A SURVEY ON DEFOLIATION AND PHYTOPHAGOUS INSECTS IN FOUR HABITAT TYPES IN SABAH, MALAYSIA

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CHUNG, A. Y. C., CHEY, V. K., SPEIGHT, M. R., EGGLETON, P. & HAMMOND, P. M. 2002. **A survey on defoliation and phytophagous insects in four habitat types in Sabah, Malaysia.** The degree of defoliation in four different habitat types (primary forest, logged forest, acacia plantation and oil palm plantation) was investigated. Logged forest was most severely defoliated in terms of absolute leaf area eaten, percentage of leaf area eaten and number of holes. This was attributed to the many fast-growing and short-lived tree species in the logged forest which were more palatable to the phytophagous insects. Phytophagous Coleoptera were more speciose and abundant in the forests compared with the plantations. Oil palm plantation recorded fewer Orthoptera compared with other sites. There were significant positive relationships between the abundance of Coleoptera and Orthoptera with the percentage of leaf area eaten. A significant positive relationship was also observed between the Coleoptera abundance and the number of holes on leaves. In this study, Coleoptera were the best predictor of defoliation compared with lepidopteran larvae and Orthoptera.

Key words: Herbivory - Coleoptera - Orthoptera - lepidopteran larvae

CHUNG, A. Y. C., CHEY, V. K., SPEIGHT, M. R., EGGLETON, P. & HAMMOND, P. M. 2002. **Satu tinjauan defoliasi dan serangga-serangga pemakan daun di empat habitat yang berlainan di Sabah, Malaysia.** Defoliasi di empat jenis habitat (hutan primer, hutan dibalak, ladang akasia dan ladang kelapa sawit) telah dikaji. Hutan yang dibalak mengalami defoliasi yang paling ketara dari segi keluasan mutlak daun dimakan, peratusan keluasan daun dimakan dan bilangan lubang pada daun. Kelimpahan spesies pokok yang tumbuh cepat serta mempunyai jangka hayat yang pendek di hutan yang telah dibalak menjadi pilihan serangga pemakan daun. Lebih banyak spesies serta bilangan Coleoptera pemakan daun dan Orthoptera dari segi spesies dan kelimpahan direkodkan di hutan berbanding dengan ladang. Ladang kelapa sawit mencatatkan bilangan Orthoptera yang lebih rendah berbanding dengan habitat lain. Hubungan positif yang bererti dikesan antara kelimpahan Coleoptera dan Orthoptera dengan peratusan daun dimakan. Begitu juga antara kelimpahan Coleoptera dengan jumlah lubang pada daun. Dalam kajian ini, Coleoptera didapati lebih berkesan sebagai penentu defoliasi berbanding dengan larva Lepidoptera dan Orthoptera.

Introduction

Phytophagous insects are the most important defoliators in tropical forests, consuming more plant material than vertebrate herbivores (Wint 1983, Lowman & Moffet 1993). The percentage of leaf area removed in different forests of the world generally ranges between 5 and 30% (Lowman 1997). Chewing insects alone take about 7 to 10% of the leaf area (Bray 1964). In the forest of Barro Colorado Island, Panama, the amount of leaf eaten per year by insects is about 12.5% and by vertebrates only 2.4% (Leigh 1975). Occasionally, some species become so abundant that they threaten the stability or output of systems having high ecological, aesthetic or economic value. Therefore, insect herbivory is central to any consideration of the ecology of tropical forests (Greenwood 1990, Anderson & Lee 1995). It is ubiquitous and often been recognised as having a significant impact on plant fitness (Dominquez & Dirzo 1994).

In an entomological context, defoliation is caused by leaf-eating insects, which include leaf-chewers, leaf-skeletonisers, leaf-miners, leaf-rollers, shoot-borers and sap feeders (Chey 1995). Common symptoms or signs of heavily defoliated trees are (1) large amounts of missing foliage, (2) browning of foliage, (3) silk shelters and web-enclosed foliage, (4) insect remains such as egg shells, shed larval skins, pupal cases, cocoons, frass and trails of silk, (5) branch mortality and top-kill and (6) tree mortality (Coulson & Witter 1984). The insects that defoliate tropical trees (not in order of importance) are most commonly moth larvae (Lepidoptera), larvae and adult beetles (Coleoptera), leaf-cutter ants (Attini, neotropical only), Orthoptera and various groups of Homoptera (Janzen 1983) as well as stick insects (Phasmida) (Seow-Choen *et al.* 1994). Some larvae of Hymenoptera (namely, sawflies) and Diptera are also leaf feeders (Coulson & Witter 1984).

This study focused on three prominent phytophagous insect groups, namely, lepidopteran larvae, adult Coleoptera and Orthoptera in order to answer the following questions:

(1) What are the levels of defoliation in different forest and plantation environments in Sabah, Malaysia?
(2) Do differences in vegetation of a habitat affect the diversity of phytophagous insects?
(3) What are the relationships between phytophagous insects and defoliation?
(4) What is the relative importance of each phytophagous insect group as defoliators?

Materials and methods

Study sites

Four study sites were selected for this study: primary forest, logged forest, forest plantation (acacia – *Acacia mangium*) and commercial crop plantation (oil palm – *Elaeis guineensis*). The choice was based on relative vegetational importance in Sabah. Forested areas cover approximately 60% of the land area of Sabah (Chai 1997). About 5.3% of Sabah land area is allocated for forest plantation (Anonymous 1994) with *Acacia mangium* being the most planted species (Anonymous 1996). Oil palm is the most important commercial crop in Sabah covering more than 12% of the land area (Anonymous 2000) The primary forest site is located at the Kabili-Sepilok Forest Reserve in eastern Sabah, about 80 km from other study sites, which are located within the Segaliud-Lokan area near central Sabah. The sites at Segaliud-Lokan are about 3 to 5 km apart.

Primary forest (Kabili-Sepilok Forest Reserve)

The Kabili-Sepilok Forest Reserve (KSFR) is situated on the east coast of Sabah (5° 45' N, 117° 45' E), adjoining the Sandakan Bay. It was first gazetted in 1931 and has an area of 2334 ha which was gradually expanded to the present area of 4294 ha. It is estimated that more than 450 species of trees exist at the KSFR and almost 40% of the known dipterocarps in Sabah are recorded there.

Logged forest (Segaliud-Lokan Forest Reserve)

The Segaliud-Lokan Forest Reserve (5° 30'N, 117° 30' E) covers an area of 57 240 ha. The reserve was gazetted in 1961 as a commercial forest reserve. Prior to logging, it was classified as lowland dipterocarp forest. Selective logging started in 1976 and continued up to 1981. Thus, the logged forest was about 16 years old during sampling. Logging was by conventional tractor with main hauling lines. Only trees with diameter at breast height of 60 cm or more were taken. The prominent vegetation found here are the climbing bamboos, *Dinochloa* spp., and pioneer species such as *Macaranga* spp.

Acacia plantation (Segaliud-Lokan Forest Plantation)

The Segaliud-Lokan Forest Plantation Research Project was established under the management of the Sabah Forestry Department. The plantation area (previously a lowland dipterocarp forest) is located at the northern most part of the Segaliud-Lokan Forest Reserve (5° 37' N, 117° 35' E). It is about 100 km (by road) south-west of Sandakan. About 100 ha are planted with acacias. Other main plantation species include *Paraserianthes falcataria*, *Gmelina arborea* and also various indigenous species. The acacia site chosen for the study is located within a 20-ha area planted in 1989 at 3 × 3 m spacing.

Oil palm plantation (Borneo Crop Sdn. Bhd.)

An oil palm plantation adjacent to the Segaliud-Lokan forest plantation station was chosen as the study site. The site, previously a lowland dipterocarp forest, is located within a 36-ha area planted in January 1990. The palms are planted at 9 m apart in a triangular pattern at a density of 143 palms per ha.

Sampling procedure

Sampling was conducted in September and October 1996. Two sets of data collection strategies were applied, first, for sampling of insects on trees, and second, for measuring levels of defoliation.

Insects were collected with a Maruyama MD300 mist-blower. A ULV nozzle was attached to the end of the emission pipe. Insecticide was added into the air stream from a 100 ml bottle behind the ULV nozzle. The discharge rate of the mist-blower was 25 ml per minute and the mist extended to a maximum height of 10 m (Chey 1994). The chemical used was Pybuthrin 2/16 (Roussel Uclaf), an environmentally-benign, pyrethroid-based insecticide. Three collecting funnels (made from cloth with rattan rings) with a 1-m diameter were placed hanging under the canopy of each tree to be sprayed. Ten trees were chosen at each site based on the accessibility of their canopy to the chemical being mist-blown. Taller trees were not chosen (Table 1). The distance between each tree was at least 10 m. Sampling was conducted on still and dry days. The tree was mist-blown from the ground for one minute. All knocked down insects dropped into a funnel attached with a killing bottle containing ethanol solution. The funnels were monitored for about one hour and beetles that were trying to escape were brushed down the funnel. Canopy cover of each sample was measured with a spherical densiometer (Crown 43888 concave-model C).

Table 1 Details of trees selected for mist-blowing

Site	Replicate	Botanical name	Family	Dbh (cm)	Height (m)	% canopy cover
Primary forest	1	*Eusideroxylon zwageri*	Lauraceae	10	15	75.1
*		*Shorea xanthophylla*	Dipterocarpaceae	3	4	
	2	*Baccaurea stipulata*	Euphorbiaceae	14	8	69.8
	3	*Aporusa acuminatissima*	Euphorbiaceae	9	7	81.3
		Alseodaphne sp.	Lauraceae	1.5	2	
		Polyalthia insignis	Annonaceae	3	3	
	4	*Koilodepas longifolium*	Euphorbiaceae	6.7	6.5	83.4
	5	*Diospyros curranii*	Ebenaceae	10	10	77.1
		Shorea xanthophylla	Dipterocarpaceae	2.3	3.5	
		Shorea xanthophylla	Dipterocarpaceae	2.5	4	
		Shorea xanthophylla	Dipterocarpaceae	2.7	4	
	6	*Mesua macranthes*	Guttiferae	14	10	59.6
	7	*Calophyllum gracilis*	Guttiferae	6	7	66.7

continued

Table 1 (continued)

Site	Replicate	Botanical name	Family	Dbh (cm)	Height (m)	% canopy cover
	8	*Koilodepas longifolium*	Euphorbiaceae	9	6	68.8
		Rinorea longiracemosa	Violaceae	2.5	2	
		Stemonurus malaccensis	Icacinaceae	3.5	3	
	9	*Cleistanthus sumatranus*	Euphorbiaceae	8.5	9	54.2
		Rinorea longiracemosa	Violaceae	3	2	
	10	*Gluta sabahana*	Anacardiaceae	9	5	75.1
		Gluta sabahana	Anacardiaceae	19	10	
Logged forest *	1	*Macaranga triloba*	Euphorbiaceae	5.8	6.5	62.6
		Homalanthus populneus	Euphorbiaceae	5.2	5.5	
	2	*Phoebe macrophylla*	Lauraceae	11	9	36.5
		Pentace laxiflora	Tiliaceae	7.5	6	
	3	*Barringtonia macrostachys*	Lecythidaceae	1.4	3	
		Aporusa nitida	Euphorbiaceae	7	6	62.6
		Maesa sp.	Myrsinaceae	5	5	
	4	*Nephelium ramboutan ake*	Sapindaceae	21	12	74.0
		Sautiria levigata	Burseraceae	7	6	
	5	*Fagraea cuspidata*	Loganiaceae	10	4.5	51.1
		Barringtonia macrostachys	Lecythidaceae	7.5	4	
		Dinochloa scabrida	Gramineae	climber	climber	
	6	*Phoebe macrophylla*	Lauraceae	7.6	5	75.1
		Neonauclea cyrtopoda	Rubiaceae	5.7	5	
		Uncaria cordata	Rubiaceae	climber	climber	
		Syzygium sp.	Myrtaceae	2.3	4	
	7	*Pentace laxiflora*	Tiliaceae	11	7	61.2
		Dinochloa trigonum	Gramineae	climber	climber	
		Korthalsia furtadoana	Palmae	rattan	rattan	
	8	*Parashorea tomentella*	Dipterocarpaceae	13	10	37.5
		Dinochloa scabrida	Gramineae	climber	climber	
	9	*Adinandra myrioneura*	Theaceae	29	15	58.4
	10	*Mallotus leucodermis*	Euphorbiaceae	7	6	55.5
Acacia plantation	1	*Acacia mangium*	Leguminosae	19	9.5	29.2
	2	"	"	16	8.5	34.4
	3	"	"	10	6	28.1
	4	"	"	12	8	27.1
	5	"	"	15	8	32.3
	6	"	"	16	8.5	36.5
	7	"	"	11	8	30.2
	8	"	"	16	10	33.4
	9	"	"	14	9.5	31.3
	10	"	"	14	9	33.4
Oil palm plantation	1	*Elaeis guineensis*	Palmae	60	6	65.7
	2	"	"	66	5.5	63.6
	3	"	"	57	5.5	65.7
	4	"	"	65	6	56.3
	5	"	"	58	4	51.1
	6	"	"	57	4.5	70.9
	7	"	"	64	5.5	69.8
	8	"	"	66	6	52.1
	9	"	"	66	6	64.6
	10	"	"	61	6	70.9

* In some replicates, more than 1 tree was mist-blown because the plants grew very near to each other in the forest. Some climbers also clung to the trees.

The leaf-chewers were picked out from the insects sampled. Three prominent groups were sorted to morphospecies, namely, lepidopteran larvae (butterflies and moths), Orthoptera (grasshoppers and crickets, including nymphs) and phytophagous adult Coleoptera (beetles). The Coleoptera included families or subfamilies from Melolonthinae, Cetoniinae, Valginae, Alleculinae, Elateridae, Mordellidae, Languriidae, Curculionidae, Chrysomelidae, Buprestidae, Attelabidae, Phalacridae and Nitidulidae. The leaf-eating families chosen here were based on Hammond (1990). Other herbivores such as the sap feeders, leaf rollers and leaf miners were excluded because it was difficult to quantify the exact degree of damage caused by these groups. Moreover, they are of little importance compared with the leaf-chewers (Wint 1983).

In each mist-blown area of a tree canopy, ten leaves were taken at random. The total leaf area, absolute leaf area eaten, percentage eaten and number of holes on each leaf were calculated by tracing the leaf onto a graph paper.

Regressions were carried out to determine which phytophagous insect group best predicted defoliation levels. The data from four sites were combined for the regression because of the low number of defoliators sampled and the problem of multiple zero-values. We realised that there were qualitative differences that affect the results when data from the four sites were combined (due to the different rates of attack at different sites).

Results

Species richness and abundance of selected phytophagous insect groups

Site was a significant factor (ANOVA, Tukey's HSD, $p < 0.05$) in explaining the variance in species richness and abundance of phytophagous Coleoptera and Orthoptera (both log-transformed) (Figures 1 and 2). However, there was no difference among sites observed in the species richness or abundance of lepidopteran larvae. Numbers of phytophagous Coleoptera were higher in both logged and primary forests compared with the acacia and oil palm plantations. In the logged forest, an average of 4.38 Coleoptera species from 8.08 individuals were determined from 1 m^2 of a tree canopy while in the oil palm plantation, only 0.71 species from 1.46 individuals were recorded. Orthopteran species collected in the oil palm plantation were singletons, with 0.13 species and individuals respectively.

Defoliation status

Generally, plants in the logged forest were more defoliated compared with other sites (Tukey's HSD, $p < 0.05$, Figure 3). An average of 123.3 cm^2 or 6.5% of the leaf area sampled was defoliated while an average of 91.8 holes were observed in each sample in the logged forest. The primary forest, acacia plantation and oil palm plantation did not differ significantly in absolute leaf area eaten, percentage of leaf eaten or the number of holes.

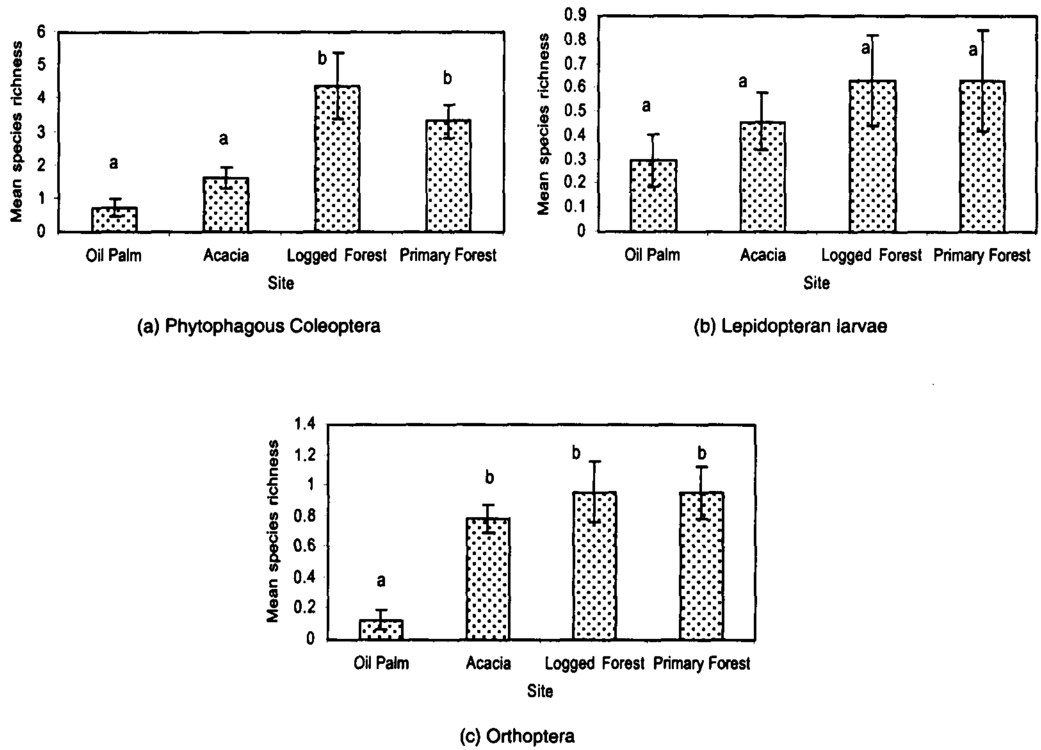


Figure 1 Mean insect defoliator species (with standard error) per m^2 of a tree canopy at study sites. Means followed by the same letter are not significantly different (Tukey's HSD, $p < 0.05$). Log-transformed data were used and the letters used refer to log-transformed data.

Which phytophagous insect group is the best predictor of defoliation levels?

The results showed that there were significant positive relationships between Coleoptera and Orthoptera abundances with the percentage of leaf eaten (Figures 4 and 5). Significant positive relationships (Figures 6 and 7) were also observed between the abundances of Coleoptera and all groups combined with the number of holes on the leaves. These suggested that the Coleoptera and Orthoptera were good predictors for percentage of leaf area eaten while Coleoptera and the three groups combined were good predictors for the number of holes on the leaves. In general, Coleoptera was the best predictor among the three groups because it was significant as predictor in two of the three defoliation measures taken.

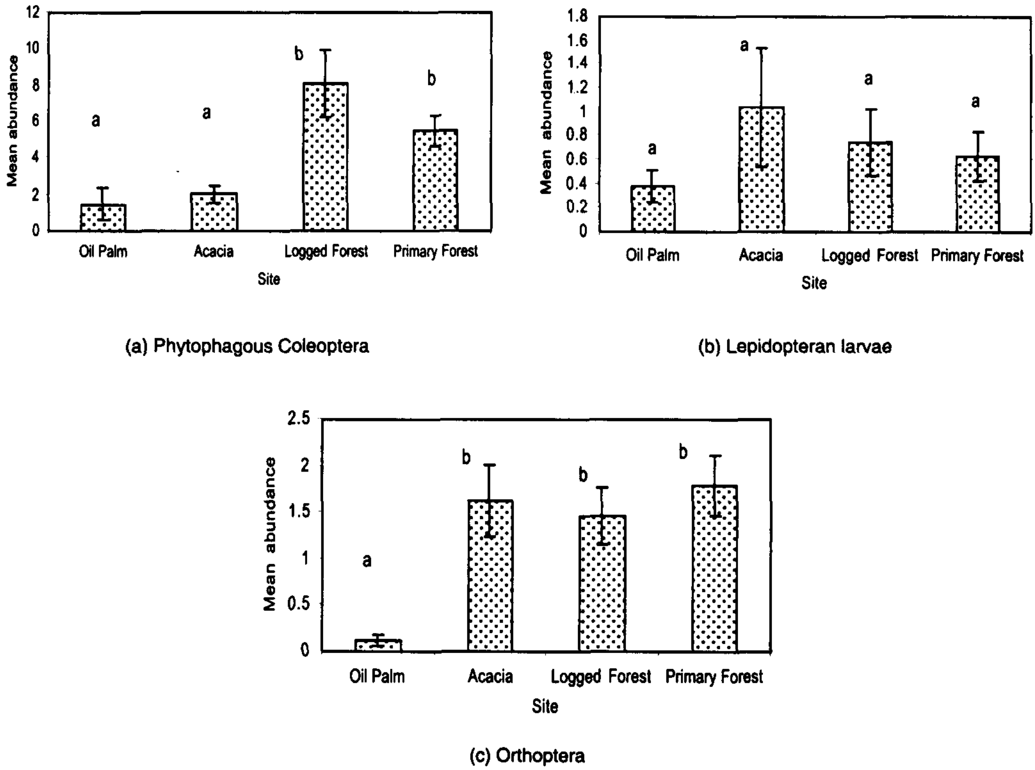


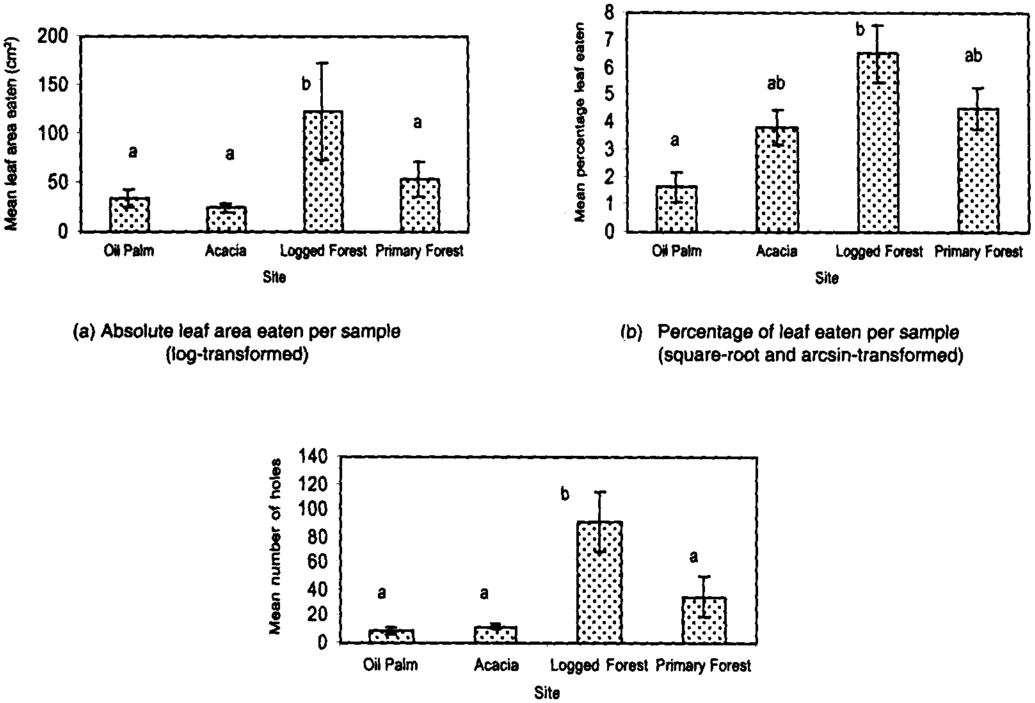
Figure 2 Mean insect defoliator abundance (with standard error) per m^2 of a tree canopy at study sites. Means followed by the same letter are not significantly different (Tukey's HSD, $p < 0.05$). Log-transformed data were used and the letters refer to log-transformed data.

Discussion

Species richness and abundance of selected phytophagous insect groups at various sites

The forest provides suitable habitats for many living organisms. The wide range of tropical vegetation types provides a variety of food for phytophagous insects. Therefore, it is not surprising that the species richness and abundance of the phytophagous insects sampled in the forests were generally higher than the plantations.

The overall higher fluctuations in temperature, humidity and light intensity may have contributed to the low number of phytophagous insects in the plantations (Speight & Wainhouse 1989). The plantation canopy was generally lower and less covered, resulting in higher temperature and low humidity during daytime compared with the forests (see Table 1). Such fluctuations may affect the adaptation of small organisms due to their high surface area to volume ratio (Szujecki 1987, Lawton 1995). Many phytophagous insects absorb water through their body cover directly from the humid air (Szujecki 1987). In the larvae of some Coleoptera, the water content amounts to 78% and can be up to 67% in adults. Low humidity will mean that the insects lose relatively large amount of their body fluids (Szujecki 1987).



(a) Absolute leaf area eaten per sample (log-transformed)

(b) Percentage of leaf eaten per sample (square-root and arcsin-transformed)

(c) Number of holes found on the leaves per sample (log-transformed)

Figure 3 Mean herbivory measures (with standard error) at study sites. Means followed by the same letter are not significantly different (Tukey's HSD $p < 0.05$). The letters refer to transformed data. The term 'per sample' refers to the area of the tree that was mist-blown.

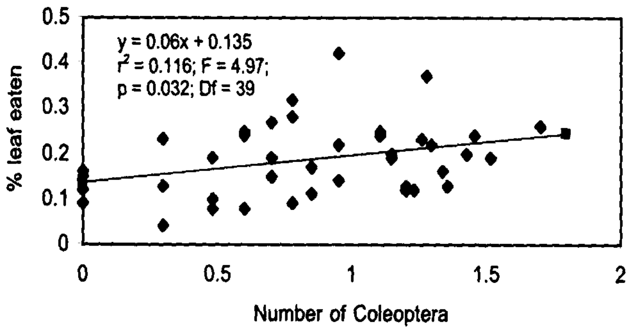


Figure 4 Relationship between Coleoptera abundance (log-transformed) and the percentage of each leaf eaten (square root and arcsin transformed). Data from four sites were used.

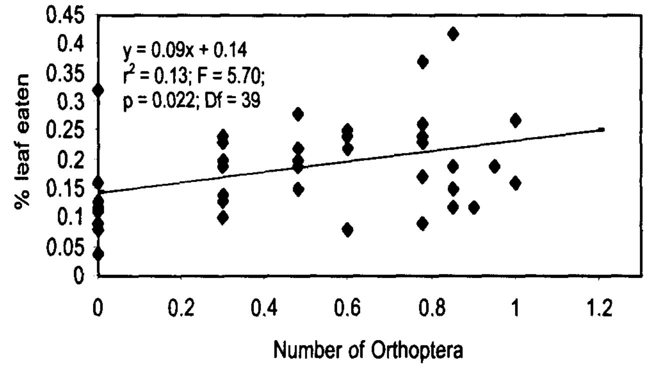


Figure 5 Relationship between Orthoptera abundance (log-transformed) and the percentage of each leaf eaten (square root and arcsin transformed). Data from four sites were used.

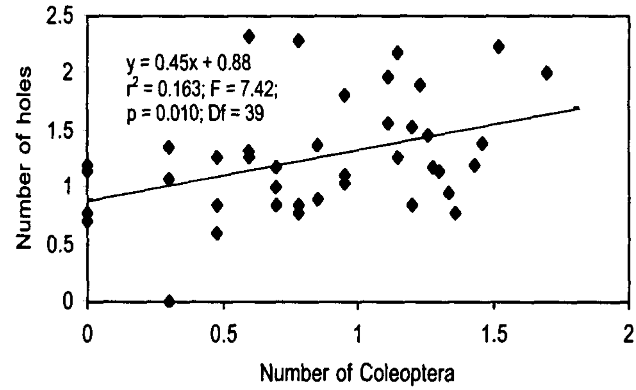


Figure 6 Relationship between Orthoptera abundance (log-transformed) and the number of holes (log-transformed). Data from four sites were used.

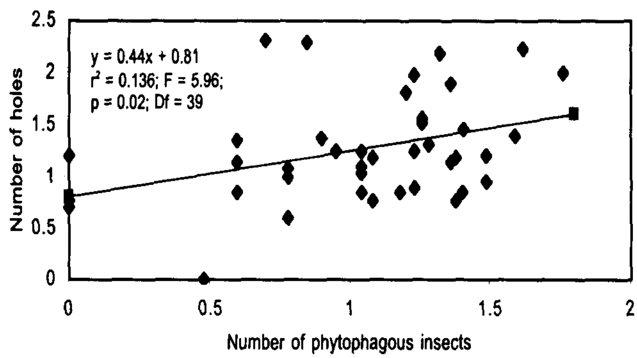


Figure 7 Relationship between all phytophagous insect abundance (log-transformed) and the number of holes (log-transformed). Data from four sites were used.

Defoliation status

Lowman (1992) stated that defoliation levels are not homogeneous between forests, but range from negligible to total foliage loss, varying with plant and defoliator species, height, light regime, phenology, age of leaves as well as individual crown. The defoliation level in the logged forest was higher than the primary forest and other sites. Although the species richness and abundance of phytophagous insects were not significantly different between primary and logged forest, the levels of defoliation, especially as reflected in leaf area eaten and number of holes, were lower in the primary forest. The logged forest comprised many pioneer species such as *Macaranga* and *Mallotus*. These fast-growing and short-lived trees are more susceptible to attack because the leaves are less tough or fibrous and more palatable to phytophagous insects (Coley 1983). Thus, the high defoliation was not due to the forest being logged but due to the presence of pioneer species which were preferred by the phytophagous insects. In this study, we realised that the sampling regime of 10 samples per site might not sufficiently characterised the forest sites of such high plant diversity but probably sufficient to represent the sites of the monocultures with low plant diversity.

The low defoliation levels observed in the plantations were probably due to low species richness and abundance of phytophagous insects. Human activities such as harvesting, manuring, weeding and chemical spraying in the oil palm plantation as well as thinning in acacia plantation might have affected the phytophagous insect fauna. Observations of pest damage in natural and plantation forests suggest that in most cases pest damage is more likely to occur in tree species monocultures than in tree species mixtures (Gibson & Jones 1977, Watt 1992). This evidence is, however, strongly biased towards observations on pests in plantation forestry only and defoliation is not well-studied in natural forests (Lowman 1992). Nonetheless, the results from this study should not be used to interpret overall herbivory in plantations. In a simple habitat such as a monoculture, certain phytophagous insect groups can prevail and become dominant over other groups, which may lead to an outbreak. Although not encountered in this study, this will consequently cause serious defoliation.

Phytophagous insect groups as predictors of defoliation levels

Among the three groups, phytophagous Coleoptera was the most species-rich and abundant. Many phytophagous Coleoptera, especially the leaf beetles (Chrysomelidae), weevils (Curculionidae) and scarabs (Scarabaeidae) are pests in the tropics. Windsor (1978) recorded Curculionidae as the most abundant diurnal insect herbivore group while Scarabaeidae were the most abundant nocturnal group, outnumbering Lepidoptera and Orthoptera. Browne (1968) reported that approximately 42 and 14% of the pests (including mammals and others) and pathogens of *Acacia* spp. and *Shorea robusta* respectively are beetles. One of the common defoliators of acacia is the gold dust weevil, *Hypomeces squamosus* (Curculionidae). It feeds on the leaf from the edge and extends inward

(Anonymous 1983, Hutacharern 1993). Chung (1998) observed that approximately 50% of the leaves of a dipterocarp, *Dipterocarpus applanatus,* are defoliated by *Exopholis hypoleuca* (Scarabaeidae). A number of beetles attack oil palms (Wood 1968, Dhileepan 1992, Hoong & Hoh 1992). One of the best known and most serious pests is the rhinoceros beetle, *Oryctes rhinoceros* (Scarabaeidae). This beetle attacked about 25% of the young oil palm area in Malaysia (Kamarudin & Wahid 1997), with adults feeding on leaves, unopened spears and, in some instances, on fruits and flowers. In this study, however, many of these commercially important pests were not sampled. This was because they were fairly large and robust, and could have flown quite a distance after being mist-blown. Many of the phytophagous beetle specimens sampled in this study were less than 1 cm in body length.

It is rather surprising that the lepidopteran larvae were not good predictors in any of the defoliation measurements. The lepidopteran larvae were found to be reliable predictors of defoliation levels on some temperate trees (Reid 1996). Lepidopteran larvae attack many of the oil palm, acacia and other forest trees. Leaf-eating caterpillars in the families Psychidae (bagworms) and Limacodidae (nettle and slug caterpillars) are the major pests in oil palm plantations (Hoong & Hoh 1992). Chey (1987) and Hutacharern (1993) reported many species of lepidopteran larvae defoliating acacia. However, despite the great diversity of forest Lepidoptera (over 120 000 species described worldwide), fewer than 15 species have been documented as forming outbreaks (Mason 1987). Many of the tropical lepidopteran larvae occur seasonally (Janzen 1993). This could be the reason for the very few larvae collected in this study. For example, the population of *Eurema blanda* (Lepidoptera) fluctuates markedly with season (Irianto *et al.* 1997). It decreases in the dry season and increases in the wet season. *Eurema blanda* is a serious defoliator in forest plantations, especially *Paraserianthes falcataria.* Leaf-eating caterpillars in oil palm plantation are also more abundant in the wet period (Hoong & Hoh 1992). This study was conducted before the wet season (the wet north-east monsoon begins in November and lasts until March) and, thus, could be the reason for fewer lepidopteran larvae sampled. Moreover, insecticide spraying in the oil palm plantation has undoubtedly suppressed the lepidopteran larvae population (Barbosa 1993). Perhaps the Coleoptera and Orthoptera have a faster recovery period because they are more mobile compared with the lepidopteran larvae.

The Orthoptera comprise the short-horned grasshoppers, katydids, locusts, crickets and other similar forms. Although the results showed that they were good predictor of the percentage of leaf eaten, they are not usually regarded as serious pests. *Nisitrus vittatus* is one of the most common crickets in this region. Both adult and nymph can cause considerable foliar damage to *Acacia mangium* seedlings (Chey 1996). Other species of Orthoptera that have been reported attacking *A. mangium* are *Valanga nigricornis* (Hutacharern 1993) and *Stenocatantops splendens* (Chey 1996). Orthoptera species have also been reported attacking oil palm but not to a serious extent (Wood 1968).

Conclusions

Defoliation is generally known to be more severe in monocultures but results in this study showed that the logged forest was most severely affected. This supports Lowman's (1992) claim that observations on defoliating pests have been biased towards plantations. The high defoliation level in the logged forest was attributed to the many fast-growing and short-lived tree species. Phytophagous Coleoptera members were better predictors of defoliation compared with lepidopteran larvae. Could this be a mere coincidence or have phytophagous Coleoptera always been underestimated as defoliators? Different environmental conditions, factors and population of predators prevail within a certain time frame and may affect the population dynamics of certain phytophagous insect groups at the study sites. In this case, the phytophagous Coleoptera might be a better predictor of defoliation during the time this study was conducted but may change at the same sites when conditions change.

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