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THE EFFECTS OF DIFFERENT FOREST MANAGEMENT PRACTICES ON GEOMETROID MOTH POPULATIONS AND THEIR DIVERSITY IN PENINSULAR MALAYSIA

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INTACHAT, J., HOLLOWAY, J.D. & SPEIGHT, M.R. 1997. **The effects of different forest management practices on geometroid moth populations and their diversity in Peninsular Malaysia.** Using geometroid moths as an indicator, the impact of various forest management practices in Peninsular Malaysia was assessed. Results obtained over 14 months of sampling showed that the diversity as measured by Williams alpha (α) was lowest in an abandoned, logged, tin mining area. The next lowest diversity was in a secondary forest that was clear-logged during the study and after that was a plantation of mixed indigenous species, mainly dipterocarps. The highest geometroid moth diversity was recorded in a secondary forest that was selectively logged. In the forest that was logged with modified Malayan Uniform System (MUS), the rate of moth population recovery after logging was found to be better than in a plantation situation where initial clearance had occurred. However, in terms of biodiversity and conservation, the creation of a mixed indigenous plantation may contribute by retaining some of the moth species associated with undergrowth plant species as well as with the indigenous tree species themselves.

Key words: Geometroidea - moths - Lepidoptera - biodiversity - conservation - logging - plantation - tropical - forest management practices - Peninsular Malaysia

INTACHAT, J., HOLLOWAY, J.D. & SPEIGHT, M.R. 1997. **Kesan pelbagai cara pengamalan pengurusan hutan ke atas populasi dan kepelbagaian rama-rama geometroid di Semenanjung Malaysia.** Impak berbagai pengamalan pengurusan hutan di Semenanjung Malaysia telah dinilai dengan menggunakan rama-rama geometroid sebagai penunjuk. Keputusan yang diperoleh daripada penyampelan selama 14 bulan menunjukkan bahawa kepelbagaian seperti yang diukur oleh Williams alpha (α) terendah di kawasan lombong timah yang telah ditebang dan ditinggalkan. Kepelbagaian terendah yang berikutnya merupakan hutan sekunder yang telah ditebang bersih semasa kajian dan selepas itu, diikuti dengan ladang campuran spesies tempatan terutamanya dipterokarpa. Kepelbagaian rama-rama geometroid yang tertinggi direkodkan di hutan sekunder yang telah ditebang secara selektif. Di hutan yang telah ditebang dengan pengubahsuaian Sistem Seragam Malaysia (MUS) kadar pemulihan populasi rama-rama selepas penebangan lebih baik daripada dalam keadaan ladang yang mengalami pembersihan kawasan sebelumnya. Walau bagaimanapun, dari segi kepelbagaian biologi dan pemuliharaan, pembentukan ladang campuran spesies tempatan mungkin boleh menyumbang dengan mengekalkan beberapa spesies rama-rama yang berkaitan dengan spesies tumbuhan bawahan dan spesies pokok tempatan.

Introduction

Over recent years, the extent of logging and conversion of natural forest land to plantations has given rise to great international concern about the potential for loss of biodiversity (Westman 1990, Holloway & Barlow 1992). Such disturbances cause changes in the physical structure of the forest habitat and this is often accompanied by a general change in the biotic processes of that habitat (Brown 1991), which in turn may cause destruction and even extinction of some plant or animal species. The level of these disturbances determines the scale of change in both the horizontal and vertical structure of the habitat. The extent of these structural changes influences the rate of recovery of the ecosystem, that is the rate at which the system is able to return to an equilibrium state after a temporary disturbance (Holloway 1973, Denslow 1985) and thus create new successional habitats along the way. Habitat heterogeneity is described by the horizontal structure, while habitat complexity is measured by the vertical structure (Brown 1991).

It has been demonstrated that an increase in floristic diversity of an open forest, in general, will result in low plant structural diversity (Young & Wang 1989). Faunistically, however, various animal groups respond differently (Bowman *et al.* 1990). Within the insects, different groups have been found to react in various ways to such changes. Holloway *et al.* (1992) have shown that Lepidoptera, with a moderately specific relationship to the floral component as herbivores, lost diversity and taxonomic quality, whereas some dung and carrion beetles (Coleoptera) were less affected following disturbance. Moeed and Meads (1992) found that the diversities of all the insect groups in their study were significantly greater in more botanically diverse areas. In Lepidoptera, this is not necessarily true as shown by Holloway (1989), Chey *et al.* (1992) and Chey (1994). Results by Chey (1994) show that some plantation forests can support moth diversity equal to that in a secondary forest and this is correlated with the rich flora of understorey plants in such plantations. Plantation forest which has an open canopy has good light penetration into the forest and this encourages the germination and growth of understorey plant species from any remaining seed bank and through invasion. He, however, did not describe the state of the secondary forest.

Except for the works by Nummelin and Hanski (1989) and Nummelin and Fuersch (1992), the effect of forestry management practices such as selective logging on the insect fauna still remains poorly understood. The effects in such cases were predicted to be less drastic than those following clear cutting (Holloway 1987, Wolda 1987).

It is therefore the intention of this paper to investigate the effects of different forest management practices and strategies on the abundance, species richness, and diversity of geometroid moths. Such practices include clear felling, abandoning of clear felling and tin mining, selective logging, and planting of mixed indigenous tree species. These sites represent different stages of succession with different regimes of disturbance.

Materials and methods

The sites

The four sites chosen were within or near to the proposed Greater Templer Park (GTP) area (Figure 1). Sites 1 and 2 were adjacent to the Serendah Forest Reserve and were located within logging areas. Site 1 represents a recent clear felling site, while site 2 represents an abandoned clear felling and tin mining site (abandoned in the early 1970s). Site 3, which was situated in compartment 17 of the Serendah Forest Reserve, represents a selectively logged site (logged in 1973), and site 4, which represents a mixed indigenous plantation forest (mainly Dipterocarpaceae, planted in 1927 over a vegetable farming area), was located in the grounds of the Forest Research Institute Malaysia (FRIM). Detailed botanical analysis was made from a 20 × 20 m plot centred on the the light-trap for all sites except site 1. The appropriate size of the plots was determined by an earlier experiment (see Intachat 1995).

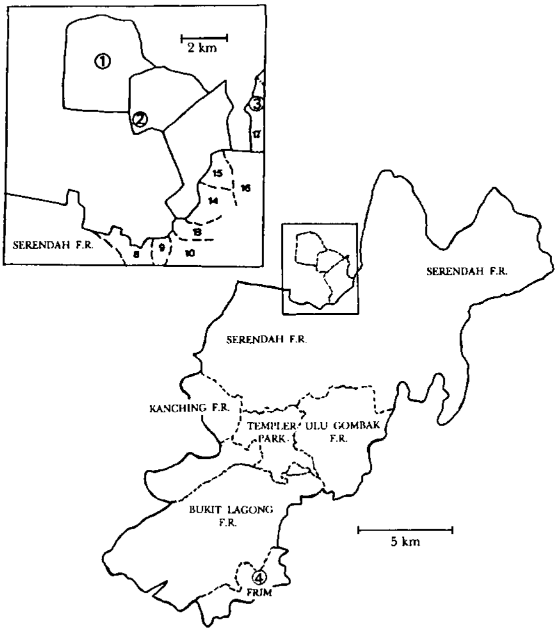

Figure 1. Trapping sites

Table 1. Summary description of the sites

Site	General description			
	Vegetative	Physical	Plant species diversity (α)	Successional stages
1	Hardly any dipterocarps (was logged for the first time in the early 1970s); dominated by *Macaranga gigantea* (Euphorbiaceae); logged again (clear felling) for the second time during the trapping period	300 m a.s.l.	n/a	Mid stage (before logging) None
2	Mainly grasses and shrubs; dominated by *Gleichenia linearis* (Gleicheniaceae); abandoned clear felling and tin mining site; abandoned in the early 1970s	Lowland	4.0 ± 0.3	Early
3	Selectively logged in the 1970s	Lowland	23.5 ± 3.2	Advanced
4	Experimental block: mixture of dipterocarps plantation; planted in 1927 over a vegetable farming area	Lowland	10.7 ± 1.6	Later

All vegetation types (climbers, shrubs, grasses, trees) occurring in the plot were counted and identified where possible; code numbers were used to distinguish different plant species that could not be identified. In site 1, however, only a qualitative description could be carried out as the area was logged soon after the first month of trapping. A summary description of all the sites is given in Table 1.

Site replication was not feasible for a number of reasons such as availability of traps, logistics of access to, and servicing of, widely separated sites contemporaneously; and the fact that the heterogenous nature of complex tropical rain forest systems [e.g. as documented by He *et al.* (1996) for the Pasoh Forest Reserve in Malaysia] may mean that valid sample replication is extremely difficult. The best approach, therefore, may be to establish as many sites as possible (in this case four) spanning ecological extremes in the system under study.

In brief, site 1 represents a post-logged area, site 2 a very disturbed, early stage successional secondary forest, site 3 represents a recovered, logged, and therefore a largely dipterocarp-reduced forest, and site 4 represents an artificially extreme form of dipterocarp-enhanced forest.

Trap design

One standard Rothamsted trap (Williams 1948) was placed in each site. Trapping at each site was carried out simultaneously to minimise any bias in samples from seasonal effect and therefore allowing samples to be compared directly. Traps were operated for about 5 h commencing from about 1900 h until 1200 h for five moonless nights in each of the trapping months. In all except site 1, trapping was carried out for 14 months, from August 1993 to September 1994. Trapping in site 1 was held up for 4 months after the first month of trapping whilst logging was carried out. There were also days within a month or months where trapping was not able to be carried out as roads leading to the site were badly eroded during heavy rainfall and the conditions of the stream prevented access by vehicle. In site 1, a total of 27 samples were obtained, whilst in sites 2, 3 and 4, 69 samples were collected.

The insects

The moths were grouped and sorted into families and subfamilies of Geometroidea. Those covered by Barlow (1982) and Holloway (1993b) were identified to species while others were identified to species if possible, but almost all to genus, with each species given a code number. The primary reason in choosing this moth group, among others mentioned in Intachat (1995), is the ability of the members (families and subfamilies) of this group to show sensitivity towards disturbance. It was suggested to be a good environmental indicator group in a comparative study of all macrolepidopteran groups by Holloway (1984).

Analysis of data

Analysis of variance (Sokal & Rohlf 1995) was carried out between these four sites for the monthly total number of species, monthly total $\log_{10}$ (catch +1), and monthly diversity. For this analysis, only data obtained for the nights or months that site 1 was in operation were used, resulting in a total of seven months data. Comparisons of these variables between sites were also carried out using least significant difference (LSD) (Sokal & Rohlf 1995). The geometroid moth diversity was measured using Williams alpha (a) that was derived from the $\log_e$-series model of species abundance in samples[1].

The degree of similarity in species composition between moth samples taken from each site (the Q-mode analysis) was made using Preston's coefficient on species presence/absence data (Preston 1962)[2], following an extensive review of similarity or dissimilarity measurements by Intachat (1995).

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[1] $S = \alpha \text{Log}_e (1 + N/\alpha)$

where S is the total number of species, N is the total number of individuals and α is the diversity index (Fisher *et al.* 1943).

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

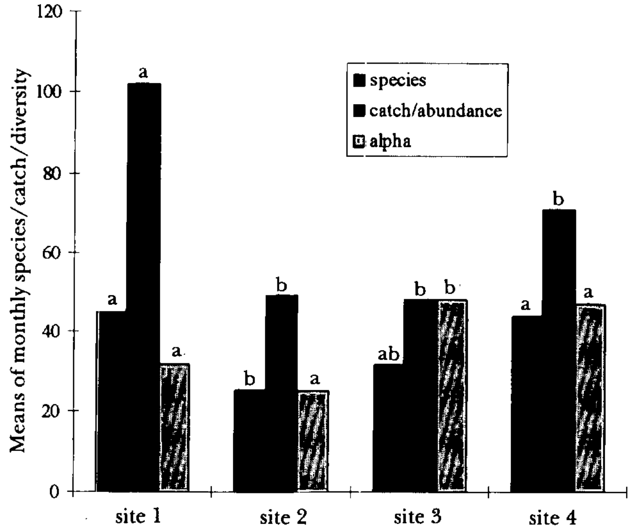
where z is the faunal dissimilarity coefficient between the samples being compared, x is the proportion of the joint fauna found in one sample and y is the proportion of the joint fauna found in the other (Preston 1962).

In addition to the above analysis, the analysis of species associations (R-mode analysis) was included to show patterns in species distributions among the sites and to try to identify the more site-specific species. For this analysis, data for the distribution of individuals amongst the sites for each species in each of the sampling nights were normalised for site sample size inequality. The normalised data were then expressed on a percentage basis. Similarity coefficients between each pair of species were calculated using a simple overlap or association coefficient (Holloway 1970)[3], as employed by Robinson (1975) and Holloway (1977, 1979). Results from this analysis are presented using single link cluster analysis (Jardine *et al.* 1967) and linkage diagrams. A total of 81 species with 10 or more individuals were used for this analysis.

Results

Monthly comparison

In the last seven months of the sampling period, the only significant differences between the sites were in the monthly diversity ($p \leq 0.05$; df = 3; ANOVA). Analysis using LSD shows that site 2 caught the fewest total numbers of species with an average of 25 species per month (Figure 2).



N.B: Means with the same letter are not significantly different at $p \leq 0.05$ (df = 24; n = 7).

Figure 2. Least significant difference (LSD) for the monthly species, catch and diversity (alpha)

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[3] The degree of overlap in the distribution of two species under comparison = $\sum b$ where b is the smaller percentage for each sample for the pair of species under comparison (Holloway 1970).

In contrast, site 1 had the highest total number of species with an average of 45 species caught per month. There were, however, no significant differences ($p \leq 0.05$; df = 24; n = 7) in the monthly total number of species caught between sites 1 and 4 and between sites 2 and 3. In terms of abundance measured by $\log_{10}$ (catch +1), site 1 had the highest average catch, significantly higher than at the other sites ($p < 0.05$; df = 24; n = 7), with 102 individuals per month. The lowest average catch came from site 3 with 48 individuals per month, but there was no significant difference between sites 2, 3 and 4. Site 3 had the highest average monthly α diversity index, 41.9 ± 11.9, while the α value for site 2 was 19.1 ± 3.8, the lowest among the four sites, but there was no significant difference between sites 3 and 4. The fluctuation of the total number of species, abundance, and diversity throughout the 14 months sampling period is shown in Figure 3. For the whole trapping season, the α value for site 1 was 58.5 ± 2.9 (S.E), site 2 was 38.0 ± 2.1 (S.E), site 3 was 73.0 ± 4.4 (S.E) and site 4 was 70.1 ± 3.6 (S.E) (Figure 4).

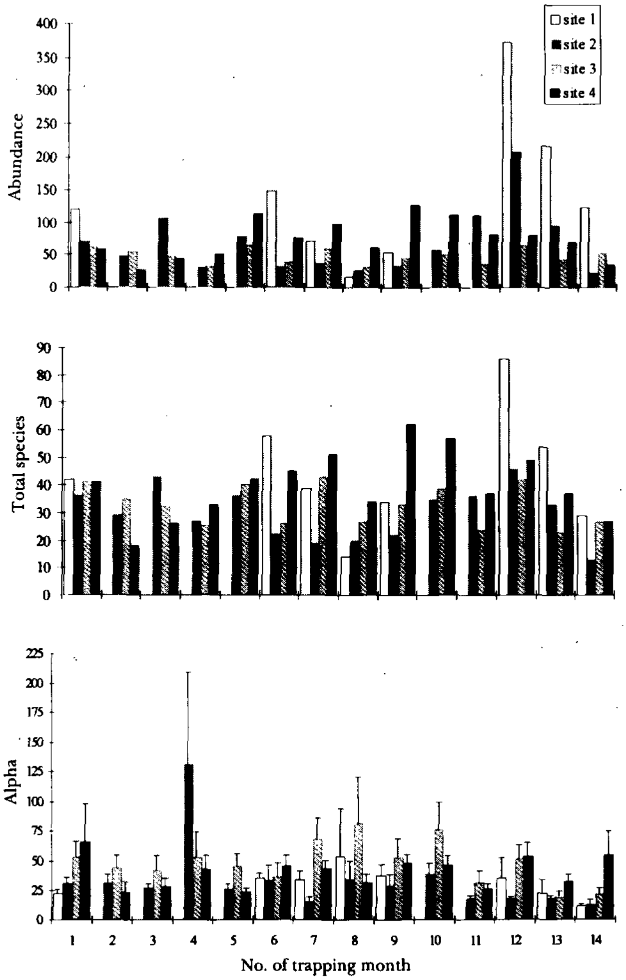
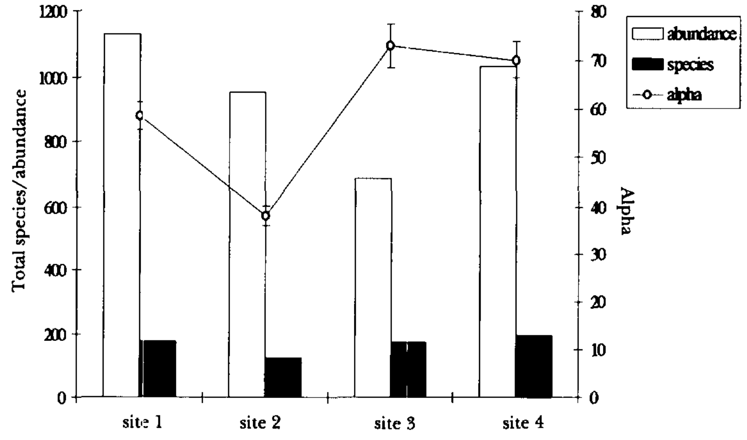


Figure 3. Monthly abundance (top), total number of species (centre) and diversity (bottom) in each site



Site 1: recent clear felling
Site 2: old tin mining and clear felled; abandoned in the early 1970s
Site 3: selectively logged in 1973
Site 4: mixed indigenous plantation; planted in 1927 over vegetable farming land

Figure 4. Total abundance (top), number of species and diversity (α ± S.E.)

Measurement of similarity (Q-mode)

Preston (1962) dissimilarity coefficients calculated between all pairs of sites are given in Table 2. Sites 2 and 4 had the most dissimilar moth species composition, and sites 2 and 3 were the most similar. Among the four sites, site 1 had the most singleton species that made up 52.3% of the total species caught in this area. Site 2, on the other hand, had the fewest numbers of singletons, representing 32.8% of its total species. In addition, site 2 also had the least number of species recorded uniquely from it, 27, while site 4 had 83 species, the largest number. Twenty-six species were common to the four sites. The commonest was *Idaea* sp.2 (1078). In site 1 alone, a total of 404 individuals of *Idaea* sp.2 (1078) were caught.

Table 2. Preston faunal dissimilarity coefficients between sites

	Site 1	Site 2	Site 3	Site 4
Site 1	-	0.66	0.67	0.71
Site 2	0.66	-	0.58	0.74
Site 3	0.67	0.58	-	0.65
Site 4	0.71	0.74	0.65	-

More than half (56.5%) of the total species caught at site 2 were ennomines, with *Hypochrosis sternaria* Guenée being the commonest. The proportion of ennomine species was lower in the other sites although ennomines were still the largest group. Site 2 had the biggest percentage of geometrine species. *Tanaorhinus rafflesii* Walker was the most abundant member of that group. Among the four sites, sterrhine and desmobathrine species were most strongly represented in site 3. Together, species of *Idaea* and *Scopula* made up 77.6% of total individuals of sterrhines caught within the area. Site 4, on the other hand, had the largest species number of larentiines, drepanids and epiplemids, whilst the uraniids were absent in site 2. *Cyclidia orciferaria* Walker was the only member of the Cyclidiidae caught in the whole trapping period. It was caught in site 4 and was represented by three individuals. The faunal composition (percentage of species in the major groups) for each site is illustrated by Figure 5. Site 4 had the highest taxonomic diversity (nine groups, most even representation) and site 2 the lowest (seven groups, ennomines dominant).

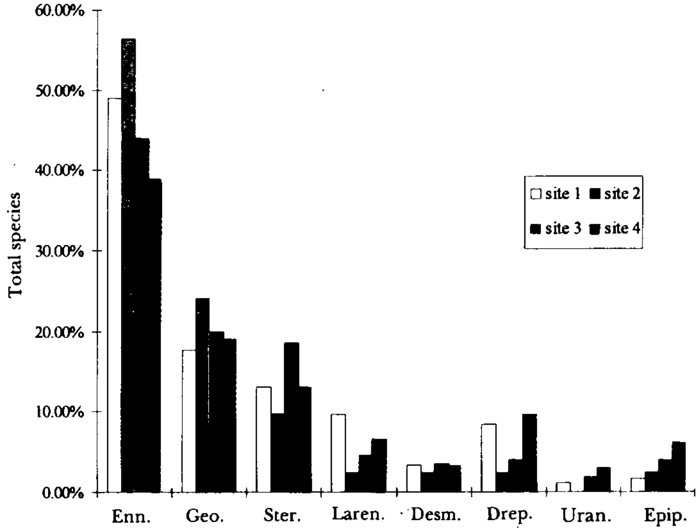


Figure 5. Proportions of species in various geometroid groups in each of the sites

Analysis of species associations (R-mode)

The single-link dendrogram clustering for all the 81 species is illustrated in Figure 6. Almost all the species have clustered together at the 80% similarity level, and clustering structure appears to be weak, perhaps indicating some sort of continuum, with a gradual turnover of species from sample to sample. The linkage diagram in Figure 7 shows all levels of 75%, and reveals five definite, but

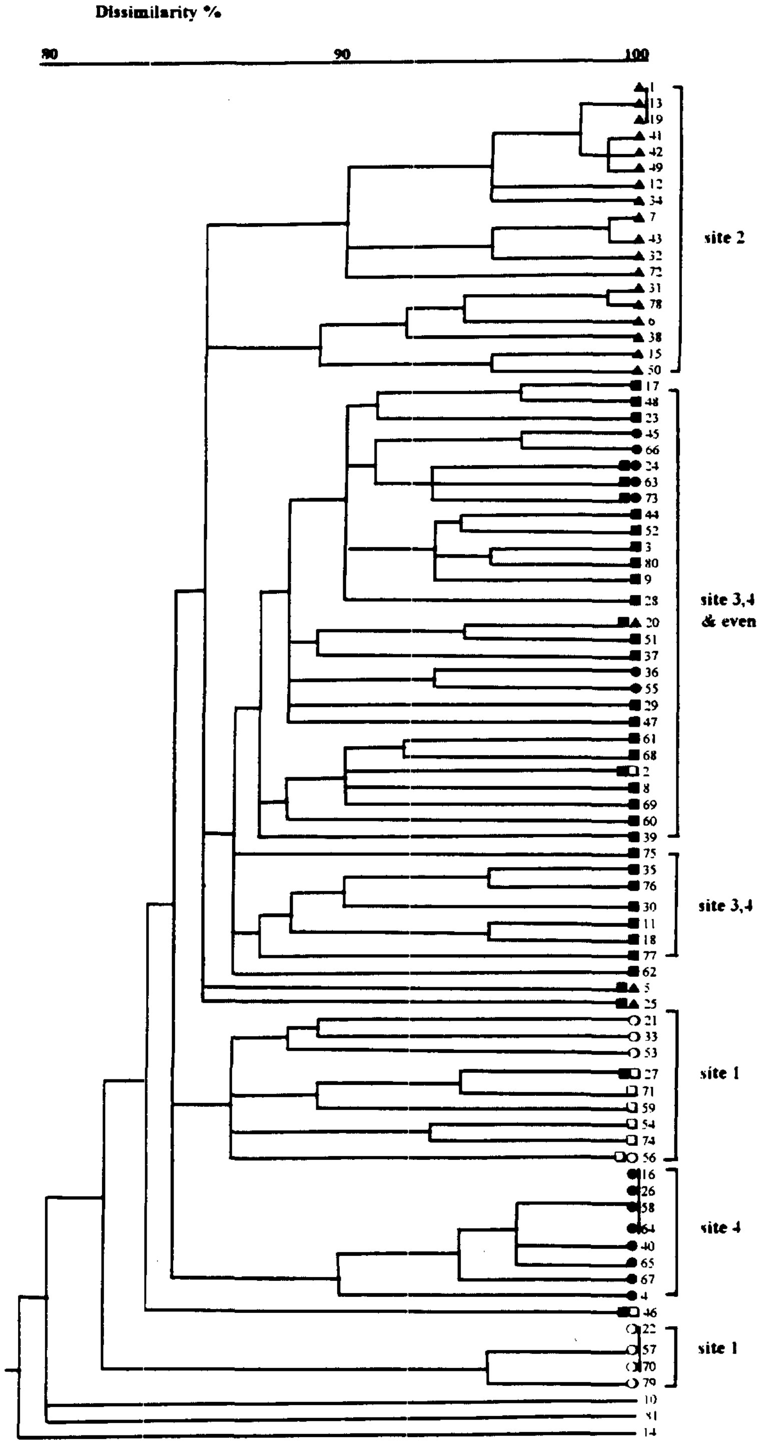


Figure 6. Single-link dendrogram for 81 species with 10 or more individuals. The symbols indicate membership of clusters recognised in Figure 7.

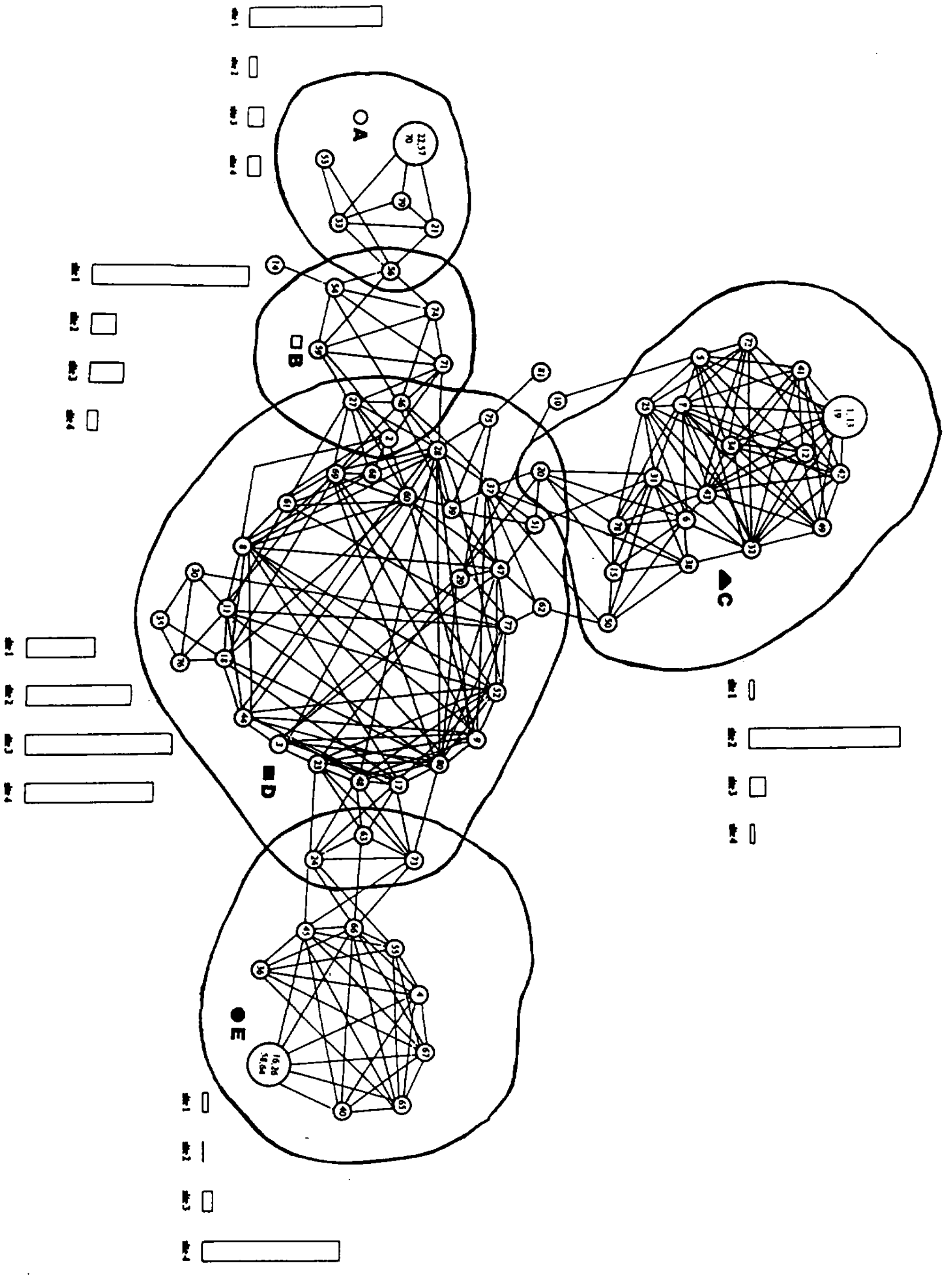


Figure 7. Linkage diagram with links 75% and above for all 81 species. On each cluster, histograms indicate % of individuals in each site, and the symbols facilitate cross-reference to Figure 6.

overlapping clusters with a high level of internal linkage. We recognise the species contained in these as associations that are likely to be responding to common ecological factors. These associations of species are listed in Table 3, and their average representation is indicated by histograms in Figure 7 that express the percentages of individuals for each across the four sites. All five species of *Ornithospila* and the only *Ectropidia* fall within the association with high representation at site 4. The few host-plant records for these genera are from the Dipterocarpaceae (Holloway 1993b, 1996): predominance at the mixed indigenous plantation site lends further support to this connection.

Discussion

Moth diversity

There are two main components of habitat structure (heterogeneity and complexity) that are important contributors to variation in the diversity of herbivorous insects (Denno & Roderick 1991). While habitat heterogeneity includes plant density, patch size and plant diversity (Kareiva 1983), habitat complexity includes plant sizes and plant structures (Southwood *et al.* 1979, Lawton 1983). Habitat structure is strongly influenced by the scale and stage of the successional sequence, and is variable both in time and space (Brown 1991), and by forces which influence and direct the development of the structure, composition and functioning of plant communities (Connell & Slatyer 1977, Shugart 1984). Disturbance is one of these forces (Harmon *et al.* 1983). While some of these disturbances may be natural, for instance landslides, tree falls and fire (White & Pickett 1985), others may be caused by humans. The scale of succession depends on the intensity of the disturbance. The greater the intensity of disturbance, the less likely it is that the forest will recover (Buschbacher *et al.* 1988).

Site 3 was logged in 1973 with the modified Malayan Uniform System (MUS) whereby the cutting limit for all species is not less than 45 cm diameter breast height (dbh) and emphasis is given to advanced growth (FDS 1993). High geometroid moth diversity at this site can most probably be attributed to the application of this selectively managed logging method, in which disturbance has been minimised and regeneration enhanced. Dipterocarps, by themselves, do not support a diverse Lepidoptera fauna, certainly not of defoliators (Holloway 1989). Hence the removal of dipterocarps might be expected to promote a generally higher diversity despite the loss of the few dipterocarp specialists that do occur (e.g. *Ornithospila;* see R-mode analysis for detail).

When a forest is logged, the action basically opens up the canopy and thus creates gaps. Canopy gaps are essential for forest regeneration because of the association between germination and light. Seedlings and saplings of the pioneer species growing in a gap compete for nutrients and light with forest floor vegetation and with other young tree species. Unlike the natural gaps created by tree falls in primary forests, these logging gaps are wide and thus competition among species for light is lessened. Brown (1993) suggests that it is the differences in the microclimates of different canopy gap sizes that act as a selection force for different species to grow. Gaps of the same size do not necessarily have the same microclimatic conditions and therefore may favour the growth of different seedling species (varying from pioneer to climax).

High plant species diversity at site 3, given in Table 1, reflects the heterogeneity of this site. A complex plant community habitat such as site 3 is therefore able to provide greater diversity of structures for insect activities such as feeding, oviposition, resting and sexual display (Brown 1991), and in turn, support for greater insect, or in this case, moth diversity.

Although disturbance in site 3 (selectively logged in 1973) occurred much later than site 4 that was planted in 1927, site 4 seems to be taking a longer time to 'recover' as indicated by both moth and plant species diversities. This could be due to the different scale of disturbance which has occurred at these sites. Site 4 was planted in an area, formerly a vegetable farming area, that had no indigenous forest plant species around at the time of planting. Land clearing preparation for vegetable farming and then for planting of forest trees was 'harsh' though it was a very much longer time ago than that of the selectively managed logged site (site 3) where many plants were left behind. Furthermore, site 4 has developed an artificial, even growth, has a closed canopy and has a managed mixed culture of dipterocarps and non-dipterocarps species that might have precluded development of a more diverse forest by shading out potential competitors and restricting more than a modicum of invasion by understorey plants.

The creation of mixed indigenous forest plantations such as at site 4 may in the long run be an important solution for conserving biodiversity, and at the same time, sustain the timber production in the country. The non-significant difference in the measurement of geometroid moth diversity between site 3 and site 4 suggests that, given enough time, a mixed indigenous forest plantation may just 'recover' in terms of undergrowth plant and moth diversities. Chey (1994) found that high moth diversity in his samples obtained from the fast-growing exotic plantations was strongly correlated with the number of undergrowth species growing in each plantation. Frugivores such as birds and bats may help in increasing the plant diversity by distributing seeds from neighbouring areas into the plantation. The 'high' undergrowth plant species diversity, in turn, will support the rather 'high' geometroid moth species diversity.

Vegetation clearance immediately following the logging of the trapping area at site 1 served to increase the trapping radius, that is, the range of influence of the light whence moths were first attracted, thus bringing 'in' species from a wider area. This is reflected in the significantly higher mean catch per month at site 1. A more open site would possibly be influenced by wind speed and direction, causing more species and individuals to move in from the adjacent areas and habitats. In particular, open sites may attract a range of mobile species adapted to ephemeral vegetation. Barlow and Woiwod (1990), however, reiterated that such effects would be unlikely to be significant with the Rothamsted light-trap because of the opaque roof (Taylor & French 1974).

At sites 2, 3 and 4 where vegetation presence and understorey can be quite dense, light penetration was blocked, whereas at site 1 there was a clear view through the understorey of adjacent areas. The significant variation in catch size is still thought to be influenced primarily by vegetation type. In addition, the sudden increase in the sample of geometroid moths after logging was observed to be less extreme than for the other, potentially more mobile moth groups caught in the same sample. The large number of species represented by one individual in the site 1 sample is no doubt a significant factor in contributing to a rather 'high' α diversity value: a similar phenomenon in an urban situation was noted by Wolda *et al.* (1994).

Heavy metals are known to have, for example, indirect effects on herbivores via changes in host plant quality (Riemer & Whittaker 1989) as they can act as a selective agent for certain heavy metal resistant type of foliation (e.g. Archambault & Winterhalder 1995) in plants. Being a former mining site, it is also quite possible that the vegetation, and indirectly, the herbivores at site 2, have been affected by the heavy metal pollutants in the soil thus making the recovery of this site different from the rest. This could be the reason for this site to still be remaining at an early stage of succession despite being abandoned from any human activities for at least 20 years, resulting in a lower moth diversity compared to other sites.

Species composition

Past disturbance at site 3 may be indicated by the presence of large numbers of sterrhine species (Holloway & Barlow 1992), particularly some species of *Idaea* and *Scopula,* genera which include a relatively high proportion of open habitat specialists. The numbers of sterrhine species were lowest at site 4 where disturbance had occurred long before and succession had progressed in the well protected area where there was little human disturbance. In contrast, there was still some disturbance in site 3 where humans were observed to enter the forest to extract forest products. Sterrhinae are mainly represented in the clusters associated with sites 1 and 3 as well as in the group of evenly distributed species (Table 3).

Table 3A-E. Species associated with each site. Possible host-plant genera or families are indicated when known.

A. ○ Site 1

Species no.	Species	Total individuals	Host-plants
21	*Heterostegane warreni* Prout	14	?Leguminosae
22	*Hypochrosis binexata* Walker	12	Sterculiaceae
33	*Tasta montana* Holloway	17	
53	*Idaea craspedota* Prout	87	
*56	*Idaea* sp. 2 (1078)	525	
57	*Idaea* sp. 3 (995)	28	
70	*Plutodes argentilauta* Prout	21	
79	*Tasta disciscura* Holloway	23	

N.B: * in overlap with other clusters

(continued)

Table 3 (continued)

B. ❑ Site 1

Species no.	Species	Total individuals	Host-plants
*2	*Alex palparia*	10	
*27	*Ozola* sp. 2 (883)	12	?Verbenaceae
*46	*Godonela nora* Walker	31	?Leguminosae
54	*Idaea phaeocrossa* Prout	127	
*56	*Idaea* sp. 2 (1078)	525	
59	*Idaea triangularis* Hampson	35	
71	*Plutodes cyclaria* Guenée	67	
74	*Scopula* sp. 1 (909)	38	

C. ▲ Site 2

Species no.	Species	Total individuals	Host-plants
1	*Achrosis* sp. 2 (1482)	18	?Ixora
5	*Cleora determinata* Walker	14	?Polyphagous
6	*Cleora inoffensa* Swinhoe	10	?Polyphagous
7	*Cleora propulsaria* Walker	14	?Polyphagous
12	*Diplurodes kerangatis* Holloway	13	
13	*Diplurodes* sp.1 (1266)	19	
15	*Dooabia puncticostata* Warren	11	
19	*Hemithea* sp. 5 (755)	10	
*20	*Fascellina castanea* Moore	19	Lauraceae
25	*Hypomecis subdetractaria* Prout	17	?Polyphagous
31	*Tanaorhinus viridiluteata* Moore	16	?Fagaceae
32	*Tasta micaceata* Walker	11	
34	*Tasta reflexoides* Holloway	15	
38	*Achrosis* nr. *alienata* (1490) Walker	53	?Ixora
41	*Cleora cucullata* Fletcher	48	?Polyphagous
42	*Diplurodes submontana* Holloway	48	
43	*Diplurodes inundata* Prout	31	
49	*Hypochrosis sternaria* Guenée	150	
50	*Hypochrosis binexata* Walker	35	
72	*Plutodes malaysiana* Holloway	20	
78	*Tanaorhinus rafflesii* Walker	28	?Fagaceae

D. ■ Sites 2, 3 and even

Species no.	Species	Total	Host-plants
*2	*Alex palparia* Walker	10	
3	*Astygisa vexillaria* Guenée	15	Rhamnaceae
8	*Comibaena inductaria* Guenée	15	
9	*Comostola meritaria* Walker	12	?Polyphagous
11	*Derambila* sp. 3 (842)	18	
17	*Ectropis bhurmitra* Walker	17	?Polyphagous

(continued)

Table 3 (continued)

D. ■ Sites 2, 3 and even

18	*Epiplema* sp. 7 (1674)	13	
*20	*Fascellina castanea* Moore	19	Lauraceae
23	*Hypomecis separata* Walker	13	?Polypgagous
*24	*Hypomecis sommereri* Sato	13	?Polyphagous
*27	*Ozola* sp. 2 (883)	12	?Verbenaceae
28	*Peratophyga venetia* Swinhoe	11	
29	*Racotis boarmiaria* Guenée	12	Lauraceae
30	*Symmacra solidaria* Guenée	13	Malvaceae
35	*Zamarada eogenaria* Snellen	11	Sterculiaceae
37	*Zythos strigata* Warren	11	
39	*Antitrygodes divisaria* Walker	20	Verbenaceae
44	*Epiplema conflictaria* Walker	33	
*46	*Godonela nora* Walker	31	?Leguminosae
47	*Godonela avitusaria* Walker	23	?Leguminosae
48	*Hemithea* sp.1 (715)	32	
51	*Hypochrosis pyrrhophaeata* Walker	126	
52	*Hypomecis costaria* Guenée	25	?Polyphagous
*60	*Idiochlora ?subexpressa* Walker	20	
61	*Micronia astheniata* Guenée	24	?Euphorbiaceae
62	*Omiza lycoraria* Guenée	30	
*63	*Ornithospila avicularia* Guenée	24	?Dipterocarpaceae
68	*Peratophyga flavomaculata* Swinhoe	32	
69	*Phazaca erosioides* Walker	23	
*73	*Pomasia vernacularia* Guenée	20	
75	*Scopula* sp. 2 (1081)	121	
77	*Spaniocentra spicata* Holloway	48	
80	*Zythos turbata* Walker	20	

E. ● Site 4

Species no.	Species	Total	Host-plants
4	*Calluga catocalaria* Moore	17	
16	*Ectropidia illepidaria* Walker	12	?Dipterocarpaceae
*24	*Hypomecis sommereri* Sato	13	?Polyphagous
26	*Hypomecis tetragonata* Walker	16	?Polyphagous
36	*Zamarada ucatoides* Holloway	10	
40	*Aplochlora* sp. (1465)	20	
45	*Epiplema* sp. 6 (1673)	25	
55	*Idaea* sp. 10 (1002)	22	
58	*Idaea* sp. 5 (996)	33	
*63	*Ornithospila avicularia* Guenée	24	?Dipterocarpaeae
64	*Ornithospila bipunctata* Guenée	24	?Dipterocarpaeae
65	*Ornithospila cincta* (Walker)	183	?Dipterocarpaeae
66	*Ornithospila submonstrans* Walker	85	?Dipterocarpaeae
67	*Ornithospila sundaensis* Holloway	24	?Dipterocarpaeae
*73	*Pomasia vernacularia* Guenée	20	

Site 2, which was logged, mined and abandoned at least about 20 years ago, represents a rather unusual situation as it includes a highly disturbed, early stage successional vegetation, located in an area that is surrounded by remnants of canopy tree species from the previous logging. The light-trap here, although enclosed by ferns and shrubs, probably attracted some primay forest canopy-flying geometroid moth species from the edge of this site. This could account for the relatively high proportion of some canopy-flying groups such as Geometrinae (Holloway 1984) represented in samples from this site compared to others.

Studies on the impact of human disturbance in parts of Indonesia (Holloway 1997) are enabling identification of a number of geometrid genera that appear to be particularly associated with disturbed and early stage successional forest. These include *Pingasa* and some *Thalassodes* in the Geometrinae, *Antitrygodes, Problepsis, Scopula, Symmacra* and *Zythos* in the Sterrhinae, the tribe Hypochrosini (especially *Hypochrosis* and *Achrosis*) and the genera *Cleora, Godonela, Hyposidra* and *Racotis* in the Ennominae. Several species in these genera are included in the associations with species abundant in sites 2 and 3, and that with species evenly distributed over most of the sites.

Conclusion

Samples obtained from the four sites demonstrate that a much reduced geometroid diversity is encountered subsequent to clearance and during the early stage of succession, confirming observations made with samples from Seram, Mulu and Danum (Holloway & Stork 1991, Holloway *et al.* 1992, Holloway 1993a). However, with good forest management strategies such as applying a selectively logging method (modified MUS method, as in this case) and planting of indigenous tree species, a 'faster' recovery of geometroid diversity is achievable.

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