THE RELATIONSHIP BETWEEN BARK-INHABITING INSECTS AND TREES IN A TROPICAL DECIDUOUS FOREST AT NONG RAWIANG, NAKHON RATCHASIMA, THAILAND

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the Degree of Master of Science in Environmental Biology

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ความสัมพันธ์ระหว่างแมลงเปลือกไม้กับชนิดไม้ยืนต้นในป่าผลัดใบเขตร้อน ที่หนองระเวียง นครราชสีมา ประเทศไทย

นางสาวปิยนุช คะเณมา

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต

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ABACETUS SP./BARK-INHABITING INSECT/DIVERSITY/TREE DENSITY/HOST SPECIES/TREE CHARACTERISTICS/CCA/ PCA/SHOREA SIAMENSIS

The aim of this study was to observe the diversity of bark-inhabiting insects at Nong Rawiang Forest, Nakhon Ratchasima Province; moreover, effects from different tree densities, different host species, different tree characteristics, and different positions within a trunk on the bark-inhabiting insect assemblages were investigated. There were 8 plots with radius per each plot of 15 m. Trees with DBH $\geq$ 12 cm. were fixed with traps at 2 heights of base - 75 cm. and 76 - 150 cm. for two months and unfixed for two months; this practice was alternated consecutively three times. The data analyses used were the Shannon-Wiener function, Principal Components Analysis (PCA), and Canonical Correspondence Analysis (CCA).

The study found 325 bark-inhabiting insects, comprising 27 morphospecies, from 123 host trees, comprising 21 species of 16 families. The most common insect was *Abacetus* sp. (Carabidae, Coleoptera) and the most common host tree was *Shorea siamensis* (Dipterocarpaceae). The diversity and evenness of the bark-inhabiting insects from the low tree density areas were lower than from the high tree density areas. From the PCA and CCA analyses, the results showed that in the low tree density areas there was greater opportunity to find *Abacetus* sp. than in the high tree density areas. Host species showed less effect on the bark-inhabiting insect assemblages and *Abacetus* sp. played the role as a host generalist. As for effect from tree characteristics, "Bark thickness" was the main factor on insect host selection. Finally, "Bark thickness" and "DBH" were the limiting factors at lower trunk level, and "Moisture of bark" at upper trunk level.

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ปิยนุช คะเณมา : ความสัมพันธ์ระหว่างแมลงเปลือกไม้กับชนิดไม้ยืนต้นในป่าผลัดใบเขตร้อนที่หนองระเวียง นครราชสีมา ประเทศไทย
(THE RELATIONSHIP BETWEEN BARK-INHABITING INSECTS AND TREES IN A TROPICAL DECIDUOUS FOREST AT NONG RAWIANG, NAKHON RATCHASIMA, THAILAND) อ.ที่ปรึกษา : ดร. พอล เจ. โกรดิ, 116 หน้า. ISBN 974-533-162-7

การวิจัยนี้เพื่อสำรวจความหลากหลายของชนิดแมลงเปลือกไม้ที่ป่าหนองระเวียง จ. นครราชสีมา นอกจากนั้น ความหนาแน่นของต้นไม้ ชนิดพืชอาศัย ลักษณะของต้นไม้ และตำแหน่งภายในลำต้นที่มีผลกระทบต่อการเลือกอยู่อาศัยของแมลงเปลือกไม้จะถูกศึกษาด้วยแปลงศึกษา 8 แปลงมีรัศมี 15 ม. เฉพาะต้นไม้ที่มีเส้นผ่าศูนย์กลางระดับอกขนาดตั้งแต่ 12 ซม. จะถูกขึงตาข่าย โดยตาข่ายล่างจากระดับโคนต้นถึง 75 ซม. และตาข่ายบนจากระดับ 76 – 150 ซม. ตาข่ายถูกขึงเป็นระยะเวลา 2 เดือนและปลดออก 2 เดือน ทำเช่นนี้สลับกัน 3 ครั้ง การวิเคราะห์ข้อมูลใช้ Shannon-Wiener function, Principal Components Analysis (PCA) และ Canonical Correspondence Analysis (CCA)

ผลการศึกษาพบแมลงเปลือกไม้ 325 ตัว 27 ชนิด จากต้นไม้ 123 ต้น 21 ชนิด 16 วงศ์ ชนิดแมลงเปลือกไม้ที่พบมากที่สุดคือ ด้วงดิน *Abacetus* sp. (Carabidae, Coleoptera) และชนิดต้นไม้ที่พบมากที่สุดคือ ต้นรัง ค่าความหลากหลายและความเท่ากันของแมลงเปลือกไม้ในพื้นที่ที่มีความหนาแน่นของต้นไม้น้อยมีค่าต่ำกว่าพื้นที่ที่มีความหนาแน่นของต้นไม้มาก ผลการวิเคราะห์โดยใช้ PCA และ CCA พบว่า ในพื้นที่ที่มีความหนาแน่นของต้นไม้น้อยมีโอกาสพบด้วงดิน *Abacetus* sp. มากกว่าพื้นที่ที่มีความหนาแน่นมาก ชนิดพืชอาศัยมีผลกระทบต่อการเลือกอยู่อาศัยของแมลงเปลือกไม้น้อย โดยด้วงดิน *Abacetus* sp. สามารถใช้พืชอาศัยได้หลายชนิด ความหนาของเปลือกไม้มีอิทธิพลมากที่สุดต่อการเลือกต้นไม้ ความหนาของเปลือกไม้และเส้นผ่าศูนย์กลางระดับอกของต้นไม้มีอิทธิพลมากต่อการเลือกอยู่อาศัยของแมลงเปลือกไม้ ณ ระดับล่างของลำต้น ส่วนความชื้นของเปลือกไม้มีอิทธิพลมากต่อการเลือกอยู่อาศัยของแมลงเปลือกไม้ ณ ระดับบนของลำต้น

สาขาวิชาชีววิทยา	ลายมือชื่อนักศึกษา__________________
ปีการศึกษา 2545	ลายมือชื่ออาจารย์ที่ปรึกษา __________________
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Piyanoot Khaneama

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CHAPTER I

INTRODUCTION

Nowadays, humans realize the importance of biodiversity and fight to preserve all species in the world because all organisms must coexist in ecosystems. Loss in one species will effect other species as well as the dynamics of equilibrium (Supangkhasen, 1999; Chapin III *et al*., 1998). In Thailand, endangered species have been protected and some native species have been recorded and managed by the appropriate methods, including insect species. However, the data are not up-to-date because the rates of deforestation and forest fragmentation tend to become higher every year. Data during the period 1990 – 1995 by the Food and Agriculture Organization (FAO) showed that the average forest reduction in the world was a decrease of 308,744 hectares/day. As for Thailand, during the period 1996 – 1999 the survey of the Royal Forest Department demonstrated the average forest reduction of 19,586.36 hectares/day (Jarubpatara, 2000).

In ecosystems, insects are consumers and scavengers. Additionally, some insects are important pollinators and seed dispersers that help plants spread and survive from extinction (Bernays, ed., 1989; Claridge, Dawah, and Wilson, 1997; Thompson, 1994). Insects are abundant and virtually everywhere on the earth's surface, excluding the extremes of climate at the poles and on the peaks of the highest mountains, because they have a short life cycle and high efficiency in adaptation.

Insects can inhabit a great variety of habitats, such as in water, soil, stones, flowers, fruits, leaves, buds, galls, or beneath bark. The last one is occupied by the groups of the cambium borers, the wood borers, the decayed wood borers, and the dry wood borers, of which almost all species are flightless (Frost, ed., 1959). These insect groups are difficult to observe because their size are small and they spend most of their life cycle hidden under the bark by constructing galleries in the inner bark surface of the cambium region or in the wood (Doane, Dyke, Chamberlim, and Borke, 1936).

Because of these difficulties, many researches neglect to study the bark insects; as well, there is little information about these insects. Few people know what and how many species of bark insects occur on a single tree or what species of bark insects get along with the host tree species or forest types. Many species of the bark insects still require investigation on species existence, especially in tropical regions.

Nong Rawiang Forest consists of dry dipterocarp forest and dry mixed deciduous forest, which are common forest types in Northeastern Thailand. It is a royally initiated preserved area under the care of Rajamangala Institute of Technology, Northeastern Campus, Nakhon Ratchasima. This area looks like an island because the surrounding sites have been converted to agricultural land; however, it is convenient for persons interested to study the forest, wild animals, or microorganisms because the flora and fauna in this area have still not been studied.

Thus, it is proposed to study the diversity of bark insects in Nong Rawiang Forest and also investigate the effects from four different parameters associated with the presence of bark insects; there were effects of different tree densities, different host species, different tree characteristics, and different positions within a trunk.

CHAPTER II

LITERATURE REVIEW

2.1 Groups of the bark insects

The bark insects, such as the cambium borers and the wood borers feed on many types of foods such as the sapwood, heartwood, decayed wood, or dry wood (Frost, ed., 1959).

2.1.1 Cambium borers

Cambium borers are common in Coleoptera (more than 600 species of the family Scolytidae), Lepidoptera, and a few species of genus *Agromyza* in Diptera (Day, Online, 1996). The adults of Scolytidae excavate tunnels through the bark for laying their eggs, but most Lepidoptera lay their eggs on the outer bark; only their larvae mine the phloem where they reach the peak of development. In some Coleoptera, such as the flathead borers (Buprestidae), roundhead borers (Cerambyridae), larvae start feeding in cambium and continually feed on sapwood and heartwood also (Doane *et al*., 1936; Frost, ed., 1959).

2.1.2 Wood borers

Insects in this group bore in the solid wood; most are Coleoptera, some Lepidoptera, Isoptera, Hymenoptera, and very few Diptera. Common ones are the flathead borers (Buprestidae) and roundhead borers (Cerambycidae), and most attack the injured, dying, or dead trees (Frost, ed., 1959).

2.2 Life cycle of the bark insects

As other insects, the life cycle of the bark insects can be classified into 4 stages, which usually occur beneath bark. The adult stage of bark insects is mostly spent in flying to a new host tree, then mating, and laying eggs which are usually laid in the bark crevices or in excavated tunnels through the bark. The larval stage is spent mostly beneath bark, tunneling under the bark, and some species eventually bore into the wood. The larvae are borers in the woody stem. The galleries under the bark are often winding, and those in the wood are oval in cross section and usually enter the wood at an angle. Most pupal stages take place in the gallery. After moulting and reaching full-growth, new adults cut a hole through the bark and emerge (Doane *et al*., 1936; Day, Online, 1996; Frost, ed., 1959).

2.3 Factors affecting the presence of the bark insects

2.3.1 Effects of the physical factors

Certainly physical factors, namely, air humidity, moisture, sunlight, temperature, and wind influence the various habitats of all insects. However, species have specific habitats as well; the bark insects in a single tree can be also affected by the microclimate. It is important to recognize that the physical factors can vary both horizontally and vertically.

2.3.1.1 Air humidity and moisture

Forest insects are affected directly by moisture and indirectly by its effect upon their host. Some insects appear to be very sensitive to air humidity and the moisture content of their food materials. The moisture content of the host tree is variable daily and seasonally, which affects the invasion of bark insects (Barbosa and Wangner, 1989). Frost (ed., 1959) showed that the life cycle of insects depends on humidity and nutrients. Under stress conditions with the lack of more suitable humidity and nutrients, wood borers have slower development and require 2 or 3 years to mature. Bark beetles prefer to live in conditions of high temperature and moderate humidity. For example, in dry inner bark the bark beetles usually die or their broods are small, but in high humidity inner bark eggs will be infected by fungi or larvae are unable to develop successfully (Doane *et al*., 1936).

2.3.1.2 Sunlight

Effects from light intensity can cause changes in life-history parameters. Light has been found to play an important role in regulating the activities of various insects. Shortening the hours of light causes insects to go to the pupal stage and prepare for hibernation. On cloudy days, some beetles are inactive or stop oviposition; on the other hand, they are very active in the bright sun. Most borers, such as the flathead borers and locust borers, prefer to attack trees exposed to the full sunlight over shaded tree trunks (Doane *et al*., 1936).

2.3.1.3 Temperature

Each insect has a specific range of temperature within which they are most active, mostly between 9 – 35°C: temperatures higher or lower than this range can retard or stop the development and activities of the insect. Temperatures of 15°C or less can cause mortality of the western pine beetles, and bark temperatures between 43 – 48°C can kill all stages of *Dendroctonus* bark beetles but are not necessarily fatal to hymenopteran parasites or flathead and roundhead bark beetles (Doane *et al*., 1936). Ohgushi and Sawada (1997) introduced the ladybird (*Epilachna niponica*) into the Botanical Garden of Kyoto University 10 years ago and found that temperatures between 20 - 25°C had significant affects, as shown by higher fecundity, higher oviposition activity, and shorter lifespan than the source population. Dijk (1994) found that at low temperature and short food supply the two carabid beetles (*Calathus melanocephalus* and *Pterostichus versicolor*) were smaller in size than those at high temperature and with more food.

2.3.1.4 Wind

Wind is connected to the ability of an insect to perceive and locate chemical messages, carrying about colonizing new habitats, spreading outbreak populations, and reducing intra-and interspecifc competition. Many insects are carried by wind over long distances (Barbosa and Wangner, 1989).

2.3.2 Effects of host trees

A single host tree for the bark insects can provide 3 habitat functions: (i) a source of food, (ii) a means of protection during the larval and pupal stages, and (iii) a home or place for rearing the broods of certain social and solitary species. Many characteristics of a single host tree, including density of trees, host tree species, plant chemicals, the diameter at breast height, bark features have some effects on bark insects.

2.3.2.1 Density of trees

The abundance or the lack of favorable food material is often an important factor in bringing about the increase or decrease of an insect species (Doane *et al*., 1936). Payne and Saarenmaa (eds., 1988) reported that tree density correlated with temperature and wind flow;

thinned stands were warmer and showed higher wind flow than unthinned stands. Moreover, they found 95% of all mountain pine beetles (*Dendroctonus ponderosae*) were trapped in higher stand density trees compared to only 5% in lower density trees.

2.3.2.2 Host tree species

Doane *et al*. (1936) reported that probably 90% of the species of the family Scolytidae favor to attack conifers, and Quiring and Butterworth (1994) and Stiling and Rossi (1995) also supported that normally more than 80% of insect species, the population density is affected by the plant genotype more than by local environmental condition.

2.3.2.3 Plant chemicals

Resin as the first line of resistance is used against all invading organisms and is found in ducts in the sapwood. When ducts are disturbed, resin flows from xylem ducts into phloem at the wound sites. Under stress condition, more susceptible trees have a reduced ability to produce resin and can be fatally injured by only a small insect population (Barbosa and Wangner, 1989; Payne and Saarenmaa, eds., 1988). Moreover, the quality of plant chemicals is associated with insect aggregation. Barbosa, Krischik, and Jones (1991) reported that after pioneers feed on host trees, insects emit some chemical compounds, as pheromones, kairomones, and allomones, which result in (i) recognition of host tree species; (ii) recognition of mate; (iii) location of prey and host predators and parasitoids; and (iv) regulation of intra- and interspecific competition.

2.3.2.4 The diameter at breast height

The diameter at breast height influences finding of the trees by host insects. For example, white pine weevils and *Dendroctonus ponderosae* prefer to land on dominant trees with a large diameter because these trees have more crevices, making successful colonization easier and more likely. Some borers prefer to invade younger trees because they have more living tissues. Almost 100% of locust borers attack older trees with DBH $\geq$ 6.5 cm. (Barbosa and Wangner, 1989; Payne and Saarenmaa, eds., 1988).

2.3.2.5 Bark features

The bark features can be classified into 9 types, namely, cracked, dippled scaly, fissured, peeling, resinous, scaly, smooth, stripping, and thorny (Chantaranothai, 1994).

Features of bark influence the oviposition of the bark insects because adults lay eggs in crevices of the bark or some excavate through the bark for laying in the inner bark (Doane *et al*., 1936). The roughness of the bark is a critical stimulus for the oviposition of borers. Only a few larvae develop in thin bark, which will produce smaller larvae than in thick bark (Barbosa and Wangner, 1989).

Few researchers have studied the diversity of insect borers. Leponce, Roisin, and Pasteels (1996) studied the diversity of arboreal termite communities in coconut plantations of Northern New Guinea and focused on a single tree. Dubbert, Tscharntke, and Vidal (1998) studied abundance of the stem-boring insect communities in grass shoots of *Calamagrostis epigeios* (L.), and Wright and Samways (1999) studied plant characteristics which determined insect borers in infructescences of *Protea* species. In tropics, study of diversity of insect borers is rarely done; however, many of the insect species are found in this region. The focus of this research was a study of the species diversity of bark insects and also an investigation of the effects of different tree density areas, different host plant species, different characteristics of host trees, and different height intervals in a single host tree on the bark insects present. The bark insects occupying the sampling plots were considered representative of the bark insects in Nong Rawiang Forest. Comparisons were made of the species diversity of bark insects among the study plots and effects of the characteristics above were calculated by ordination analyses. Effects of tree density areas and of host plant species were investigated by using Principal Components Analysis (PCA) and effects of characteristics of host trees and of different height intervals in a single host tree were calculated by using Canonical Correspondence Analysis (CCA).

CHAPTER III

STUDY SITE AND METHODS

3.1 Equipment and chemicals

3.1.1 Equipment for sampling plots

- Map of Nong Rawiang (scale 1: 15,000)
- Camera
- Compass
- Eslon tape
- Hammer
- Knife

3.1.2 Equipment and chemicals for collecting bark insect data

- Drying oven
- Stereoscope with attached camera
- Compound microscope
- Nikon SLR camera
- Drawing utensil
- Insect boxes
- Killing bottle
- Insect pins
- Nails
- Modeling clay
- Nylon netting
- Nylon string
- Wire
- Ethyl acetate
- 75% and 95% Ethyl alcohol

- Xylene
- Naphthalene

3.1.3 Equipment and chemicals for collecting plant data

- Clinometer
- Analytical balance
- Plant presses
- Pruning shears
- Knife
- Chisel
- String
- Measuring tape
- Plastic bags
- Notebook
- Naphthalene
- Red lime

3.2 General description of the study site

3.2.1 The study site

The study area is located at Nong Rawiang, Nong Rawiang Subdistrict, Muang District, Nakhon Ratchasima, at latitude $14^{\circ}56'$N to $14^{\circ}57'$N and longitude $102^{\circ}10'$E to $102^{\circ}11'$E, approximately 12 kilometers from the city of Nakhon Ratchasima, or 6 kilometers east from the Nakhon Ratchasima – Chok Chai road (Figure 3.1). Total area is 400 hectares. Most of the area is a level plain with an average altitude of 197 m above mean sea level. The northern, southern, and western edges are adjacent to public roads, while the east borders the public land. Nong Rawiang in the past was public land, but since 1969 it has been land belonging to Rajamangala Institute of Technology, Northeastern campus, Nakhon Ratchasima, for the objectives of field study and management for future expansion. Currently, the area is classified into 4 parts, namely, (i) the Royal Garden of Queen Sirikit, (ii) the area for buildings, (iii) the area for field studies and cultivated plants, and (iv) the plant preservation area, which are approximately 32, 32, 176, and 160 hectares, respectively (Ratree, ed., 1994).

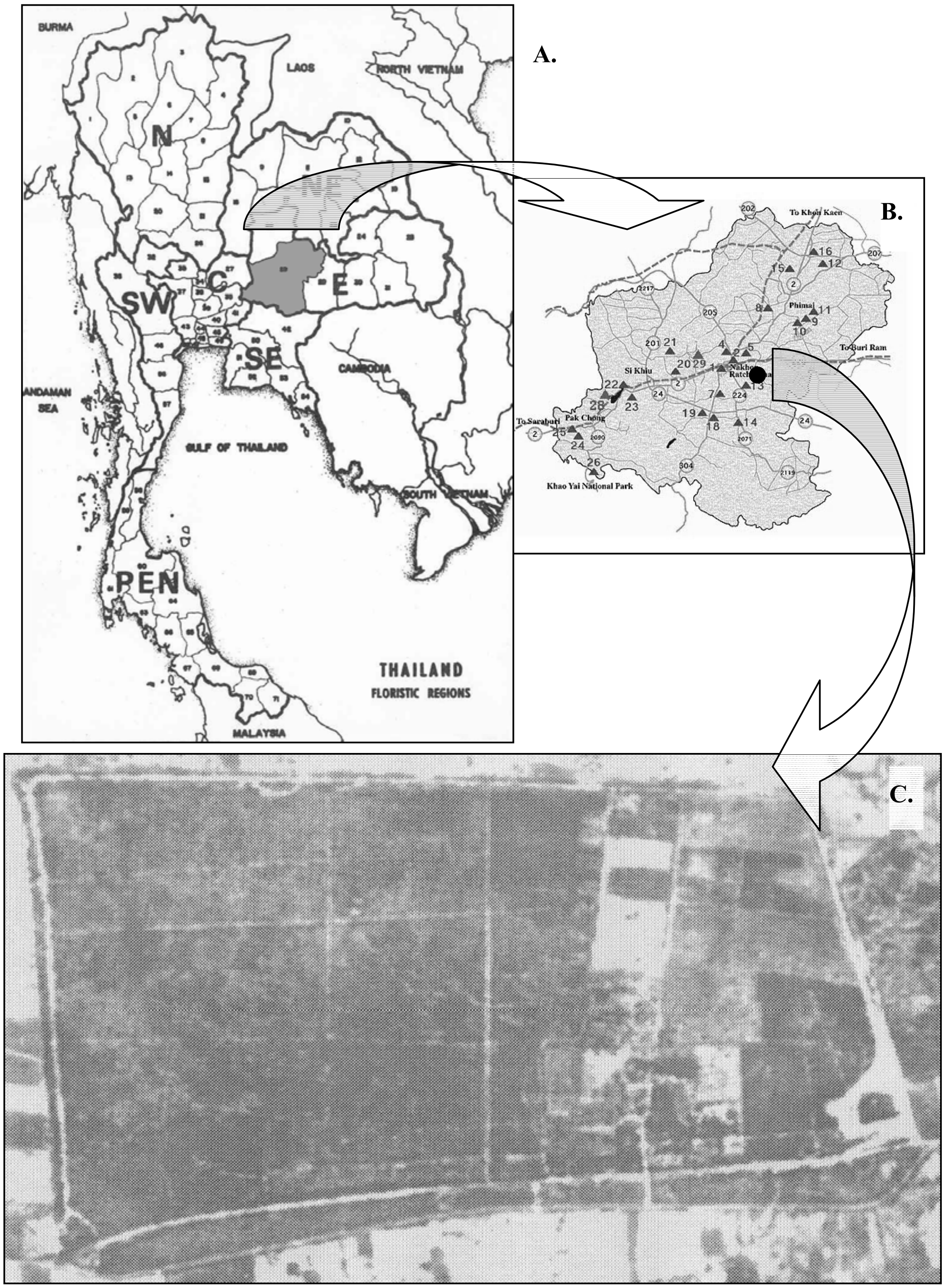


Figure 3.1. Showing the location of Nakhon Ratchasima Province (A. and B.) and geographical features of the Royally Initiated Project for the Conservation of Plant Genetic Resources (C.). Map of Thailand from *Flora of Thailand*.

As for the last one, the preserved area is the part of the Royal Initiated Project for the Conservation of Plant Genetic Resources under Her Royally Highness Princess Maha Chakri Sirindhorn, of which this research was located in this area.

3.2.2 Physical features of the land

The preserved area is classified into 2 different sites according to the density of trees. The higher density site has 46 species of woody trees and the average is around 173 individuals/hectare. Dominant species are *Lannea coromandelica*, *Cratoxylum formosum*, and *Urobotrya siamensis*. Sixty species of shrubs and herbs are found, and the average is around 1,262 individuals/hectare. Dominant understory species are *Arundinaria pusilla*, *Murdannia loureirii*, and *Erythroxylum oblanceolatum*. The averages of total height, the height of lowest limbs, and the diameter at breast height of the woody trees are 4.3 m., 1.5 m., and 5.7 cm., respectively. In the lower density site, there are 35 species of woody trees and the average is around 72 individuals/hectare. Dominant species are *Lannea coromandelica*, *Erythrophleum succirubrum*, and *Litsea glutinosa*. Shrubs and herbs comprise more than 37 species and the average is around 4,159 individuals/hectare. The dominant understory species is *Vietnamosasa pusilla*. The average of total height, the height of lowest limbs, and the diameter at breast height of the woody trees are 2.6 m., 0.9 m., and 4.6 cm., respectively (Ratree, ed., 1994).

The forest types covering the preserved area are dry mixed deciduous forest and dry dipterocarp forest with an age of the native plants at around 25 – 30 years. Dry mixed deciduous forest has a greater diversity in tree species per area than dry dipterocarp forest, 9 and 7 species/hectare, respectively. The dominant species of dry mixed deciduous forest are *Lannea coromandelica*, *Acacia comosa*, *Erythrophleum succirubrum*, *Aporosa villosa*, *Sindora siamensis*, and *Phyllanthus emblica*, and of dry dipterocarp forest are *Shorea siamensis*, *Sindora siamensis*, *Lannea coromandelica*, *Erythrophleum succirubrum*, and *Xylia xylocarpa* (Ratree, ed., 1997).

3.2.3 Climate

The climate of Nakhon Ratchasima Province is affected by easterly, northwesterly, and southwesterly winds. According to the meteorological data for 30 years (1961 – 1990), the climate can be separated approximately into 3 seasons: a hot season starting from February to May; a rainy season starting from June to September; and winter season starting from October to January (Meteorological Station of Nakhon Ratchasima, 1991). As for meteorological data during the period 1990 – 1999, the maximum mean temperature was around 36.7°C in April and the minimum mean temperature was 18.4°C in December. For the rainfall data, September and December were the months of maximum and minimum mean rainfall at 195.57 and 3.19 mm., respectively. The maximum mean humidity was in September at 78.97% and the minimum mean humidity was in February at 58.31%. The maximum mean evaporation was 6.08 mm. in April and the minimum mean evaporation was 3.75 mm. in October. The maximum mean radiation was in April, 476.97 cal/cm^2/day, and the minimum mean was in December, 401.67 cal/cm^2/day (Data from Meteorological Station of Nakhon Ratchasima, and Huay Ban Yang Agricultural Irrigation Research Station, Nakhon Ratchasima) (Figure 3.2).

3.3. Method

3.3.1 Method for determining the study plots

The field study used a "Line plot system" to determine plots (Watcharakitti, 1992). The dirt road was determined to be the base line, which runs in a north and south direction. Four parallel cruise lines are perpendicular to the base line, each line separated by 200 m. The starting point was chosen 50 m. from the base line and then each sampling plot was set at a distance of 200 m. There are 2 plots in each line with a collecting radius of 15 m., so there are a total of 8 plots in the sampling area (Figure 3.3).

3.3.2 Method for determining the study plants

From a preliminary study, it was found that few bark insects lived in trees with low diameter at breast height (DBH). Base on the results of graphing DBH versus the cumulative species numbers of bark insects, it was found to be suitable to study trees with a DBH greater than or equal to 12 cm. in each plot.

3.3.3 Method for fixing traps

Traps made from refined nylon were used to catch the emerging bark insects from tree trunks (Figure 3.4). Traps were fixed at two levels above the ground: lower traps fixed from the base to a height of 75 cm. and upper traps fixed at a height of 76 to 150 cm. Before fixing, however, insects found on the outer bark were removed, and then at the fixing position small grooves were made to protect the emerging bark insects from being lost. The last step was

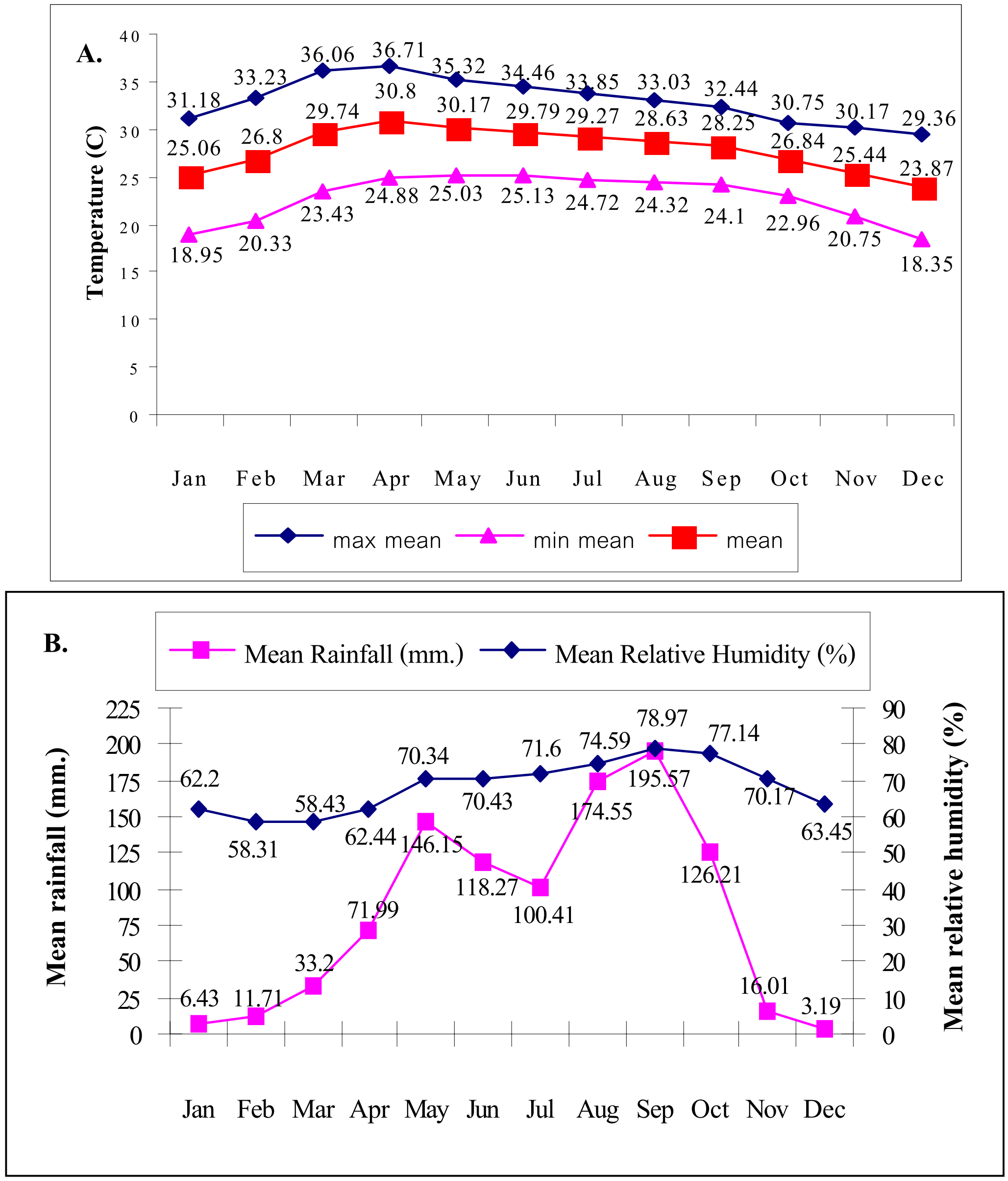
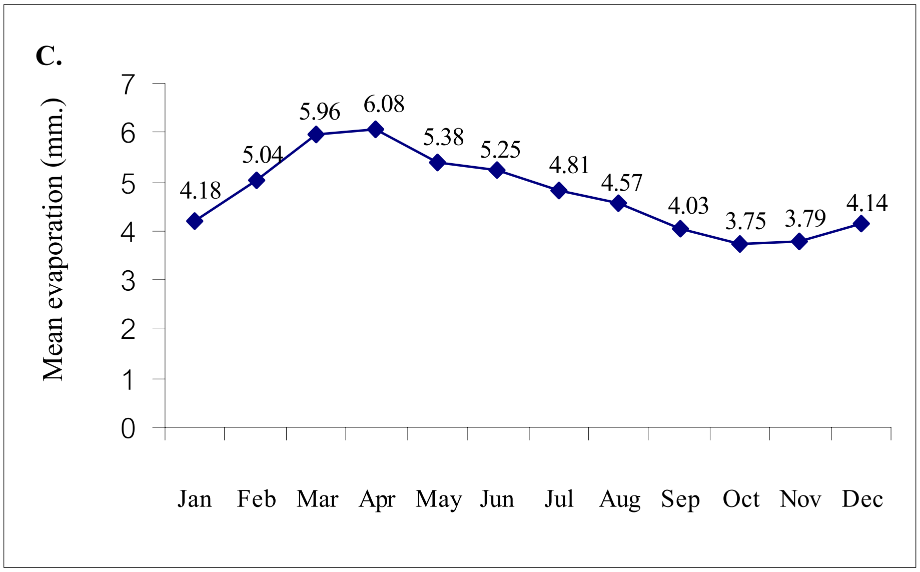


Figure 3.2. Showing the diagram of the climatological data of Nakhon Ratchasima Province during the period 1990 – 1999: A. Mean air temperature; B. Mean rainfall and mean relative humidity; C. Mean evaporation; and D. Mean radiation (Data from Meteorological Station of Nakhon Ratchasima, and Huay Ban Yang Agricultural Irrigation Research Station, Nakhon Ratchasima).



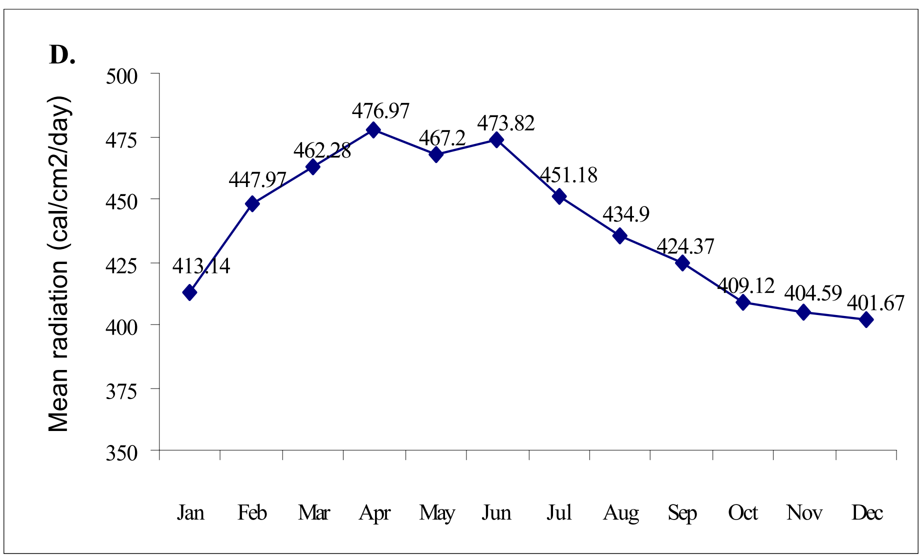


Figure 3.2. (cont.)

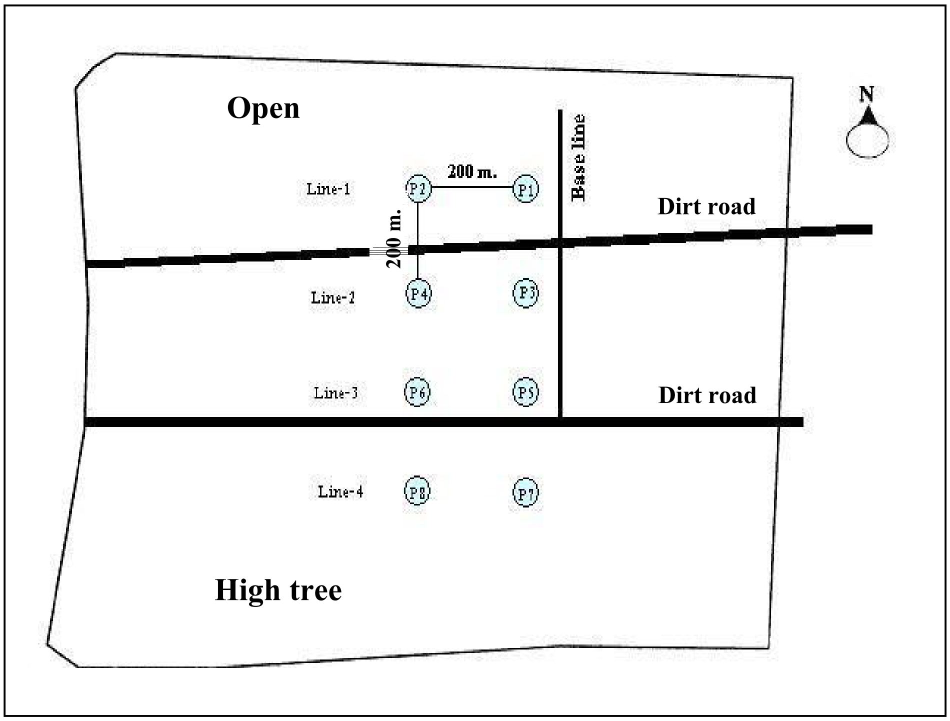


Figure 3.3. Showing the location of the sampling plots in the preserved area at Nong Rawiang Forest (not to scale). "P" refers to plot number, for example, P1 means Plot number 1.

Figure 3.4. Showing trap fixing.

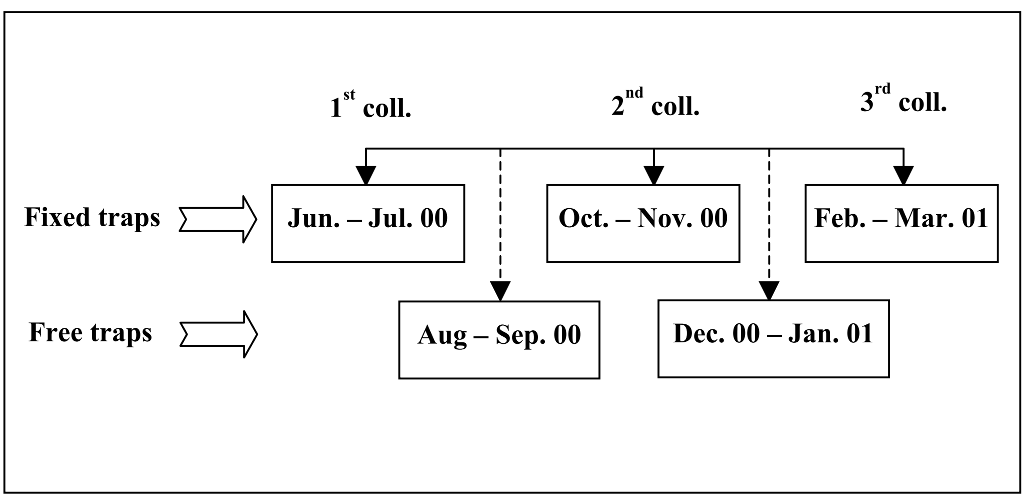


Figure 3.5. Showing the schedule for collecting bark insects.

filling modeling clay into the small grooves and fixing the nylon netting. Trap fixing was replicated three times by alternating every two months and checking every two weeks (Figure 3.5).

3.3.4 Method for collecting bark insect data

The bark insects collected from the field were brought to the laboratory and separated by size. Then, all insects, except those of very small size, were killed with ethyl acetate in a killing bottle and set with insect pins. Next, the bark insects were dried in a drying oven for one day at a temperature of 50°C and preserved in the insect boxes. The very small bark insects were killed with X. A. mixture (xylene 1: ethyl alcohol 1) and preserved in 75% ethyl alcohol. Finally, each insect was identified and photographed with color print film. Labels were prepared listing scientific name, family, host plant name, plot number, host plant number, collecting date, and collecting number. For identification, the following keys were used Arnett, Downie, and Jaques (1980) and Bright and Stark (1973). Balduf (1969), Doane et al (1936), and Graham (1963) were also helpful to study the groups of bark insects. The identifications were confirmed with the Department of Agriculture and the Royal Forest Department.

3.3.5 Method for collecting plant data

Host plants from the study plots were identified to species. Voucher specimens were collected, pressed and dried, then prepared as herbarium sheets. These sheets were stored in plastic bags and preserved with naphthalene. Plant specimens were identified by using keys (*Flora of Thailand* and *Flora of Java*), compared with specimens in the herbarium of Suranaree University of Technology, and by checking with experts such as Dr. Paul J. Grote and Assoc. Prof. Dr. Sompong Thammathaworn. For each host tree, data of scientific name, tree number, height, the diameter at breast height (at 130 cm.), bark type, and percentage of moisture content of bark were recorded.

3.3.6 Method for collecting environmental data

Meteorological data as air temperature, rainfall, and relative humidity was received from Meteorological Station of Nong Rawiang, Nakhon Ratchasima Province.

3.4 Statistical analyses

3.4.1 The diversity and evenness

The diversity and evenness of the bark insects were calculated by using the Shannon-Wiener function (Krebs, 1978). The results could be interpreted as species richness, abundance, and equilibrium, which were compared among the study plots.

Shannon-Wiener function:

$$\boxed{H = -\sum_{i=1}^{S}(p_i)(\log_2 p_i)}$$

H = index of species diversity (bits/individual)

S = number of species

p_i = proportion of total sample belonging to ith species

Evenness:

$$\boxed{E = \frac{H}{H\ \max}}$$

E = Equitability of allotment of individuals among the species

H = index of species diversity (bits/individual)

$H_{max} = \log_2 S$ = species diversity under conditions of maximal equitability

3.4.2 Ordination analyses

Ordination analyses are a family of mathematical elements for studying complex data sets; these methods organize sampling entities along gradients defined by combinations of interrelated variables. The original data can be defined as new composite variables as weights of linear combinations of the original variables and interpreted as a map with few dimensions and minimum loss of information. Moreover, these analyses try to extract the dominants under gradients of variation among sampling units from a set of multivariate observations. Distances between samplings reflect the dissimilarity of their components, such as species, abundance, or biomass; for example, too close points mean that the samplings have very similar components or too far apart points mean that the sampling have very different components. Research of Hobson (2000), Rakocinski, et al. (Online, 1997), and Wright and Samways (1999) were a few of many works that used ordination analyses; books by Jongman, Ter Braak, and Van Tongeren (eds., 1997), McGarigal, Cushman, and Stafford (2000), and Walker (1999) were very helpful for the interpretation of results and were as one of references in this study. Principal Components Analysis (PCA) and Canonical Correspondence Analysis (CCA) were chosen in this research for investigating effects of different parameters to the bark insect presence; the PCA analyzed “Effects of tree densities” and “Effect of host plant species”, while the CCA analyzed “Effects of tree characteristics” and “Effect of different positions within trunk levels”.

3.4.2.1 Principal Components Analysis (PCA)

Principal Components Analysis (PCA) is an unconstrained ordination technique, of which the main purpose is to organize sampling entities along meaningful gradient base on interrelationship among a large number of interdependent variables. The method is to reduce the original dimensions of the data set, where each dimension is defined by one variable, into fewer new dimensions, where each new dimension is defined by a linear combination of the original variables. As for analysis, the first principal component axis can explain the maximum amount of variation possible in a single dimension; the second principal component axis is perpendicular to the first and maximizes the remaining variance; and likewise for the next axes.

3.4.2.2 Canonical Correspondence Analysis (CCA)

Canonical Correspondence Analysis (CCA) is a constrained ordination technique in which the dominant gradient of variation in one set of variables (such as dependent variables, usually species abundance) are computed as linear combinations of explanatory variables (usually environmental characteristics) in a second set. CCA extracts the major gradients in the data that can be accounted for by the measurement explanatory variables. CCA is different from the unconstrained ordination techniques like PCA, where, for example, the axes are major gradients within the species data themselves, irrespective of any ecological explanatory variables. In CCA, the value of canonical correlation is a measure of the multiple correlation between each pair of canonical variates (linear combinations of the original variables) where one variate is from each set of variables. The range of canonical correlation is between 0 - 1; a value of 0 means no relationship between the groups and the canonical function, while large values represents increasing degrees of association.

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Species composition

4.1.1 Flora composition

Eight plots were sampled, which were distributed along 4 lines in different areas. Line-1, comprising plots 1 and 2, was at the forest edge between the forest and open habitat, and consisted predominantly of grass, small saplings, and a few low trees. Line-2, next to the south of Line-1, comprising plots 3 and 4, was in the area of greater tree density than Line-1; this area was found trees with medium and high heights and young saplings, such as *Shorea siamensis* and *Acacia comosa*. Line-3 and Line-4, comprising plots 5, 6, 7, and 8, can clearly be called dry dipterocarp forest and were in the forest interior with greater tree density. In this study, Line-1 and Line-2 were regarded as "The low tree density areas" and Line-3 and Line-4 were called "The high tree density areas" (Figure 4.1).

Altogether in the 8 plots were found 123 host trees with DBH $\geq$ 12 cm. comprising 21 species of 16 families (Appendix I). There were *Allophylus cobbe, Aporosa villosa, Bombax anceps, Canarium subulatum, Catunaregam tomentosa, Cordia dichotoma, Ellipanthus tomentosus, Erythrophleum succirubrum, Lannea coromandelica, Mitragyna brunosis, Morinda coreia, Ochna integerrima, Pterocarpus macrocarpus, Schleichera oleosa, Shorea siamensis*, *Sindora siamensis*, *Spondias pinnata, Stereospermum neuranthum, Vitex pinnata, Xylia xylocarpa,* and *Zizyphus cambodiana* (Table 4.1). The most common tree was *Shorea siamensis* (Dipterocarpaceae) with 77 individuals (62.60% of total trees) and the second was *Sindora siamensis* (Caesalpiniaceae) with 10 individuals (8.13% of total trees). Plot 7 had the greatest number of trees with 28 individuals and plot 2 had the least with 5 individuals. Consistent with being the most common host, *Shorea siamensis* was the most common in plot 7 with 20 of 28 individuals. Moreover, *Shorea siamensis* was abundant in every plots, except plot 1 and plot 2, where it was not present (Figure 4.2.).

A.

B.

Figure 4.1. Showing the differences of the study plots between (A.) the low tree density area and (B.) the high tree density area.

Table 4.1. Showing trees present in the study plots.

Host plant	No.
1. Anacardiaceae	
- *Lannea coromandelica*	6
- *Spondias pinnata*	2
2. Bignoniaceae	
- *Stereospermum neuranthum*	1
3. Bombacaceae	
- *Bombax anceps*	1
4. Burseraceae	
- *Canarium subulatum*	1
5. Caesalpiniaceae	
- *Erythrophleum succirubrum*	6
- *Sindora siamensis*	10
6. Connaraceae	
- *Ellipanthus tomentosus*	1
7. Dipterocarpaceae	
- *Shorea siamensis*	77
8. Ehretiaceae	
- *Cordia dichotoma*	1

Host plant	No.
9. Euphobiaceae	
- *Aporosa villosa*	1
10. Mimosaceae	
- *Xylia xylocarpa*	3
11. Ochnaceae	
- *Ochna integerrima*	1
12. Papilionaceae	
- *Pterocarpus macrocarpus*	1
13. Rhamnaceae	
- *Zizyphus cambodiana*	1
14. Rubiaceae	
- *Catunaregam tomentosa*	3
- *Mitragyna brunosis*	1
- *Morinda coreia*	2
15. Sapindaceae	
- *Allophylus cobbe*	1
- *Schleichera oleosa*	1
16. Verbenaceae	
- *Vitex pinnata*	2
Total	**123**

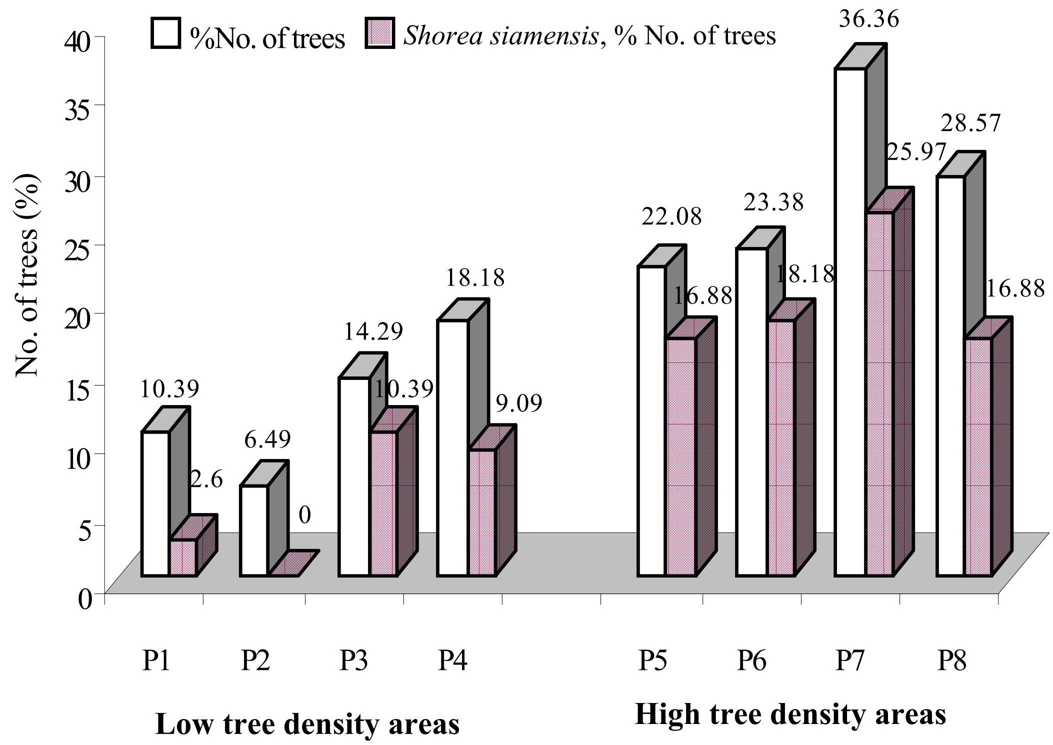


Figure 4.2. Showing percent total tree numbers and percent *Shorea siamensis* from total tree numbers separated by the study plots.

4.1.2 Bark-inhabiting insect composition

There were 325 bark-inhabiting insects found in this study comprising the 4 orders, Coleoptera, Embioptera, Hemiptera, and Hymenoptera, which few numbers were true bark insects (Appendix I; Appendix II for weather data). Approximately 95% were Coleoptera, and 3.69%, 0.921%, and 0.31% were Hymenoptera, Hemiptera, and Embrioptera, respectively. The identification could be made at the family level to 11 families and 7 unknowns, at the generic level to 9 genera and 18 unknowns, and at species level to 27 morphospecies. The known insect families were Braconidae, Brentidae, Carabidae, Curculionidae, Cydnidae, Elateridae, Leiodidae, Lygaeidae, Rhysodidae, Staphylinidae, and Tenebrionidae. *Abacetus* sp. (Carabidae, Coleoptera) was the most common insect with 241 individuals (74.15% of total insects). The next were *Scleron* sp. (Tenebrionidae, Coleoptera), *Cotesia* sp. (Braconidae, Hymenoptera), Leiodidae (Coleoptera), *Cardiophorus* sp. (Elateridae, Coleoptera), and Unknown E (Coleoptera), with 15, 12, 10, 8, and 6 individuals, respectively, and the remaining were very rare species with 3 individuals or fewer. For convenience, the bark-inhabiting insects found in this study were classified into 5 groups according to their feeding behavior or their influence on a host tree: (i) Bark eaters (B); (ii) Fungus eaters (F); (iii) Parasitoids (Pa); (iv) Predators (P); and (v) Shelter seekers (S) (Table 4.2). The predator group, including *Abacetus* sp., was the most common insect in this study with 266 individuals (81.85% of total insects), and the next were fungus eaters, bark eaters, parasitoids, and shelter seekers with 22, 21, 12, and 4 individuals (6.77, 6.46, 3.69, and 1.23% of total insects), respectively. From figure 4.3, it was seen that only one species of the bark-inhabiting insects in this study was very common but many remaining insects were very rare. Moreover, most insects found were from *Shorea siamensis*, except 9 morphospecies of Curculionidae (S), Cydnidae (P), Elateridae sp. 4 (P), Lygaeidae (P), Rhysodidae (F), Unknown B (F), Unknown C (S), Unknown D (F), and Unknown F (B) (Figure 4.4).

According to the Shannon-Wiener function, the diversity of bark-inhabiting insects collected from eight plots were 1.24, 1.23, 0.66, 1.01, 0.74, 1.42, 2, and 2.61 bits/individual, respectively, and the evenness were 0.44, 0.62, 0.28, 0.44, 0.47, 0.51, 0.54, and 0.82, respectively (Figure 4.5). Comparing among plots, both the diversity and evenness had highest

Table 4.2. Showing the bark-inhabiting insects collected from the study plots.

Order	Morphospecies	Number (individuals)	Insect mode
Coleoptera	**Brentidae**	1	Fungus eater
	Carabidae		
	- *Abacetus* sp.	241	Predator
	- *Brachinus* sp.	2	Predator
	- *Graniger* sp.	2	Predator
	Curculionidae	3	Shelter seeker
	Elateridae		
	- *Adeloura* sp.	1	Predator
	- *Agrypnus aegualia*	3	Predator
	- *Cardiophorus* sp.	8	Predator
	- sp. 4	2	Predator
	- sp. 5	3	Predator
	Leiodidae	10	Fungus eater
	Rhysodidae	1	Fungus eater
	Staphylinidae	1	Predator
	Tenebrionidae		
	- *Mesomorphus* sp.	1	Bark eater
	- *Scleron* sp.	15	Bark eater
	- sp. 3	3	Bark eater
	- sp. 4	1	Bark eater
	Unknown A	1	Fungus eater
	Unknown B	1	Fungus eater
	Unknown C	1	Shelter seeker
	Unknown D	2	Fungus eater
	Unknown E	6	Fungus eater

Table 4.2. (cont.)

Order	Morphospecies	Number (individuals)	Insect mode
Embioptera	**Unknown F**	1	Bark eater
Hemiptera	**Cydnidae**	1	Predator
	Lygaeidae	1	Predator
	Unknown G	1	Predator
Hymenoptera	**Braconidae**		
	- *Cotesia* sp.	12	Parasitoid
	Total	325	

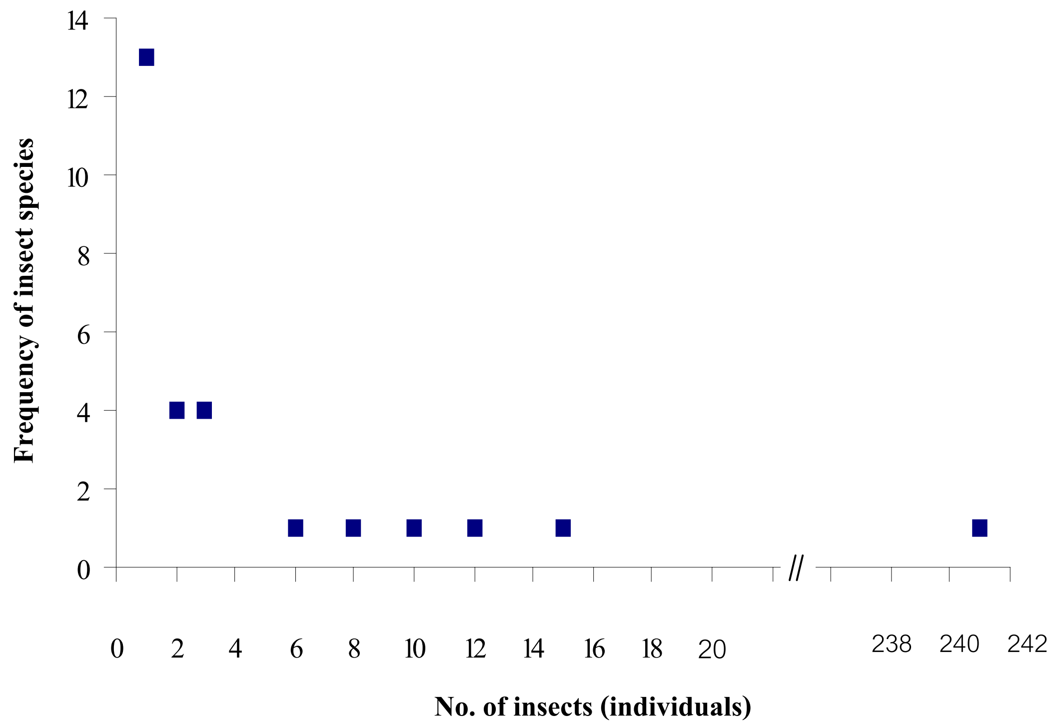


Figure 4.3. Showing rank abundance of the bark-inhabiting insects.

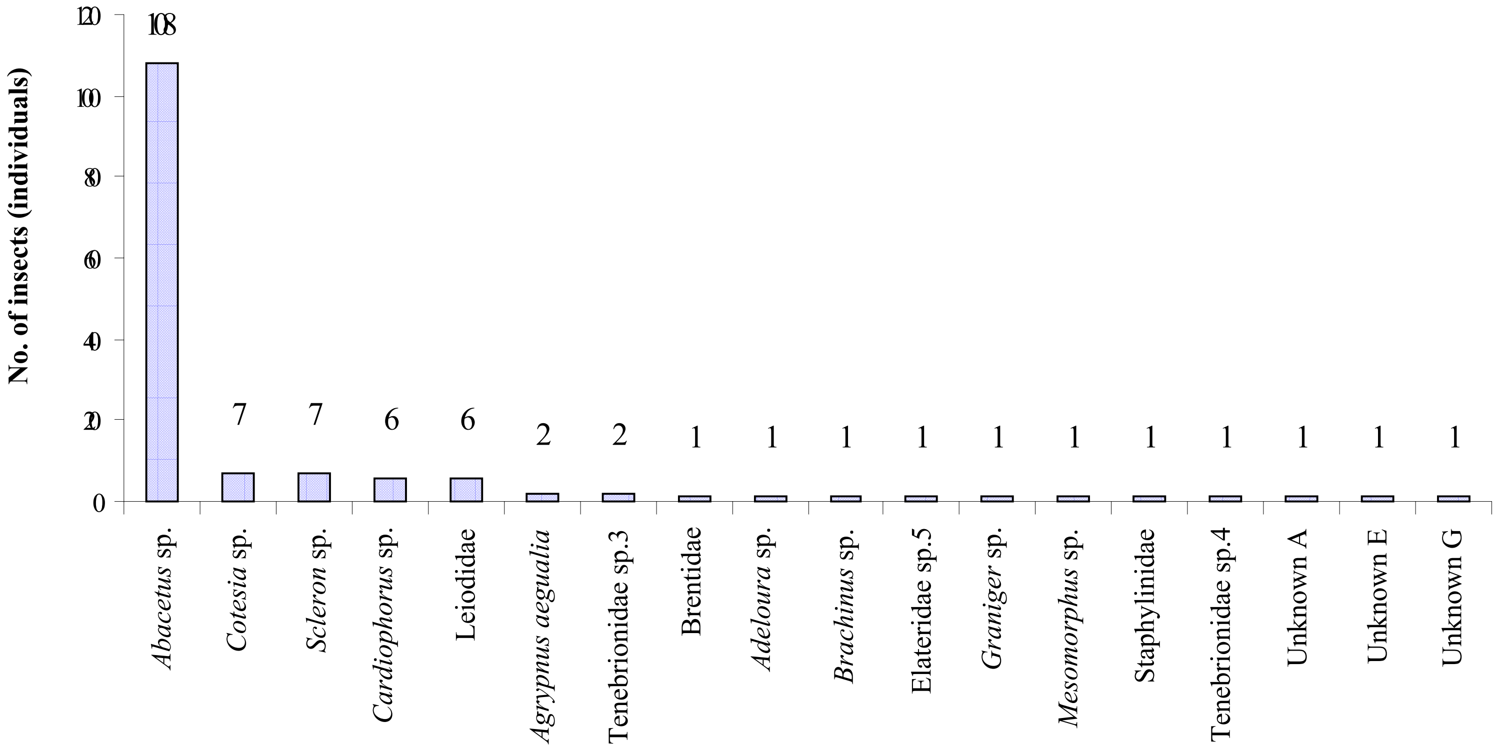


Figure 4.4. Showing species and numbers of the bark-inhabiting insects present in *Shorea siamensis*.

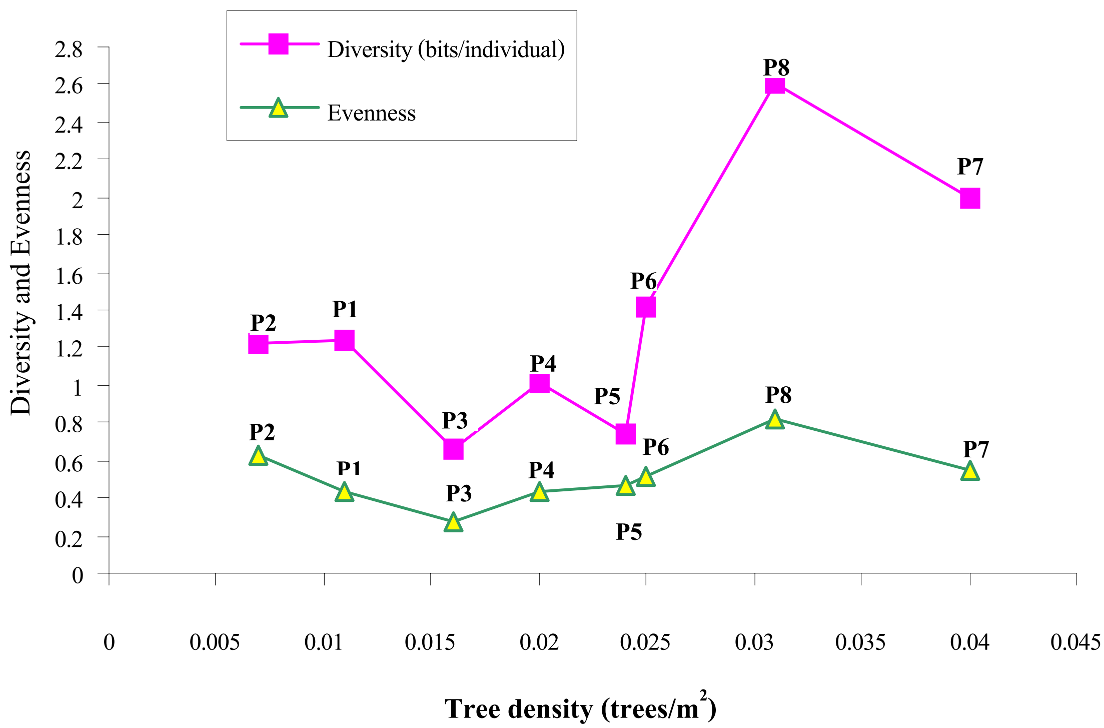


Figure 4.5. Showing the diversity and evenness of the bark-inhabiting insects based on the Shannon – Wiener function separated according to tree density.

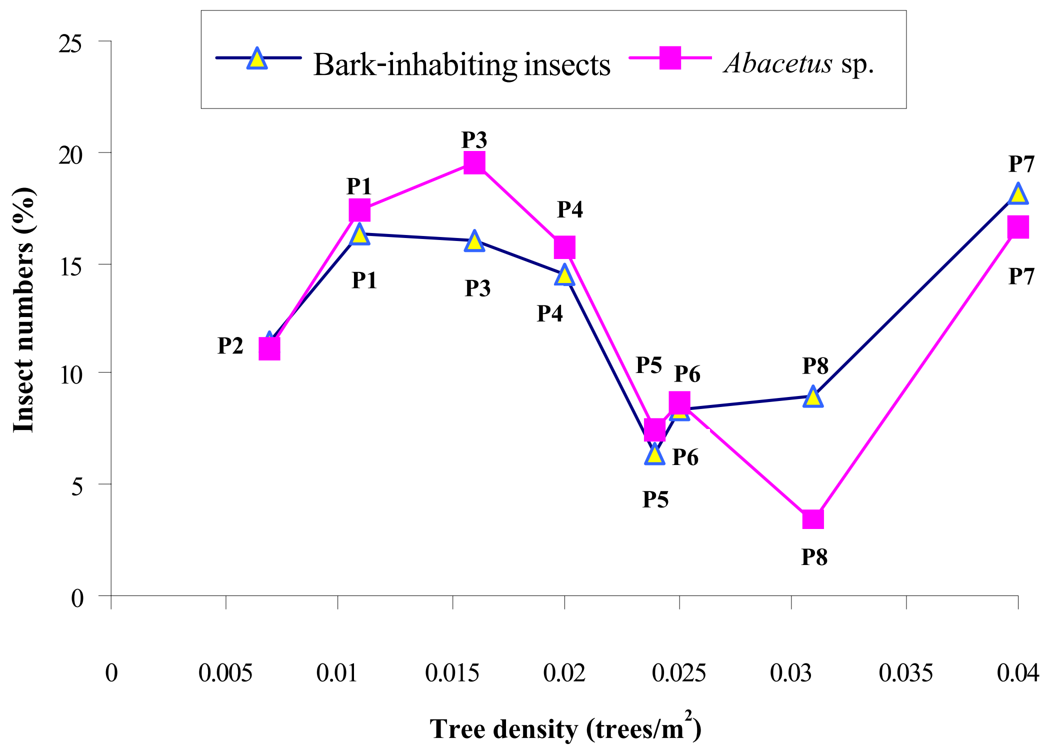


Figure 4.6. Showing percent total bark-inhabiting insects and percent total *Abacetus* sp. numbers separated according to tree density.

values at plot 8 and least values at plot 3; moreover, the trends seemed to be high in the high tree density areas and low in the low tree density areas. The diversity of insects was positively correlated with diversity of vegetation stratification that provided more heterogeneity both horizontally and vertically for insect habitats (Dajoz, 2000). On the other hand, the low tree density areas had both greater total insect numbers and *Abacetus* sp. numbers than the high tree density areas, as shown by Figure 4.6. The insect numbers from eight plots comprised 53, 37, 52, 47, 21, 27, 59, and 29 individuals, respectively, and the numbers of *Abacetus* sp. comprised 42, 27, 47, 38, 18, 21, 40, and 8 individuals, respectively.

Most insects found in this study were not true bark insects; however, the insects such as carabids or curculionids still had some relationship with tree trunks. Carabidae, the predatory family with the great abundance in this study, normally feed on bark- and wood-boring beetles; furthermore, they have some forms that can be found beneath the bark or maybe spend their whole lives within the tree, namely, *Dromius melanocephalus*, *D. quadrinotatus*, *or Lebia scapularis* (Stebbing, 1914; Dajoz, 2000). Some carabids were used as beneficial predators of insect pests such as *Agonum dorsale*, *Bembidion lampros*, *B. obtusum*, *Demetrias atricapillus*, *Pterostichus melanarius*, *P. madidus*, and *Trechus quadristriatus* (Kielty, Allen-Williams, and Underwood, 1999, quoted in Garner, Allen, Gundrey, Luff and Mole, Online, 2000; Lovei and Sunderland, 1996, quoted in Garner *et al*.; Luff, 1987, quoted in Garner *et al*.; Sunderland and Vickerman, 1980, quoted in Garner *et al.*). As for Curculionidae, these species live in variety habitats, and some species in the pupal stage inhabit sapwood or thick bark (Stebbing). Therefore, the group of curculionids was difficult to distinguish as “true bark insects” or “shelter seekers”. Other insects also had more influence on tree trunks, such as Leiodidae using trunks as places for finding fungi, or *Cotesia* sp. (Braconidae), for finding insect hosts. *Cotesia* sp. is a parasitoid wasp on larvae of Coleoptera, Diptera, and Lepidoptera; however, because of a narrow range of hosts and a preference for cool temperate regions some researchers such as Lewis and Whitfield (1999) used them to be a bioindicator of faunal changes during forest disturbance. In this study, there was not enough evidence on the study of braconids because only one species, *Cotesia* sp., from two host trees was found. At the time of collecting insects, small holes were observed near the top of several traps, which seem to have been the results of chewing by insects. It is possible that some small insects could have escaped through the holes. Approximately five traps had holes at the bottom possibly chewed by ants, which may have allowed some insects to escape from the traps.

4.2 Ordination analyses

4.2.1 Effect of different tree densities on the bark-inhabiting insect assemblages

From Principal Components Analysis (PCA), the greatest relationship with the PC1 axis was "*Abacetus* sp. (P)" (r = 0.89), with the PC2 axis, "Unknown E (F)", "Leiodidae (F)", and "*Scleron* sp. (B)" (r = 0.57, r = - 0.55, and r = 0.46, respectively), and with the PC3 axis, "Unknown E (F)" and "Leiodidae (F)" (r = - 0.58 and r = - 0.54) (Figure 4.7; Appendix III). The distribution of study plots in the PCA graph was arranged according to the components within each plot, namely, species or abundance of the bark-inhabiting insects living in the plot. For example, close plots mean similarity of plot components and more distinct plots mean greater difference of plot components. Plots 1, 3, 4, and 6 were close together, but plots 2, 5, 7 and 8 were separated from the group. Plots 1, 3, 4, 6 and 8 were closely correlated with the PC1 axis, plot 3 being the most positive and plot 8 being the most negative; however, plots 2, 7, and 5 were not near the PC1 axis. Thus, according to the PC1 axis, the conclusion was that in plots 1, 3, 4, and 6 there was a high opportunity of finding *Abacetus* sp., and in plots 2, 5, 7, and 8, a lower opportunity. Furthermore, plot 3 showed the greatest opportunity to find *Abacetus* sp., but plot 8 showed the least opportunity.

Abacetus sp. seemed to prefer the low tree density areas over the high tree density areas, as shown by the PCA analysis. Moreover, *Abacetus* sp. utilized many host trees in the low tree density areas, 31 of 38 trees (81.58%), but fewer in the high tree density areas, 29 of 85 trees (34.22%). The results of this study were consistent with research of Koivula (Online, 2001), Magura, Tóthmérész, and Molnár (2001), and Warriner, Nebeker, Leininger, and Meadows (2002) who found that carabid assemblages were greater in the thinned stands than in the unthinned stands. Other insects also showed a response to variation of host plant density. For instance, the abundance of aphids, *Aphis craccivora*, and leafhoppers, *Empoasca fabae*, declined with increasing host plant densities (Farrell, 1976, quoted in Bell, McCoy, and Mushinsky, 1991; Mayse, 1978, quoted in Bell *et al.*). In this study, there were three possible factors that related greater *Abacetus* sp. abundance in the low tree density areas than in the high tree density areas: (i) the edge effect, (ii) density-dependent effect, and (iii) few predatory birds.

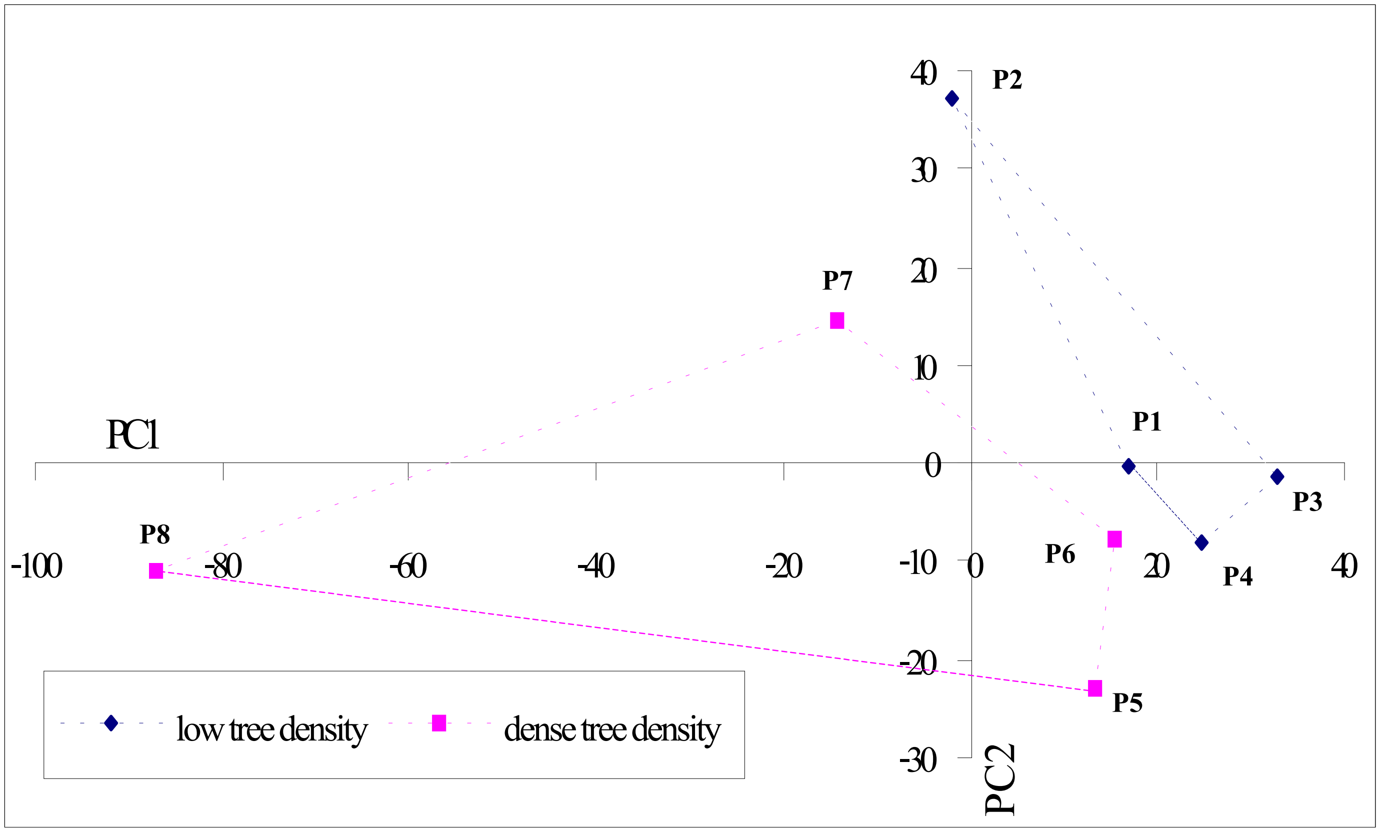


Figure 4.7. Result from the PCA analysis for investigating effect of different tree densities on the bark-inhabiting insect assemblages, as shown by plot arrangement according to the PC1 and PC2 axes.

The low tree density areas were in or near the forest edge where normally abiotic and biotic factors contribute to greater population and species diversity of invertebrates than in the forest interior. Moreover, patterns of the abundance and species richness did not change even in passing seasons (Dajoz, 2000; Kotze and Samways, 2001). The edge areas are a transitional zone between the two different adjacent habitats; for example, both abiotic and biotic factors such as particular microclimate, physiology, and phenology of trees were intermediate between the habitats (Dajoz; Magura *et al*., 2001). Specifically, wind could blow freely in the open forests and allow unimpeded plant or insect chemical distribution (Hunter, 1990). The insects could better receive messages from wind in the open forests than in the dense forest and could fly directly to the targets (Byers, 1988). In addition, Magura *et al*. found that gradients of ground temperature, relative air temperature, and cover of the herbs in the forest edge were correlated with assemblage size of carabids. Thus, all these factors could be possible explanations of why this study found numerous bark-inhabiting insects in the low tree density areas more than in the high tree density areas.

Further from the edge effect, one reason expected to enhance great numbers of the bark-inhabiting insects was the density- dependent effect. Most insects in this study were predators, and one factor, other than climatic effects, secondary predation, and competition, affecting change of predatory populations is prey density. For example, outbreaks of predator *Calosoma* (Carabidae), such as *C. sycophanta* or *C. inquisitor*, occur quite often during outbreaks of processionary caterpillars (Dajoz, 2000). Moreover, Dajoz further commented that carabid beetles were one of the important forest insects, which had more impact on their prey populations. However, Verley, Gradwell, and Hassell (1973) offered that the consideration of predator and prey density should be separated according to each particular stage of development of the predator. Verley *et al*. referred to research of Dixon (1958) that in the larval instar the coccinellid, *Adalia decempunctata*, had a better chance in success of prey capturing of the nettle aphid, *Microlophium evansi*, than in the adult stage.

Finally, few enemies at the forest edge influenced directly an increase in invertebrates. Nong Rawiang Forest is like an island and the north of the preserved area was highly disturbed from human activities. There has been no clear study of bird distribution in the forest, but it could be suggested that bird habitats in the forest edge have more disturbance than in the forest interior. From Krebs (1978), grassland or shrubs normally have less vertical stratification for bird nesting than the forest interior, resulting in less species diversity of insect predators. Also, Carlson and Hardman (2001) studied the response of bird populations to landscape fragmentation and found an enhanced rate of nest predation at the edge. In Michigan, researchers found that at the forest edge the nest predation rate was higher than in the forest interior, and nests were also highly parasitized by brown-headed cowbirds (Gates and Gysel, 1978, quoted in Hunter, 1990). In another case, within 100 m. of the forest edge, nests were parasitized by cowbirds with a high percentage (67% of the nests parasitized), but the rate decreased beyond 300 m. from the edge (18% of the nests parasitized) (Brittingham and Temple, 1983, quoted in Hunter). Hunter also had some particular suggestions that there was no absolute true relationship between bird density and the forest edge, and few bird species were edge specialists. Thus, in the future there should be a study of bird distribution at Nong Rawiang Forest for checking the assumption of relationship between the bark-inhabiting insects and birds in the forest edge.

Many researchers studied carabids and used them as bioindicators for monitoring environmental quality and habitat disturbance (Brandmayr, Zetto, and Pizzolotto, Online, 1998; Gardner *et al*., Online, 2002; Hartley, Montes de Oca, Spence, Online, 1999; Jaganyi and Samways, Online, 1998; Kodzhabashev and Penev, Online, 1999; Koivula, Online, 2001; Magura *et al*., 2001; Niemalä and Kotze, Online, 2000; Penev, Online, 1998; Schowalter, 1994; Schweiger and Frenzel, Online, 2002; Stoyanov and Penev, Online, 1999; Warriner *et al*., 2002), because carabids can distribute to many biotopes and are sensitive and responsive to variation of vegetation cover. Moreover, the well-known taxonomy and high global densities can encourage the use of carabids to be a good bioindicator (Brumwell, Craig, and Scudder, 1998). For instance, Koivula studied environmental change after habitat disturbance by investigating carabid distribution. Koivula separated carabids into three groups: (i) closed stand specialists; (ii) open habitat specialists; and (iii) forest habitat generalists. By his definitions, the first group preferred only the forest interior, the second group preferred only the open habitat, and the last group could live in both habitats. In addition, Koivula further separated the third group into two subgroups, (iiia) more abundance with increasing openness of canopy and (iiib) more abundance with decreasing openness canopy. Therefore, according to Koivula, this study grouped *Abacetus* sp. as “a forest-habitat generalist” with more abundance with increasing openness of canopy. Although in this research the plots did not cover the open habitat, north of Line-1, the preliminary study showed that most *Abacetus* sp. had more preference for trees with large DBH. This carabid arrangement can benefit the predictions of forestry status of Nong Rawiang Forest both at present and in the future; for example, at present it was seen that the north of the preserved area was disturbed more than the south, and future work can use the results of research as baseline data for comparing and investigating the carabid distribution, the forest disturbance, or the forest change in the future.

4.2.2 Effect of different host plant species on the bark-inhabiting insect assemblages

From PCA analysis, "*Abacetus* sp. (P)" showed the greatest relationship with the PC1 axis (r = -0.95), "Leiodidae (F)", with the PC2 axis (r = -0.89), and "*Cardiophorus* sp. (P)" and "Tenebriodinae sp. 3 (B)", with the PC3 axis (r = -0.44 and r = 0.83) (Figure 4.8; Appendix III). From the graph, it could be seen that most host plant species were distributed near the PC1 axis or the center, but individual trees did not show clear separation by host species group. *Abacetus* sp. was the most common insect and had the greatest relative weight with the PC1 axis; therefore, in this analysis, attention was paid to this insect species. In conclusion, there was no or little effect of host plant species on the bark-inhabiting insect assemblages and *Abacetus* sp. played the role of "a host plant generalist".

At the trophic level, the main function of some members of Carabidae are predators feeding on bark- and wood-boring beetles (Stebbing, 1914); therefore, this may be the main reason of *Abacetus* sp. being a host plant generalist. *Abacetus* sp. demonstrated that it was not specific to *Shorea siamensis*, as shown by 108 individuals (44.81% of total *Abacetus* sp. numbers) inhabiting *Shorea siamensis*, and 133 individuals (55.19% of total *Abacetus* sp. numbers) inhabiting other host plant species. In addition, *Abacetus* sp. was found from 16 of 21 host species. As for the remaining 5 host species, it is suggested that *Abacetus* sp. avoided them naturally or randomly. Moreover, it seemed that there was greater effect from "Tree density" than "Host plant species". The evidence was that the host utilization of *Abacetus* sp., such as on *Shorea siamensis*, *Lannea coromandelica*, and *Xylia xylocarpa*, was greater in the low tree density areas than in the high tree density areas (Figure 4.9). Consistent with research of Spence, Langor, Niemalä, Carcamo, and Currie (1996, quoted in Magura *et al*., 2001), "Habitat structure" had greater effect on carabid assemblage than "Host plant species". However, the relationship between insects and plants is not consistent, and it can vary according to geographical or spatial scales.

Although this study showed less effect of host plants on *Abacetus* sp. assemblage, from the aspects of safety, energy and time, volatiles from host plants are important on host discovery by true bark insects among nonhosts, and also have benefits on the insect aggregation. For true bark insects, pioneers were often attracted by mixed volatile chemicals

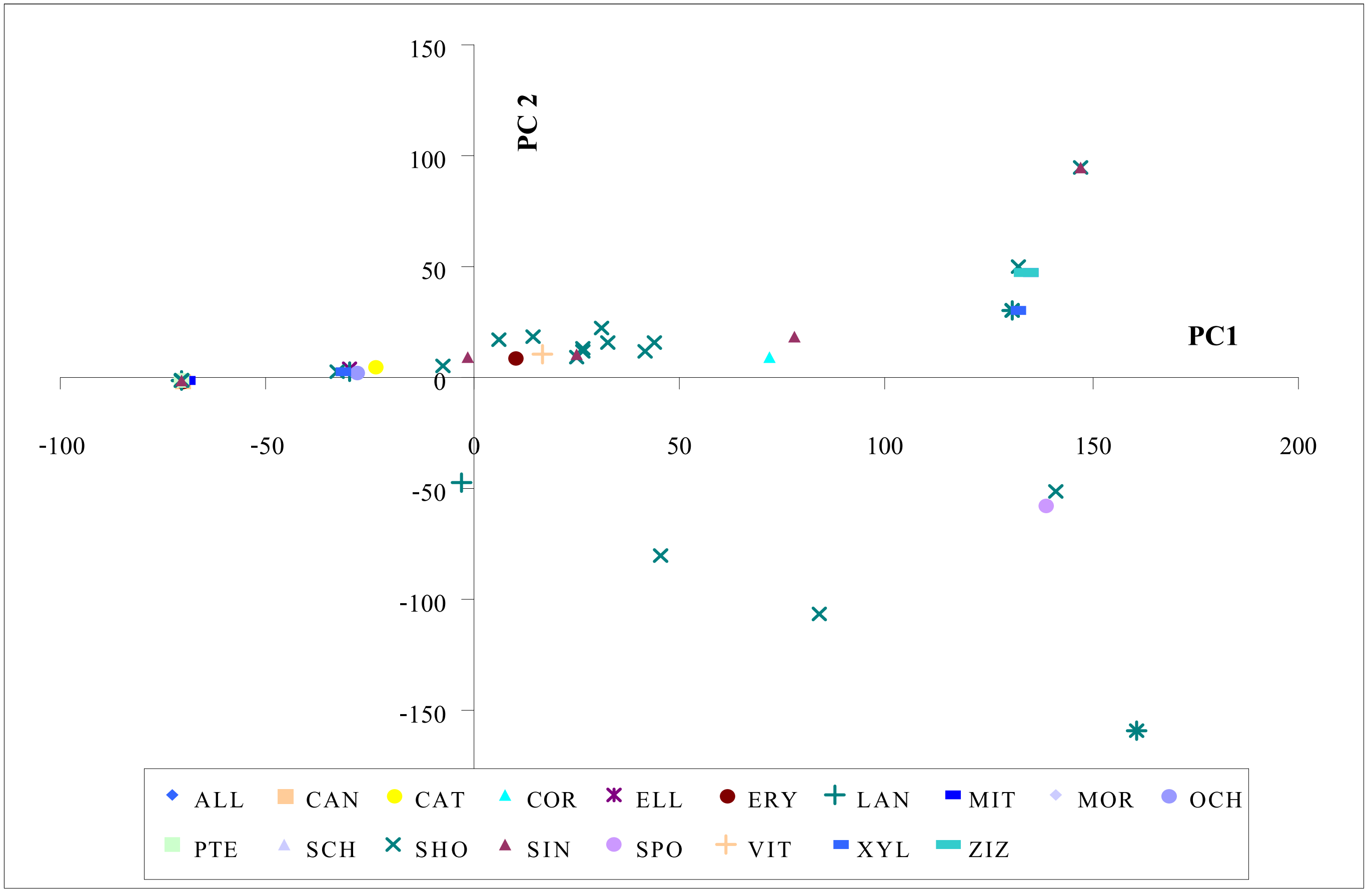


Figure 4.8. Result from the PCA analysis for investigating effect of different host species on the bark-inhabiting insect assemblages, as shown by host species arrangement according to the PC1 and PC2 axes (the signals refer to the first three letters of the scientific names of the host species, for example, SHO from *Shorea siamensis*).

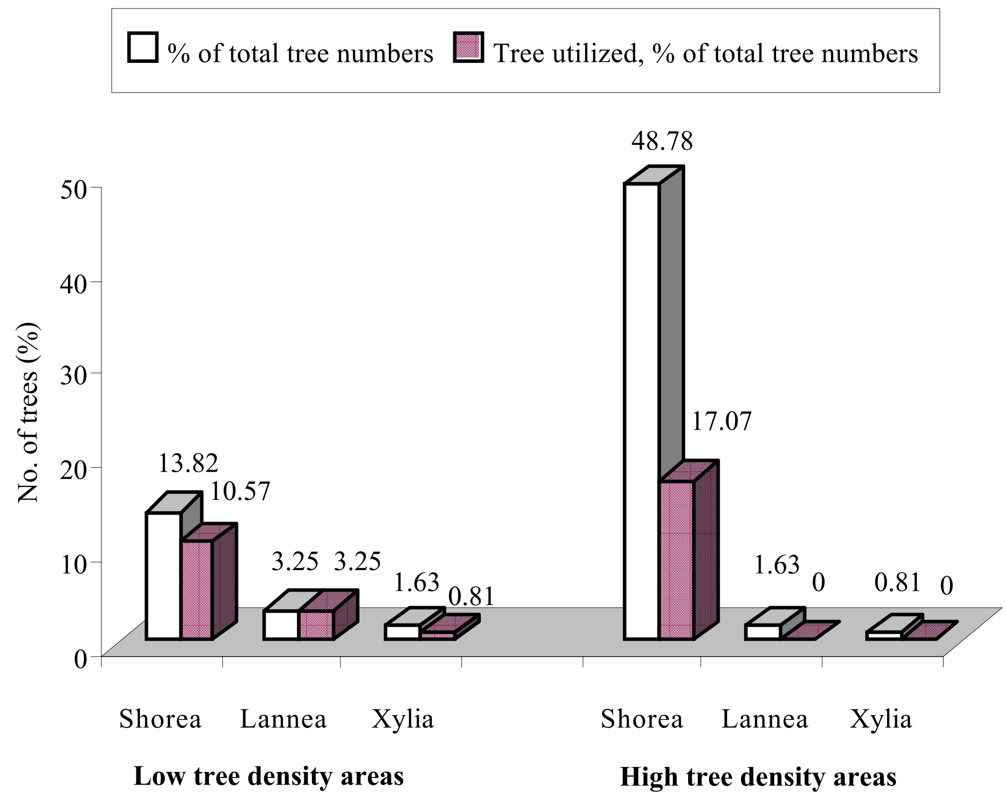


Figure 4.9. Showing the comparisons of host utilization of *Abacetus* sp. on *Shorea siamensis*, *Lannea coromandelica*, and *Xylia xylocarpa*, between the low and high tree density areas.

released from host plants such as strong volatiles from logs alone of Scots pines attracting with subsequent penetration of *Tomicus piniperda* (Byers, Lanne, Löfqvist, Schlyter, and Bergström, 1985). The immediate release of host plant volatile chemicals upon damage to the tree, such as from a storm, could attract directly true bark insects to aggregate on the host because they knew host susceptibility and lower resistance appeared at that time (Byers *et al.*, 1985). Most chemical mixtures, released at the same time as resin upon host damage, comprise terpenes and alcohol derivatives, which could attract true bark insects. For example, pioneers of *Trypodendron lineatum* respond specifically to mixtures of α–pinene and ethanol released from conifers, and *T. domesticum* respond only to ethanol released from oaks (Nijholt and Schönherr, 1976, quoted in Dajoz, 2000). Moreover, *Ergates faber* and *Spondylis buprestoides* of family Cerambycidae can be attracted by terpenes from conifers, while *Cerambyx cerdo* can be attracted by ethanol and ethyl acetate from oaks (Döhring, 1955, quoted in Dajoz). Verbenone, a volatile inhibitory, could also help *Tomicus piniperda* to discover their hosts, Scots pines (Byers, Lanne, and Löfqvist, 1989). Three monoterpenes, (+/-)-a-pinene, (+)-3-carene, and terpinolene, released from wounds were mechanisms of the bark beetles to recognize their host trees among non-hosts (Byers *et al*., 1989). Pioneers of some bark insects could convert "toxic monoterpenes" of hosts to "non-toxic compounds" for insect aggregation (Dajoz; Raffa, Online, 2000). Barbosa, Krischik *et al*. (1991) also found that spruce bark beetles produced chemicals by detoxification of "alpha-pinene" from the host tree to "cis-verbenol" which attracted both sexes for mating and constructing the community. Nakamuta, Gotoh, Tokoro, and Nakashima (Online, 2000) found a combination of volatiles from host attractant and male pheromone could improve female's detection of a certain location of males. However, there was an argument from Byers (1996) that primary attractants from host volatiles had less efficiency on host finding of the bark beetles by concluding from a model of encounter rate of bark beetle populations searching at random for susceptible hosts. Moreover, Byers (1996) supposed that evolution between host volatiles and true bark insects appeared in low host plant densities or widely dispersed hosts, or both.

In addition, predators can use plant volatile chemicals for benefits in prey searching. For example, Raffa (2000) found that aggregation pheromones of bark beetles, which used host compounds as precursors and synergists, acted as chemical signals to their predators. Moreover, the predatory beetle, *Trogossita japonica* (Trogossitidae, Coleoptera), which feeds on wood boring insects, *Monochamus alternatus* (Cerambycidae, Coleoptera), detects prey by using “the prey-host tree odor complex” (Nakamuta, Usha Rani, Tokora, and Nakashima, Online, 2000). The process was that after *M. alternatus* transmitted pine wood nematodes, the pathogen of the pine wilt disease of *Pinus densiflora* and *P. thunbergii*, monoterpenoids, especially alpha-pinene, emitted from nematod-infected pine trees oriented the prey location of *T. japonica.* Also, Margolies, Sabelis, and Boyer (Online, 2002) found that herbivore-induced plant volatiles emitted from spider mite-infested bean plants were attractive to *Phytoseiulus persimilis*, a predator of spider mites.

Moreover, plant volatile chemicals could also benefit host searching of parasitoids. There was evolution among different trophic levels, host plants, insects, and parasitoids, that plant odors cued parasitoids to their host location. Mainly, plant odors are composed of “terpenoid compounds” that parasitoids could distinguish from green leaf volatiles (Roachell, Online, 1996). Plant odors occurred as a secondary host-plant response by producing toxins against insects and pathogens. Gouinguené, Degen, and Turlings (Online, 2000) found that light intensity was the most important factor affecting odor emission, and others were soil, humidity, and temperature; on the other hand, there was no or little effect from larva instar. Moreover, the amount of volatiles emitted was correlated negatively with plant age. Meiners and Hilker (Online, 2000) found only oviposition behavior of the elm leaf parasite, *Xanthogaleruca luteola*, on their host plants *Ulmus minor*, *U. campestris*, and *U. procera* induced specific kairomones to attract the parasitoid *Oomyzus gallerucae*.

4.2.3 Effect of different tree characteristics on the bark-inhabiting insect assemblages

From Canonical Correspondence Analysis (CCA), “Bark thickness” could be used to explain variation of host exploitation by the bark-inhabiting insects as shown by strong correlation with the CCA1 axis (r = -0.64) (Figure 4.10; Appendix III). Explanation from the CCA results was that a bark-inhabiting insect with a high positive score on the CCA1 axis was restricted to thin bark, and a bark-inhabiting insect with a large negative score was restricted to thick bark. Thus, the insect groups of *Abacetus* sp. (P), *Agrypnus aegualia* (P), *Brachinus* sp. (P), *Cardiophorus* sp. (P), *Cotesia* sp. (Pa), Cydnidae (P), Elateridae sp. 4 (P), *Graniger* sp. (P), Lygaeidae (P), *Mesomorphus* sp. (B), *Scleron* sp. (B), Unknown C (S), Unknown D (F), and Unknown G (P), having in a high positive score of bark thickness could be suggested to be “the thin bark-specific insects”. On the other hand, the insect groups of *Adeloura* sp. (P), Brentidae (F), Curculionidae (S), Elateridae sp. 5 (P), Leiodidae (F), Rhysodidae (F), Staphylinidae (P), Tenebrionidae sp. 3 (B), Tenebrionidae sp. 4 (B), Unknown A (F), Unknown B (F), Unknown E (F), and Unknown F (B), with in a negative score of bark thickness could be suggested to be “the thick bark-specific insects”.

Even though some insects, namely, fungus eaters, parasitoids, predators, and shelter seekers, did not bore into the cambium or wood as well as the true bark insects, bark thickness still had more relationship with their lifestyle. For example, thick bark such as in *Erythrophleum succirubrum*, *Lannea coromandelica*, *Shorea siamensis*, or *Sindora siamensis*, which had more crevices, seemed to be the safe places for insect prey more than thin bark, such as in *Allophylus cobbe, Catunaregam tomentosa, Cordia dichotoma,* or *Mitragyna brunosis*, which had few crevices. Bark, normally covered with wax, suberin, or lignin, is the first barrier to obstruct insect borers (Dajoz, 2000). From the figure of weights of bark-inhabiting insect species, the insects such as Brentidae (F), Curculionidae (S), Staphylinidae (P), and Unknown B (F) showed more preference for thick bark; on the other hand, the insects such as Lydgaeidae (P), *Mesomorphus* sp. (B), Unknown C (S), and Unknown D (F) showed more preference for thin bark. Moreover, all carabid species, including *Abacetus* sp., seemed to favor thin bark more than thick bark. Other insect families, namely, Elateridae (P) and Tenebrionidae (B), except *Mesomorphus* sp., seemed to show intermediate preference between

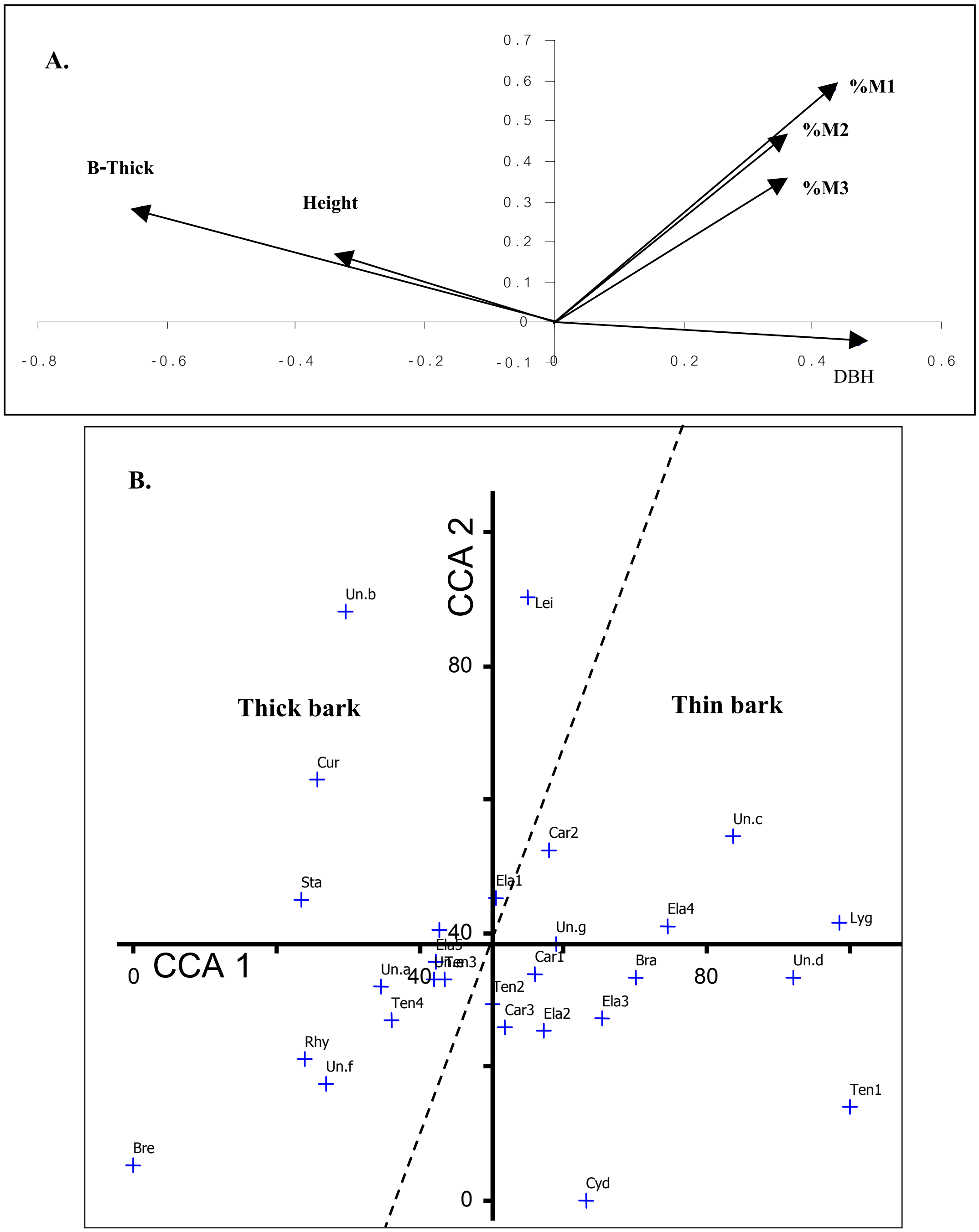


Figure 4.10. Showing results from the CCA analysis for investigating effect of different tree characteristics on the bark-inhabiting insect assemblages, as shown by (A.) the graph of canonical correlation for six variables of tree characteristics and (B.) the graph of the bark-inhabiting insect arrangement according to the CCA1 and CCA2 axes.

thick and thin bark. The study also found that trees with thick bark had less moisture, but trees with thin bark had more moisture, as shown by the negative correlation between arrows of bark thickness and moisture in the CCA correlation graph. Therefore, enough humidity and ease in finding prey caused most predators to be specific on trees with thin bark. However, research from the temperate region showed that fissured bark such as in oak trees had cambium temperature not exceeding 30°C, but smooth bark such as in beech trees had cambium temperature reaching 40°C (Dajoz). Wright and Samways (1999) studied insect borers on infructescences of *Protea* species and found that wall thickness played the major role in determining the borer abundance, as shown by CCA analysis. Most bark-inhabiting insects specific to thick bark were found from host trees with small DBH, but most bark-inhabiting insects specific to thin bark were found from host trees with large DBH, as shown by the negative correlation between arrows of bark thickness and DBH in the CCA correlation graph.

Tree characteristics and insect host selection are a complex story, especially for more sensitive endophagous insects as compared to exophagous insects. Tree characteristics can be one factor to determine abundance of insect species inhabiting a tree. Number, size, and deposition of resin vary within individual trees. For example, trees with high resin flux could eliminate larvae from their galleries (Dajoz, 2000). Components of each tree such as canopy or trunk architecture could affect bark-inhabiting insect selection. Canopy structure relates light shining on the ground, temperature and moisture within trunks, and growth rate of larvae. Trunk architecture is also one of the main factors and a cause of visual attraction on bark-inhabiting insect landing, even at short distances. Most bark beetles prefer to land on black, brown, and red bark more than on yellow bark, and they favor to land on vertical trunks more than on horizontal trunks (Dajoz). For instance, Strom, Goyer, and Shea (2001) found a greater percentage of *Dendroctonus brevicomis* catch in black traps than in white-painted traps. Trunk diameter also affected infestation of the bark insects, as shown by an increase in percent of attacks of *Dendroctonus ponderosae* on *Pinus contorta* when at large diameter, and more host susceptibility for diameters over 60 cm. (Dajoz). Trees with small diameter had fewer findings of insects, such as *Ips typographus* on susceptible Norway spruce, *Picea abies* (Byers, 1996). On the contrary, trees with large diameter can attract many scolytids, as shown by percent of invasion increasing with large diameter (Rolling and Kearby, 1977, quoted in Dajoz). Physical status of hosts such as water balance is related to encounters, growth and survival of larvae (Graham, 1963). Reeve, Ayres, and Lorio (1995) found that moderate drought stress of hosts still reduced reproductive succession of *D. frontalis*, as shown by 63-85% reduction. A tree near suitable hosts also had high opportunity for attack by bark insects, normally during outbreak period. For example, Byers (1987) and Schlyter, Byers, Löfqvist (1987a, quoted in Byers, 1987) found that a blank trap nearby traps releasing high concentrations of chemical attractants could also have high numbers of entering insects.

4.2.4 Effect of different positions within a trunk on the bark-inhabiting insect assemblages

From CCA analysis, at lower trunk level the main factors affecting the bark-inhabiting insect present were “Bark thickness” and “DBH” (Figure 4.11; Appendix III), and at upper trunk level the main factor was “Moisture of bark” (Figure 4.12; Appendix III). Clearly, at lower trunk level “Bark thickness” and “DBH” had the longest arrows, more correlative with the CCA1 axis ($r = 0.71$ and $r = -0.51$). At upper trunk level, all variables of “Moisture of bark” had the longest arrows, more correlative with the CCA1 axis ($r = 0.67$, $r = 0.66$, and $r = 0.57$, respectively). Thus, this study concluded that “Bark thickness”, “DBH”, and “Moisture of bark” were the important limiting factors within individual trees affecting the niche of each bark-inhabiting insect species.

Normally bark-inhabiting insects require more moisture; however, this was not a problem at lower trunk level, because of moisture from soil and shade from covering plants, as shown by shorter arrows of bark moisture in the CCA correlation graph. On the contrary, at upper trunk level moisture showed more importance on the present of bark-inhabiting insects, as shown by longer arrows of bark moisture. This study found that total insect numbers including total numbers of the first five common insects, except Leiodidae (F), at lower trunk level were greater than at upper trunk level (Figure 4.13); however, as for the remaining insect species they could not be concluded because of the few numbers. According to niche, *Abacetus* sp. (P), *Cardiophorus* sp. (P), Leiodidae (F), and *Scleron* sp. (B) had wide niches because they could be found both levels, but *Cotesia* sp. (Pa) did not. *Cotesia* sp. had a narrow niche with a greater preference for lower trunk level. Therefore, it was seen that the lower trunk level seemed to be a more suitable habitat for the bark-inhabiting insects because of enough moisture and space.

Physical factors could create “a complex microclimate” on the bark surface or within a trunk (Prinzing, 2001; Willmer, 1986); for example, some researchers found that water content, temperature within trunks, and DBH were also the limiting factors in determining bark-inhabiting insect appearance. Water content was very important in limiting *Trypodendron lineatum* occupation, as shown by a short range of relative humidity of woods (Dajoz, 2000).

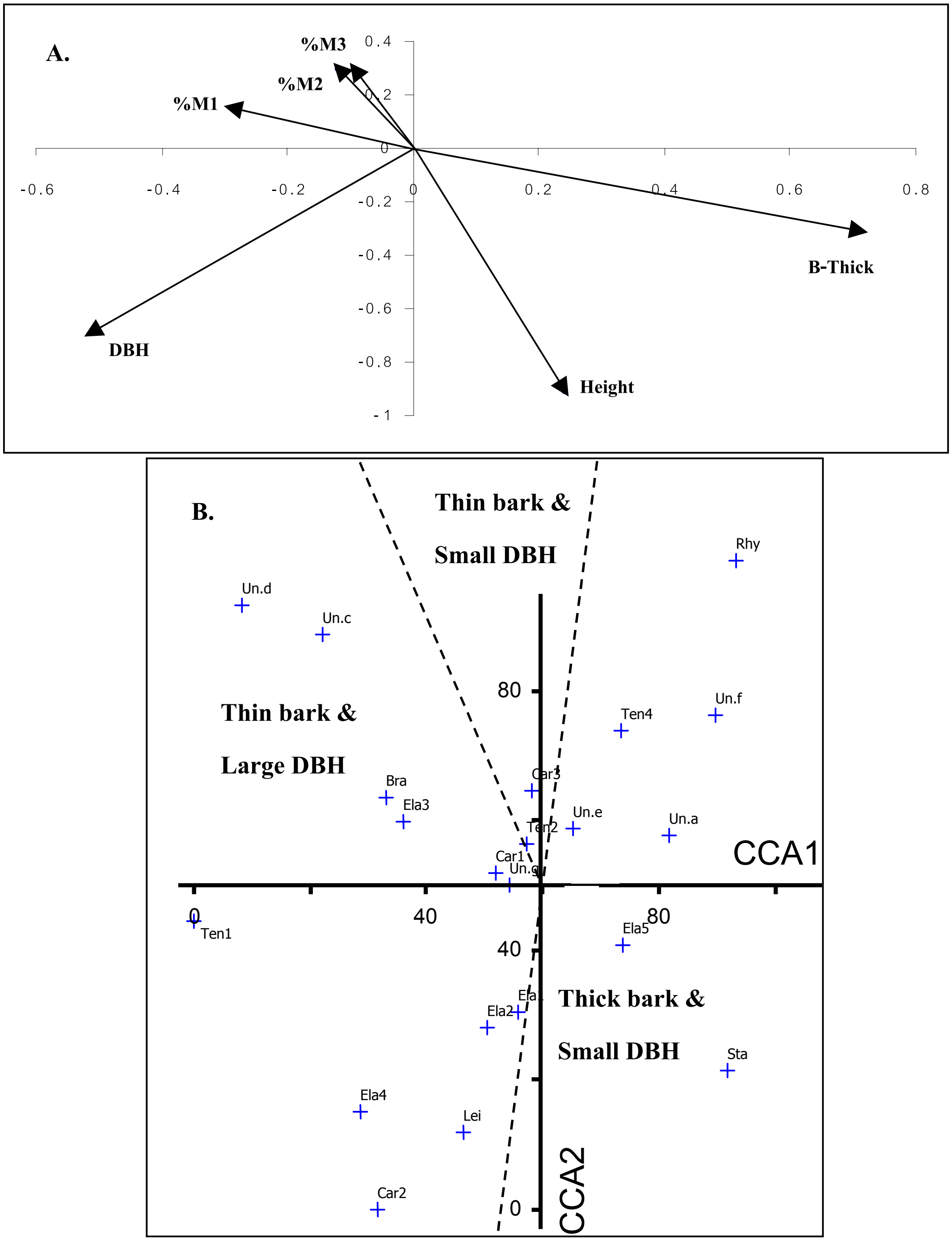


Figure 4.11. Showing results from the CCA analysis for investigating effect of different positions within a trunk on the bark-inhabiting insect assemblages at lower trunk level, as shown by (A.) the graph of canonical correlation for six variables of tree characteristics and (B.) the graph of the bark-inhabiting insect arrangement according to the CCA1 and CCA2 axes.

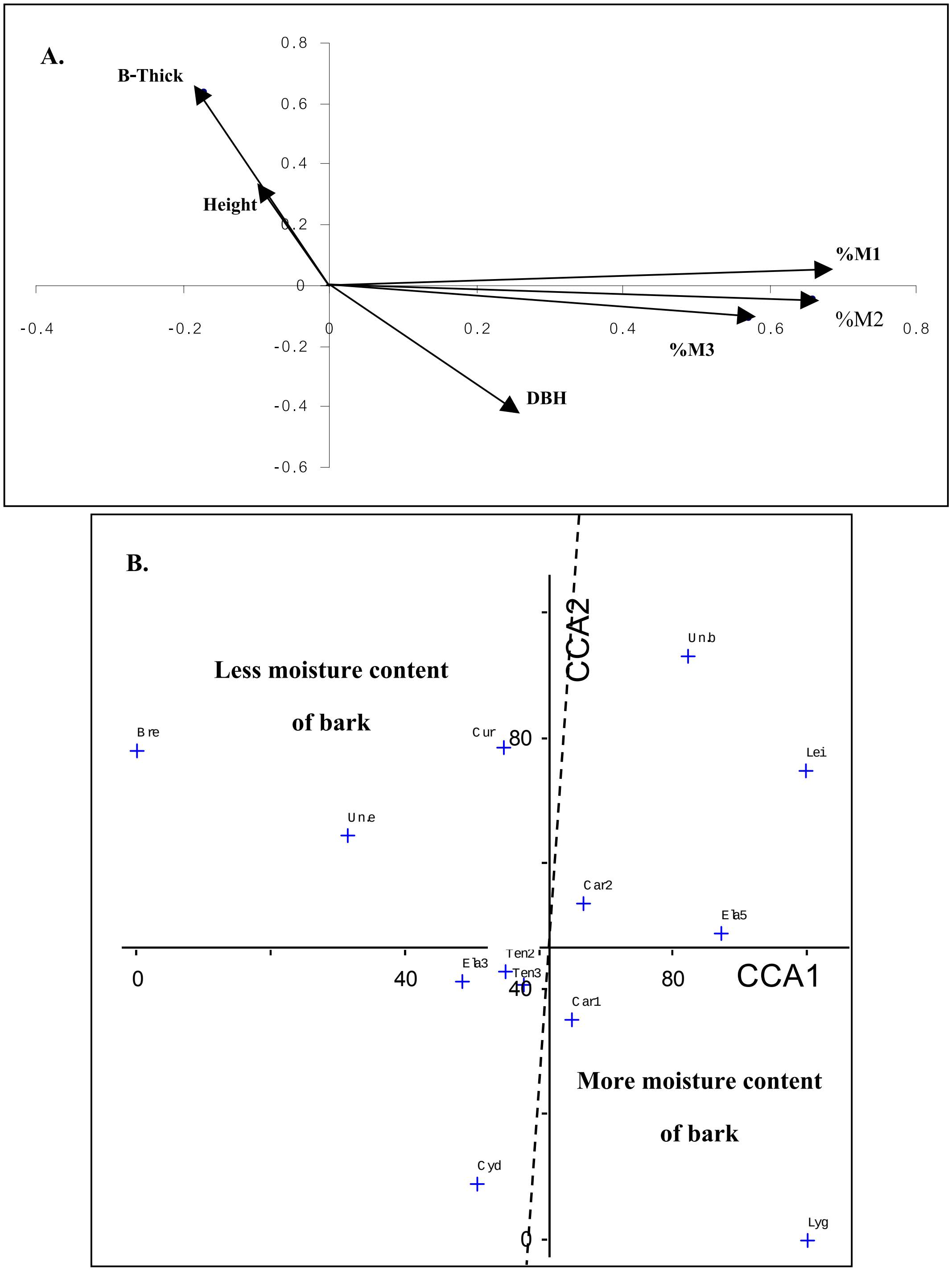


Figure 4.12. Showing results from the CCA analysis for investigating effect of different positions within a trunk on the bark-inhabiting insect assemblages at upper trunk level, as shown by the graph of canonical correlation for six variables of tree characteristics and (B.) the graph of the bark-inhabiting insect arrangement according to the CCA1 and CCA2 axes.

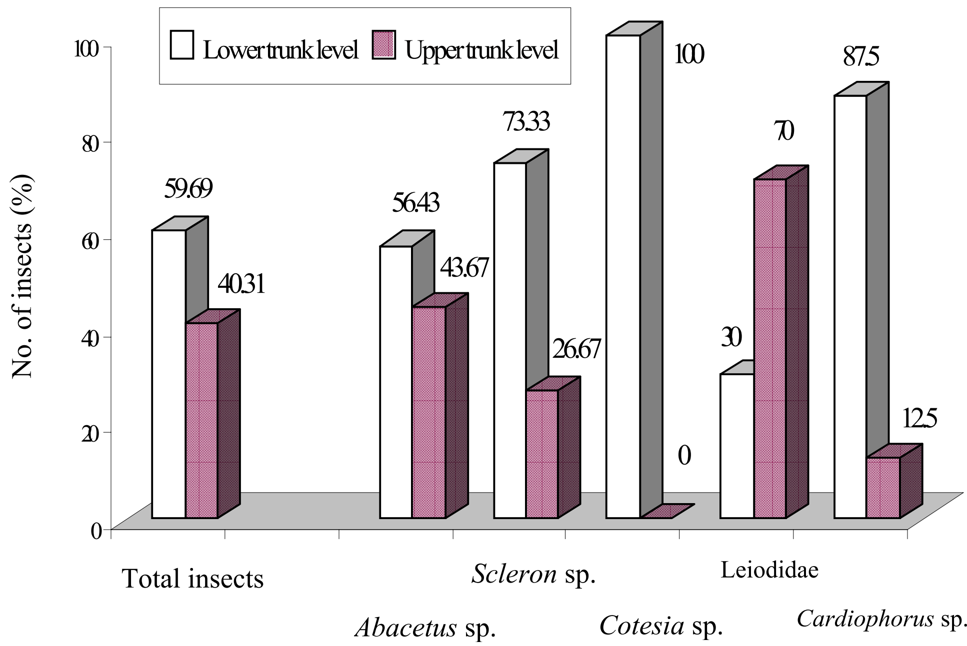


Figure 4.13. Comparing percent total insect numbers and percent total numbers of the first five common insects, *Abacetus* sp., *Scleron* sp., *Cotesia* sp., Leiodidae, and *Cardiophorus* sp., between lower and upper trunk level.

Temperatures between 14 - 26°C narrowed the niche of *Tomicus minor* and was a cause of never finding them at upper trunk level of Scots pine (Dajoz). Moreover, phloem area was the important factor relative to interior temperature and moisture, and large bark beetles preferred large phloem area (Schowalter, 1994). Large DBH supported increased attack by the insects, as shown by the trend of emerging *Dendroctonus ponderosae* increasing at large DBH of *Pinus contorta* (Safranyik, 1970, quoted in Dajoz). In ecosystems, there is often found overlap of niche of species, especially in limited resources like trunks, which is a cause of intra-and interspecific competition.

However, some insect species learn to avoid or minimize high level of competition by using many tactics. For instance, verbenone from colonized beetles of *Ips typographus* inhibited *Pityogenes chalcographus* from coming, and chalcogran and methyl (E, Z)-2,4-decadienoate from *P. chalcographus* inhibited colonization of *I. typographus* (Byers, 1993). In additional, heterospecific signal pheromones from three sympatric species of *Ips* bark beetles, *I. grandicollis*, *I. perroti*, and *I. pini*, acted as a deterrent at large insect population size and as a attractant for solitary insects (Ayers, Ayers, Abrahamson, and Teale, 2001). Likewise, the inhibitory chemicals, namely, *trans*-verbenol, verbenone, and ipsdienol, released by *Dendroctonus brevicomis* were a cause of reduced competition in their infested areas (Byers, Wood, Craig, and Hendry, 1984). Concentration at 10^{-9} g each/μl. of a mixture pheromones of ipsenol, *cis*-verbenol, and ipsdienol released from *I. paraconfusus* could attract *D. brevicomis*, but more or less than this rate could not act (Byers and Wood, 1980).

CHAPTER V

CONCLUSION

From the study at Nong Rawiang Forest, the species of bark-inhabiting insects and trees present in the study plots were observed, and the diversity and evenness of the bark-inhabiting insects were calculated and compared among the plots. In addition, effects from four different parameters, tree density, host species, tree characteristics, and positions within a trunk, on variation of bark-inhabiting insect assemblages were investigated.

1. There were 8 plots in this study where plots 1 and 2 (Line-1) and plots 3 and 4 (Line-2) were in the low tree density areas and plots 5 and 6 (Line-3) and plots 7 and 8 (Line-4) were in the high tree density areas. Only trees with DBH $\geq$ 12 cm. in the plots were studied. One hundred and twenty three trees were representative trees in the forest and the most common tree was *Shorea siamensis* with 77 individuals (62.60% of total trees). The bark-inhabiting insects found were 325 individuals, with few true bark insects, comprising the 4 orders, Coleoptera, Embrioptera, Hemiptera, and Hymenoptera. The identification could be made at family level to 11 families and 7 unknowns, at generic level to 9 genera and 18 unknowns, and at species level to 27 morphospecies. Furthermore, the insects found were separated into 5 groups according to their feeding behavior or their influence on a host tree: (i) Bark eaters (B); (ii) Fungus eaters (F); (iii) Parasitoids (Pa); (iv) Predators (P); and (v) Shelter seekers (S). *Abacetus* sp. (Carabidae, Coleoptera), an insectivore predator, was the most common insect with 241 individuals (74.15% of total insects). According to the Shannon-Wiener function, both the diversity and evenness of the bark-inhabiting insects had low values at the low tree density areas and high values at the high tree density areas, but the total insect numbers and *Abacetus* sp. numbers were negatively correlated.

2. From Principal Components Analysis (PCA), plots 1, 3, 4, and 6 had greater opportunity of finding *Abacetus* sp. than plots 2, 5, 7, and 8. It was seen that *Abacetus* sp. preferred the low tree density areas over the high tree density areas, and the causes of greater preference for the low tree density areas were suggested from three possible factors: (i) the

edge effect, (ii) density-dependent effect, and (iii) few predatory birds. According to Koivula (2001), *Abacetus* sp. could be classified as "a forest-habitat generalist" preferring increasing openness of canopy.

3. The results from the PCA analysis showed that host species had no or little effect on the bark-inhabiting insect assemblages and *Abacetus* sp. played the role as "a host plant generalist".

4. The results from Canonical Correspondence Analysis (CCA) showed that "bark thickness" was the main factor of effect of tree characteristics. According to the CCA results, the insects with a greater preference for thick bark were *Adeloura* sp. (P), Brentidae (F), Curculionidae (S), Elateridae sp. 5 (P), Leiodidae (F), Rhysodidae (F), Staphylinidae (P), Tenebrionidae sp. 3 (B), Tenebrionidae sp. 4 (B), Unknown A (F), Unknown B (F), Unknown E (F), and Unknown F (B). On the contrary, the insects with a greater preference for thin bark were *Abacetus* sp. (P), *Agrypnus aegualia* (P), *Brachinus* sp. (P), *Cardiophorus* sp. (P), *Cotesia* sp. (Pa), Cydnidae (P), Elateridae sp. 4 (P), *Graniger* sp. (P), Lygaeidae (P), *Mesomorphus* sp. (B), *Scleron* sp. (B), Unknown C (S), Unknown D (F), and Unknown G (P).

5. As for effect of different positions within a trunk, the CCA results showed that "bark thickness" and "DBH" were the main limiting factors on the bark-inhabiting insects present at lower trunk level, and "moisture of bark" was the main limiting factor at upper trunk level. The total insect numbers and total numbers of *Abacetus* sp. (P), *Scleron* sp. (B), *Cardiophorus* sp. (P), and *Cotesia* sp. (Pa) were greater at lower trunk level than at upper trunk level.

Suggestions

1. At Nong Rawiang Forest, it will be beneficial for the predictions of the forestry status if in the future there are continual studies of the diversity of bark-inhabiting insects and investigation of the carabid distribution, including *Abacetus* sp.

2. For future works, the physical factors such as light intensity, soil humidity, phloem temperature, or wind speed should be objects of highly concentration, and characteristics of a host tree such as basal area, canopy structure, distances from ground to canopy base, or distances from a host to another one should also be included.

3. Also, there should be a study of bird distribution at Nong Rawiang Forest, especially in the forest edge, and comparison of the distribution with the insect density.

4. Moreover, the study of effects of forest fragmentation and the size reduction should be included in the future research because it directly affects the diversity of flora and fauna both in the forest edge and in the forest interior.

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APPENDICES

APPENDIX I

DETAILS OF TREES AND THE BARK-INHABITING INSECTS PRESENT IN THE STUDY PLOTS

1. Details of trees present in the study plots.

Plot no.	tree no.	Tree sp.	Height (m.)	DBH (cm.)	Bark type	Bark thickness (cm.)	%moisture		
							%m1[st]	%m2[nd]	%m3[rd]
P.1	1	*Lannea coromandelica*	5.78	19.65	Cracked	1.15	69.1	71.09	68.46
	2	*Lannea coromandelica*	6.88	15.22	Cracked	1.35	68.95	70.28	70.98
	3	*Lannea coromandelica*	5.76	15.83	Cracked	1.1	70.28	68.59	69.98
	4	*Schleichera oleosa*	4.6	12.77	Fissured	0.55	45.29	39.93	41.95
	5	*Shorea siamensis*	9.9	27.71	Fissured	1.1	42.76	46.87	41.03
	6	*Catunaregam tomentosa*	6.88	22.1	Smooth and Thorny	0.55	29.7	34.86	35.36
	7	*Shorea siamensis*	6.01	27.01	Fissured	0.95	42.43	47.14	40.73
	8	*Allophylus cobbe*	5.11	16.56	Dippled scaly	0.55	49.71	47.12	50.06
P.2	9	*Pterocarpus macrocarpus*	8.26	18.15	Cracked	2.05	60.46	53.49	57.78
	10	*Sindora siamensis*	5.36	12.6	Cracked	1.45	38.29	42.59	37.98
	11	*Lannea coromandelica*	6.03	12.55	Cracked	1.1	74.96	78.99	75.52

Plot no.	tree no.	Tree sp.	Height (m.)	DBH (cm.)	Bark type	Bark thickness (cm.)	%moisture		
							%m1st	%m2nd	%m3rd
	12	*Sindora siamensis*	8.35	12.7	Cracked	1.35	42.41	38.5	32.45
	13	*Xylia xylocarpa*	8.3	16.05	Cracked	1.15	60.62	62	59.98
P.3	14	*Canarium subulatum*	9.91	14.55	Dippled scaly	1.1	42.2	63.99	56.22
	15	*Shorea siamensis*	8.71	19.36	Fissured	1	38.65	52.26	38.67
	16	*Shorea siamensis*	9.45	20.41	Fissured	1.2	41.51	44.42	42.19
	17	*Shorea siamensis*	9.08	13.79	Fissured	1.05	39.76	48.64	45.18
	18	*Shorea siamensis*	9.03	15.32	Fissured	1	36.95	47.23	43.59
	19	*Shorea siamensis*	7.93	13.44	Fissured	0.8	42.61	41.34	38.49
	20	*Erythrophleum succirubrum*	9.18	22.99	Cracked	0.65	49.23	46.8	35.73
	21	*Shorea siamensis*	8.45	12.64	Fissured	1.05	34.89	42.58	43.65
	22	*Catunaregam tomentosa*	7.56	17.83	Smooth and Thorny	0.65	23.76	33.23	28.89
	23	*Shorea siamensis*	7.92	12.74	Fissured	0.95	40.87	38.98	38.4
	24	*Shorea siamensis*	8.49	14.01	Fissured	1.05	45.43	50.15	34.55
P.4	25	*Shorea siamensis*	5.6	12.58	Fissured	0.85	39.13	42.03	45.67
	26	*Shorea siamensis*	3.92	13.15	Fissured	1.25	41.78	40.51	42.35
	27	*Shorea siamensis*	6.55	19.36	Fissured	1	39.28	39.85	36.18

Plot no.	tree no.	Tree sp.	Height (m.)	DBH (cm.)	Bark type	Bark thickness (cm.)	%moisture		
							%m1st	%m2nd	%m3rd
P.4	28	*Erythrophleum succirubrum*	8.5	18.18	Cracked	1.05	57.37	44.23	39.13
	29	*Xylia xylocarpa*	6.44	14.68	Cracked	0.65	45.72	54.36	62.2
	30	*Erythrophleum succirubrum*	8.5	21.72	Cracked	0.8	45.33	46.08	39.62
	31	*Vitex pinnata*	6.31	15.92	Dippled scaly	0.75	46.94	47.22	41.38
	32	*Shorea siamensis*	11.51	18.2	Fissured	1.53	8.01	0	0
	33	*Shorea siamensis*	5.94	13.06	Fissured	0.95	36.02	45.7	44.02
	34	*Shorea siamensis*	7.2	16.43	Fissured	0.9	40.99	41.11	30.37
	35	*Cordia dichotoma*	5.67	14.97	Smooth	0.2	61.08	55.03	57.56
	36	*Erythrophleum succirubrum*	7.14	14.36	Cracked	1	50.94	44	39.9
	37	*Shorea siamensis*	7.56	19.11	Fissured	0.8	42.77	44	31.39
	38	*Morinda coreia*	7.77	14.33	Fissured	0.8	9.77	0	0
P.5	39	*Shorea siamensis*	10.95	18.03	Fissured	1.25	51.64	48.09	48.56
	40	*Shorea siamensis*	8.57	15.51	Fissured	1.7	48.35	44.08	44.46
	41	*Shorea siamensis*	7.66	13.76	Fissured	1.25	49.66	45.85	43.82
	42	*Shorea siamensis*	8.85	15.38	Fissured	1.7	43.05	50.1	41.47
	43	*Mitragyna brunosis*	7.55	15.51	Scaly	0.85	61.75	61.69	63.02

Plot no.	tree no.	Tree sp.	Height (m.)	DBH (cm.)	Bark type	Bark thickness (cm.)	%moisture		
							%m1[st]	%m2[nd]	%m3[rd]
P.5	44	*Shorea siamensis*	7.51	18.22	Fissured	1.2	47.67	43.76	43.78
	45	*Shorea siamensis*	11.12	17.1	Fissured	1	48.66	47.65	45.43
	46	*Aporosa villosa*	5.39	17.2	Fissured	1.55	26.15	23.42	30.52
	47	*Ochna integerrima*	5.48	13.09	Fissured	0.35	37.01	40.5	43.57
	48	*Shorea siamensis*	8.46	16.94	Fissured	1.1	52.42	52.57	38.36
	49	*Shorea siamensis*	8.85	14.14	Fissured	1.25	55.34	49.98	45.84
	50	*Shorea siamensis*	10.07	17.55	Fissured	0.95	52.39	48.81	39.94
	51	*Shorea siamensis*	10.04	15.25	Fissured	1.05	46.76	42.95	46.54
	52	*Shorea siamensis*	9.42	16.46	Fissured	1.15	53.71	49.57	45.05
	53	*Stereospermum neuranthum*	6.81	13.76	Dippled scaly	0.9	52.92	51.97	44.59
	54	*Shorea siamensis*	8.28	16.21	Fissured	1.1	50.33	43.84	42.91
	55	*Shorea siamensis*	8.8	15.54	Fissured	1.45	45.55	46.89	41.13
P.6	56	*Shorea siamensis*	9.52	18.38	Fissured	1.25	43.92	45.58	28.92
	57	*Bombax anceps*	6.42	15.1	Cracked	1.05	54.86	68.88	74.1
	58	*Erythrophleum succirubrum*	11.46	21.82	Cracked	0.95	51.72	51.97	38.9
	59	*Shorea siamensis*	9.97	16.78	Fissured	1.05	52.78	41.93	36.71

Plot no.	tree no.	Tree sp.	Height (m.)	DBH (cm.)	Bark type	Bark thickness (cm.)	%moisture		
							%m1st	%m2nd	%m3rd
P.6	60	*Shorea siamensis*	9	16.18	Fissured	0.9	46.85	39.6	47.5
	61	*Shorea siamensis*	6.26	22.93	Fissured	1.1	40.58	43.78	40.94
	62	*Shorea siamensis*	9.84	14.33	Fissured	1.05	46.69	36.06	40.14
	63	*Lannea coromandelica*	6.72	16.56	Dippled scaly	1.05	53.28	62.83	45.23
	64	*Shorea siamensis*	8.1	14.11	Fissured	0.8	48.8	44.37	40.05
	65	*Shorea siamensis*	9.62	17.64	Fissured	1	38.34	40.11	46.32
	66	*Shorea siamensis*	9.59	18.66	Fissured	1.2	47.65	41.13	38.5
	67	*Shorea siamensis*	12.08	17.74	Fissured	1.2	44.99	41.95	51.28
	68	*Shorea siamensis*	10.14	18.6	Fissured	0.65	52.66	40.08	45.62
	69	*Shorea siamensis*	9.87	20.38	Fissured	1.15	45.76	40.8	37.44
	70	*Shorea siamensis*	11.56	20.32	Fissured	1.1	44.36	45.11	38.46
	71	*Erythrophleum succirubrum*	10.92	24.33	Fissured	1.2	50.43	47.88	33.42
	72	*Shorea siamensis*	9.38	17.26	Cracked	0.7	50.05	30.15	31.53
	73	*Shorea siamensis*	7.47	16.37	Fissured	1.85	46.05	45.29	46.86
	74	*Ellipanthus tomentosus*	9.02	13.38	Cracked	0.6	51.56	52.66	46.13
	75	*Lannea coromandelica*	5.77	14.33	Cracked	0.6	70.86	67.03	63.7

Plot no.	tree no.	Tree sp.	Height (m.)	DBH (cm.)	Bark type	Bark thickness (cm.)	%moisture		
							%m1st	%m2nd	%m3rd
P.7	76	*Shorea siamensis*	12.48	19.43	Fissured	0.95	47.03	44.69	35.89
	77	*Shorea siamensis*	11.72	14.65	Fissured	1.05	49.67	53.15	40.6
	78	*Shorea siamensis*	7.64	17.2	Fissured	1.6	40.91	45.54	40.63
	79	*Sindora siamensis*	9.55	19.12	Cracked	1.8	28.53	33.96	28.8
	80	*Shorea siamensis*	8.5	16.56	Fissured	1.25	48.19	42.06	36.41
	81	*Shorea siamensis*	9.54	17.2	Fissured	1.9	50.33	53.64	51.14
	82	*Shorea siamensis*	11.05	20.06	Fissured	1.15	43.58	38.49	39.31
	83	*Shorea siamensis*	12.81	16.88	Fissured	1.15	39.85	44.56	38.48
	84	*Shorea siamensis*	9.03	18.47	Fissured	1.2	42.53	43.22	41.59
	85	*Shorea siamensis*	9.58	15.29	Fissured	1.15	43.23	44.92	48.77
	86	*Shorea siamensis*	9.66	15.92	Fissured	1.3	41.94	43.47	40.12
	87	*Shorea siamensis*	9.34	16.88	Fissured	1.15	36.1	43.34	50.46
	88	*Sindora siamensis*	8.98	16.56	Cracked	1.2	34.68	33.36	36.01
	89	*Shorea siamensis*	9.6	16.24	Fissured	1.7	38.06	43.94	40.6
	90	*Shorea siamensis*	8.71	13.06	Fissured	1.35	42.39	52.61	46.55
	91	*Shorea siamensis*	12.32	30.57	Fissured	1.3	34.96	42.7	38.6

Plot no.	tree no.	Tree sp.	Height (m.)	DBH (cm.)	Bark type	Bark thickness (cm.)	%moisture		
							%m1st	%m2nd	%m3rd
P.7	92	*Vitex pinnata*	9.6	16.24	Dippled scaly	0.85	51.24	52.16	58.54
	93	*Shorea siamensis*	10.67	19.43	Fissured	1.05	35.38	40.68	35.84
	94	*Shorea siamensis*	10.6	17.83	Fissured	1.25	41.72	49.37	38.47
	95	*Shorea siamensis*	8.46	15.61	Fissured	0.65	38.85	46.37	42
	96	*Shorea siamensis*	9.05	16.88	Fissured	1.5	45.63	47.33	43.97
	97	*Shorea siamensis*	11.59	16.24	Fissured	1.45	41.23	42.69	40.54
	98	*Shorea siamensis*	14.91	19.43	Fissured	1.25	40.16	53.15	46.25
	99	*Sindora siamensis*	9.5	17.52	Cracked	1.1	31.81	38.78	27.61
	100	*Sindora siamensis*	8.6	16.72	Cracked	1.4	39.84	35.87	26.86
	101	*Xylia xylocarpa*	7.86	21.97	Cracked	0.65	59.97	57.01	58.46
P.8	102	*Shorea siamensis*	12.33	24.04	Fissured	1.3	47.09	44.45	38.38
	103	*Sindora siamensis*	10.09	17.52	Cracked	1.2	44.11	42.07	38.34
	104	*Shorea siamensis*	10.89	13.69	Fissured	1.15	44.86	44.15	41.01
	105	*Shorea siamensis*	9.71	17.52	Fissured	1	39.94	44.42	41.88
	106	*Shorea siamensis*	11.21	20.06	Fissured	1.2	36.11	42.27	44.53
	107	*Spondias pinnata*	9.15	14.1	Fissured	2.1	74.23	76.39	77.05

Plot no.	tree no.	Tree sp.	Height (m.)	DBH (cm.)	Bark type	Bark thickness (cm.)	%moisture		
							%m1st	%m2nd	%m3rd
P.8	108	*Shorea siamensis*	8.42	18.47	Fissured	0.65	44.28	45.89	47.09
	109	*Sindora siamensis*	6.87	15.29	Cracked	0.95	34.08	34.39	34.3
	110	*Sindora siamensis*	8.17	20.38	Cracked	1.3	34.88	33.65	32.34
	111	*Morinda coreia*	7.83	13.69	Fissured	1	38.59	47.88	39.4
	112	*Shorea siamensis*	10.2	22.61	Fissured	0.95	48.95	47.55	44.88
	113	*Catunaregam tomentosa*	7.83	14.33	Smooth and Thorny	0.25	38.09	30.25	29.74
	114	*Sindora siamensis*	7.56	15.29	Cracked	1	43.92	41.4	38.11
	115	*Zizyphus cambodiana*	4.94	15.29	Smooth and Thorny	0.45	53.62	54.41	51.82
	116	*Shorea siamensis*	9.42	15.29	Fissured	1.6	45.83	43.67	38.07
	117	*Spondias pinnata*	7.31	12.65	Cracked	1.05	75.53	73.17	75.87
	118	*Shorea siamensis*	8	15.29	Fissured	1.05	51.35	58.37	42.6
	119	*Shorea siamensis*	9	18.15	Fissured	1.45	47.51	51.14	41.11
	120	*Shorea siamensis*	8	14.97	Fissured	0.85	51.5	50.99	43.01
	121	*Shorea siamensis*	11.42	15.92	Fissured	1	42.3	45.11	46.07
	122	*Shorea siamensis*	9.96	16.24	Fissured	1	44.9	44.41	41.52
	123	*Shorea siamensis*	9.22	17.52	Fissured	0.9	43.82	43.77	38.98

2. Details of the bark-inhabiting insects found in this study.

No.	Bark insect			Host tree		Lower trap			Upper trap			Total
	Order	Family	Species	No.	Species	1st	2nd	3rd	1st	2nd	3rd	
1	**Coleoptera**	**Brentidae**	-	32	*Shorea siamensis*	0	0	0	1	0	0	
					Total	0	0	0	1	0	0	**1**
2	**Coleoptera**	**Carabidae**	***Abacetus sp.***	1	*Lannea coromandelica*	0	0	0	2	0	0	
				2	*Lannea coromandelica*	3	0	0	7	0	0	
				3	*Lannea coromandelica*	1	0	0	2	0	0	
				4	*Schleichera oleosa*	2	0	0	1	0	0	
				5	*Shorea siamensis*	3	0	0	0	0	0	
				6	*Catunaregam tomentosa*	3	0	0	3	0	0	
				7	*Shorea siamensis*	4	0	0	6	0	0	
				8	*Allophylus cobbe*	2	0	0	3	0	0	
				9	*Pterocarpus macrocarpus*	0	0	0	1	0	0	
				10	*Sindora siamensis*	1	0	0	1	0	0	
				11	*Lannea coromandelica*	0	0	0	7	0	0	

No.	Bark insect			Host tree		Lower trap			Upper trap			Total
	Order	**Family**	**Species**	**No.**	**Species**	**1st**	**2nd**	**3rd**	**1st**	**2nd**	**3rd**	
2	**Coleoptera**	**Carabidae**	***Abacetus sp.***	12	*Sindora siamensis*	2	0	0	0	0	0	
				13	*Xylia xylocarpa*	11	0	0	4	0	0	
				14	*Canarium subulatum*	4	0	0	0	0	0	
				15	*Shorea siamensis*	1	0	0	8	0	0	
				16	*Shorea siamensis*	10	0	0	6	0	0	
				17	*Shorea siamensis*	1	0	0	1	0	0	
				18	*Shorea siamensis*	0	0	0	2	0	0	
				19	*Shorea siamensis*	3	0	0	0	0	0	
				20	*Erythrophleum succirubrum*	4	0	0	3	0	0	
				22	*Catunaregam tomentosa*	2	0	0	2	0	0	
				25	*Shorea siamensis*	3	0	0	0	0	0	
				26	*Shorea siamensis*	1	0	0	1	0	0	
				27	*Shorea siamensis*	0	0	0	1	0	0	

No.	Bark insect			Host tree		Lower trap			Upper trap			Total
	Order	**Family**	**Species**	**No.**	**Species**	**1st**	**2nd**	**3rd**	**1st**	**2nd**	**3rd**	
2	**Coleoptera**	**Carabidae**	***Abacetus sp.***	28	*Erythrophleum succirubrum.*	5	0	0	0	0	0	
				30	*Erythrophleum succirubrum*	2	0	0	0	0	0	
				32	*Shorea siamensis*	0	0	0	1	0	0	
				33	*Shorea siamensis*	1	0	0	1	0	0	
				35	*Cordia dichotoma*	2	0	0	0	0	0	
				37	*Shorea siamensis*	15	0	0	3	0	0	
				38	*Morinda coreia*	2	0	0	0	0	0	
				39	*Shorea siamensis*	1	0	0	0	0	0	
				43	*Mitragyna brunosis*	6	0	0	0	0	0	
				44	*Shorea siamensis*	2	0	0	0	0	0	
				47	*Ochna integerrima*	4	0	0	4	0	0	
				51	*Shorea siamensis*	1	0	0	0	0	0	

No.	Bark insect			Host tree		Lower trap			Upper trap			Total
	Order	**Family**	**Species**	**No.**	**Species**	**1st**	**2nd**	**3rd**	**1st**	**2nd**	**3rd**	
2	**Coleoptera**	**Carabidae**	***Abacetus sp.***	58	*Erythrophleum succirubrum*	3	0	0	1	0	0	
				61	*Shorea siamensis*	1	0	0	0	0	0	
				64	*Shorea siamensis*	2	0	0	1	0	0	
				65	*Shorea siamensis*	0	0	0	1	0	0	
				66	*Shorea siamensis*	1	0	0	0	0	0	
				68	*Shorea siamensis*	0	0	0	1	0	0	
				69	*Shorea siamensis*	0	0	0	1	0	0	
				70	*Shorea siamensis*	0	0	0	3	0	0	
				71	*Erythrophleum succirubrum*	2	0	0	1	0	0	
				72	*Shorea siamensis*	3	0	0	0	0	0	
				74	*Ellipanthus tomentosus*	3	0	0	8	0	0	
				79	*Sindora siamensis*	5	0	0	7	0	0	
				80	*Shorea siamensis*	1	0	0	0	0	0	

No.	Bark insect			Host tree		Lower trap			Upper trap			Total
	Order	**Family**	**Species**	**No.**	**Species**	**1st**	**2nd**	**3rd**	**1st**	**2nd**	**3rd**	
2	**Coleoptera**	**Carabidae**	***Abacetus sp.***	81	*Shorea siamensis*	2	0	0	0	0	0	
				82	*Shorea siamensis*	1	0	0	0	0	0	
				88	*Sindora siamensis*	1	0	0	0	0	0	
				91	*Shorea siamensis*	1	0	0	0	0	0	
				92	*Vitex pinnata*	2	0	0	4	0	0	
				93	*Shorea siamensis*	0	0	0	3	0	0	
				94	*Shorea siamensis*	0	0	1	1	0	0	
				102	*Shorea siamensis*	0	0	0	1	0	0	
				106	*Shorea siamensis*	1	0	0	0	0	0	
				108	*Shorea siamensis*	0	0	0	1	0	0	
				122	*Shorea siamensis*	4	0	0	1	0	0	
					Total	135	0	1	105	0	0	**241**
3	**Coleoptera**	**Carabidae**	***Brachinus sp.***	58	*Erythrophleum succirubrum*	1	0	0	0	0	0	
				76	*Shorea siamensis*	0	0	0	1	0	0	

No.	Bark insect			Host tree		Lower trap			Upper trap			Total
	Order	Family	Species	No.	Species	1st	2nd	3rd	1st	2nd	3rd	
3	**Coleoptera**	**Carabidae**	***Brachinus sp.***		**Total**	1	0	0	1	0	0	**2**
4	**Coleoptera**	**Carabidae**	***Graniger sp.***	33	*Shorea siamensis*	1	0	0	0	0	0	
				58	*Erythrophleum succirubrum*	1	0	0	0	0	0	
					Total	2	0	0	0	0	0	**2**
5	**Coleoptera**	**Curculionidae**	**-**	79	*Sindora siamensis*	0	0	0	2	0	0	
				107	*Spondias pinnata*	0	0	0	0	0	1	
					Total	0	0	0	2	0	1	**3**
6	**Coleoptera**	**Elateridae**	***Adeloura sp.***	66	*Shorea siamensis*	1	0	0	0	0	0	
					Total	1	0	0	0	0	0	**1**
7	**Coleoptera**	**Elateridae**	***Agrypnus aegualia***	6	*Catunaregam tomentosa*	0	1	0	0	0	0	
				65	*Shorea siamensis*	0	1	0	0	0	0	
				76	*Shorea siamensis*	0	1	0	0	0	0	
					Total	**0**	**3**	**0**	**0**	**0**	**0**	**3**
8	**Coleoptera**	**Elateridae**	***Cardiophorus sp.***	7	*Shorea siamensis*	3	0	0	0	0	0	

No.	Bark insect			Host tree		Lower trap			Upper trap			Total
	Order	Family	Species	No.	Species	1st	2nd	3rd	1st	2nd	3rd	
8	**Coleoptera**	**Elateridae**	***Cardiophorus sp.***	18	*Shorea siamensis*	0	0	0	1	0	0	
				19	*Shorea siamensis*	1	0	0	0	0	0	
				68	*Shorea siamensis*	1	0	0	0	0	0	
				79	*Sindora siamensis*	1	0	0	0	0	0	
				115	*Zizyphus cambodiana*	0	0	1	0	0	0	
					Total	6	0	1	1	0	0	**8**
9	**Coleoptera**	**Elateridae**	**sp. 4**	112	*Sindora siamensis*	0	0	2	0	0	0	
					Total	0	0	2	0	0	0	**2**
10	**Coleoptera**	**Elateridae**	**sp. 5**	2	*Lannea coromandelica.*	0	0	0	1	0	0	
				88	*Sindora siamensis*	1	0	0	0	0	0	
				94	*Shorea siamensis*	1	0	0	0	0	0	
					Total	2	0	0	1	0	0	**3**
11	**Coleoptera**	**Leiodinae**	**-**	3	*Lannea coromandelica*	0	0	0	1	0	0	
				50	*Shorea siamensis*	0	0	0	1	0	0	
				51	*Shorea siamensis*	0	0	0	1	0	0	

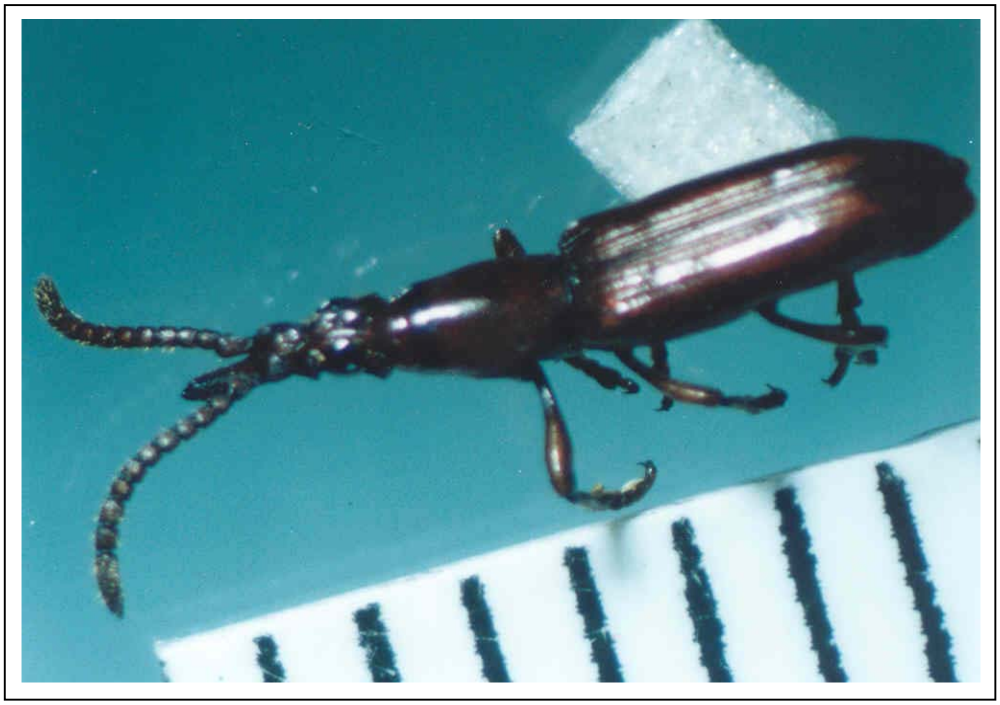
No.	Bark insect			Host tree		Lower trap			Upper trap			Total
	Order	**Family**	**Species**	**No.**	**Species**	**1st**	**2nd**	**3rd**	**1st**	**2nd**	**3rd**	
11	**Coleoptera**	**Leiodinae**	**-**	63	*Lannea coromandelica*	0	0	0	0	0	1	
				102	*Shorea siamensis*	1	0	0	1	0	0	
				107	*Spondias pinnata*	0	0	0	0	0	2	
				123	*Shorea siamensis*	2	0	0	0	0	0	
					Total	3	0	0	4	0	3	**10**
12	**Coleoptera**	**Rhysodidae**	**-**	10	*Sindora siamensis*	1	0	0	0	0	0	
					Total	1	0	0	0	0	0	**1**
13	**Coleoptera**	**Staphylinidae**	**-**	97	*Shorea siamensis*	1	0	0	0	0	0	
					Total	1	0	0	0	0	0	**1**
14	**Coleoptera**	**Tenebrionidae**	***Mesomorphus sp.***	7	*Shorea siamensis*	0	1	0	0	0	0	
					Total	0	1	0	0	0	0	**1**
15	**Coleoptera**	**Tenebrionidae**	***Scleron sp.***	7	*Shorea siamensis*	4	0	0	0	0	0	
				10	*Sindora siamensis*	3	0	0	1	0	0	
				74	*Ellipanthus tomentosus*	0	0	0	1	0	0	
				92	*Vitex pinnata*	0	0	3	0	0	0	

No.	Bark insect			Host tree		Lower trap			Upper trap			Total
	Order	**Family**	**Species**	**No.**	**Species**	**1st**	**2nd**	**3rd**	**1st**	**2nd**	**3rd**	
15	**Coleoptera**	**Tenebrionidae**	***Scleron sp.***	94	*Shorea siamensis*	0	0	1	0	0	0	
				106	*Shorea siamensis*	0	0	0	0	0	2	
					Total	7	0	4	2	0	2	**15**
16	**Coleoptera**	**Tenebrionidae**	**sp. 3**	76	*Shorea siamensis*	0	0	0	1	0	0	
				87	*Shorea siamensis*	0	0	0	0	0	1	
				103	*Sindora siamensis*	1	0	0	0	0	0	
					Total	1	0	0	1	0	1	**3**
17	**Coleoptera**	**Tenebrionidae**	**sp. 4**	23	*Shorea siamensis.*	1	0	0	0	0	0	
					Total	1	0	0	0	0	0	**1**
18	**Coleoptera**	**Unknown A**	**-**	78	*Shorea siamensis*	1	0	0	0	0	0	
					Total	1	0	0	0	0	0	**1**
19	**Coleoptera**	**Unknown B**	**-**	107	*Spondias pinnata*	0	0	0	0	0	1	
					Total	0	0	0	0	0	1	**1**
20	**Coleoptera**	**Unknown C**	**-**	75	*Lannea coromandelica*	1	0	0	0	0	0	

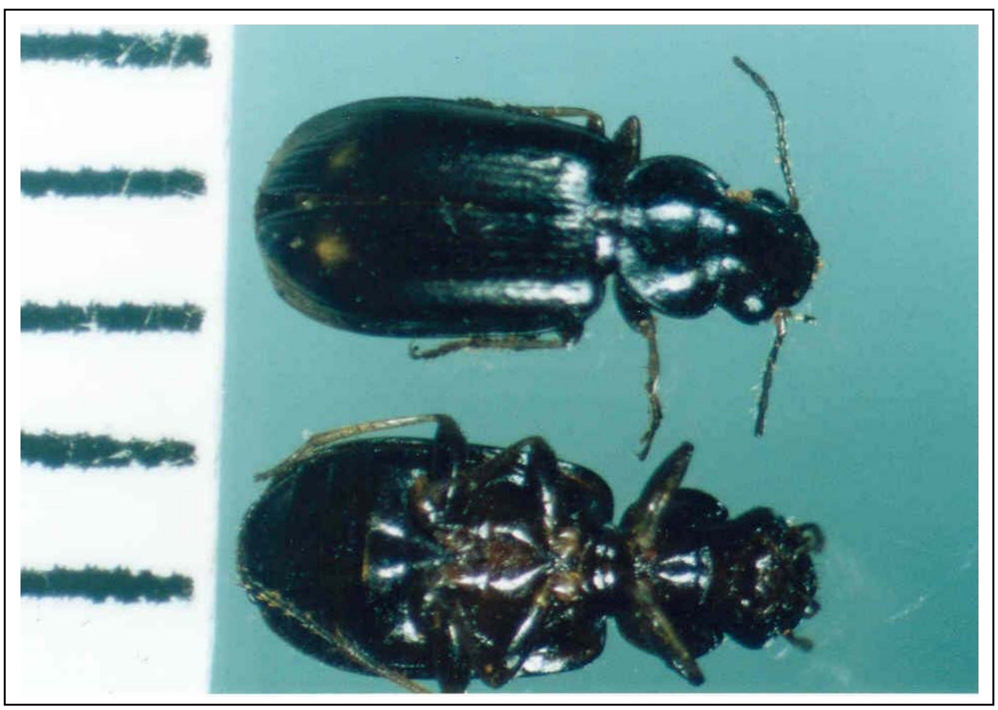
No.	Bark insect			Host tree		Lower trap			Upper trap			Total
	Order	**Family**	**Species**	**No.**	**Species**	**1st**	**2nd**	**3rd**	**1st**	**2nd**	**3rd**	
20	**Coleoptera**	**Unknown C**	**-**		**Total**	1	0	0	0	0	0	**1**
21	**Coleoptera**	**Unknown D**	**-**	35	*Cordia dichotoma*	2	0	0	0	0	0	
					Total	2	0	0	0	0	0	**2**
22	**Coleoptera**	**Unknown E**	**-**	10	*Sindora siamensis*	1	0	0	3	0	0	
				13	*Xylia xylocarpa*	1	0	0	0	0	0	
				16	*Shorea siamensis*	1	0	0	0	0	0	
					Total	3	0	0	3	0	0	**6**
23	**Embioptera**	**Uknown F**	**-**	21	*Shorea siamensis*	1	0	0	0	0	0	
					Total	1	0	0	0	0	0	**1**
24	**Hemiptera**	**Cydnidae**	**-**	47	*Ochna integerrima*	0	0	0	1	0	0	
					Total	0	0	0	1	0	0	**1**
25	**Hemiptera**	**Lygaeidae**	**-**	101	*Xylia xylocarpa*	0	0	0	1	0	0	
					Total	0	0	0	1	0	0	**1**
26	**Hemiptera**	**Unknown G**	**-**	92	*Vitex pinnata*	1	0	0	0	0	0	

No.	Bark insect			Host tree		Lower trap			Upper trap			Total
	Order	**Family**	**Species**	**No.**	**Species**	**1st**	**2nd**	**3rd**	**1st**	**2nd**	**3rd**	
26	**Hemiptera**	**Unknown G**	**-**		**Total**	1	0	0	0	0	0	**1**
27	**Hymenoptera**	**Braconidae**	***Cotesia* sp.**	35	*Cordia dichotoma*	5	0	0	0	0	0	
				123	*Shorea siamensis*	7	0	0	0	0	0	
					Total	12	0	0	0	0	0	**12**
					Total of all collections	**182**	**4**	**8**	**123**	**0**	**8**	**325**

3. Pictures of the bark-inhabiting insects found in this study.



Brentidae (Coleoptera)



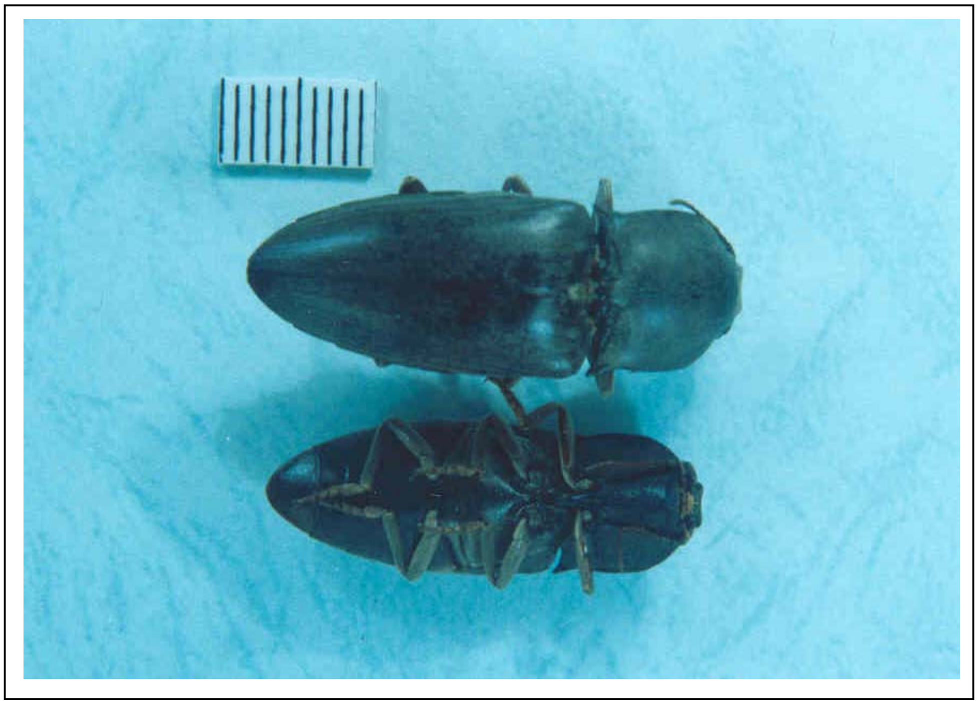
***Abacetus* sp. (Carabidae, Coleoptera)**

***Brachinus* sp. (Carabidae, Coleoptera)**

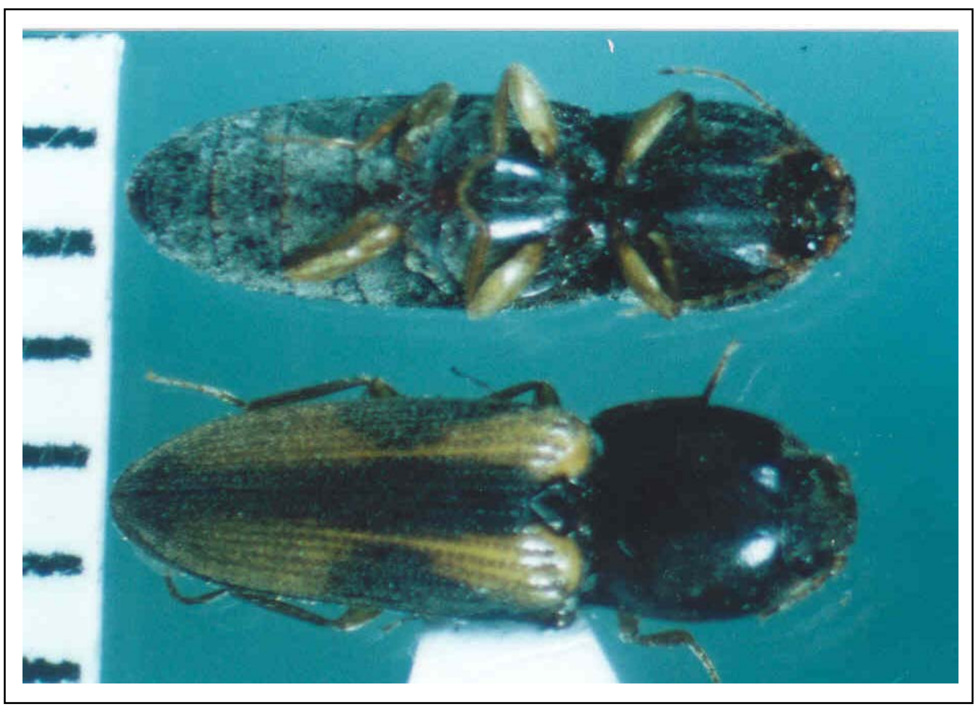
***Graniger* sp. (Carabidae, Coleoptera)**

Curculionidae (Coleoptera)

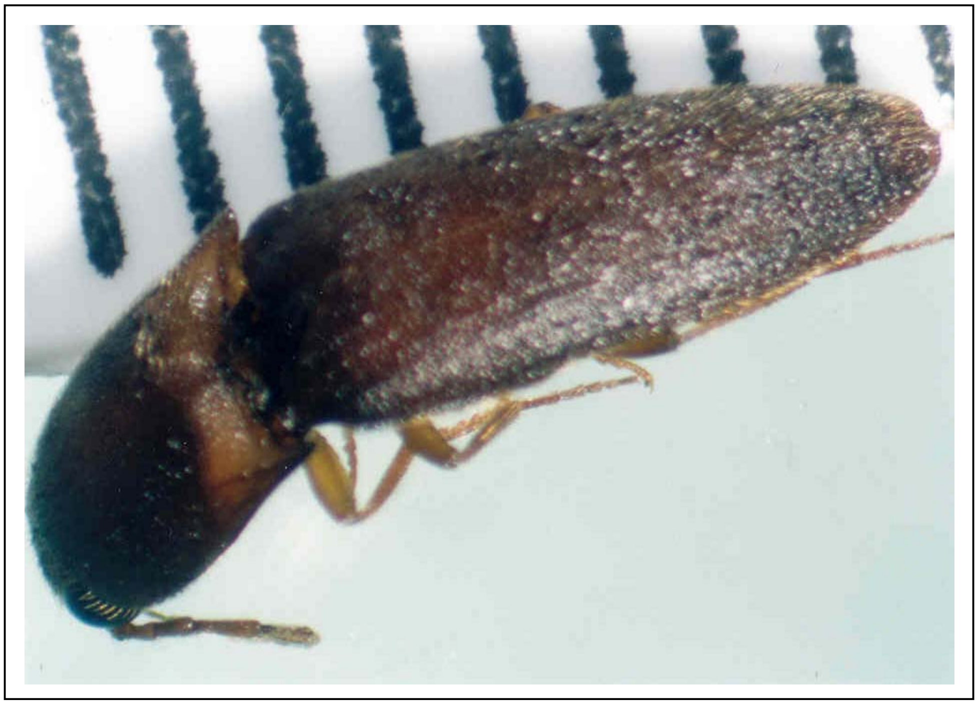
***Adeloura* sp. (Elateridae, Coleoptera)**



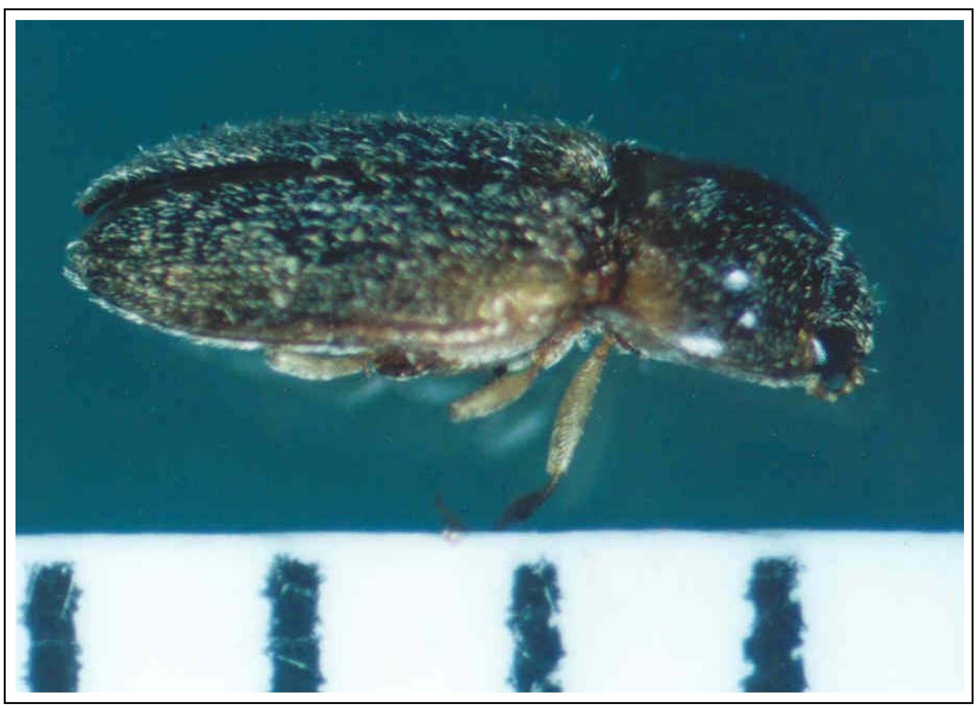
Agrypnus aegualia **(Elateridae, Coleoptera)**



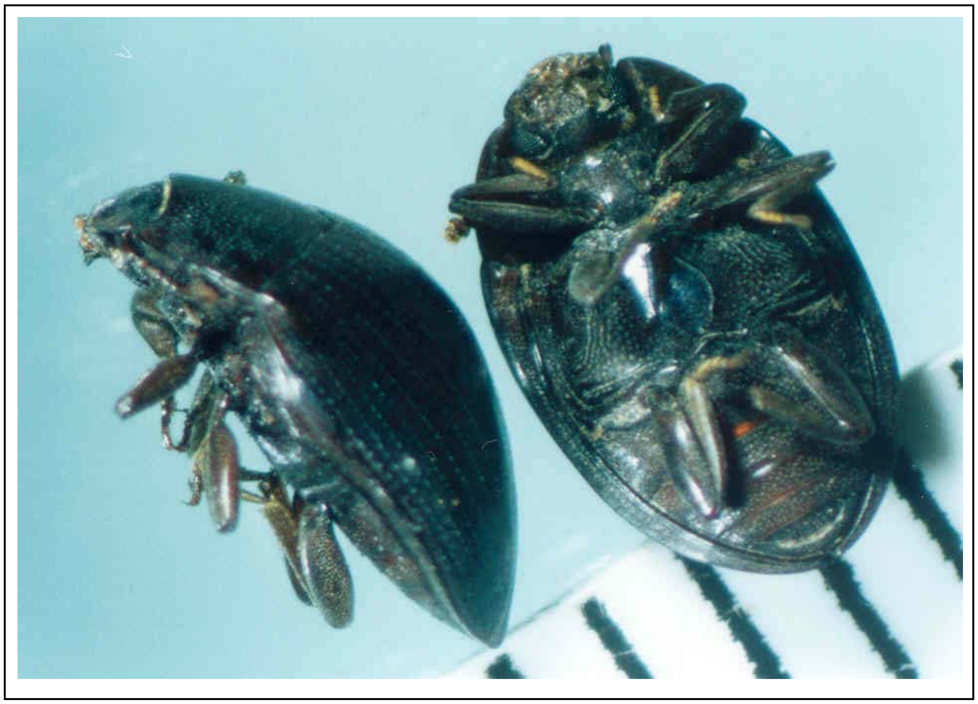
Cardiophorus **sp. (Elateridae, Coleoptera)**



Elateridae sp. 4 (Coleoptera)



Elateridae sp. 5 (Coleoptera)

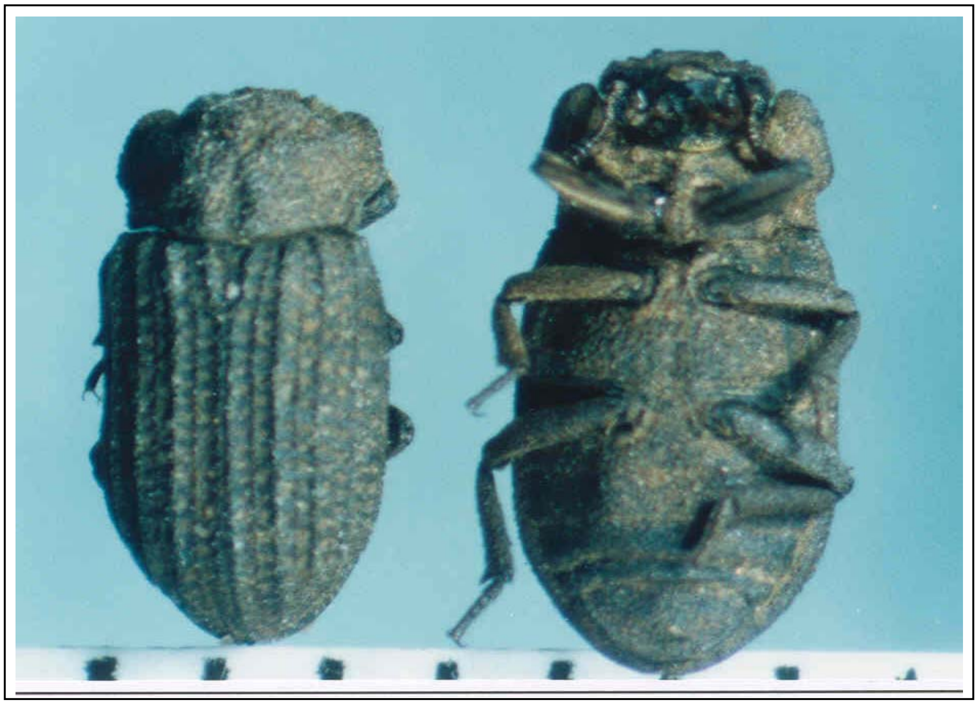


Leiodidae (Coleoptera)

Rhysodidae (Coleoptera)

Staphylinidae, Coleoptera (L.) and Lygaeidae, Hemiptera (R.)

***Mesomorphus* sp. (Tenebrionidae, Coleoptera)**

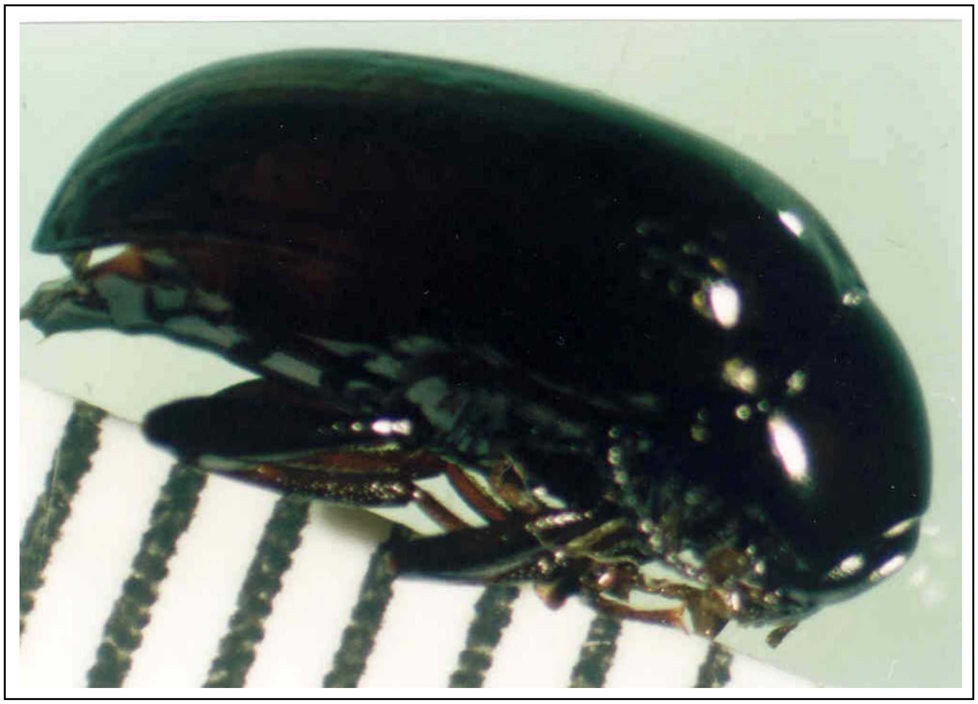


***Scleron* sp. (Tenebrionidae, Coleoptera)**

Tenebrionidae sp. 3 (Coleoptera)

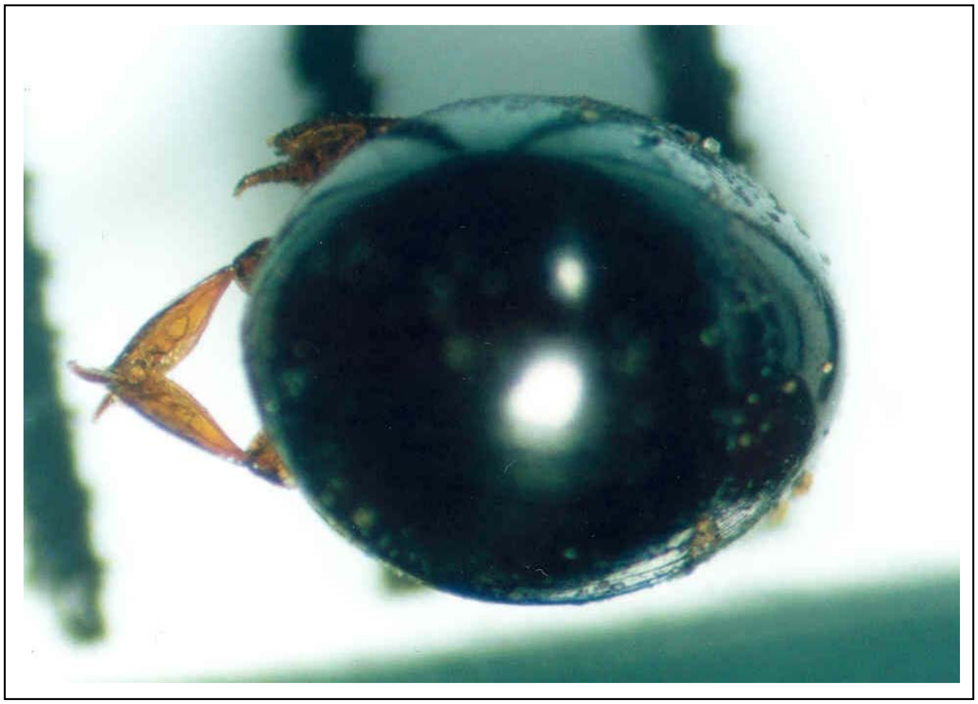
Tenebrionidae sp. 4 (Coleoptera)

Unknown A (Coleoptera)



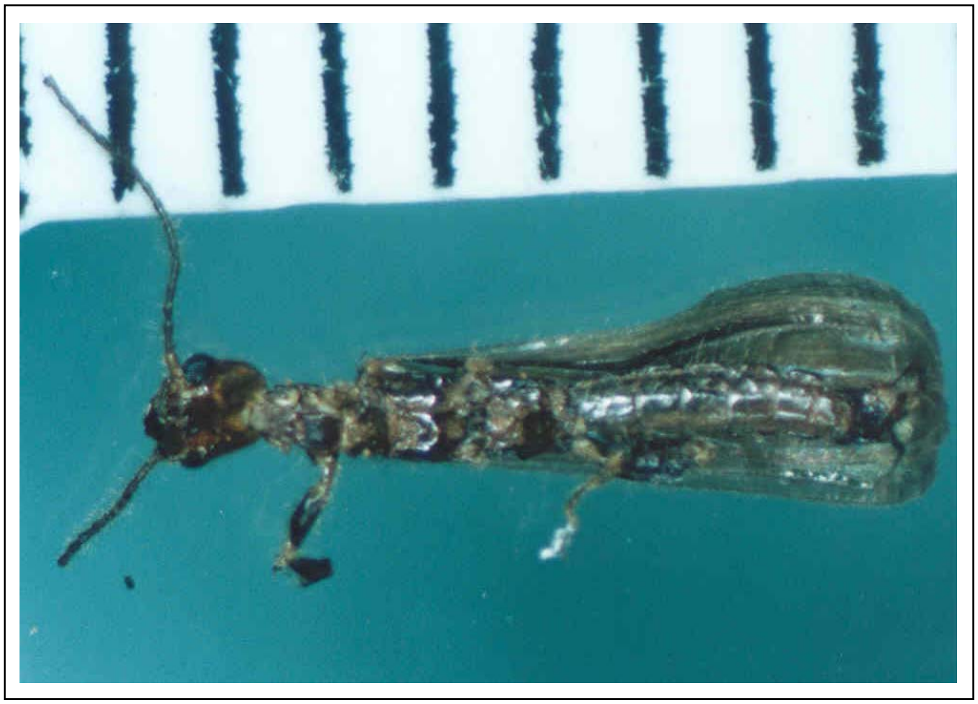
Unknown B (Coleoptera)

Unknown C (Coleoptera)



Unknown D (Coleoptera)

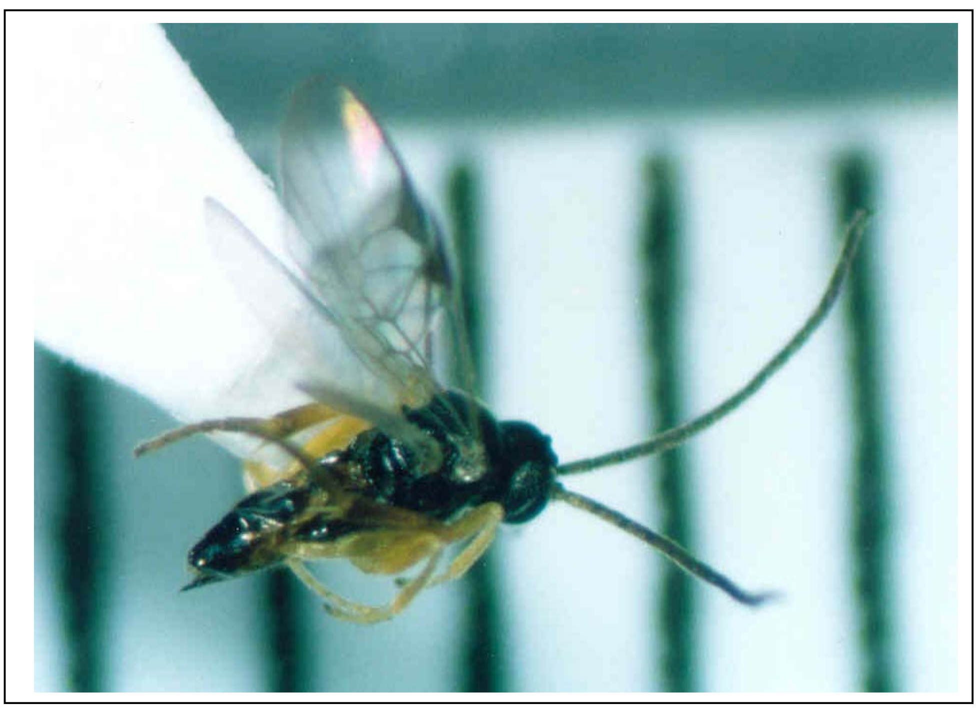
Unknown E (Coleoptera)



Unknown F (Embioptera)

Cydnidae (Hemiptera)

Unknown G (Hemiptera)

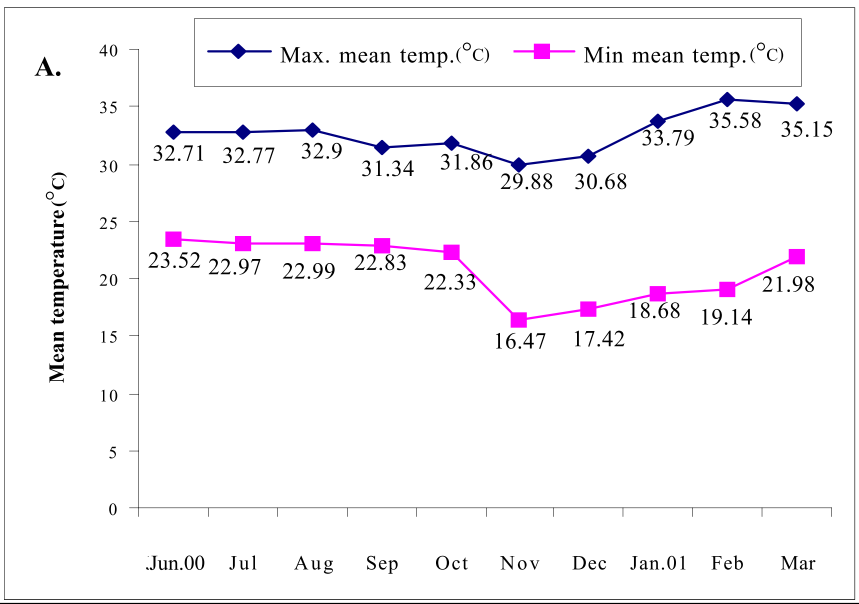


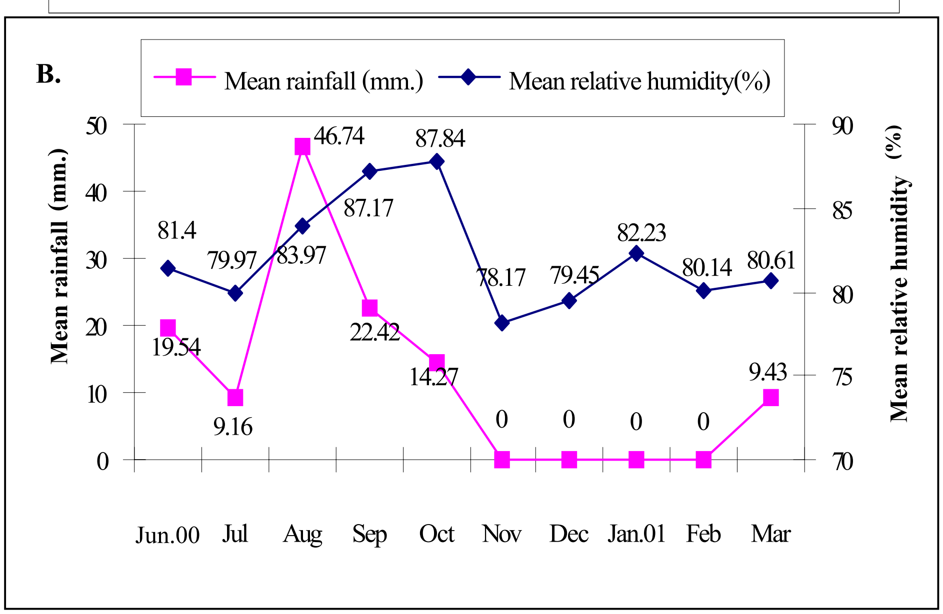
***Cotesia* sp. (Braconidae, Hymenoptera)**

APPENDIX II

WEATHER DATA

1. **Diagrams of weather data at Nong Rawiang Forest during the period June 2000 – March 2001, as shown by figure A of the maximum and minimum mean air temperature, and figure B of the mean rainfall and the mean relative humidity (Data from Meteorological Station of Nong Rawiang, Nakhon Ratchasima Province).**





2. Table of weather data for the maximum and minimum air temperature, the rainfall, and the relative humidity at Nong Rawiang Forest during the period June 2000 – March 2001 (Data from Meteorological Station of Nong Rawiang, Nakhon Ratchasima Province).

June 2000									
Date	**Air temp.**		**Rainfall**	**R.H.**	**Date**	**Air temp.**		**Rainfall**	**R.H.**
	Max.	**Min.**	**(mm.)**	**(%)**		**Max.**	**Min.**	**(mm.)**	**(%)**
1	32.2	22.5	22.4	82	**16**	33.5	22.6	77.5	86
2	32	22	25.8	91	**17**	32.5	23	0	91
3	33	22.5	9	90	**18**	32.2	23.5	0	82
4	32.5	23.1	0	82	**19**	32	23.3	5.1	78
5	31	23	0	86	**20**	32.5	23.5	20.5	86
6	33	24.5	0	83	**21**	33	24	0	82
7	33.5	24	0	78	**22**	33	24.7	4.6	79
8	34	24.5	0	78	**23**	32.5	24	0	82
9	34	24	0	78	**24**	33	23.5	0	78
10	32.5	23.1	0	86	**25**	32.5	23	6.7	82
11	33.2	23.5	0	74	**26**	30.5	23.5	0	86
12	32.5	23.5	0	62	**27**	31.2	23.7	0	82
13	33	24.7	0	74	**28**	33	23	4.3	82
14	34.5	25	0	75	**29**	33.5	23.1	0	87
15	33	24.2	0	78	**30**	32.5	23	0	82
					Total	**981.3**	**706.0**	**175.9**	**2442.0**
					Avar.	**32.71**	**23.52**	**5.86**	**81.40**

July 2000									
Date	**Air temp.**		**Rainfall**	**R.H.**	**Date**	**Air temp.**		**Rainfall**	**R.H.**
	Max.	**Min.**	**(mm.)**	**(%)**		**Max.**	**Min.**	**(mm.)**	**(%)**
1	33.5	23	14.9	91	**16**	32.5	23	0	71
2	33	22.8	0	82	**17**	33	23.1	0	71
3	32.5	23.5	0	83	**18**	33	23.5	0	75
4	32.2	24	0	75	**19**	33	23.4	0	67
5	31	23	4.9	91	**20**	32.6	22.5	0	82
6	31.3	23.2	0	82	**21**	33	22	0	78
7	32	24	0	86	**22**	34	22.5	0	82
8	32	23	0	82	**23**	34.5	22	0	75
9	32.5	22.7	4.6	86	**24**	34.5	22.5	0	62
10	30.5	23	5.3	82	**25**	34.7	22.7	0	91
11	27	22	19.6	90	**26**	35	23.5	0	82
12	30	22	19.1	90	**27**	35	23	0	70
13	31	23.5	0	68	**28**	34.5	23.5	5.9	75
14	31	22.6	0	86	**29**	34.6	23.1	7.1	82
15	32	22.5	1	74	**30**	34.9	24	0	86
					31	35.5	23	0	82
					Total	**1015.8**	**712.1**	**82.4**	**2479.0**
					Avar.	**32.77**	**22.97**	**2.66**	**79.97**

August 2000									
Date	**Air temp.**		**Rainfall**	**R.H.**	**Date**	**Air temp.**		**Rainfall**	**R.H.**
	Max.	**Min.**	**(mm.)**	**(%)**		**Max.**	**Min.**	**(mm.)**	**(%)**
1	35	23.5	0	75	**16**	34	23	0	75
2	34.6	23	0	82	**17**	34	24.7	0	86
3	34.6	23	0	75	**18**	33	23.5	0	91
4	34.5	23.5	0	82	**19**	35	23	0	91
5	33	23.7	0	82	**20**	34	22	0	86
6	32.5	23	49.5	86	**21**	34.5	24	0	82
7	32.5	21	90	82	**22**	31.1	23	41.7	91
8	32	22.5	16.6	86	**23**	26	20.7	126.5	90
9	32	23	8.5	90	**24**	30	21.5	33	90
10	33	23	0	83	**25**	31.2	21.5	8.1	87
11	34.5	22	0	87	**26**	31.7	22	0	86
12	34	23.5	0	83	**27**	32.5	22.5	0	82
13	33.4	24	0	87	**28**	32	23.5	0	86
14	34.5	25	0	71	**29**	32.3	23.5	0	82
15	35	22.5	0	79	**30**	31.5	24	0	86
					31	32	24	0	82
					Total	**1019.9**	**712.6**	**373.90**	**2603.0**
					Avar.	**32.90**	**22.99**	**12.06**	**83.97**

September 2000									
Date	**Air temp.**		**Rainfall**	**R.H.**	**Date**	**Air temp.**		**Rainfall**	**R.H.**
	Max.	**Min.**	**(mm.)**	**(%)**		**Max.**	**Min.**	**(mm.)**	**(%)**
1	31.5	23	0	82	**16**	32.5	25	0	82
2	31	23.5	0	91	**17**	32.8	24	0	90
3	30	23	0	91	**18**	33.1	24	0	86
4	29	21.5	22.5	86	**19**	34	23.5	0	82
5	27	22.5	10	90	**20**	34	24	0	74
6	30	22.5	0	90	**21**	31.7	22	17.2	83
7	31.5	23	0	82	**22**	31	23	19.5	82
8	30.6	23.5	1	91	**23**	32	23	0	91
9	31	23.5	4	90	**24**	32.5	22	68.5	82
10	30.5	22	15.5	90	**25**	32.5	22	9	91
11	29	23	26	90	**26**	32	22.5	0.5	90
12	31	22.5	0	90	**27**	32	21.5	87.2	86
13	31.5	23.5	9.5	90	**28**	31.5	22	23.5	90
14	31.5	24	0	90	**29**	30.6	23	0	90
15	31	20	0	82	**30**	32	22.5	0	91
					Total	**940.3**	**685.0**	**313.9**	**2615.0**
					Avar.	**31.34**	**22.83**	**10.46**	**87.17**

October 2000									
Date	**Air temp.**		**Rainfall**	**R.H.**	**Date**	**Air temp.**		**Rainfall**	**R.H.**
	Max.	**Min.**	**(mm.)**	**(%)**		**Max.**	**Min.**	**(mm.)**	**(%)**
1	31.5	22	0	82	**16**	32	21	0	90
2	32	22	0	90	**17**	29	22	0	90
3	34	22.5	0	90	**18**	32.5	24	0	90
4	33	22	0	91	**19**	34	24.5	0	91
5	33.5	22.5	0	91	**20**	33	23	0	83
6	32.5	22.2	0	86	**21**	33.5	22.5	0	91
7	32	22	0	91	**22**	32	22.5	0	86
8	33	23	0	90	**23**	31.5	22.5	22.6	90
9	33	22	0	90	**24**	30	22.5	0	83
10	31.5	24.5	0	83	**25**	31.5	22	13.1	91
11	32	24	7.1	90	**26**	31.5	22.5	0	91
12	32.2	23.5	0	91	**27**	30	22	0	82
13	31	23	0	91	**28**	32.5	21	0	90
14	31.5	24	0	90	**29**	31	21	0	81
15	31.6	23	0	86	**30**	30	16.5	0	81
					31	29.5	20.5	0	81
					Total	**987.8**	**692.0**	**42.8**	**2723.0**
					Avar.	**31.86**	**22.33**	**1.38**	**87.84**

November 2000									
Date	**Air temp.**		**Rainfall**	**R.H.**	**Date**	**Air temp.**		**Rainfall**	**R.H.**
	Max.	**Min.**	**(mm.)**	**(%)**		**Max.**	**Min.**	**(mm.)**	**(%)**
1	28	15	0	72	**16**	31.5	21	0	90
2	28	18	0	70	**17**	31.5	17	0	81
3	26.5	12	0	79	**18**	30	14	0	80
4	25	12	0	80	**19**	30	14	0	63
5	28.5	10.5	0	90	**20**	31	15	0	63
6	30	11.5	0	89	**21**	29	14	0	62
7	31	13	0	81	**22**	29	14	0	63
8	32	14.5	0	81	**23**	27	15	0	80
9	30.5	15	0	90	**24**	30	19.5	0	72
10	30.5	18	0	82	**25**	29	18	0	81
11	31	19.5	0	82	**26**	30.5	20.5	0	72
12	30.5	19.5	0	89	**27**	32	20	0	82
13	28.5	18.5	0	81	**28**	31	20	0	73
14	30	19.5	0	81	**29**	31.5	19	0	73
15	31	18	0	81	**30**	32.5	18.5	0	82
					Total	**896.5**	**494.0**	**0.0**	**2345.0**
					Avar.	**29.88**	**16.47**	**0.0**	**78.17**

December 2000									
Date	**Air temp.**		**Rainfall**	**R.H.**	**Date**	**Air temp.**		**Rainfall**	**R.H.**
	Max.	**Min.**	**(mm.)**	**(%)**		**Max.**	**Min.**	**(mm.)**	**(%)**
1	31	19	0	82	**16**	30	19	0	84
2	30	19	0	82	**17**	31	16.5	0	72
3	33	17.5	0	81	**18**	32.5	17.5	0	81
4	29	14.5	0	80	**19**	31	19	0	81
5	29.5	14	0	76	**20**	30.5	15	0	81
6	30	15.5	0	80	**21**	29.5	15	0	80
7	31	19.5	0	89	**22**	29	14	0	75
8	30.5	20	0	73	**23**	29	14	0	70
9	31	18	0	81	**24**	28	10	0	79
10	31.5	18.5	0	80	**25**	30	15	0	79
11	32	17.5	0	89	**26**	30.5	17	0	79
12	32	17.5	0	90	**27**	31	19	0	70
13	31	19	0	81	**28**	32	19.5	0	73
14	29	17	0	80	**29**	32	20	0	73
15	30	18	0	80	**30**	32.5	22	0	81
					31	32	23	0	81
					Total	**951.0**	**540.0**	**0.0**	**2463.0**
					Avar.	**30.68**	**17.42**	**0.0**	**79.45**

January 2001									
Date	**Air temp.**		**Rainfall**	**R.H.**	**Date**	**Air temp.**		**Rainfall**	**R.H.**
	Max.	**Min.**	**(mm.)**	**(%)**		**Max.**	**Min.**	**(mm.)**	**(%)**
1	32	20	0	80	**16**	32	16	0	70
2	31	14	0	89	**17**	30	15.5	0	80
3	32	13.5	0	71	**18**	31	20	0	80
4	33	16	0	80	**19**	32	21	0	81
5	32	15	0	72	**20**	32	22	0	90
6	32	16	0	90	**21**	34	22	0	81
7	33	17	0	80	**22**	35	23	0	90
8	34	17.5	0	82	**23**	35	24	0	82
9	34	18	0	90	**24**	35.5	25.5	0	91
10	35	19.5	0	82	**25**	37	20	0	82
11	34	19.5	0	90	**26**	36.5	21	0	74
12	33.5	22.5	0	81	**27**	36	20.5	0	82
13	32	20	0	89	**28**	37	20	0	82
14	33.5	16.5	0	89	**29**	37	15	0	80
15	33	16	0	70	**30**	37	16	0	80
					31	36.5	16.5	0	89
					Total	**1047.5**	**579.0**	**0.0**	**2549.0**
					Avar.	**33.79**	**18.68**	**0.0**	**82.23**

February 2001									
Date	**Air temp.**		**Rainfall**	**R.H.**	**Date**	**Air temp.**		**Rainfall**	**R.H.**
	Max.	**Min.**	**(mm.)**	**(%)**		**Max.**	**Min.**	**(mm.)**	**(%)**
1	36.7	17	0	81	**16**	31	15.5	0	89
2	37	18	0	77	**17**	33	13	0	80
3	36.5	20	0	77	**18**	34	12	0	72
4	36	21	0	77	**19**	34	14	0	90
5	37.5	22	0	77	**20**	35	16	0	81
6	36	20	0	81	**21**	35.5	19	0	81
7	35.5	19	0	75	**22**	35.5	21	0	82
8	37	20	0	81	**23**	37	21	0	82
9	37.5	22	0	90	**24**	37	20.5	0	82
10	36.5	22	0	81	**25**	38	20	0	73
11	36.5	23	0	82	**26**	37	21	0	74
12	37	24	0	74	**27**	37	21	0	82
13	32	20	0	82	**28**	36	23	0	82
14	34.5	15	0	80	**Total**	**996.2**	**536.0**	**0.0**	**2244.0**
15	30	16	0	79	**Avar.**	**35.58**	**19.14**	**0.0**	**80.14**

March 2001									
Date	**Air temp.**		**Rainfall**	**R.H.**	**Date**	**Air temp.**		**Rainfall**	**R.H.**
	Max.	**Min.**	**(mm.)**	**(%)**		**Max.**	**Min.**	**(mm.)**	**(%)**
1	36.5	24	0	82	**16**	35	21.5	0	80
2	36	22	0	73	**17**	36.5	22	0	75
3	37	22	0	81	**18**	37	23	0	75
4	37	23	0	81	**19**	37	23	0	82
5	37.5	22	0	90	**20**	37	23	1.5	75
6	37	21	0	73	**21**	28	24	15	90
7	38	23	0	81	**22**	38	25	0	82
8	35	22	16.6	83	**23**	37	21.5	0	82
9	34	21	0	90	**24**	36	22	0	83
10	32	22	0	81	**25**	35.6	23	0	82
11	30.5	20	0	65	**26**	35	22.5	0	90
12	29	19	4.6	81	**27**	36	23	0	83
13	30	19	0	89	**28**	36	22	0	83
14	31	19	0	81	**29**	37	21	0	75
15	36	22.5	0	81	**30**	37	21.5	0	75
					31	35	22	0	75
					Total	**1089.6**	**681.5**	**37.70**	**2499.0**
					Avar.	**35.15**	**21.98**	**1.22**	**80.61**

APPENDIX III

RESULTS FROM ORDINATION ANALYSES

1. Table of the variance extracted and the eigenvectors from the PCA analysis for investigating effect of different tree densities on the bark-inhabiting insect assemblages ($|r| \geq 0.39$*).

	PC1	PC2	PC3
% of Variance	67.83	15.68	6.75
Cum. % of variance	67.83	83.50	90.25
Eigenvectors of the bark-inhabiting insects			
Braconidae (*Cotesia* sp.)	-0.22	-0.20	0.04
Brentidae	0.02	-0.03	0.04
Carabidae (*Abacetus* sp.)	**0.89**	-0.20	-0.16
Carabidae (*Brachinus* sp.)	0.01	0.00	0.14
Carabidae (*Graniger* sp.)	0.03	-0.06	0.09
Curculionidae	-0.09	-0.00	0.11
Cydnidae	0.02	-0.15	-0.28
Elateridae (*Adeloura* sp.)	0.01	-0.03	0.05
Elateridae (*Agrypnus aegualia*)	0.02	0.00	0.18
Elateridae (*Cardiophorus* sp.)	-0.01	-0.06	0.20
Elateridae sp. 4	-0.11	-0.06	-0.02
Elateridae sp. 5	0.00	0.06	0.21
Leiodinae	-0.32	**-0.55**	**-0.54**
Lygaeidae	-0.01	0.03	0.09
Rhysodidae	-0.00	0.16	-0.17
Staphylinidae	-0.01	0.03	0.09
Tenebrionidae (*Mesomorphus* sp.)	0.01	0.00	0.03
Tenebrionidae (*Scleron* sp.)	-0.12	**0.46**	-0.04

	PC1	PC2	PC3
Tenebrionidae sp. 3	-0.10	0.02	0.17
Tenebrionidae sp. 4	0.02	0.00	0.01
Unknown A	-0.01	0.03	0.09
Unknown B	-0.08	-0.05	-0.01
Unknown C	-0.01	0.03	0.09
Unknown D	0.02	-0.04	0.05
Unknown E	0.02	**0.57**	**-0.58**
Unknown F	0.02	0.00	0.01
Unknown G	-0.01	0.03	0.09

* The significant values followed to Rakocinski *et al*. (1997).

2. Table of the variance extracted and the eigenvectors from the PCA analysis for investigating effect of different host species on the bark-inhabiting insect assemblages ($|r| \geq 0.39$*).

	PC1	PC2	PC3
% of Variance	44.30	9.68	6.73
Cum. % of variance	44.30	53.98	60.71
Eigenvectors of the bark-inhabiting insects			
Braconidae (*Cotesia* sp.)	0.05	-0.05	-0.02
Brentidae	0.01	0.01	-0.01
Carabidae (*Abacetus* sp.)	**-0.95**	-0.11	0.10
Carabidae (*Brachinus* sp.)	0.02	0.03	0.04
Carabidae (*Graniger* sp.)	0.00	0.01	0.00
Curculionidae	-0.02	-0.03	-0.01
Cydnidae	0.00	0.00	0.00
Elateridae (*Adeloura* sp.)	0.01	0.01	-0.01
Elateridae (*Agrypnus aegualia*)	0.02	0.04	0.04
Elateridae (*Cardiophorus* sp.)	-0.07	0.14	**-0.44**

	PC1	PC2	PC3
Elateridae sp. 4	0.05	0.06	-0.09
Elateridae sp. 5	0.01	0.02	-0.02
Leiodinae	0.20	**-0.89**	0.23
Lygaeidae	0.05	0.06	-0.09
Rhysodidae	0.00	0.00	-0.01
Staphylinidae	0.05	0.06	-0.09
Tenebrionidae (*Mesomorphus* sp.)	0.00	0.00	-0.01
Tenebrionidae (*Scleron* sp.)	0.03	0.05	-0.07
Tenebrionidae sp. 3	0.14	0.38	**0.83**
Tenebrionidae sp.4	0.05	0.06	-0.09
Unknown A	0.05	0.06	-0.09
Unknown B	0.02	-0.03	0.00
Unknown C	0.05	0.06	-0.09
Unknown D	0.01	0.00	-0.01
Unknown E	0.00	0.01	-0.01
Unknown F	0.05	0.06	-0.09
Unknown G	0.00	0.00	0.00

* The significant values followed to Rakocinski *et al*. (1997).

3. Results from the CCA analysis for investigating effect of different tree characteristics on the bark-inhabiting insect assemblages.

3.1 Table of the correlation values for 6 tree characteristics ($|r| \geq 0.50$*).

	CCA1	CCA2	CCA3
Eigenvalues	0.35	0.22	0.15
Species-environmental correlation	0.64	0.54	0.44
Tree characteristic variables			
Bark thickness	**-0.64**	0.28	-0.35

	CCA1	CCA2	CCA3
DBH	0.47	-0.05	**-0.85**
Tree height	-0.32	0.17	**-0.51**
%Moisture of bark (1^{st})	0.43	**0.58**	0.48
%Moisture of bark (2^{nd})	0.35	0.45	0.43
%Moisture of bark (3^{rd})	0.35	0.34	0.46

* The significant values followed to Wright and Samways (1999).

3.2 Table of the final scores for 27 morphospecies of the bark-inhabiting insects.

	CCA1	CCA2	CCA3
Braconidae (*Cotesia* sp.)	2.27	-0.49	2.10
Brentidae	-5.74	-3.23	-5.75
Carabidae (*Abacetus* sp.)	0.68	-0.44	-0.43
Carabidae (*Brachinus* sp.)	0.89	1.37	-1.99
Carabidae (*Graniger* sp.)	0.20	-1.22	0.46
Curculionidae	-2.78	2.39	-0.46
Cydnidae	1.49	-3.74	3.83
Elateridae (*Adeloura* sp.)	0.04	0.68	-1.19
Elateridae (*Agrypnus aegualia*)	0.82	-1.27	-1.77
Elateridae (*Cardiophorus* sp.)	1.76	-1.09	1.33
Elateridae sp. 4	2.80	0.25	-3.21
Elateridae sp. 5	-0.91	-0.26	-0.25
Leiodinae	0.56	5.06	-1.10
Lygaeidae	5.53	0.32	-0.72
Rhysodidae	-3.01	-1.68	2.22
Staphylinidae	-3.04	0.66	-1.15
Tenebrionidae (*Mesomorphus* sp.)	5.70	-2.37	-6.07
Tenebrionidae (*Scleron* sp.)	0.01	-0.87	-0.97
Tenebrionidae sp. 3	-0.75	-0.51	-1.10

	CCA1	CCA2	CCA3
Tenebrionidae sp.4	-1.60	-1.11	2.78
Unknown A	-1.79	-0.61	-1.53
Unknown B	-2.33	4.86	2.33
Unknown C	3.84	1.57	5.77
Unknown D	4.81	-0.48	5.29
Unknown E	-0.94	-0.52	0.75
Unknown F	-2.65	-2.03	2.19
Unknown G	1.01	0.00	1.41

4. Results from the CCA analysis for investigating effect of different positions within a trunk on the bark-inhabiting insect assemblages.

4.1 The lower trunk level.

4.1.1 Table of the correlation values for 6 tree characteristics ($|r| \geq 0.50$*).

	CCA1	CCA2	CCA3
Eigenvalues	0.24	0.13	0.10
Species-environmental correlation	0.51	0.40	0.35
Tree characteristic variables			
Bark thickness	**0.71**	-0.31	-0.28
DBH	**-0.51**	**-0.69**	-0.48
Tree height	0.24	**-0.91**	0.22
%Moisture of bark (1)	-0.28	0.14	**0.61**
%Moisture of bark (2)	-0.09	0.29	0.37
%Moisture of bark (3)	-0.12	0.30	0.36

* The significant values followed to Wright and Samways (1999).

4.1.2 Table of the final scores for 21 morphospecies of the bark-inhabiting insects.

	CCA1	CCA2	CCA3
Braconidae (*Cotesia* sp.)	-2.73	1.44	2.30

	CCA1	CCA2	CCA3
Carabidae (*Abacetus* sp.)	-0.78	0.19	-0.72
Carabidae (*Brachinus* sp.)	-2.87	-5.37	2.55
Carabidae (*Graniger* sp.)	-0.15	1.57	-0.98
Elateridae (*Adeloura* sp.)	-0.40	-2.10	0.37
Elateridae (*Agrypnus aegualia*)	-0.94	-2.35	0.06
Elateridae (*Cardiophorus* sp.)	-2.42	1.06	0.29
Elateridae sp. 4	-3.18	-3.75	-0.77
Elateridae sp. 5	1.44	-1.00	-1.33
Leiodinae	-1.37	-4.10	1.50
Rhysodidae	3.46	5.36	-3.73
Staphylinidae	3.29	-3.07	1.23
Tenebrionidae (*Mesomorphus* sp.)	-6.14	-0.59	-9.93
Tenebrionidae (*Scleron* sp.)	-0.24	0.69	-2.24
Tenebrionidae sp. 4	1.41	2.56	1.52
Unknown A	2.28	0.82	-4.64
Unknown C	-3.84	4.14	5.50
Unknown D	-5.26	4.61	4.43
Unknown E	0.57	0.94	-1.21
Unknown F	3.09	2.80	-0.11
Unknown G	-0.54	0.00	2.54

4.2 The upper trunk level.

4.2.1 Table of the correlation values for 6 tree characteristics ($|r| \geq 0.50$*).

	CCA1	CCA2	CCA3
Eigenvalues	0.21	0.19	0.10
Species-environmental correlation	0.52	0.48	0.47

	CCA1	CCA2	CCA3
Tree characteristic variables			
Bark thickness	-0.17	**0.64**	0.48
DBH	0.25	-0.40	-0.20
Tree height	-0.09	0.30	-0.34
%Moisture of bark (1)	**0.67**	0.06	**0.56**
%Moisture of bark (2)	**0.66**	-0.04	**0.59**
%Moisture of bark (3)	**0.57**	-0.11	**0.66**

* The significant values followed to Wright and Samways (1999).

4.2.2 Table of the final scores for 13 morphospecies of the bark-inhabiting insects.

	CCA1	CCA2	CCA3
Brentidae	-7.08	3.33	-6.42
Carabidae (*Abacetus* sp.)	0.36	-1.20	0.01
Carabidae (*Brachinus* sp.)	0.56	0.75	-4.02
Curculionidae	0.81	3.40	5.94
Cydnidae	-1.24	-3.98	-2.44
Elateridae (*Cardiophorus* sp.)	-1.51	-0.57	-1.03
Elateridae sp. 5	2.92	0.27	7.81
Leiodinae	4.38	3.02	-1.77
Lygaeidae	4.42	-4.95	0.94
Tenebrionidae (*Scleron* sp.)	-0.76	-0.40	-0.62
Tenebrionidae sp. 3	-0.45	-0.63	-1.07
Unknown B	2.37	4.94	11.73
Unknown E	-3.48	1.91	3.73

CURRICULUM VITAE

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