Journal of Tropical Forest Science 11(1):61–78 (1999)

THE IMPACT OF LOGGING ON GEOMETROID MOTH POPULATIONS AND THEIR DIVERSITY IN LOWLAND FORESTS OF PENINSULAR MALAYSIA

J. Intachat,

Forest Research Institute Malaysia, Kepong, 52109 Kuala Lumpur, Malaysia

J. D. Holloway

Department of Entomology, The Natural History Museum, Cromwell Road, London WS7 5BD, United Kingdom

&

M. R. Speight

Department of Zoology, Oxford University, South Parks Road, Oxford, OX1 3PS, United Kingdom

Received December 1996

INTACHAT, J., HOLLOWAY, J. D. & SPEIGHT, M. R. 1999. The impact of logging on geometroid moth populations and their diversity in lowland forests of Peninsular Malaysia. Direct comparisons between geometroid moth samples collected from paired sites in primary forests and logged, secondary forests of the same type around Peninsular Malaysia showed that species diversity (α) did not differ significantly between logged and unlogged forests. However, there was some reduction in the numbers of species and abundance of individuals in the logged forests. There was also a shift in geometroid moth species composition. The higher number of unique species in primary forests indicates that, even after considering that a well-managed logged forest is able to sustain the majority of the original species, the danger of disappearance of specialist species is still present.

Key words: Moths - impact - logging - lowland forests - Peninsular Malaysia

INTACHAT, J., HOLLOWAY, J. D. & SPEIGHT, M. R. 1999. Kesan pembalakan ke atas populasi dan kepelbagaian rama-rama geometroid di hutan tanah pamah Semenanjung Malaysia. Perbandingan secara langsung antara sampel dua rama-rama geometroid yang dikutip dari pasangan tempat dalam hutan primer dan hutan yang telah dibalak daripada jenis hutan yang sama di sekitar Semenanjung Malaysia menunjukkan bahawa kepelbagaian spesies (α) tidak berbeza secara bererti antara hutan yang telah dibalak dan hutan yang belum dibalak. Walau bagaimanapun, terdapat pengurangan bilangan spesies dan kelimpahan individu di hutan yang telah dibalak. Terdapat juga peralihan komposisi spesies rama-rama geometroid. Bilangan spesies unik yang tinggi di hutan-hutan primer menandakan bahawa setelah diambil kira bahawa pengurusan pembalakan hutan yang baik mampu untuk menampung sebahagian besar spesies-spesies asli tetapi kehilangan spesies-spesies yang pakar masih wujud.

Introduction

Many foresters view the process of logging as a modification (intensification) of the process of natural tree falls that is a part of the pattern of natural disturbance in forests. The theories of tree falls and gap dynamics have been developed principally through the study of patterns and processes in natural forest disturbances (Attiwill 1994). Such studies have provided the basis for many forest management strategies.

There has been extensive research on tree fall and gap dynamics (see Pickett 1983, Canham 1989, Platt & Strong 1989, Whitmore 1989, Denslow & Spies 1990). All seem to support Grubb's (1977) conclusions that tree fall creates a wide diversity of gaps. Plant species which might fill in these gaps have varying ecological requirements. For instance, understorey shrub species have different growth requirements compared to regenerating pioneer tree species, and competition between the two groups of plant species might arise depending on which one establishes first (Denslow & Spies 1990). Such disturbances change the species composition and community structure and function at a given site and thus increase the heterogeneity and variability of that site. Martínéz-Ramos *et al.* (1988) suggest that it is the temporal and spatial variance of tree fall disturbances which provides for greater diversity in tropical forests compared with temperate ones. However, to date, there have been no detailed analyses comparing species diversity in tropical forests in relation to the frequency and intensity of tree fall, be it natural or enhanced by logging or other drastic types of disturbance.

With the concept of selective logging in mind, Attiwill (1994) proposed:

> *'Harvesting a forest for all of its benefits, including its timber products, can be controlled so that it creates a disturbance, the effects of which do not differ from those of natural disturbance'.*

If this is true, then the diversity of natural primary forests and secondary forests where logging has been carried out under controlled conditions should not differ significantly at any given locality.

Attiwill's proposal has been investigated using various groups of insects. These include dung beetles (Nummelin & Hanski 1989), coccinellid beetles (Nummelin & Fursch 1992) and butterflies (Hill *et al.* 1995). This paper, however, investigates Attiwill's proposal in relation to geometroid moth (Lepidoptera: Geometroidea) populations and diversity by directly comparing primary and secondary forests. Primary in this case refers to pristine unlogged forest, while secondary refers to forests where logging, usually selective logging, has been carried out. Due to logistic constraints and the availability of areas for such direct comparison, only six different localities were strategically sampled around Peninsular Malaysia for this pilot study.

Materials and methods

The sites

For each locality, samples collected from the primary and secondary forests were treated as pairs. Six paired sites (Figure 1) were chosen within the lowland forest categories (Wyatt-Smith 1995). Each pair of sites consisted of primary and secondary (logged-over forest), and the two sites in each were at least 3 km apart except for that at Panti (250 m apart). Samples from the logged areas were obtained from areas where a modified Malayan Uniform System (MUS) (Wyatt-Smith 1995) logging method had been applied, mostly in the 1970s.

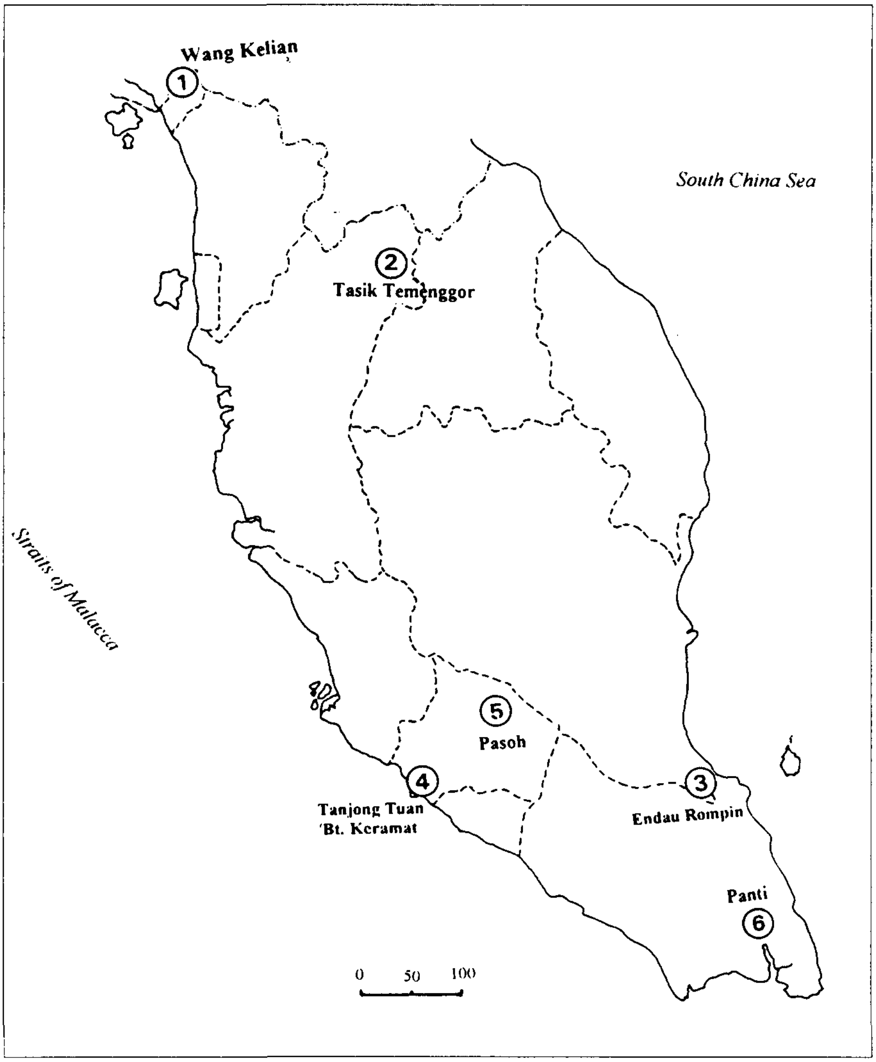

Figure 1. Sites with sampling pairs

Vegetation description

Pair 1: Rompin Endau

The natural state of the forest here was characterised by poor drainage with the presence of Dipterocarpaceae of the genus *Dipterocarpus*, such as *D. baudii*, *D. cornutus* and *D. costulatus*: these are often associated with *Dryobalanops oblongifolia*, *Hopea mengarawan* and *Shorea lepidota* (Wyatt-Smith 1995). Other common species are *Koompassia malaccensis* and *Palaquium* spp. The secondary forest site in this area was logged in the early 1970s, and trails for many vehicles accessing other areas pass through it.

Pair 2: Tasik Temenggor

Gyekis (1967) categorised the forest in this area of Perak near the border with Thailand as Red Meranti-Merbau Lowland Forest. Species of the Red Meranti group of *Shorea* (Dipterocarpaceae) such as *S. acuminata*, *S. leprosula*, *S. macroptera*, *S. ovalis* and *S. parvifolia* are the commonest and, with merbau (*Intsia palembanica*), make up the majority of the important species. Other important species include *Cynometra inaequifolia*, *Dialium platysepalum*, *Cedrela serrata* and *Koompassia excelsa*. The virgin forest site was selected 200 m up the ridge trail from the base camp of the Malaysian Nature Society Belum Project while the logged site was about 10 min boat ride from the base camp and about 100 m from the boat landing. The secondary site was logged in the early 1970s.

Pair 3: Wang Kelian

The forest at the extreme northwest of the Peninsula was categorised as White Meranti-Gerutu (seasonal) type by Wyatt-Smith (1995), with a mixture of vegetation on limestone. Among the common species found of the White Meranti group of the genus *Shorea* were *Shorea hypochra*, *S. sericeiflora*, *S. assamica* f. *globifera* and *S. talura*. Other common species of Dipterocarpaceae are *Parashorea lucida*, *Hopea ferrea*, *Dipterocarpus grandiflorus* and *Anisoptera oblonga*. On the limestone, clumps of *Pandanus* spp. and small herbs and rockface species in the family Gesneriaceae such as *Boea* spp., *Paraboea* spp. and *Chirita* spp. are common. The secondary site was logged in the early 1970s.

Pair 4: Pasoh

A major part of the Pasoh Forest Reserve is under lowland dipterocarp forest of 'Mixed Red Meranti' forest merging into 'Red Meranti' forest (Salleh 1968). It was described by (Wyatt-Smith 1995) as lowland dipterocarp forest of the central and southern 'Red Meranti-Keruing' type. This forest is covered with about 1000 ha of hill dipterocarps towards the northeastern boundary. Approximately 650 ha is in pristine condition, while the surrounding buffer zone comprises regenerating lowland forest that was selectively logged between 1955 and 1960. Within an area of 50 ha, a total of 335 256 trees with stems above 1 cm diameter breast height (dbh) from 814 species, 294 genera and 78 families have been recorded (Manokaran *et al.* 1992). The most common smaller trees are in the families Euphorbiaceae and Annonaceae. Dipterocarpaceae, Leguminosae and Burseraceae species are among the bigger trees. The logged site in this study was situated near the edge of the regenerated forest and was illegally logged in the early 1990s.

Pair 5: Panti

Classified as a primary lowland dipterocarp forest, the primary area has an emergent layer that is even at 30 m in height. Among the common species occurring in the area were *Koompassia malaccensis, Shorea parvifolia, Hopea nervosa, Scaphium macropodum, Dipterocarpus verucosus* and *Parkia speciosa.* The main canopy was at approximately 22 m with *Elateriospermum tapos, Calophyllum pulcherrimum, Artocarpus maingayi, Palaquium maingayi* and *Lithocarpus wallichianus* being the common species. Regeneration was good with the presence of *H. nervosa, D. verrucosus, Licuala* sp. and *Rhopaloblaste singaporensis.* Adjacent to the site is a newly (about 5-6 y) logged-over single tree layer secondary forest full of *Macaranga heynei, M. gigantea* and *Endospermum malaccense.* Traps were placed about 250 m apart, separated by a high slope.

Pair 6: Tanjong Tuan/Bukit Keramat

Covering an area of about 120 ha, the Tanjong Tuan (Cape Ricardo) Forest Reserve has been designated as a Virgin Jungle Reserve (VJR). In the remaining high forest, a variety of emergent tree species typical of coastal hills is found. The species include those from the family Dipterocarpaceae such as *Shorea curtisii, Dipterocarpus kerrii, D. grandiflorus* and *Artocarpus lanceifolius.* Other well-represented species that reach the emergent layer are *Alstonia angustifolia, Artocarpus maingayi, Dialium wallichii, Koompassia malaccensis, Shorea leprosula, S. parvifolia, S. pauciflora, Sindora coriacea* and *Swintonia schwenkii.* Bukit Keramat covers less than 20 ha and is managed as a reserve of the State Government of Negeri Sembilan. Several large emergent trees of *Ctenolophon parvifolius* and *Sindora coricea* stand out conspicuously. Although human encroachment into the forest is strictly prohibited, the forest was noted to be very disturbed. Some clearing or logging had obviously been carried out in the area, though no records were available. These sites were included as they represented good undisturbed and disturbed coastal forests sites in the Peninsula.

Trapping techniques

Following the results of comparing light-trap types in Intachat (1995) and the requirement for a method that yields a large sample rapidly, two Robinson 125 W mercury vapour traps were used. In addition, a sheet was placed behind each trap and collection was carried out from both sides of the sheets and the surrounding areas. This was to maximise the catch due to the limitations of this type of trap as discussed in detail by Intachat (1995). Trapping in each paired site was carried out simultaneously for five hours from 1900 to 2400 h for three consecutive nights. Trapping was carried out simultaneously, allowing direct comparison to be made between the primary and secondary sites. In total, 36 samples were obtained between October 1993 and May 1994 where seasonal effect was intentionally taken into account.

The insects

Moths caught were sorted into families and subfamilies of the superfamily Geometroidea (including Drepanidae). This group was chosen based on the strength of its potential use as an indicator group for detecting the impact of changes in the forest environment (Holloway 1985, Intachat 1995). Identifications carried out on this group were based on Barlow (1982), Holloway (1993, 1996, 1997) and through reference to the collections in The Natural History Museum, London. Unidentified species were given code numbers, but genitalia were dissected and examined for all complex species groups where identification using wing pattern alone was difficult.

Data analysis

The alpha-statistic from the log-series (Fisher *et. al.* 1943) was used as a measure of diversity. We checked our data for ANOVA assumptions and found that logarithmically transformed catch or abundance data (total individuals) to $\log_{10}$ (catch) are normally distributed on a logarithmic scale whilst the total numbers of species (richness) are normally distributed on a arithmetic scale. Data from primary and secondary forest environments were analysed using three-way ANOVA. Comparison between the means for all the species taken into account was also carried out using Least Significant Difference (LSD). In comparing the abundance of the species shared between the two forest environments, shared species with a combined total of 10 or more individuals (in total 68) was analysed using three-way ANOVA.

Measurement of similarity (Q-mode)

In making comparison between faunal samples taken from different sites or communities, it is profitable to take advantage of existing similarity or dissimilarity measurements. There are, however, some problems with these measurements. While some of these measurements take into account only the presence and absence of species in the samples, others include species frequency distribution: the full abundance data. The value of these measurements was brought into question by Huhta (1979) who found that the results of all the measurements tested depend largely on the measurement chosen. A careful evaluation of these measurements was carried out by Wolda (1981) and showed that Morisita's index (Morisita 1959) is the measurement for fully quantified data that is most independent of sample size and diversity, though it was later shown to be highly sensitive to the abundance of the most abundant species (Magurran 1988).

The advantage of using presence/absence data over fully quantified data in sample comparisons is that the comparisons are much less influenced by such dominance effects, with weight given to the rarer species that may be more habitat-specific and therefore important in categorising samples. This was illustrated by Holloway (1979) for moth samples made in New Caledonia. Most coefficients applied to presence/absence data, e.g. the Jaccard measure (Wolda 1981, Hayek 1994), tend to give decreasing similarity measures with increasing difference in species numbers between the faunas or samples being compared. This may not be critical when total faunas are being compared, but is a disadvantage when samples (incomplete) of faunas are involved, and one requires an indication of the extent to which they might be drawn from the same 'universe'.

For this reason, some workers (e.g. How & Kitchener 1997) have used the Simpson Index, which is effectively the proportion of shared species in the smaller fauna or sample. If the faunas or samples range over extremes of species number, with the species in many of the smaller all being shared with many of the larger, this can lead, as in the study of How and Kichener (1997), to an array of coefficients that departs significantly from the metric: e.g. for faunas A, B and C, measure AB is never greater than AC + BC, etc. in a metric array. This non-metric quality is likely to be prevalent in sets of samples with highly variable species richness when compared using this measure, as species in a small sample from the same universe as a larger one are likely to be the commoner ones and therefore will probably all be represented in the larger. Cluster analysis methods require that the array of coefficients be metric.

The Preston measure of faunal resemblance (Preston 1962)[1] , based on a hypothetical canonical log-normal relationship of species abundance, appears to be less prone to this disadvantage than other measures, and does not depart from the metric as seriously as the Simpson Index in situations where small and large sets of species are being compared except when all species of the smaller set are represented in the larger set: in this case, the Preston equation is insoluble, but the value can be set arbitrarily at 1 or 0, depending on whether the equation

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[1] $x^{1/z} + y^{1/z} = 1$

where z is the faunal dissimilarity coefficient between two primary areas, x is the proportion of the joint fauna found in one area and y is the proportion of the joint fauna found in the other (Preston 1962).

is otherwise being solved for similarity or dissimilarity. There may well be a threshold of disparity in species number beyond which comparison using available measures is pointless. In our study, the smallest sampel (Rompin Endau secondary) had a species total that was about 15% of the largest (Panti secondary) with which it is compared in our analysis.

Robinson and Tuck (1993, 1996), noting limitations of the Preston measure [see also Hengeveld (1990) and Hayek (1994)], suggested using as a measure the ratio of observed to expected shared species. The expected shared species values are derived by comparing the size of two random computer samples from a large (million individuals), artifically generated log-series population with diversity parameters as in the two field samples pooled. This method has yet to be tested, however, over a wide range of data, particularly where extremes in the evenness component occur in the samples.

Therefore, despite its limitations, the Preston coefficient was used in this study. Its use also permits comparison with other studies of moth diversity in Malaysia and elsewhere in the Oriental tropics, e.g. Holloway (1985) and Holloway *et al.* (1990), where this measure was also used. Estimates of faunal dissimilarity using the Preston measure were made pairwise between all primary samples, all secondary samples and between primary and secondary samples in the same locality.

Results

Numbers and diversity

A total of 2774 individuals comprising 322 species, and 2620 individuals comprising 288 species were caught in the primary and secondary forests respectively. Table 1 shows the analysis of variance for the total abundance as expressed by $\log_{10}$ (catch), total number of species and diversity as measured by α.

LSD showed that the primary forests were found to be catching significantly higher mean $\log_{10}$ (catch) and total number of species per night than secondary forests (overall significance = 0.05). The mean catch per night for primary forests was 80.8 individuals compared to 46.5 individuals in secondary forests whilst the mean total number of species caught in the primary forest was 45.6 compared to 38.2 species in the secondary forests. The mean catch, total number of species, and the diversity per night for each of the six localities are given and compared in Table 2 whilst the comparisons within each site are given in Figure 2.

Table 1. Analysis of variance

Source	df	Log_{10} (catch)			No. of species			Diversity (α)		
		ms	F	P	ms	F	P	ms	F	P
Locality (L)	5	0.700	44.80	≤ 0.001	3865.978	80.94	≤ 0.001	39550069.681	3.81	≤ 0.05
Nights (N)	2	0.021	1.33	ns	19.194	0.40	ns	10364365.785	1.00	ns
Forest environment (Fe)	1	0.517	33.05	≤ 0.001	498.778	10.44	≤ 0.01	39975818.721	3.85	ns
P x Fe	5	0.056	3.60	≤ 0.05	273.511	5.73	≤ 0.01	39520533.109	3.81	≤ 0.05
P x N	10	0.029	1.89	ns	157.328	3.29	≤ 0.05	10346832.670	1.00	ns
N x Fe	2	0.024	1.52	ns	208.028	4.36	≤ 0.05	10350742.066	1.00	ns
Residual	10	0.016			47.761			10378136.220		

Note: ns = not significant.

Table 2. Mean number of individuals, total number of species and diversity of the moths caught from both types of forest in one sampling night at a particular locality

Locality	No. individuals (LSD = 1.238)	Total number of species (LSD = 8.8903)	Diversity (α) (LSD = 4144.2)
Rompin Endau	17.0^{d}	16.0^{d}	6331^{a}
Tasik Temenggor	50.1^{c}	33.2^{c}	43^{b}
Wang Kelian	68.7^{bc}	34.3^{c}	27^{b}
Pasoh	76.7^{b}	43.8^{b}	46^{b}
Panti	195.1^{a}	90.3^{a}	72^{b}
Tanjong Tuan/Bukit Keramat	60.9^{bc}	33.7^{c}	25^{b}

Note: Means with the same letter(s) are not significantly different at p = 0.05.

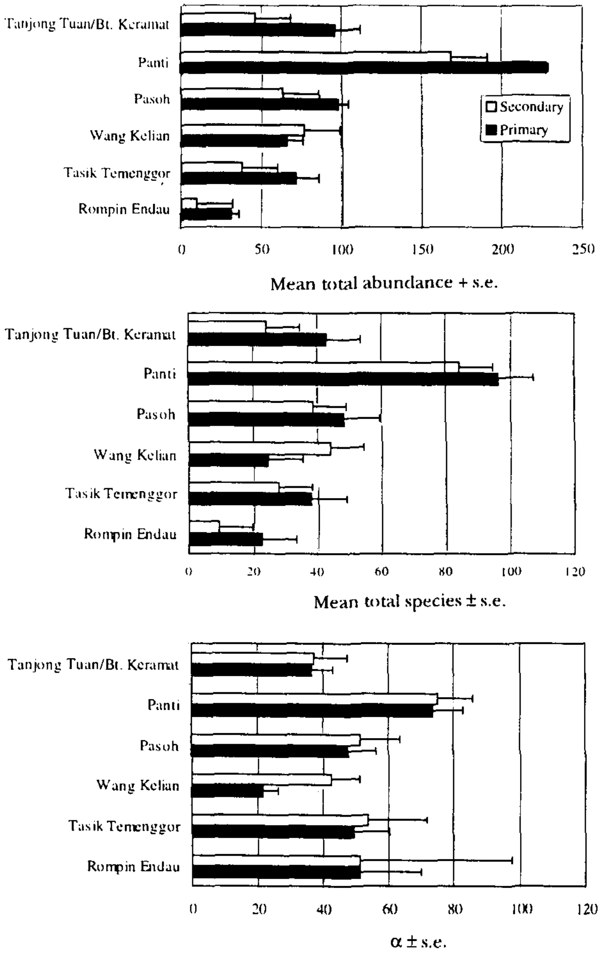

Figure 2. Mean total abundance ± s.e., mean total species ± s.e. and α ± s.e. for each paired sites

Species composition

Table 3 shows that 55.9% and 62.5% of the species caught in the primary and secondary forests respectively were shared between the two types of forest. The number of species caught only in primary forests was also higher than for species caught only in secondary forests. Similarly, the abundance of geometroid moths was higher in primary forests.

For the 68 most abundant shared species, three-way analysis of variance of $\log_{10}$ (catch) showed that there was a significant difference in the two forest environments after the effects of localities and nights were taken into account [$F(1,10) = 33.56$; $p<0.001$]. Of the shared species, 35.6% had their number of individuals reduced to 50% or less in the samples obtained from secondary forest environments compared to the primary samples. In contrast, 17.2% of the shared species had their number of individuals increased by 50% or more in the secondary samples compared to the primary samples.

Table 3. Total number of species and abundance in primary and secondary forests

	Total no. of species	Total abundance
Unique to primary	142	350
Unique to secondary	108	196
Shared by primary & secondary	180	2424
Primary	322	2774
Secondary	288	2620

The primary ratios of species captured in primary and secondary forests are provided in Table 4. For the primary forest samples, *Lophophleps phoenicoptera,* possibly a dipterocarp seed feeder (Holloway 1997), was the most abundant species. In the secondary forest samples, *Ourapteryx fulvinervis* was the highest recorded, though this species was unique to the Wang Kelian site and may reach its southern limits in the north of Peninsular Malaysia. Species like *Ornithospila bipuncta, O. cincta, O. submonstrans, O. sundaensis* and *Ectropidia illepidaria* that appear to be associated with dipterocarps (Intachat *et al.* 1997) were found to be unique to the primary forests. The mean total number of species in each of the subfamilies of Geometridae and the families of Geometroidea together with their abundance are given in Table 5.

The faunal dissimilarity between pairwise locality comparisons for primary samples versus secondary samples follows a similar pattern, with only minor changes (compare values in upper half of matrix in Table 6 with the lower half) although in general, they are rather high compared with results from lowland forest in other localities. In some of these compared localities, dissimilarity in species composition increases in the secondary forest when compared to primary forest, while in others the dissimilarity decreases.

The faunal dissimilarities between primary and secondary forests from the same locality (Table 6, diagonal) were found to be generally still high with the exception of the comparisons at Pasoh, Panti and Tanjong Tuan where they are lower than any other values in Table 6. This could suggest that at least some of the moth fauna unique to these particular forests have not been lost through disturbance by logging. Overall, the Preston's faunal dissimilarity coefficient for samples pooled over the six localities between primary and secondary forests was 0.49.

Table 4. Species with ≥ 10 individuals, arranged in descending order according to primary proportions

Species	Primary ratio (%)	Total catch
Diplurodes triangulata Holloway	100	23
Hypomecis tetragonata Walker	100	20
Lophophleps phoenicoptera Hampson	100	28
**Ornithospila bipunctata* Walker	100	10
**Ornithospila cincta* Walker	100	10
Zamarada scriptifasciata Walker	100	12
**Ectropidia fimbripedata* Warren	96.4	28
Hypomecis dentigerata Warren	93.3	15
Teldenia specca Wilkinson	93.3	15
Hypochrosis binexata Walker	88.9	18
**Ornithospila avicularia* Guenée	88.9	27
Lophophleps triangularis Hampson	87.2	86
Diplurodes inundata Warren	84.8	33
Orothalassodes hypocrites Walker	83.3	12
Cleora repetita Butler	81.8	11
Dindica polyphaenaria Guenée	80	10
Cleora determinata Walker	77.8	18
Berta annulifera Warren	77.1	35
Hypomecis separata Walker	76.9	39
Hypomecis costaria Guenée	76.6	128
Hypomecis subdetractaria Prout	76.5	17
**Ornithospila submonstrans* Walker	76	25
Hypochrosis sternaria Guenée	75	12
Idaea squamipunctata Warren	74.2	66
Coremecis maculata Warren	72.7	11
Cleora cucullata Fletcher	69.7	33
Petelia paroobathra Prout	68.8	16
Idaea craspedota Prout	68.6	118
Omiza lycoraria Guenée	68.6	35
Hyposidra infixaria Walker	66.7	30
Lomographa luciferata Walker	64.7	17
Phazaca erosioides Walker	64.7	17
Acolutha pictaria Moore	63.6	11
Oenospila flavifusata Walker	62.5	16
Herochroma subtepens Walker	61.9	21
Calichodes subrugata Walker	61.5	13
Tanaorhinus rafflesii Moore	61.5	13
Protuliocnemis partita Walker	60	10
Spaniocentra spicata Holloway	60	10
Idaea semisericea neanica Warren	60	10
Epiplema quadricaudata Walker	59	39
Uliocnemis biplagiata Moore	58.8	17
Calletaera subexpressa Walker	57.9	19
Thalassodes sp. (596)	55.6	36
Scopula vacuata Guenée	54.5	11
Tridrepana albonotata Moore	54.5	22
Plutodes cyclaria Guenée	54.3	46
Scopula succrassula Prout	53.8	26
Godonela avitusaria Walker	52.9	17
Epiplema conflictoria Walker	52.4	21
Idiochlora olivata Warren	50	10
Urapteroides astheniata Guenée	49.4	87
Comostola laesaria Walker	47.1	17
Canucha specularis Moore	46.2	13

(continued)

Table 4 (continued)

Peratophyga venetia Swinhoe	44.4	27
Sundagrapha tenebrosa Swinhoe	43.8	16
Plutodes malaysiana Holloway	42.9	28
Tasta reflexoides Holloway	41.7	24
Tasta montana Holloway	37.1	70
Herochroma flavibasalis Warren	35.5	31
Comostola meritaria Walker	35.1	37
Comibaena attenuata Warren	34.1	41
Peratophyga flavomaculata Swinhoe	31.3	32
Idaea carnearia Warren	28.6	14
Zamarada ucatoides Holloway	28.6	35
Antitrygodes divisaria Walker	27.3	11
Pingasa ruginaria Guenée	23.5	17
Curbia martiata Guenée	17.9	28
Plutodes argentilauta Prout	16.7	12
Thalassodes dissitoides Holloway	16.7	18
Heterostegane warreni Prout	15.4	13
Hyposidra talaca Walker	14.3	14
Pelagodes semihyalina Walker	14.3	14
Zamarada baliata Felder & Rogenhofer	5	20
Ourapteryx fulvinervis Warren	0	14

Note: * Possible 'dipterocarp' indicators (Intachat *et al.* 1997).

Table 5. Mean total number of species in each subfamily of the family Geometridae and the families of Geometroidea ± s.d. together with their mean total abundance ± s.d. from the six localities

Group	Primary		Secondary	
	Total species ± s.d.	Total abundance ± s.d.	Total species ± s.d.	Total abundance ± s.d.
Geometridae	80.0 ± 42.5	261.2 ± 176.07	68.3 ± 39.80	179.2 ± 135.98
Ennominae	39.0 ± 20.31	132.0 ± 105.73	30.5 ± 17.59	90.2 ± 69.98
Geometrinae	21.8 ± 14.72	60.0 ± 57.53	21.7 ± 15.64	57.5 ± 55.38
Sterrhinae	13.0 ± 6.10	56.7 ± 46.58	11.2 ± 5.60	24.3 ± 11.99
Larentiinae	2.8 ± 2.73	8.5 ± 10.63	1.5 ± 1.64	2.2 ± 2.79
Desmobathrinae	2.5 ± 2.51	4.0 ± 4.05	3.5 ± 3.56	5.0 ± 4.82
Drepanidae	5.0 ± 4.29	8.5 ± 9.33	5.5 ± 3.62	8.3 ± 7.37
Epiplemidae	4.0 ± 2.19	10.2 ± 7.52	3.2 ± 1.60	6.8 ± 5.91
Uraniidae	1.3 ± 0.82	6.7 ± 9.69	0.5 ± 0.84	3.0 ± 5.62

Discussion

The primary forest samples showed clearly that geometroid moth species richness and abundance were usually higher there than in the secondary forests, although the general trend for the measurement of diversity showed that the secondary forests had higher diversity indices. The differences in diversity indices, however, were not significant. A low abundance in the sample obtained from the primary forest at Wang Kelian could be due to competition between the moth traps and the lights at a border checkpoint station nearby, and the low species richness and diversity in this site may be caused by the clearing of undergrowth, done for security reasons. The primary forest here was therefore not a good representative site for primary forest.

Table 6. Faunal dissimilarity among the six localities for primary (top right) and secondary (bottom left) sites, and between primary and secondary for each locality (diagonal & in bold)

0.84	0.80	0.93	0.82	0.77	0.86	1	**P**
0.89	**0.77**	0.84	0.85	0.81	0.84	2	**R**
0.90	0.80	**0.73**	0.84	0.83	0.82	3	**I**
0.77	0.79	0.75	**0.62**	0.70	0.80	4	**M**
0.78	0.76	0.80	0.75	**0.55**	0.75	5	**A**
0.89	0.83	0.87	0.84	0.78	**0.66**	6	**R**
1	2	3	4	5	6		**Y**
SECONDARY							

Note: Value of 1 = dissimilar, 0 = similar.

Locality :

1. Rompin Endau
2. Tasik Temenggor
3. Wang Kelian
4. Pasoh
5. Panti
6. Tanjong Tuan/ Bt. Keramat

Very high diversity value for the Rompin Endau site (Table 2) was due to the high representation of species with one individual that could be unique to this site. A high number of species unique to primary forest suggests a potential 'loss' in some of these species when the primary forest is logged. This is shown in the absence from the secondary forest samples of the four *Ornithospila* species and an *Ectropidia* species that are unique to primary forests and may be dipterocarp indicators. The 'disappearance' of some species and the 'appearance' of 'new' species together with the reduction or increment in the number of some of the shared species between the primary and secondary forests indicate a shift in species composition. This shift in the moth species composition and abundance may be due to the change in the habitat structure that supported them. The variation in within-pair faunal dissimilarity measures suggests that such effects differ across the forests sampled, though it is not clear whether this is due to different forest properties or different degrees of disturbance.

Disturbance such as logging creates gaps. The light regime within the gap is dependent on the tree height (Canham *et al.* 1990) and on the nature of canopy damage caused by tree falls (Lawton 1990), i.e. the gap size. The amount of light penetrating to the forest floor, on the other hand, affects the rates of growth of seeds (non-pioneer and pioneer species) found on the forest floor. A general model was developed by Howe (1990), showing that, as the size of the gap increases, the availability of space for shade-tolerant species decreases. That is, in smaller gaps, shade-tolerant species establish more densely, while in larger gaps, shade-intolerant species establish more densely (Lawton & Putz 1988). Moreover, the differences in the microclimates of gaps of different sizes may act as a selection force for different species to grow (Brown 1993). Pioneer species were found to establish poorly in selectively logged forests, while the early and late secondary species established better there (Chandrashekara & Ramakrishnan 1993). The response of different plant species depends on gap age and gap type (whether the gap was created naturally or through selective logging) (Chandrashekara & Ramakrishnan 1994).

The growth of these different plant species, in turn, creates new and more diverse life support systems for the new and existing moth species. Depending on the established plant species, moth species that are more localised and/or host specific cannot tolerate such changes and would eventually disappear from parts of the disturbance mosaic.

The high representation of some *Idaea* spp. that may be associated with disturbance (Intachat *et al.* 1997) in the primary forest samples may indicate that there was already some degree of disturbance in these areas. This disturbance was actually caused by periodic tree falls and landslides leaving natural gaps within the primary forests. Such disturbances are unavoidable, and natural to primary forest systems (Attiwill 1994). There was also little change in the proportions of different moth subfamilies and families. The small change in the species composition as reflected by the Preston faunal dissimilarity coefficients between pairwise locality comparisons for samples from primary and secondary forests indicates that the disturbance caused by logging has little effect on species composition, that is, logging does not appear to reduce between-site diversity by encouraging a more generally distributed faunal component. If this reduction in beta-diversity had occurred, the values between all pairs of secondary forest samples would have been significantly lower than those between all pairs of primary forest samples. However, the differences in species composition between primary and secondary forests for the same locality are still high in most localities, except for Panti and Pasoh, which suggest that, in some areas, the logging method applied is still unsuccessful in retaining some of the primary species. The low overall faunal dissimilarity from the pooled samples of both the primary and secondary forest may suggest that, provided logging is carried out under control, it is possible to retain some of the primary species within a more extensive landscape mosaic.

Logging, when managed properly, does not necessarily cause loss of moth diversity. In turn, it may well facilitate a faster rate of moth species 'recovery' compared to the total clearing of primary forest (Intachat *et al.* 1997). By having paired samples that enabled direct comparison, the results illustrated that there was no significant reduction in moth diversity, although comparisons were only made in six paired sites. An overall reduction of moth diversity is most likely to happen when floristic diversity is reduced drastically. In terms of conservation, when an area is being logged, it is important that a certain amount of the original representation of plant species (in the case of moths, their food plant) be retained to sustain the existing moth population in reservoirs from which recolonisation of more disturbed areas can occur. Besides, relatively few species of moths feed specifically on the principal commercially logged timber groups such as the dipterocarps (see Holloway 1993, 1996 & 1997).

So, by only taking into consideration diversity, that is, in this case, the diversity of geometroid moths as measured by α, the proposal of Attiwill (1994) still stands. However, it is important to remember that, in discussing diversity, species richness, quality (in terms of taxonomic diversity, percentage endemism, etc.) and numbers of individuals are equally valuable attributes (Spellerberg 1991, Vane-Wright *et al.* 1991). Therefore, when taking into consideration all the attributes together, the results of this pilot study qualify support for Attiwill's proposal. Nonetheless, a better insight to this question might be obtained by manipulative experiments such as applying different regimes of logging methods to a primary forest, with pristine primary forest as a control site, and sampling the geometroid moth population over a longer period, commencing prior to the disturbance event. Alternatively, further carefully designed long term comparative studies need to be carried out before the complexities of the problem can be fully understood.

Acknowledgements

This paper forms part of the first author's D.Phil. thesis under the supervision of M. R. Speight, Department of Zoology, Oxford University, United Kingdom and J. D. Holloway, then at CAB International Institute of Entomology, London, United Kingdom. This study was supported by ODA/FRIM sub-programme 1, Project 5 (The Impact of Forest Development on Faunal Diversity) and IRPA's project RA 103-01-001 D02 (Biodiversity and Forest Conservation). The alpha diversity measurements and Preston coefficients were calculated from software provided by G. S. Robinson, the Natural History Museum, United Kingdom. We are also grateful to the Forestry Department, H. T. Chan and E. S. Quah for their assistance in the description of the Tanjong Tuan/Bukit Keramat sites, and Saimas Ariffin, H. H. Heah, Hamzah Shamsudin, Mohd. Bohari Ehwan and Masuda Abd. Samad for their assistance in the field. We would also like to thank H. Staines from the Division of Mathematical Sciences, University of Abertay Dundee, United Kingdom and the reviewers for their comments.

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