Chung, A.Y.C., Maycock, C.R., Khoo, E., Chey, V.K. & Kendrick, R.C. (2011). New records of florivory on dipterocarp flowers. *Malayan Nature Journal* 63(3): 577-590.

New records of florivory on dipterocarp flowers

ARTHUR Y.C. CHUNG[1]*, COLIN R. MAYCOCK[1], EYEN KHOO[1], CHEY VUN KHEN[1] and ROGER C. KENDRICK[2]

Abstract. Mass flowering was observed at the Kabili-Sepilok Forest Reserve, Sabah from early to mid 2010, which provided an opportunity to study the insect florivores of the dipterocarp flowers. Twelve host dipterocarp species were investigated in this study, half of which were endemic to Borneo. Larvae of 20 lepidopteran species were documented feeding on the flowers. All are new records as there are few past studies on florivory in the dipterocarp canopy. The most frequently encountered species was *Etanna breviuscula* Walker (Lepidoptera: Nolidae), which was recorded from five dipterocarp species, followed by *Dudua aprobola* Meyrick (Lepidoptera: Tortricidae) and *Mesotrophe intortaria* Guenée (Lepidoptera: Geometridae). A few insect predators of the flower feeders were also observed.

Keywords: Florivory, dipterocarp flowers, Lepidoptera, mass flowering.

---

[1]*Forest Research Centre, Forestry Department, P. O. Box 1407, 90715 Sandakan, Sabah, Malaysia*
[2]*C&R Wildlife, 129 San Tsuen, Lam Tsuen, Tai Po, N.T., Hong Kong*
** Author for correspondence. Email: Arthur.Chung@sabah.gov.my*

INTRODUCTION

Mass flowering and mast fruiting of dipterocarps seem to occur on an irregular five to seven year cycle in both Peninsular Malaysia and Borneo, and this can be related to a decrease in rainfall and prolonged drought (MacKinnon et al. 1996, Sakai et al. 2006). Appanah (1993) noted that the environmental cue for this mass flowering can be traced to a small dip of about 2˚C below the mean night-time temperature for a few nights during El Niño events. During heavy flowering, almost half of the mature individuals and over 80% of the canopy and emergent tree species in a forest may flower simultaneously over a short period of three to four months. From March to June 2010, a mass flowering event occurred in many dipterocarp forests throughout

eastern Sabah, including the Kabili-Sepilok Forest Reserve. This paper documents observations of insect florivory of dipterocarp flowers made during this event.

At the same time, there is a proliferation of insects, such as pollinators and florivores visiting the flowers due to the super-abundance of food. There is a migration of pollinators, *e.g.* thrips and bees from the fringes of forest to forage on the flowers (Appanah 1993), followed by seed predators when the fruits are being formed. A few hypotheses have been proposed to explain this phenomenon. One of the widely accepted hypotheses is insect-related, that is the predator-satiation theory (Begon et al. 1996), which suggests that through synchronization of fruiting at around the same time, it not only prevents the build-up of seed predator population, the heavy fruiting is also a means of defence to prevent seed predators from wiping out the whole crop of seeds, thus ensuring survival of some of the seeds to germinate and grow into seedlings.

Florivory and seed predation are among the factors that can regulate the reproductive success of plants. Insects that consume flower buds and flowers can destroy much of the plant potential seed crop and seed predators often kill a majority of the seeds produced by the plant (Janzen 1971). Studies have shown that pre-dispersal seed predation by insects could be extremely severe, frequently leading to losses greater than 50% of the total seed crop (Fenner and Thompson 2005). Dipterocarp seed predation was investigated by Daljeet-Singh (1974), Chey (1986, 2002) and Nakagawa et al. (2005). The predators were mainly weevils (Coleoptera: Curculionidae) and micromoths (Lepidoptera: Pyralidae and Tortricidae), feeding on the seeds collected from the forest floor (Chey 2002). Comparatively, information on dipterocarp florivory is scarce because of the inaccessibility and difficulty of getting to the towering dipterocarp canopy to sample the flower feeders. This study was made possible with the skill of the second author in tree climbing.

STUDY AREA

The study was conducted at the Kabili-Sepilok Forest Reserve. It is situated on the east coast of Sabah (5˚ 45’ N 117˚ 45’ E), adjoining the Sandakan Bay. Covering an area of 4,294 ha, it is a rich tropical rain forest comprising the lowland dipterocarp forest (about 30 m above sea level), sandstone hill dipterocarp forest, and heath forest with mangrove forest at the southern part of the reserve. It is estimated that more than 450 species of trees found in the Kabili-Sepilok Forest Reserve and almost 40% of the known dipterocarps in Sabah are recorded here. The dipterocarps are of prime importance to the economy of Sabah (Fox 1973).

The mean daily temperature is 30˚C. Annual rainfall averages 3,100 mm while maximum humidity is to about 90%. Based on the temperature and rainfall scale in the Holdridge Life Zone Classification scheme in Groombridge (1992), this area is classified as tropical lowland moist forest. This forest is situated on the Sandakan Formation of mudstone and siltstone. Red yellow podzolic soils are widespread, with alluvial soils on the lower reaches of the rivers (Fox 1973).

Originally established as an area for conducting experimental forestry techniques, the reserve has become better known as a place for rehabilitation for orphaned orang-utans (*Pongo*

pygmaeus). The Orang-utan Rehabilitation Centre, Forest Research Centre and Rainforest Discovery Centre are situated at the northern edge of the reserve (Fig. 1).

MATERIALS AND METHODS

Fresh flowers were obtained from the lowland dipterocarp forest canopy in the early morning and late evening between March and June, 2010 through mixed rope climbing techniques. The flowers were also sampled from the canopy bridge at the Rainforest Discovery Centre, Sepilok. Dipterocarp flowers that were sampled with florivores in this study are listed in Table 1. Half of the host tree species are endemic to Borneo. Florivores from the flowers of *Dipterocarpus caudiferus* and *D. confertus* (both Bornean endemics), and *D. humeratus* were also sampled but none of the insect adults emerged. Hence, they are not listed in Table 1.

Any insect larva that was spotted feeding on the dipterocarp flowers was collected and placed in a plastic container embedded with tissue paper. The life cycle of the larva was monitored in captivity at a mean temperature of 28˚C. The larva was fed with dipterocarp flowers of the same species until it pupated. Close-up photographs of various stages of the insect were taken with a Nikon DSLR camera D300 with 105 mm macro lens to facilitate monitoring and identification. Emerged adult florivores were killed and put in triangle papers, placed in a container of a refrigerator at 8˚C. When the florivore breeding stage was over, representatives of the insect species were dry-mounted and the specimens (including unmounted specimens) are deposited at the Insect Museum of the Forest Research Centre, Sepilok.

Identification of the adult moth specimens was based on Holloway (1985, 1989, 1996, 1997, 1998, 2003, 2009), Robinson et al. (1994) and Baixeras et al. (2009), while the identification of butterfly specimens was based on Seki et al. (1991). The fifth author identified many of the difficult insect species. Determination of whether host plant records were new was mainly based on Robinson et al. (2001) and other sources through internet search.

RESULTS

Larvae of 20 lepidopteran species were documented feeding on dipterocarp flowers at the Kabili-Sepilok Forest Reserve (Table 2). The most frequently encountered flower predator was *Etanna breviuscula* Walker (Lepidoptera: Nolidae), which was recorded from five dipterocarp species. Hence, it was the most important species, followed by *Dudua aprobola* Meyrick (Lepidoptera: Tortricidae) and *Mesotrophe intortaria* Guenée (Lepidoptera: Geometridae). Most of the flower feeders were small in size, measuring between 10 to 20 mm. As such, their life cycle was relatively short and this would enable the insects to complete their life cycle on the flowers. Similarly, the dipterocarp pollinators, *i.e*. thrips, have very short generation time of eight days and an average fecundity of 27 eggs per female, allow them to rapidly increase their population as soon as the millions of flower buds appear on each tree (Appanah 1993, MacKinnon et al. 1996). The biggest flower feeder recorded from this study was the larva of *Cypa decolor* Walker (Lepidoptera: Sphingidae), measuring up to 50 mm. To achieve this size, it fed voraciously and pupated within a short period.

DISCUSSION

All the dipterocarp florivores in this study are recorded for the first time. The description, life cycle and other ecological information of the new records are provided here.

Comibaena attenuata Warren (Lepidoptera: Geometridae: Geometrinae)

This is an interesting species because of its ingenious camouflage strategy of the larva. The body of this looper was wrapped with silken thread in which fragments of the host plant flowers were attached to it (Fig. 2.1). Such an appearance would make it difficult for predatory or parasitic insects to spot it. It was always in a highly looped posture, rocking backwards and forwards. The looper was only about 10 mm in length. Pupation was in loose, silken cocoon, also incorporating flower particles and frass. The pupa was brown, measuring 8 mm.

After seven days, the adult moth emerged (Fig. 2.2). In contrast to the cryptic appearance of the larval and pupal stages, the moth was rather spectacular, with bright chartreuse green and uniform brown patches on both fore- and hindwings. It was identified as *Comibaena attenuata* Warren, based on Holloway (1996). The emerged adult was a male, as the antennae were strongly bipectinate. The body length was 10 mm, while the wing span of this moth was 20 mm.

Robinson et al. (2001) recorded larvae of this species feeding on flowers and leaves of *Nephelium lappaceum*; *Shorea xanthophylla* is a new record. Another similar looper was found feeding on the flowers of *Shorea multiflora*. It pupated, but the adult did not emerge. Hence, the species could not be determined and remained as *Comibaena* sp.

Hemithea marina Butler (Lepidoptera: Geometridae: Geometrinae)

This is another small species, with a wing span of 20 mm and body length of 10 mm, darker and bluer green in colour (Fig. 2.3). Descriptions of the larva and pupa are given by Holloway (1996). The larva feeds on the flowers, young leaves and pods of a variety of plants from Leguminosae, Cruciferae, Rutaceae, Euphorbiaceae, Verbenaceae, Anacardiaceae, Fagaceae and Melastomataceae (Holloway 1996, Robinson et al. 2001). Dipterocarpaceae has not been recorded previously.

Ornithospila submontrans Walker (Lepidoptera: Geometridae: Geometrinae)

Compared with *Comibaena attenuata*, this is a larger species with a wing span of 38 mm and a body length of 15 mm, and with a much brighter chartreuse green (Fig. 2.4). Species within this genus are very similar in appearance. *Ornithospila submontrans* can be distinguished from others by the wavy wing fasciae and a red discal chevron mark on the hindwing. This species is common in the lowland but was found as high as almost 2000 m (Holloway 1996). Unlike *C. attenuata*, this looper did not conceal itself with floral debris. It was a broad-sized looper, yellowish-green in colour measuring up to 25 mm (Fig. 2.5). Pupation was about 8 days. The larva was recorded feeding on the leaves of *Shorea parvifolia* (Robinson et al. 2001).

Unidentified Eupitheciini moths (Lepidoptera: Geometridae: Larentiinae)

Three species of unidentified, small geometrid moths from the tribe Eupitheciini were recorded feeding on dipterocarp flowers. Eupitheciini sp. 1 (0960) fed on the flowers of *Shorea xanthophylla*. The adult has a wing span of 14 mm and a body length of 6 mm (Fig. 2.6). Eupitheciini sp. 2 (0995), with a wing span of 17 mm and a body length of 7 mm fed on *Parashorea tomentella* (Fig. 2.7). The third species, Eupitheciini sp. 3 (0997) was the smallest, with a wing span of 14 mm and a body length of only 5 mm, fed on *Shorea xanthophylla* (Fig. 2.8). The larvae of many Eupitheciini species are florivores (Holloway 1997, Porter 1997).

Mesotrophe intortaria Guenée (Lepidoptera: Geometridae: Sterrhinae)

This species is cream in colour, dotted with reddish pigments, with a wing span of 25 mm and a body length of 8 mm (Fig. 2.9). A few specimens emerged from the flowers of *Shorea acuminatissima* and *S. argentifolia*. All were females. Description of both sexes is given by Holloway (1997). This species is uncommon, recorded from lowland secondary forest and *Eucalyptus deglupta* plantation. There had been no hostplant information (Robinson et al. 2001).

Rapala manea ingana Fruhstorfer (Lepidoptera: Lycaenidae: Lycaeninae)

This is the only butterfly recorded from this study, feeding on *Shorea argentifolia* and *S. johorensis*. The brownish-green larva had characteristically soft, spiny tubercles along its body (Fig. 2.10). The mature larva measured up to 18 mm. Pupation was about 10 days. The emerged adult has a wing span of 30 mm and a body length of 13 mm. Like many other Lycaenidae, the

upperside of the wings was deep blue while the underside was brown. It has a distinct tornus with a dark spot surrounded by a white line at the posterior corner of the hindwing (Fig. 2.11). The larva feeds on a variety of plants, including *Bauhinia blakeana*, *Lantana camara* and *Nephelium lappaceum* (Seki et al. 1991, Robinson et al. 2001).

Prometopus asahina Kobes (Lepidoptera: Noctuidae: Amphipyrinae)

This species has greenish forewings, more brownish towards the dorsum and a conspicuous white patch in the middle of the forewing. The larva was quite unusual, green in colour with dorsal and dorsolateral thin longitudinal white stripes, and three dorsal conical tubercles in the middle segments (Fig. 2.12). The mature larva measured up to 30 mm. The pupal stage lasted more than two weeks. The emerged adult has a wing span of 22 mm and a body length of 12 mm. Holloway (1989) noted that this species was found in lowland rain forest and dry heath forest. No information is provided on the hostplant (Robinson et al. 2001).

Eublemma commoda Walker (Lepidoptera: Noctuidae: Eublemminae)

The larvae of this genus can be easily mistaken as a Geometridae because of their looper-like appearance. It is a beautiful caterpillar with prominent spoon-like setae (Fig. 2.13). Detailed descriptions of the larva and pupa are provided by Holloway (2009). From this study, the mature larva measured up to 20 mm. The pupal stage was about 13 days. The emerged adult was rather dull, grayish-brown with a wing span of 22 mm and a body length of 9 mm (Fig. 2.14). The crenate margins of the wings and the strong tornal black bar at the hindwing are distinctive features of this species. Besides lowland and lower montane forests, Chey (1994) also recorded this species from lowland softwood plantations. The recorded larval hostplants are from the plant family Sapindaceae, Oleaceae, Melastomataceae and Anacardiaceae (Holloway 2009, Robinson et al. 2001).

Eublemma abrupta Walker (Lepidoptera: Noctuidae: Eublemminae)

This is another interesting looper-like caterpillar, with conical tubercles and setae along its body. A detailed description is given by Holloway (2009). The blackish larva moved in a highly looped manner among the flowers (Fig. 2.15). The mature larva measured about 15 mm. The pupal stage lasted about two weeks and the emerged orangey moth has a wing span of 15 mm and a body length of 8 mm. While in resting position, a broad horizontal line is prominent, running across the wings. The pale whitish spot at both ends of the line is a distinctive feature of this species (Fig. 2.16). This species has been recorded from lowland and highland, up to 1,600 m. The larva feeds on a variety of plants from Melastomataceae, Anacardiaceae, Euphorbiaceae, Leguminosae, Moraceae, Oleaceae, Rutaceae, Sapindaceae and Verbenaceae (Holloway 2009).

Penicillaria meeki Bethune-Baker (Lepidoptera: Noctuidae: Euteliinae)

The stout, cylindrical larva was green in colour (including the head) and measured up to 16 mm (Fig. 2.17). After about two weeks of pupation, the adult emerged. The moth has a wing span of 20 mm and a body length of 9 mm. The forewings were reddish black while the hindwings were

basally white with a broad border of greyish black. Details of the adult description are given by Holloway (1985). There is no hostplant information provided by Robinson et al. (2001).

Etanna breviuscula Walker (Lepidoptera: Nolidae: Chloephorinae)

The identification of this species was difficult and was earlier mistaken as an olethreutine Tortricidae. The colour intensity and pattern of the wings vary considerably (Fig. 2.18). Our species identification was later confirmed by the larval description provided by Holloway (2003). The distinctly segmented, brownish cylindrical larva measured up to 17 mm (Fig. 2.19). The pupal stage was about two weeks. Details of the pupa and adult are also given by Holloway (2003). This was the commonest species feeding on dipterocarp flowers in Sepilok in this study. It is a widely distributed species from the coastal area to the upper montane zone at around 1,800 m. Family hostplant records for both flower and foliage feeding include Anacardiaceae, Leguminosae, Ulmaceae and Dipterocarpaceae (Holloway 2003, Robinson et al. 2001). In Dipterocarpaceae, only the genus *Shorea* was recorded. Hence, the five *Shorea* species recorded from this study are new records. There was another species, possibly an *Etanna* sp. that fed on the flowers of *Shorea almon* (Fig. 2.20).

Nola fasciata Walker (Lepidoptera: Nolidae: Nolinae)

This small lymantriid-like larva was about 15 mm in length when it was found feeding on the flowers of *Shorea xanthophylla* (Fig. 2.21). It was moderately hairy, black with orangey yellow lines on its body. The pupal stage was about 10 days. The emerged adult was white with some grey patterns on the forewings (Fig. 2.22). The wing span was 10 mm and the body length was 6 mm. This is a common and widely distributed species from lowland to about 1,500 m (Holloway 2003). The recorded larval host is *Lantana* of the family Verbenaceae (Robinson et al. 2001).

Unidentified (0928) (Lepidoptera: Pyralidae: Phycitinae)

Phycitinae moths generally rest with their wings tightly wrapped around a short, narrow body. The larvae are mostly internal feeders, boring in seeds, stems and galls (Robinson et al. 1994). In this study, an unidentified species (0928) was found feeding on the flowers of *Shorea xanthophylla* (Fig. 2.23). This species has a body length of 9 mm and resembles the typical ground plan and pattern of the genus *Assara*, some species of which are aphidophagous, *e.g. Assara subterebrella* (Snellen 1880) from Sumatra and Peninsular Malaysia (Roesler 1983).

Many phycitines are well known stored-product pests (*e.g. Plodia interpunctella, Cadra cautella*, *Ephestia* spp.), as well as stem and seed borers (Robinson et al. 1994).

Cypa decolor Walker (Lepidoptera: Sphingidae)

This was the largest species sampled from the dipterocarp flowers in this study. The voracious, green caterpillar measured up to 50 mm (Fig. 2.24). The yellowish 'horn' at the dorsal part is a familiar feature of Sphingidae larvae. The pupal stage was only six days, which was shorter than many of the smaller moths. The pupa was dark brown, measuring 27 mm. The emerged hawk-

like, brown adult has a wing span of 32 mm and a body length of 22 mm (Fig. 2.25). Descriptions of the male and female adults are given by Holloway (1998). The moth is found in the lowlands and distributed up to 2,000 m. This larva was observed feeding only on the flowers and not the leaves of its hostplant *Dryobalanops lanceolata*. Robinson et al. (2001) recorded *Dipterocarpus tuberculatus* as its hostplant.

Dudua aprobola Meyrick (Lepidoptera: Tortricidae: Olethreutinae)

The forewing colour and pattern of this species are rather variable, ranging from brownish shade to dark greyish blue (Fig. 2.26). Description of this species is given by Robinson et al. (1994). Identification was also based on images from Baixeras et al. (2009). The 15 mm mature larva was bluish white with a dark head capsule (Fig. 2.27). At the earlier instars, the larva was thin and very agile. The pupal stage lasted about eight days. The larva and pupa were often concealed within the flower tissues and debris. The adult had a wing span of 20 mm and a body length of 11 mm. Robinson et al. (1994) noted that this is one of the commonest species of Olethreutinae in S.E. Asia, feeding on a wide range of plants. It is known to be a polyphagous leafroller (Robinson et al. 2001).

Homona sp. (Lepidoptera: Tortricidae: Tortricinae)

Like many Tortricinae, this orangey brown moth is distinctly bell-shaped, with a wingspan of 16 mm and a body length of 8 mm (Fig. 2.28). The whitish, slender larva with a dark, shining head was about 20 mm in length. Pupal stage was about 12 days. Hostplants for the genus *Homona* are from the family Rubiaceae, Lauraceae, Leguminosae, Rosaceae, Sapotaceae, Sterculiaceae and Verbenaceae (Robinson et al. 2001). Hence, *Shorea parvifolia* of Dipterocarpaceae appears to be an undocumented larval host.

Predators of the dipterocarp flower feeders

While searching for florivores among the flowers of *Shorea argentifolia*, a few larvae of green lacewings, most likely *Chrysopa* sp. (Neuroptera: Chrysopidae) were sampled. They were small, measuring about 6 mm. Their body was covered with debris which camouflaged them (Fig. 2.29). With their prominent, sickle-like jaws, they are voracious predators, attacking insects of suitable size, especially soft-bodied ones, *e.g*. aphids and caterpillars (Hill and Abang 2005). The adult emerged after about 10 days. It was a delicate insect, bright green in colour, with a wing span of 26 mm and a body length of 10 mm. The adult feeds on pollen, nectar and honeydew supplemented by mites, aphids and other small arthropods but some *Chrysopa* species are predatory.

A parasitic wasp was recorded emerging from a container with a few pupae on *Shorea acuminatissima* flowers. The unidentified tiny wasp (Hymenoptera: Ichneumonidae) was about 9 mm in length (Fig. 2.30).

ACKNOWLEDGEMENTS

We thank the Director of the Sabah Forestry Department, Datuk Sam Mannan and the Deputy Director (R&D), Dr Lee Ying Fah for their support. Benny Tuzan, Richard Majapun, Kirsty Nutt, Momin Binti, John L. Yukang and Petronella Dasim have kindly assisted in this study. This project was funded by the Sabah State Government.

REFERENCES

Appanah, S. 1993. Mass flowering of dipterocarp forests in the aseasonal tropics. *Journal of Biosciences* 18: 457-474.

Ashton, P.S. 2004. Dipterocarpaceae. In *Tree Flora of Sabah and Sarawak* - Volume Five, ed. E. Soepadmo, L.G. Saw and Chung, R.C.K. Sabah Forestry Department, Forest Research Institute Malaysia & Sarawak Forestry Department, pp 63-388.

Baixeras, J., Brown, J.W. and Gilligan, T.M. 2009. T@RTS: online world catalogue of the Tortricidae (ver. 1.3.1). http://www.tortricidae.com/catalogue.asp.

Begon, M. Harper, J.L. and Townsend, C.R. 1996. *Ecology: Individuals, Populations, and Communities.* 3rd edition. Cambridge, Massachusetts, USA: Blackwell Science Ltd.

Chey, V.K. 1986. A preliminary report on insects infesting the fruits of some forest trees. *FRC Publication* No. 27. Sabah Forest Department.

Chey, V.K. 1994. Comparison of biodiversity between plantation and natural forests in Sabah using moths as indicators. Unpublished D.Phil. thesis, Oxford University. 284 pp.

Chey, V.K. 2002. Dipterocarp seed predators. *Malaysian Naturalist* 55: 46-49.

Daljeet-Singh, K. 1974. Seed pests of some dipterocarps. *Malaysian Forester* 37: 24-36.

Fenner, M. and Thompson, K. 2005. *The Ecology of Seeds.* Cambridge: Cambridge University Press.

Fox, J.E.D. 1973. A handbook to Kabili-Sepilok Forest Reserve. *Sabah Forest Record* No. 9. Sabah Forest Department.

Groombridge, B. (ed.) 1992. *Global Biodiversity - Status of the Earth's Living Resources*. London: WCMC, Chapman & Hall.

Hill, D. and Abang, F. 2005. *The Insects of Borneo*. Sarawak: Universiti Malaysia Sarawak.

Holloway, J.D. 1985. Moths of Borneo (part 14): family Noctuidae: subfamilies Euteliinae, Stictopterinae, Plusiinae, Pantheinae. *Malayan Nature Journal* 38: 157-317.

Holloway, J.D. 1989. *The Moths of Borneo (Part 12): Family Noctuidae, trifine subfamilies: Noctuinae, Heliothinae, Hadeninae, Acronictinae, Amphipyrinae, Agaristinae*. Kuala Lumpur: Southene Sdn. Bhd.

Holloway, J.D. 1996. The moths of Borneo: family Geometridae, subfamilies Oenochrominae, Desmobathrinae and Geometrinae. *Malayan Nature Journal* 49: 147-326.

Holloway, J.D. 1997. The moths of Borneo (part 10): family Geometridae, subfamilies Sterrhinae & Larentiinae. *Malayan Nature Journal* 51: 1-242.

Holloway, J.D. 1998. *The Moths of Borneo (Part 3): Superfamily Bombycoidea: Families Lasiocampidae, Eupterotidae, Bombycidae, Brahmaeidae, Saturniidae, Sphingidae*. Kuala Lumpur: Southene Sdn. Bhd.

Holloway, J.D. 2003. *The Moths of Borneo (Part 18): Family Nolidae.* Kuala Lumpur: Southene Sdn. Bhd.

Holloway, J.D. 2009. The moths of Borneo (part 13): family Noctuidae, subfamily Pantheinae (part), Bagisarinae, Acontiinae, Aediinae, Eustrotiinae, Bryophilinae, Araeopteroninae, Aventiinae, Eublemminae and further miscellaneous genera. *Malayan Nature Journal* 62: 1-240.

Janzen, D.H. 1971. Seed predations by animals. *Annual Review of Ecology and Systematics* 2: 465-492.

MacKinnon, K., Hatta, G., Halim, H. and Mangalik, A. 1996. *The Ecology of Kalimantan, Indonesian Borneo*. Hong Kong: Periplus Editions (HK) Ltd.

Nakagawa, M., Takeuchi, Y., Kenta, T. and Nakashizuka, T. 2005. Predispersal seed predation by insects vs. vertebrates in six dipterocarp species in Sarawak, Malaysia. *Biotropica* 37: 389-396.

Porter, J. 1997. *The Colour Identification Guide to Caterpillars of the British Isles*. Middlesex, UK: Viking, Harmondsworth.

Robinson, G.S., Ackery, P.R., Kitching, I.J., Beccaloni, G.W. and Hernandez, L.M. 2001. *Hostplants of the Moth and Butterfly Caterpillars of the Oriental Region.* The Natural History Museum, London and Southdene Sdn. Bhd.

Robinson, G.S., Tuck, K.R. and Shaffer, M. 1994. *A Field Guide to Smaller Moths of South-east Asia.* The Natural History Museum, London and Malaysian Nature Society.

Roesler, U. 1983. Die Phycitinae von Sumatra (Lepidoptera: Pyralidae). *Heterocera Sumatrana* 3.

Sakai, S., Harrison, R.D., Momose, K., Kuraji, K., Nagamasu, H., Yasunari, T., Chong, L. and Nakashizuka, T. 2006. Irregular droughts trigger mass flowering in aseasonal tropical forests in Asia. *American Journal of Botany* 93: 1134-1139.

Seki, Y., Takanami, Y. and Otsuka, K. 1991. *Butterflies of Borneo*. Volume 2, No. 1 – Lycaenidae. Japan: Tobishima Corporation.

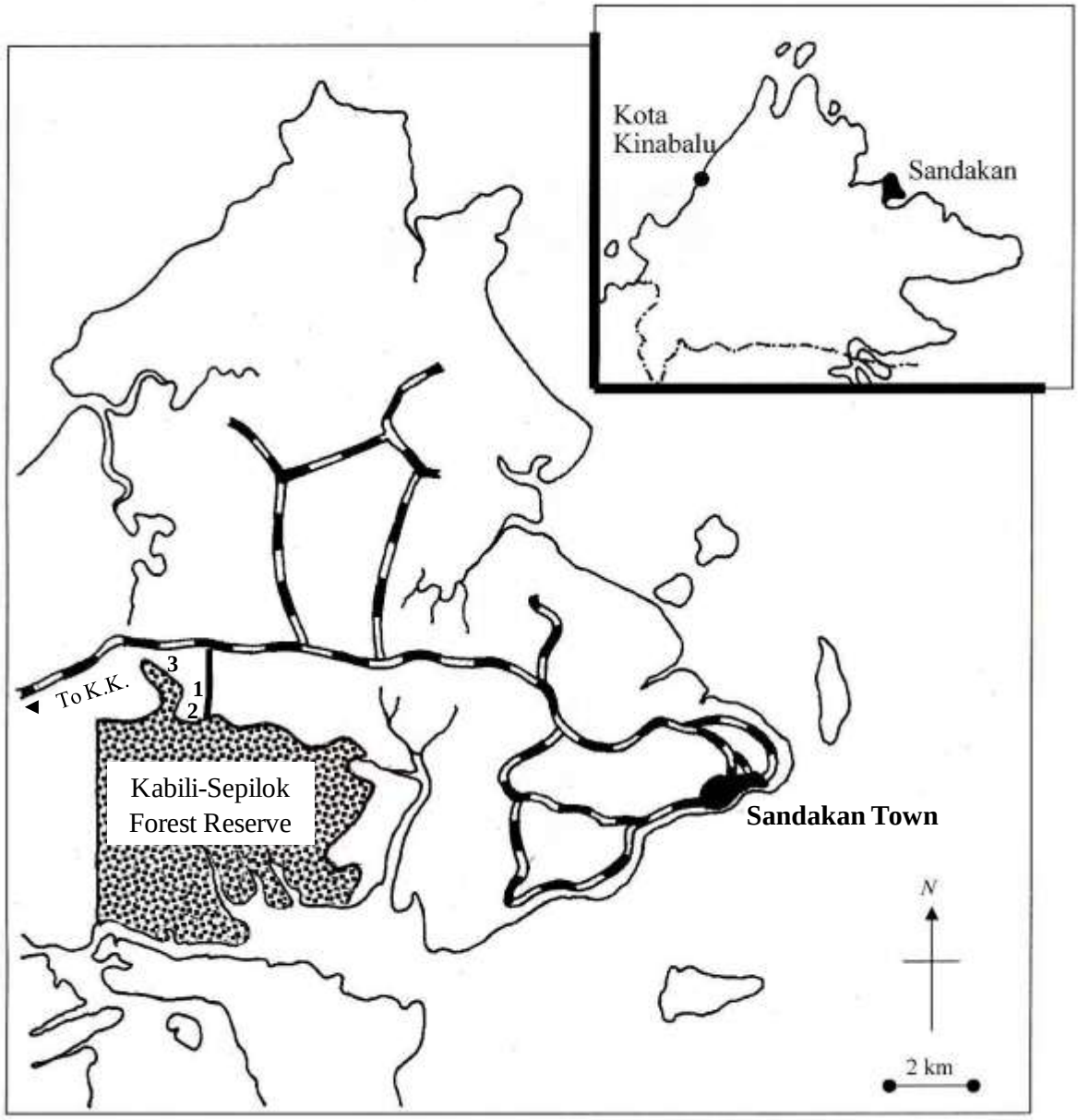


Figure 1. Location of Sandakan in Sabah (Inset), and the Kabili-Sepilok Forest Reserve (dotted area), (1 = Forest Research Centre; 2 = Orang-utan Rehabilitation Centre; 3 = Rainforest Discovery Centre).

Table 1. Host dipterocarp species (Dipterocarpaceae) that were investigated in this study.

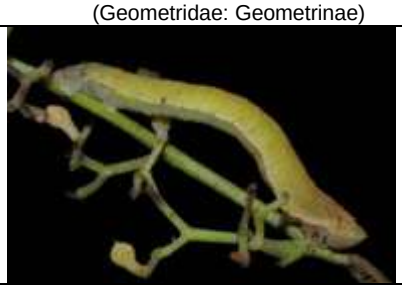
No.	Species	Vernacular name	Distribution	No. of flowers examined
1	*Dryobalanops lanceolata* Burck	Kapur paji	Endemic to Borneo but common and widespread in Sabah	100-200
2	*Parashorea tomentella* (Sym.) Meijer	Urat mata beludu	Endemic to Borneo, found in Sabah and East Kalimantan	100-200
3	*Shorea acuminatissima* Sym.	Seraya kuning runcing	Endemic to Borneo	1,000-2,000
4	*Shorea almon* Foxw.	Seraya kerukup	Borneo and Philippines	1,000-2,000
5	*Shorea argentifolia* Sym.	Seraya daun mas	Endemic to Borneo	1,000-2,000
6	*Shorea gibbosa* Brandis	Seraya kuning gajah	Sumatra, Peninsular Malaysia, Singapore and Borneo	1,000-2,000
7	*Shorea johorensis* Foxw.	Seraya majau	Sumatra, Peninsular Malaysia and Borneo	1,000-2,000
8	*Shorea multiflora* (Burck) Sym.	Banjutan	Sumatra, Peninsular Malaysia and Borneo	1,000-2,000
9	*Shorea parvifolia* Dyer	Seraya punai	Peninsular Thailand, Peninsular Malaysia and Borneo	1,000-2,000
10	*Shorea seminis* (de Vriese) van Slooten	Selangan batu terendak	Borneo and Philippines	1,000-2,000
11	*Shorea symingtonii* Wood	Melapi kuning	Endemic to Borneo	100-200
12	*Shorea xanthophylla* Sym.	Seraya kuning barun	Endemic to Borneo	1,000-2,000

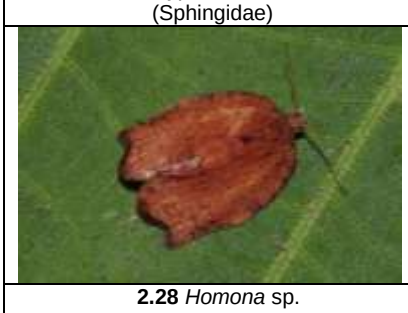
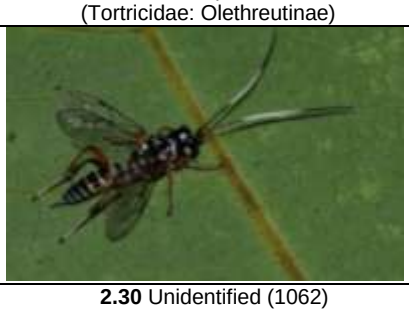
Source: Ashton (2004)

Table 2. Lepidopteran dipterocarp florivores recorded at the Kabili-Sepilok Forest Reserve.

No.	Family	Subfamily	Species	Host tree(s)	No. of adults bred
1	Geometridae	Geometrinae	*Comibaena attenuata* Warren	*Shorea xanthophylla*	1
2		Geometrinae	*Comibaena* sp.	*Shorea multiflora*	1
3		Geometrinae	*Hemithea marina* Butler	*Shorea gibbosa*	1
4		Geometrinae	*Ornithospila submontrans* Walker	*Shorea xanthophylla*	1
5		Larentiinae	Eupitheciini sp. 1 (0960)	*Shorea xanthophylla*	2
6		Larentiinae	Eupitheciini sp. 2 (0995)	*Parashorea tomentella*	1
7		Larentiinae	Eupitheciini sp. 3 (0997)	*Shorea xanthophylla*	1
8		Sterrhinae	*Mesotrophe intortaria* Guenée	*Shorea acuminatissima* *Shorea argentifolia*	6
9	Lycaenidae	Lycaeninae	*Rapala manea ingana* Fruhstorfer	*Shorea argentifolia* *Shorea johorensis*	5
10	Noctuidae	Amphipyrinae	*Prometopus asahina* Kobes	*Shorea argentifolia*	1
11		Eublemminae	*Eublemma commoda* Walker	*Shorea argentifolia*	1
12		Eublemminae	*Eublemma abrupta* Walker	*Shorea acuminatissima*	1
13		Euteliinae	*Penicillaria meeki* Bethune-Baker	*Shorea xanthophylla*	3
14	Nolidae	Chloephorinae	*Etanna breviuscula* Walker	*Shorea acuminatissima* *Shorea argentifolia* *Shorea gibbosa* *Shorea parvifolia* *Shorea symingtonii*	16
15		Chloephorinae	?*Etanna* sp.	*Shorea almon*	1
16		Nolinae	*Nola fasciata* Walker	*Shorea xanthophylla*	1
17	Pyralidae	Phycitinae	Unidentified (0928)	*Shorea xanthophylla*	4
18	Sphingidae		*Cypa decolor* Walker	*Dryobalanops lanceolata*	1
19	Tortricidae	Olethreutinae	*Dudua aprobola* Meyrick	*Parashorea tomentella* *Shorea xanthophylla*	9
20		Tortricinae	*Homona* sp.	*Shorea parvifolia*	1

Figure 2. Lepidopteran dipterocarp florivores (Figures 2.1-2.28) at the Kabili-Sepilok Forest Reserve, Sabah, and predators of the florivores (Figures 2.29-30).

		
2.1 *Comibaena attenuata* larva (Geometridae: Geometrinae)	**2.2** *Comibaena attenuata* adult (Geometridae: Geometrinae)	***2.3*** *Hemithea marina* (Geometridae: Geometrinae)
		
2.4 *Ornithospila submontrans* adult (Geometridae: Geometrinae)	**2.5** *Ornithospila submontrans* larva (Geometridae: Geometrinae)	**2.6** Eupitheciini sp. 1 (Geometridae: Larentiinae)
		
2.7 Eupitheciini sp. 2 (Geometridae: Larentiinae)	**2.8** Eupitheciini sp. 3 (Geometridae: Larentiinae)	***2.9*** *Mesotrophe intortaria* (Geometridae: Sterrhinae)
		
2.10 *Rapala maena* larva (Lycaenidae: Lycaeninae)	**2.11** *Rapala maena* adult (Lycaenidae: Lycaeninae)	***2.12*** *Prometopus asahina* (Noctuidae: Amphipyrinae)
		
2.13 *Eublemma commoda* larva (Noctuidae: Eublemminae)	**2.14** *Eublemma commoda* adult (Noctuidae: Eublemminae)	**2.15** *Eublemma abrupta* larva (Noctuidae: Eublemminae)

		
2.16 *Eublemma abrupta* adult (Noctuidae: Eublemminae)	**2.17** *Penicillaria meeki* larva (Noctuidae: Euteliinae)	**2.18** *Etanna breviuscula* adult (Nolidae: Chloephorinae)
		
2.19 *Etanna breviuscula* larva (Nolidae: Chloephorinae)	**2.20** ?*Etanna* sp. (Nolidae: Chloephorinae)	**2.21** *Nola fasciata* larva (Nolidae: Nolinae)
		
2.22 *Nola fasciata* adult (Nolidae: Nolinae)	**2.23** Unidentified (0928) (Pyralidae: Phycitinae)	**2.24** *Cypa decolor* larva (Sphingidae)
		
2.25 *Cypa decolor* adult (Sphingidae)	**2.26** *Dudua aprobola* adult (Tortricidae: Olethreutinae)	**2.27** *Dudua aprobola* larva (Tortricidae: Olethreutinae)
		
2.28 *Homona* sp. (Tortricidae: Tortricinae)	**2.29** ?*Chrysopa* sp. larva (Neuroptera: Chrysopidae)	**2.30** Unidentified (1062) (Hymenoptera: Ichneumonidae)