an example of endozoochory (van der Pjil, 1972). *Chloropsis* spp. and *Hypsipetes flavala* acted in this way (Table 2). Bulbuls are known to retain seeds in their gut for up to 40 minutes and could disperse seeds over considerable distances over that time (Whittaker and Jones, 1994). Moreover, *Hypsipetes flavala* held the fruits and flew away. When fruits were transported within the birds' digestive system, the pulp would have been digested. *P. cerasoides* fruits are drupes, with a thick, woody endocarp surrounding the seed. This would have protected the embryo from digestion so that it was still capable of germination after being deposited when the birds defaecate. This is in agreement with the findings of Yagihashi *et al.* (1999) who reported that pulp removal through bird ingestion enabled rapid germination of *Prunus ssiori*.

All bird species that fed on *P. cerasoides* fruits pecked at the pulp because the pulp is juicy and attractive to animals. Pecking at the pulp often dislodged the seeds from the tree so that primary dispersal can occur. Therefore, *Chloropsis cochinchinensis* was a primary disperser. In my observations, feeding time in the tree of these animals was short, due to the location of the parent tree. Three observed trees were of medium size and near to the road and were therefore frequently disturbed by passing vehicles. This shortened the visits to the trees of some animals and disrupted their behaviour.

Seed dispersal of *Balakata baccata*

No fruits were observed to be swallowed by birds, because *B. baccata* fruits are larger than the gape of most birds at 14.9 x 14.3 x 12.1 mm. Red-whiskered Bulbuls were primary dispersers; a result contradicts the report of Kitamura *et al.* (2002) who reported that no Bulbuls feed (either swallowed them whole or pecked at the outside of them) on *B. baccata* fruits.

In case of the Blue-throated Barbet, if they brought the fruits to their cavity for storage and/or for feeding to their chicks, secondary dispersal could still occur when the seeds are swallowed and expelled out from the tree cavity. On the other hand, if the birds feed on the pulp only and leave the seeds in their cavity, this could make the seed has no chance to germinate.

Squirrels played the role in primary dispersal. This result contrasts with the report of Kitamura *et al*. (2002) who stated that squirrels are predators on *B. baccata* fruits. However, they did not report species name of squirrels they observed so they might have been different from those I observed. The condition of the *B. baccata* fruits that were dropped by squirrels was that the pulp had been removed and 1 or 2 seeds remained. For *B. baccata*, there were many primary dispersers, such as birds, squirrels, but no evidence of endozoochory. However, *B. baccata* seedlings were commonly observed in the natural habitat around the parent tree. This means that this species must have effective secondary dispersal mechanisms even though such mechanisms were not directly observed.

Seed dispersal of *Manglietia garrettii*

M. garrettii fruits are big. It would have been very difficult for whole fruits to be dispersed any distance away from the parent tree. *M. garrettii* fruits are aromatic odorous, they smell like volatile oil and contain many red arilloid seeds. The black seeds are small at 10 x 4 mm. Seeds were small enough for birds and squirrels to swallow them whole. It was clear that endozoochory was being carried out by many birds and squirrels. Red aril of seeds in family Magnoliaceae is lipid-rich structure (Webb, 2001). This provides birds and squirrels with a good source of energy. In addition, fruiting period of *M. garrettii* was at beginning of winter. Eating the seeds provide substance for birds and squirrels that stay for the winter. All bird species observed in this study helped to disperse the seeds well away from parent tree.

Observations of seed dispersal showed that visitation of seed dispersal agents depended on quantity of ripe fruit in the tree, that visited and fed on the fruits was high in the tree that there were more ripe fruits. Moreover, location of the trees influenced visitation. The tree located in area disturbed by human activities revealed less number of individual dispersal agents

From this study of three framework tree species, it was shown that animals played an important role in seed-dispersed, with birds and squirrels as the principle seed dispersal agents. Birds showed clear dispersal behaviour. Bulbuls were the most important frugivores and dispersal agents. Bulbuls are common residents and tolerant of both forests and disturbed habitats. White-eyes and Yuhinas are small birds with a limited gape width (Corlett, 1998). They are good dispersal agents for small fruit or seeds that they can swallow. Squirrels are also adaptable to live in areas that have been disturbed by human activities. We could see squirrels in the fruiting trees feed on the fruits everywhere. Squirrels may also play another important role in dispersal that we can apply to accelerate forest ecosystem regeneration. Squirrels also carry out scatter-hoarding, by collecting an excess of fruits and burying them to eat later (Chou *et al*, 1985 referred to by Corlett, 1998). If the squirrels die or forget where the fruit has been buried, then seeds germinate having been planted in ideal conditions for germination. However, I did not observed anything like this in this research. Thus, further studies of squirrel feeding behaviour and movement could greatly benefit development of better forest restoration techniques.

Animal-plant interactions are important in the forest ecosystems. Dispersal mechanisms form the base of food requirements for animals, while plants get to disperse their seeds and reproduce. Plant characteristics must be suitable to attract suitable animal dispersers. The three tree species that I observed produced fruits that were red or black when ripe. The fruit colour is one of the factors that help to attract frugivores. Many birds have tetrachromatic vision and can discriminate surface colours in the ultra violet (300-400 nm) region of the spectrum (Tovee, 1995 referred to by Corlett, 1998). Unripe fruits/seeds are green or pale colour, because they are not ready to disperse. Unripe fruits/seeds colours are more difficult for frugivores to visualize than ripe fruits/seeds. Fruits are eaten when black or red. Fruit and seed size are also important. Small fruits/seeds have chance to be eaten by a wide range of animals and be dispersed. Fruit chemistry also contributes to the attractiveness of fruits or seeds to frugivores. Flesh of fruit that contains sugar or lipid-rich arils satisfies frugivores. Edible parts encourage animals to visit, eat and then help to disperse. In the case of *M. garrettii*, the fruits have a unique smell. It is not important to attract birds because birds have a weak sense of smell, or none at all (van der Pjil, 1972). Investigation about fruit characteristics and the result of observations of three selected tree species, supported that *Prunus cerasoides*, *Balakata baccata* and *Manglietia garrettii* were animal dispersed species that require secondary dispersers.

Seed dispersal is a natural interaction that can be manipulated to facilitate forest restoration. First, selecting framework tree species for plantation on degraded areas. Forest restoration aims to bring back forest ecosystems, plants that attract more animals are good. When the trees in plantation site are fruiting, frugivores will visit and feed on the fruits. Fruits and/or seeds from plantation site will be dispersed to other places. In addition, the frugivores probably contain other kind of fruits and/or seeds in their guts that can be expelled on the plantation site and germinate. It is the way to increase the number of seedlings in plantation. In fact, the trees at the beginning of plantation are not high but birds require perches to hold, therefore establish artificial perches may help attract birds (Scott *et al*. 2000). Moreover, ability to attract the dispersal is not enough for dispersal agents in degraded area. If we would like to bring the animals back to area, we can prepare food resources to always support the animals. Seed dispersal studies can fill the gap about what animal consume the tree products. In addition, no close relation between fruits and birds, birds consume the all range of fruit types that fruit seasonally. We can select the tree species that are birds' foods to plant in the area and make the food resources for seed dispersal agents all year. Production food resources needs phenological studies of each tree species.

Seed removal from the ground of Manglietia garrettii

In the seed predation experiment, there was no unequivocal evidence that *M. garrettii* seeds were being predated. The data showed high percent removal of seeds and some tracks of animals that might play a role as secondary seed dispersers or seed predators. I will discuss this below.

M. garrettii seed had a high percent removal from the sample units on the ground. The color of the seeds was one of the factors. Red arilloid seeds were easily observed on the ground. The aromatic smell of seeds probably also attracted those animals that carried out removal. In addition, chemistry of the seeds and aril, particularly carbohydrates, lipids and sugars may have provided attractive food for the animals.

According to this experiment, distance from the parent tree and density of seeds had no effect on survival of *M. garrettii* seeds. This result did not support the Janzen-Connell hypothesis. Wherever seeds were on the ground surrounding the parent tree, the probability of seed lost was not different. I used 15-meter long line transects. Using longer line transects may have produced different results.

Observations of animal tracks showed that animals definitely visited the SU's and were probably responsible for seed removal. Ants and tracks of pheasants appeared in SU's where seeds were removed a day after the seeds had been placed. Sand traps revealed that Common Wild Pigs may also have been involved in seed removal.

I assumed that there were 3 groups of animals that removed seeds from the SU's. Wild pheasants were implicated, although there is very little information on the fate of seeds that they consume (Corlett, 1998). The digestive system of *Phasianids* includes a gizzard with grit which grinds food. It was possible that the *M. garrettii* seeds would be destroyed in their digestive tract, and therefore they would be classed as seed predators.

The role of pigs as seed dispersers or predators was also unclear, many researchers (Ridley, 1930; Leightons and Leightons, 1983 referred to by Corlett, 1998) stated that pigs probably destroy the seeds of most of the species that they consume, but Payne (1956 referred to by Corlett, 1998) reported that pigs feed only on freshy parts leaving the seed near the parent tree. In this case, *M. garrettii* seeds were too small for pigs to gnaw at the aril and leave the seeds undamaged. It was possible that pigs swallow them whole. Therefore, more studies are needed to determine the precise fate of seeds removed from the ground.

The last groups of seed removers were ants. The entrances to ants' nests were observed in the SU's. Although I couldn't see seeds being transported by ants directly, I could observe that seeds were moved towards the entrances to ants' nests. Aril is lipid-rich structure. Lipids are an important food resource for ants, serving a variety of purposes that include nutrition, physiological constituents and behavioural releasers (Beattie, 1985 referred to by Pizo and Oliveira, 2001). Large ants could transport seeds to their nests or long distance from the parent tree, seeds were protected from seed predators. Smaller ants were observed to feed on the aril and leave the small black seeds behind on the ground. This could benefit to seed survival. Observation showed that intact seeds that were not moved or removed the aril on the ground usually died because of fungi infestation. This information links with the results from the seed germination experiment in the nursery, where it was shown that aril removal increases germination. Therefore, ants were probably not seed predators but assisted the seeds to germinate. They probably played a small role in secondary seed dispersal and induced seeds to germinate faster.

If we would like to determine predation or secondary dispersal, we will have to have a technique to follow seeds. Tagging seeds with tin tag has been used in China (Hong and Zhi, 2003). In addition, using nylon fishing line (Sharp, 1995) to attach to seeds has also been used. When seeds are removed, we can follow the tag or nylon fishing line and determine the survival of seeds. Determining the potential of removal *M. garrettii* seeds by ants in the forest, we would use boxes containing seeds and allowing only ants to entrance those boxes. Data of seed removal or aril removed would be recorded and calculated. In addition, studying and identification ant species that interacted with the seeds should be done for more understanding.

Seed germination in the nursery

It was assumed that the red aril affected germination of *M. garrettii* seeds. In the forests, the fruiting period of *M. garrettii* is in October, so it fruits late in the rainy season and at the beginning of winter. The fruiting period of *M. garrettii* is not suitable for mature seeds to germinate and survive, because the seed is subject to low temperature and lack of water. Therefore, there is an advantage for the seeds to be dormant until the dry season and I hypothesized that the aril may play a role in dormancy. The aril might inhibit water absorption into the embryo or contain chemical inhibitors. Seeds must therefore wait for natural processes to destroy the aril before they can germinate. This was the logic behind a germination test with aril removed.

The statistic result showed that the median length of dormancy (MLD) of seeds with arils retained was significantly longer than seeds with arils removed. (t value = -3.44, $P<0.05$). It meant that the red aril affected the timing of germination.

The hypothesis was red aril would slow down uptake of water and oxygen by the embryo. The aril of seed was lipid-rich. Oily substances might block the way of water and nutrients. Further testing of this hypothesis would be studying of aril chemistry. Nutrition of aril-lipids, carbohydrate, sugar, etc. should be measured and this could explain why animals removed the seeds so fast, too.

Moreover, the experiment could be set for determining aril substance that inhibited seed germination. Aril crude extract of *M. garrettii* seeds should be treated to mix with soil that used as germination medium or soak the seeds before sowing, compare with control that not interfere with aril crude extract. Easily germination seeds, for example soybeans should be used in this experiment.

In natural conditions, the red aril is probably related to seed dormancy whilst also providing an attraction for seed-dispersing animals. The seeds were removed very fast. If this resulted in secondary dispersal, this was an advantage for the tree but in contrast, if seeds were removed by seed predators, reproduction of *M. garrettii* would be hindered. This may cause *M. garrettii* to become a vulnerable species. The seeds can be dispersed by animals but dispersed seeds were removed fast from the ground which not clear in seed fate. Although secondary dispersal occurred by ants, seedling establishment in the forest has been difficult. *M. garrettii* should be helped to reintroduce to the nature. *M. garrettii* is the framework tree species that effectively attracts animals. Therefore, it is recommended that this species is raised in tree nurseries. The seed of *M. garrettii* can be collected directly from trees in the fruiting period; October to November. The aril should be removed before sowing the seeds.

Chapter 6
Conclusions

Based on the results of this study it can be concluded that

1. *Prunus cerasoides* D. Don, *Balakata baccata* (Roxb.) Ess. and *Manglietia garrettii* Craib are animal-dispersed tree species.

2. Important seed dispersal agents of three framework tree species are birds and squirrels, especially Bulbuls (Pycnonotidae) and Pallas's squirrel (*Callosciurus erythraeus*).

3. *Manglietia garrettii* Craib has high seed removal rate under natural conditions. Proximity of seeds to the parent tree has no effect on seed removal from the ground. Seed removal of this species is density- and distance-independent.

4. Animal seed removers were *Sus scrofa*, *Phasianids* and ants. Further studying needs to indicate the role of *Sus scrofa* and *Phasianids*. Ants are secondary seed dispersal agents.

5. The red aril of *Manglietia garrettii* Craib seeds probably play a role in seed dormancy. Removing the aril before sowing, increases seed germination rate.

6. *Manglietia garrettii* Craib needs nursery techniques for seed germination, taking care the seedlings and reintroduction to the forest for conservation this tree species. Direct seeding is not suitable for *Manglietia garrettii* Craib.

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Appendix

Percent germination equation

$$\textit{Percent germination} = \frac{\textit{total germinated seeds}}{\textit{total sown seeds}} \times 100$$

Percent seed removal equation

$$\textit{Percent seed removal} = \frac{\textit{total seeds removed}}{\textit{total seeds placed}} \times 100$$

Table 1 Seed germination statistical result of t-Test (two-sample assuming equal variances)

	no aril	aril
Mean	65.67	10.67
Variance	22.33	4.33
Observations	3	3
Pooled Variance	13.33	
Hypothesized Mean Difference	0	
df	4	
t Stat	18.45	
P(T<=t) one-tail	2.54E-05	
t Critical one-tail	2.13	
P(T<=t) two-tail	5.08E-05	
t Critical two-tail	2.78	

Table 2 Median length of dormancy (MLD) statistical result of t-Test (two-sample assuming equal variances)

	no aril	aril
Mean	35	51.67
Variance	21	49.33
Observations	3	3
Pooled Variance	35.17	
Hypothesized Mean Difference	0	
df	4	
t Stat	-3.44	
P(T<=t) one-tail	0.01	
t Critical one-tail	2.13	
P(T<=t) two-tail	0.02	
t Critical two-tail	2.78	

Table 3 Seed germination data sheet, showing the number of germinated seeds in each replication, average and median length of dormancy (MLD)

	Seed with removed the aril				Seed with retained the aril			
Date	Rep. 1	Rep. 2	Rep.3	Average	Rep. 1	Rep. 2	Rep. 3	Average
5/11/2004	0	0	0	0	0	0	0	0
12/11/2004	0	0	0	0	0	0	0	0
19/11/2004	0	0	0	0	0	0	0	0
26/11/2004	0	0	0	0	0	0	0	0
3/12/2004	5	15	30	16.67	1	0	2	1
12/12/2004	23	39	49	37	2	1	3	2
17/12/2004	34	48	56	46	4	1	4	3
24/12/2004	44	52	62	52.67	7	3	6	5.33
30/12/2004	47	55	65	55.67	9	4	12	8.33
6/01/2005	51	56	67	58	9	6	12	9
15/01/2005	55	56	67	59.33	9	7	12	9.33
21/01/2005	56	57	67	60	9	7	12	9.33
28/01/2005	60	59	67	62	10	8	12	10
5/02/2005	64	62	71	65.67	10	9	13	10.67
MLD (days)	40	34	31	35	45	59	51	51.67