

## SECTION 6: CANOPY INSECTS

### CANOPY ARTHROPODS AND BUTTERFLY SURVEY: PRELIMINARY REPORT

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#### 6.1 Introduction:

Arthropod diversity in tropical forests represents a concentration of biodiversity locally, regionally and globally. Arthropods carry out many significant ecosystem processes, notably decomposition, herbivory and pollination, and they also represent a food source for many vertebrate species. A few Lepidoptera are even a direct source of income in parts of Indonesia and elsewhere. Forest clearance, whether partial or complete, represents a major threat to arthropod diversity. The size of this threat is, however, unknown, as are the consequences for ecosystem 'health'. Theoretical predictions of species extinctions as a result of forest clearance are no substitute for direct measurement of biodiversity. Among the many problems with theoretical predictions based on supposed species-area relationships is the assumption that areas, once cleared of forest, are no longer suitable for any species. This is clearly untrue - secondary forest, plantations of rubber and other tree species and other types of land use all have the potential to contain many arthropods and other species. We are clearly correct in assuming that some forms of land use have lower levels of biodiversity than intact forest, but few studies have actually measured the effect of land-use change on biodiversity. The main problem with actually measuring biodiversity (and the attraction of theoretical approaches) is that biodiversity is impossible to measure in its entirety. Rapid biodiversity assessment methods have therefore been developed to allow comparisons of biodiversity in different places, or the same place at different times, by sampling a subset of biodiversity in a statistically rigorous way in as short a time as possible. The lowland forests of Sumatra have been logged and cleared to such an extent that very little intact forest remains. Clearance has resulted in a range of land uses including secondary forest, rubber plantations and *Imperata* grassland. The effect on biodiversity of such dramatic changes in land use is not known, and there is an urgent need to develop a rational strategy for the conservation of biodiversity. This strategy might entail the protection of remaining fragments of intact forest or the promotion of alternative land uses which are both productive and rich in biodiversity. Such a strategy requires a much better understanding of the variation in biodiversity in the mosaic of land uses in lowland Sumatra.

As part of an overall programme to carry out a rapid biodiversity assessment in the Jambi Province of Sumatra, assessment of arthropod diversity was measured in several ways. This report describes canopy arthropod and butterfly surveys. Separate reports describe termite diversity assessment (Jones *et al.* 1988), light trapping and general insect survey. The aim of this part of the project was to assess the impact of logging and other land use changes on the diversity of arthropods in central Sumatra. Canopy arthropods were surveyed because previous studies indicate that arthropod diversity reaches a maximum in the canopies of tropical forest trees. However, few studies have compared the diversity of arthropods in the canopies of intact forest and plantation trees. Butterfly surveys were carried out to provide a comparison of insect diversity in all sites -- several land-use types surveyed had no tree canopy.

The following land use types were surveyed:

- Intact forest
- Logged forest
- Secondary forest
- Jungle rubber
- Rubber plantation
- *Paraserianthes* plantation
- Cassava fields
- *Chromolaena* fallow
- *Imperata* grassland

Full site descriptions are given by Gillison *et al.* (this report).

## **6.2 Aims and objectives:**

The aim of this project was to assess the impact of logging and other land use changes on the diversity of arthropods in central Sumatra and so provide baseline data for biodiversity assessment based on arthropod diversity.

The objectives of this project were:

- To assess the abundance and diversity of the *canopy arthropod* community of selected land-use types.
- To assess the abundance and diversity of the *butterfly* community of selected land-use types.

## **6.3 Personnel:**

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## **6.4 Methods:**

### **6.4.1 Review of existing methods:**

#### **6.4.1.1 Introduction:**

A wide range of methods is used to assess the diversity of insects in tropical forests and other habitats. These include canopy fogging and butterfly transects; the two methods used here and discussed below. Other methods include a) general collecting, b) ground quadrat or transect sampling (as used to estimate termite and ant diversity (Jones *et al.* 1988)), c) light trapping, and d) Malaise and flight interception trapping. These methods are discussed at length elsewhere and will not be described in detail here. It is worth pointing out that some methods are more suitable for collection of specimens for taxonomic work, and other methods are more suitable for biodiversity assessment. The key requirement for the latter is comparability. Many methods do not provide data that are comparable or are only comparable after analytical methods, which are not designed for biodiversity assessment (such as rarefaction). Broadly speaking, techniques which employ standardised sampling across transects or grids are the best methods and general collecting over non-standardised time periods are the worst. Trapping techniques should also be avoided where possible (at least in rapid surveys) because unless the

traps are used under the same environmental conditions (e.g. cloud cover and moonlight for light trapping), the results will not be comparable. Additional problems exist for 'passive' traps, such as Malaise traps, whose catches are affected by the degree to which they are located in open (e.g. grassland) or closed habitats (e.g. intact forest). This is a problem which may not be overcome, and results may be obtained which reflect the movement of insects within and through plots, rather than the diversity of insects within them.

#### **6.4.1.2 Canopy arthropods:**

The sampling of canopy arthropods has only been made possible through the development of canopy fogging methods. A full review of canopy sampling is given by Stork, Adis and Didham (1995). The techniques as applied in this project are outlined below.

#### **6.4.1.3 Butterfly sampling:**

A number of different approaches can be used to sample butterflies, including trapping and netting, but perhaps the most significant development in butterfly survey has been the use of 'butterfly walks' (Pollard and Yates 1993). This method was originally developed for European species and has proved useful in quantifying temporal and spatial trends in the abundance and diversity of species in the UK and elsewhere (e.g. Pollard, Moss and Yates 1995). It has now also been adapted for use in tropical forests (e.g. Hill *et al.* 1995, Watt *et al.* 1997, Lawton *et al.* 1998, Stork *et al.* in prep.).

### **6.4.2 Field methods used on this survey:**

#### **6.4.2.1 Plot locations:**

Two plots were chosen in each land-use type, apart from *Chromolaena* fallow and secondary forest (where single plots were surveyed). The plots in intact forest, logged forest and *Paraserianthes* plantation were distinct enough spatially to be regarded as replicates for the arthropod survey, but the rubber plantation, jungle rubber, Cassava and *Imperata* plots were situated very close to each other and should be regarded as 'psuedo-replicates'. The data from these plots have not been combined for the purposes of this report, but this problem is discussed below.

#### **6.4.2.2 Canopy fogging:**

Canopy fogging was done at all 11 plots with tree canopies, *i.e.* the forest and plantation plots. A 'King' fogger [specifications available] was used to fog the canopy with a pyrethroid-based insecticide diluted with diesel. In each plot, apart from the jungle rubber plots, 25 1m<sup>2</sup> collecting trays were suspended on ropes strung between trees. In each of the jungle rubber plots, 20 trays were used. The collecting trays were placed within, or close to, the 4×50 m transects used for the plant surveys (Gillison *et al.* 1988). Approximately two trays were placed under each tree so that about twelve trees were fogged in each plot. A collecting bottle was attached to each tray with approximately 2 cm of 70% alcohol. A pre-printed label was placed in each collecting bottle identifying the location of each sample. One hour after fogging, the trays were washed down with 70% alcohol and the collecting bottles (and trays) were removed. The arthropod samples were then cleaned, transferred to glass tubes and sorted as described below.

### **6.4.2.3 Butterfly transects:**

Butterfly transects were done in all plots, i.e. those with and without tree canopies. Two butterfly transects were sampled in each plot, so that each of the two available recorders could work independently without disturbance. Each transect comprised about half the 'plant' transects plus another 25m. The observers walked up and down their transect for 30 minutes and then moved to the other transect. Thus each plot was surveyed for two person-hours. The observers attempted to catch any butterfly flying close to them. Captured butterflies were placed in paper envelopes on which were written the date, time, plot number and recorder. Butterfly abundance in each plot was measured by additionally recording the number of butterflies seen and not caught. All butterflies were identified to family level in the field. Captured butterflies were removed for sorting to morpho-species.

### **6.4.3 Analysis:**

#### **6.4.3.1 Canopy fogging:**

Canopy fogging was used to assess the abundance of arthropods in different orders and the diversity of ants, spiders and beetles. Thus, during the field survey ants, beetles and spiders were removed from each sample, the samples were fully sorted to order, and the abundance of each group recorded.

The aim of post-field survey work is to:

1. Sort the ants, beetles and spiders to morpho-species.
2. Sort all samples to order.

For this report, preliminary analyses on the data were carried out as described in the results section. After sorting to morpho-species, further analyses were being carried out, including estimation of species richness (Colwell and Coddington and Coddington 1994) and comparison of the species composition of different sites (Krebs 1989).

#### **6.4.3.2 Butterfly transects:**

It was concluded that there were insufficient individual butterflies caught, as a result of the time available for surveying butterflies, to allow comparisons of species richness and composition. Analysis of butterfly abundance, including the abundance of different families of butterflies was carried out.

### **6.4.4 Data storage and access:**

At present copies of all data are held by the consultants and CIFOR. Long-term arrangements for data storage and access will be made during early 1998. (Annex III, Table 8,9,10)

## **6.5 Preliminary results:**

### **6.5.1 Canopy arthropod abundance:**

#### *Total arthropod abundance*

The mean number of arthropods varied from about 20 to 290 arthropods m<sup>-2</sup> (Figure 6.1). Arthropods were most abundant in one of the jungle rubber plots (BS11) and least abundant in

one of the *Paraserianthes* plots (BS6). Note that Figure 6.1 and subsequent figures show mean abundances and standard errors.

*Abundance of different arthropod groups*

Table 6.1 shows the average number of arthropods in each of the groups sorted to order (or family). Note that all the data discussed below are from partial sorting, apart from the ants, beetles and spiders, and must be considered to be preliminary. The most abundant groups were the ants and the termites, on average 32 and 21 m<sup>-2</sup>, respectively. Together these two groups made up 67% of the total number of arthropods sampled. The next most abundant groups were the Coleoptera, Diptera, Hemiptera, Thysanoptera, and spiders (Araneae). Together these group, plus the ants and termites, made up 85% of the total number of arthropods. Psocoptera, Hymenoptera (other than ants), Collembola and several other groups made up the remaining 15%. Each group is considered separately below.

*Ants*

Not surprisingly, the pattern of abundance of ants in different plots was very similar to the pattern of abundance of total arthropods (Figure 6.2). Ants were notably abundant in the jungle rubber plots (BS11 in particular), one of the intact forest plots (BS1), and the secondary forest plot. Ants were notably few in numbers in the rubber plantation plots.

*Termites*

Termites were the most patchily distributed group across the different plots (Figure 6.3). They were only recorded in four plots and abundant in only two of those: one of the intact forests plots (BS2), and one of the logged forest plots (BS5).

**Table 6.1**  
**The mean and percentage abundance of different arthropod groups recorded from canopy fogging at Pasir Mayang area, Jambi, Sumatra Nov. 1997.**

<b>Order</b>	<b>Mean</b>	<b>Percentage</b>
Ants	31.7	32.7
Termites	20.7	21.3
Coleoptera	8.3	8.6
Diptera	6.4	6.6
Hemiptera	5.5	5.7
Thysanoptera	5.2	5.4
Spiders	4.6	4.7
Psocoptera	4.4	4.5
Hymenoptera	3.5	3.6
Collembola	2.7	2.8
Lepidoptera	1.5	1.6
Acari	0.9	0.9
Orthoptera	0.8	0.8
Blatodea	0.5	0.6
Neuroptera	0.1	0.1
<b>Total</b>	<b>97.0</b>	<b>100.0</b>

### *Coleoptera*

Coleoptera were most abundant in the jungle rubber plots and one of the rubber plantation plots (Figure 6.4). Elsewhere, they were more-or-less equally abundant.

### *Diptera*

Diptera were most abundant in the rubber plantation plots, the jungle rubber plots, one of the logged forest plots (BS5) and one of the *Paraserianthes* plots (BS7) (Figure 6.5).

### *Hemiptera*

Hemiptera were more abundant in the logged and secondary forest plots, the jungle rubber plots and one of the *Paraserianthes* plots (BS7) than elsewhere (Figure 6.6).

### *Thysanoptera*

Thysanoptera were particularly abundant in the jungle rubber plots and one of the logged forest plots (BS4) (Figure 6.7).

### *Spiders*

Spiders were most abundant in one of the jungle rubber plots (BS11) and more or less evenly abundant elsewhere (Figure 6.8).

### *Psocoptera*

Psocoptera were most abundant in one of the jungle rubber plots and least abundant in one of the *Paraserianthes* plots (BS7) (Figure 6.9).

### *Hymenoptera*

Hymenoptera other than ants were notably abundant in one of the jungle rubber plots (BS11) and notably few in number in one of the *Paraserianthes* plots (BS6) and one of the intact forest plots (BS2) (Figure 6.10).

### *Collembola*

Collembola were most abundant in the forest plots, recorded in low numbers in the jungle rubber and rubber plantation plots and absent from the *Paraserianthes* plots (Figure 6.11).

### *Lepidoptera*

Lepidoptera were notably abundant in only one plot, the BS8 *Paraserianthes* plots (Figure 6.12).

### *Acari*

Acari were more abundant in the secondary forest plot and one of the logged plots (BS4) than elsewhere (Figure 6.13).

### *Orthoptera*

Orthoptera were uncommon in all plots, particularly the rubber plantation plots, and were not recorded in the *Paraserianthes* plots (Figure 6.14).

### *Blattodea*

Small numbers of Blattodea were recorded but they were most abundant in the secondary forest plot and one of the jungle rubber plots (BS11) and not recorded in the *Paraserianthes* plots (Figure 6.15).

### *Neuroptera*

Very few Neuroptera were recorded in the survey, none at all in the jungle rubber and *Paraserianthes* plots (Figure 6.16).

## **6.5.2 Butterfly transects:**

### **6.5.2.1 Total butterflies:**

The total number of butterflies caught or seen in an hour ranged from almost 50 in one of the rubber plantation plots to less than one in the *Imperata* grassland plots (Figure 6.17). Butterflies were particularly uncommon in the *Imperata* and Cassava plots and in one of intact forest plots (BS2), and most abundant in the jungle rubber, *Chromolaena*, one of the logged forest plots (BS4) and one of the rubber plantation plots (BS9). Figure 6.18 shows the numbers of butterflies seen; that is, it excludes the relatively small numbers of butterflies caught. It is included to show the variation between different sampling periods. The number of butterflies recorded in each family is described below.

### *Papilionidae*

The greatest numbers of papilionids were recorded in the jungle rubber plots and one of the rubber plantation plots (BS9), and none were recorded in the Cassava and *Imperata* plots (Figure 6.19).

### *Pieridae*

Large numbers of pierids were recorded in one of the rubber plantation plots (BS9), intermediate numbers were recorded in the jungle rubber plots and one of the logged forest plots (BS4), and few or none were recorded elsewhere (Figure 6.20).

### *Nymphalidae*

Nymphalids were more abundant in the jungle rubber plots and the *Chromolaena* plot than elsewhere (Figure 6.21).

### *Lycaenidae*

Lycaenids were more abundant in the jungle rubber, rubber plantation and one of the logged forest sites than elsewhere and notably absent from the Cassava, *Imperata* and one of the intact forest plots (BS2) (Figure 6.22).

## **6.6 Discussion:**

### **6.6.1 Preliminary results:**

#### **6.6.1.1 Canopy fogging:**

It must be emphasised that the above results are preliminary, subject to amendment after the final order sorting and include no species diversity information. The following tentative observations should, however be highlighted as a basis for subsequent discussion.

- Eleven plots were surveyed, producing a total of 22,700 arthropods, an average of 97m<sup>-2</sup>.
- The most abundant groups were ants and termites.
- The abundance and composition of arthropod taxa was affected by land use as follows:
  - total arthropod abundance and the abundance of ants, Coleoptera, spiders, Hemiptera, Thysanoptera, Hymenoptera (other than ants) and Blattodea was greatest in the jungle

rubber plots; however, these plots contained relatively low numbers of Collembola, Acari and Neuroptera;

- the abundance of arthropods in the intact forest plots was surprisingly low but these plots, like all 'forest' plots, contained relatively high numbers of Collembola;
- arthropod numbers in the logged and secondary plots were greater than or similar to those found in the intact forest plots;
- total arthropod numbers were lowest in the plantation plots; the rubber plantation plots had particularly low numbers of ants, Collembola, Orthoptera and Blattodea and the *Paraserianthes* plots contained no Collembola, Orthoptera, Blattodea and Neuroptera.

In discussing these results, their unique nature must be borne in mind: no other study of the effects of land use on arthropod diversity has included such a range of land uses. Thus we can compare the results of this study with surveys of intact and disturbed forest elsewhere, but we cannot compare the jungle rubber and plantation plots with studies elsewhere, because this is the first time this has been attempted. Nevertheless:

- The mean total number of arthropods recorded in this survey is in line with that recorded elsewhere (e.g. Watt *et al.* (1997a) in Cameroon).
- The numbers of ants and other taxa accord with other studies, but the number of termites is markedly higher than found elsewhere.
- This study is similar to a few others (e.g. Eggleton *et al.* 1996, Watt *et al.* 1997ab, Lawton *et al.* 1998) in finding that the replacement of intact forest with other land uses tends to result in a decrease in the abundance of several groups of arthropods.
- This survey suggests that some land-use alternatives to intact forest, such as jungle rubber, may be rich in arthropods.

Differences in arthropod abundance do not necessarily lead to parallel differences in arthropod diversity so it must again be emphasised that these comments are tentative.

#### **6.6.1.2 Butterfly survey:**

The butterfly survey suffered from being too rapid. Because of the priority given to canopy sampling in as many plots as possible, we were only able to spend a maximum of two person hours in each plot. This meant that the numbers of butterflies caught were too small to permit analysis, and we have relied instead on the numbers seen during the transect walks. Even these data are not as useful as they would have been if we had been able to spend about twice as long in each plot. There is also the concern that the numbers of butterflies were particularly low because of the recent drought.

It would, therefore, be wrong to conclude too much from this survey. However the following tentative conclusions may be made:

- Butterfly abundance in most families was notably high in the jungle rubber plots.
- The total number of butterflies in one of the rubber plantation plots was higher than elsewhere, mainly due to the particularly high number of pierids recorded there.
- Numbers of butterflies in one the intact forest plots was particularly low (lower than in any of the other forest or plantation plots).

- The number of butterflies, particularly nymphalids, in the *Chromolaena* plot was surprisingly high. However, the proximity of this very small plot to the jungle rubber plots should be noted - these plots also had similar numbers of nymphalids.
- Very small numbers of butterflies were recorded in the Cassava and *Imperata* plots.

## **6.6.2 Review of methods:**

### **6.6.2.1 Canopy fogging:**

Eleven sites were fogged and the material collected partially sorted in ten days (excluding time spent travelling and organising). Excluding sorting time (travel *etc.*), each plot took six whole days (or approximately 30 person days, comprising twelve person days of the consultant's time, six person days from technical support staff and twelve person days from labourers). A total of about ten person days were spent partially sorting arthropods during and immediately after the survey. It is critically important that fogging surveys produce comparable data. This can only be guaranteed by the selection of representative plots and complete coverage of the canopy of each plot by the insecticide fog. We consider that all the plots chosen were representative of the land-use types in the survey area. We also consider that some plot types were more affected than others by the recent exceptional dry season. In particular, the intact forest plots and the *Paraserianthes* plots had much less canopy foliage than the rubber (jungle and plantation) plots.

Most of the plot 'pairs' within each land use provided adequate replicates. However, the jungle rubber plots and the rubber plantation plots may have been too close to be considered true replicates for arthropod survey. The finding that there was marked variability in the abundance of arthropods in these plots demonstrates how spatially variable arthropod communities are in forests and plantations.

### **6.6.2.2 Butterfly survey:**

As mentioned above, insufficient time was given to the butterfly survey because of other priorities. Two (person) hours were spent collecting and recording the numbers of butterflies present in each plot. Surprisingly, this led to relatively little variation within the numbers of butterflies seen - note the errors in Figure 6.18. A relatively small increase in the amount of time spent recording butterfly abundance would have yielded much more useful data. Considerably more time would have been needed to collect useful data on species composition. The recent drought is likely to have reduced the number of butterflies in the area and this factor, plus the small amount of time spent surveying butterflies, means that we have probably considerably underestimated the abundance and diversity of butterflies in the study area.

The comments above regarding replication apply to the butterfly survey as well. For example, many individual butterflies were seen flying from one plot to another in the rubber plantation. Plot size is likely to have affected the results in at least one case: the surprisingly numbers of butterflies recorded in the relatively small *Chromolaena* plot may have been dispersing from the nearby jungle rubber plots.

## **6.6.3 Relevance of study at regional and global levels:**

As mentioned above, no previous study has investigated the effects of such a range of land uses on arthropod diversity. It is therefore unique regionally and one of a very few similar studies globally (Eggleton *et al.*, 1996; Watt *et al.*, 1997; Lawton *et al.*, 1998).

#### **6.6.4 Relevance to Rapid Biodiversity Assessment:**

This survey is relevant to Rapid Biodiversity Assessment (RBA) first, because arthropods comprise the largest component of terrestrial biodiversity. Second, the techniques employed fulfilled the criterion of 'rapid' because of the short time spent collecting samples in the field. Third, both methods were designed to produce comparable results.

#### **6.6.5 Need for further surveys in this and other regions:**

Generally, many more surveys such as this are needed to assess the impact of land use change on biodiversity. These surveys should include as many land-use types as possible. For example, a similar survey in many other parts of Sumatra should include oil palm (not yet widely planted in the part of Jambi where this survey was conducted). Specifically, surveys such as this should be repeated where there is significant seasonal variation in the abundance of the taxa being considered or where particular conditions prevail. It is likely, for example, that this survey was affected by the severe drought which preceded it.

#### **6.7 Conclusions:**

Tentative conclusions are presented above at the start of the Discussion section. The main conclusions are summarised below:

- This study is similar to a few others in finding that the replacement of intact forest with other land uses tends to result in a decrease in the abundance of several groups of canopy arthropods.
- However, this survey suggests that some land use alternatives to intact forest, such as jungle rubber, may be rich in canopy arthropods.
- The butterfly survey was of limited value apart from demonstrating that arthropod abundance and diversity in Cassava and *Imperata* was considerably poorer than in all other land use types.

#### **6.8 Recommendations:**

It is recommended that:

- Further studies such as this are carried out to assess the impact of land use change on biodiversity.
- Such studies should use RBA techniques because it is more important to survey many land-use types adequately than a few sites in unnecessary detail.
- More research is therefore needed to establish suitable RBA techniques, particularly standard techniques for particular taxa.
- RBA projects should follow the multi-taxa approach adopted here (Gillison *et al.* 1998), so that as much biodiversity as possible is sampled without any assumptions being made about 'indicator' taxa, and so that relationships between the diversity of different taxa can be better understood and, perhaps, lead to the development of reliable biodiversity indicators.

## 6.9 References<sup>1</sup>

- Colwell, R. K., and J. A. Coddington. (1994). Estimating terrestrial biodiversity through extrapolation. *Philosophical Transactions of the Royal Society of London Series B-Biological Sciences* **345**:101-118.
- Eggleton, P., D. E. Bignell, W. A. Sands, N. A. Mawdsley, J. H. Lawton, and N. C. Bignell. (1996). The diversity, abundance and biomass of termites under differing levels of disturbance in the Mbalmayo Forest Reserve, southern Cameroon. *Philosophical Transactions of the Royal Society of London Series B-Biological Sciences* **351**:51-68.
- Gillison, A.N. (1988). A Plant Functional Attribute Proforma for Dynamic Vegetation Studies and Natural Resource Surveys. Tech. Mem. 88/3, CSIRO Div. Water Resources, Canberra.
- Hill, J. K., K. C. Hamer, L. A. Lace, and W. M. T. Banham. (1995). Effects of selective logging on tropical forest butterflies on Buru, Indonesia. *Journal Applied Ecology* **32**:754-760.
- Krebs, C. J. (1989). *Ecological Methodology*, 1st Edition. Harper Collins, New York.
- Lawton, J. H., D. E. Bignell, B. Bolton, G. F. Bloemers, P. Eggleton, P. M. Hammond, M. Hodda, R. D. Holt, T. B. Larsen, N. A. Mawdsley, N. E. Stork, D. S. Srivastava, and A. D. Watt. (1998). Biodiversity inventories, indicator taxa and effects of habitat modification in tropical forest. *Nature* **391**:72-76.
- Pollard, E., and T. J. Yates. (1993). *Monitoring Butterflies for Ecology and Conservation*. Chapman and Hall, London.
- Pollard, E., D. Moss, and T. J. Yates. (1995). Population trends of common british butterflies at monitored sites. *Journal Applied Ecology* **32**:9-16.
- Stork, N., J. Adis, and R. K. Didham, editors. (1995). *Canopy Arthropods*. Chapman and Hall, London.
- Watt, A. D., N. E. Stork, P. Eggleton, D. Srivastava, B. Bolton, T. B. Larsen, and M. J. D. Brendell. 1997a. Impact of forest loss and regeneration on insect abundance and diversity. Pp. 274-286 in A. D. Watt, N. E. Stork and M. D. Hunter, (eds.) *Forests and Insects*. Chapman and Hall, London.
- Watt, A. D., N. E. Stork, C. McBeath, and G. L. Lawson. 1997b. Impact of forest management on insect abundance and damage in a lowland tropical forest in southern Cameroon. *Journal Applied Ecology* **34**:985-998.

<sup>1</sup>References to other reports in this series to be inserted.

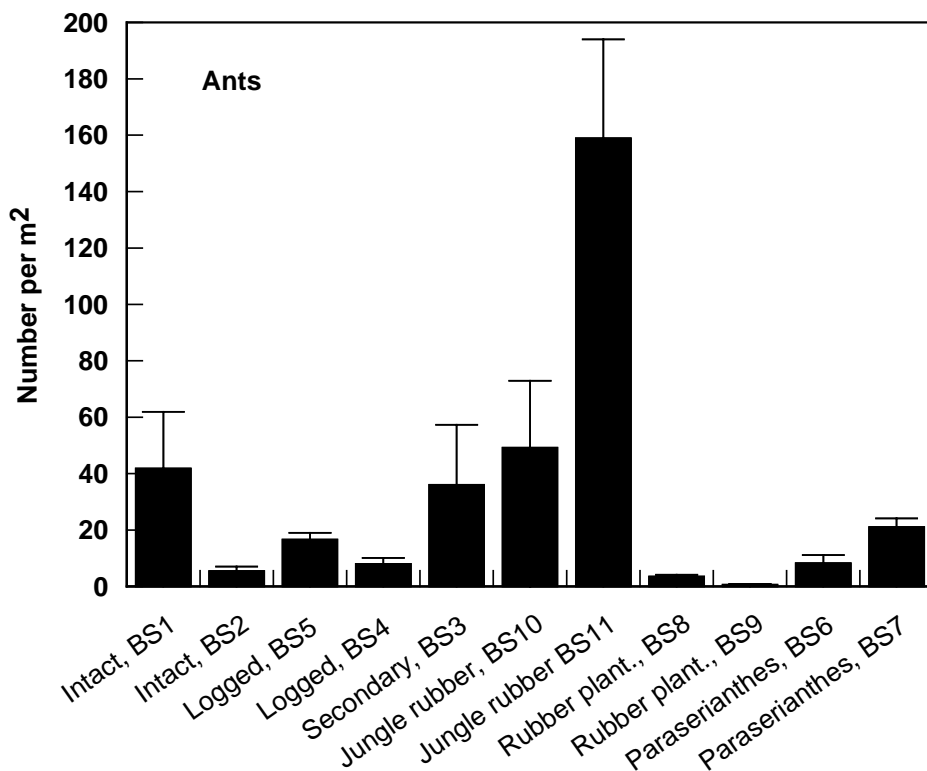
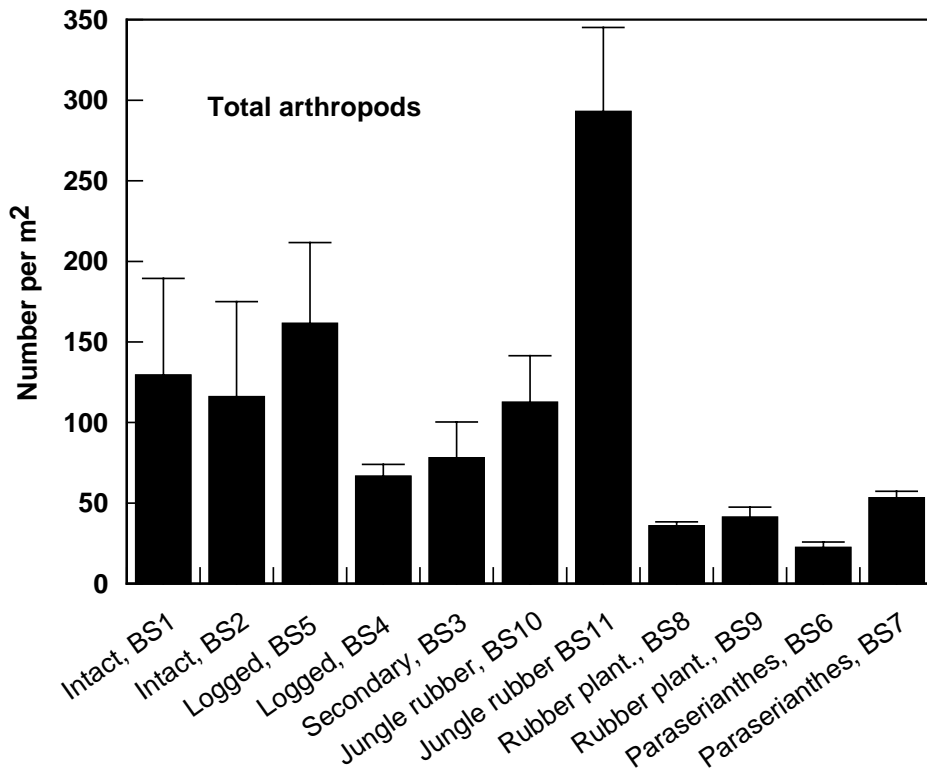


Figure 1 (above) and 2 (below): mean abundance of total arthropods and ants, respectively, assessed by canopy fogging in the Pasir Mayang area, Jambi, Sumatra, November 1997.

**Figures 6.1. & 6.2**

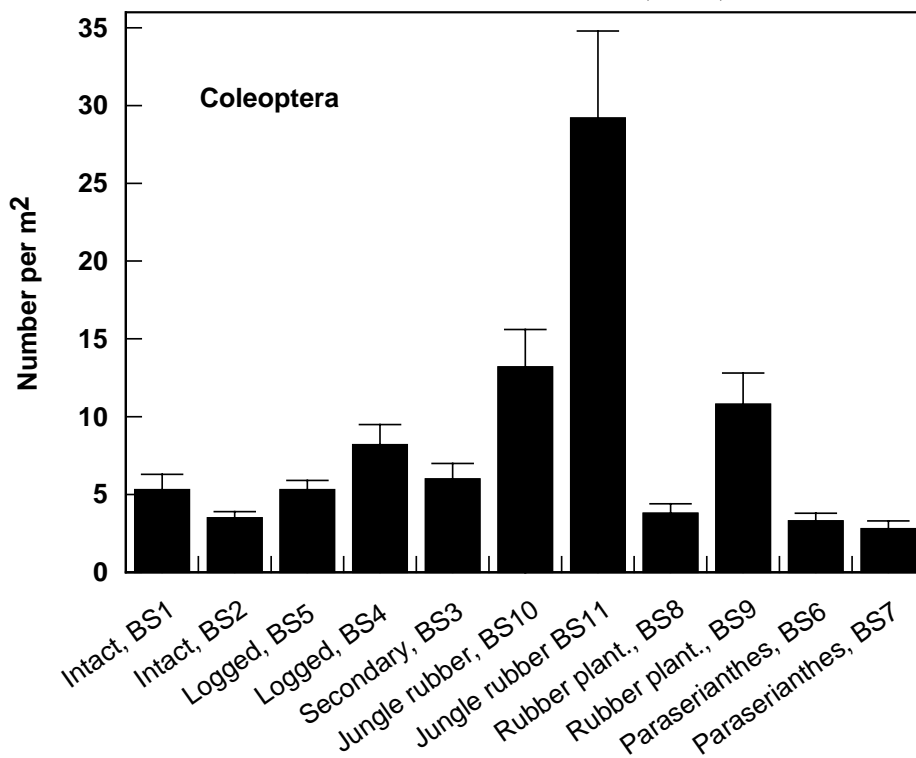
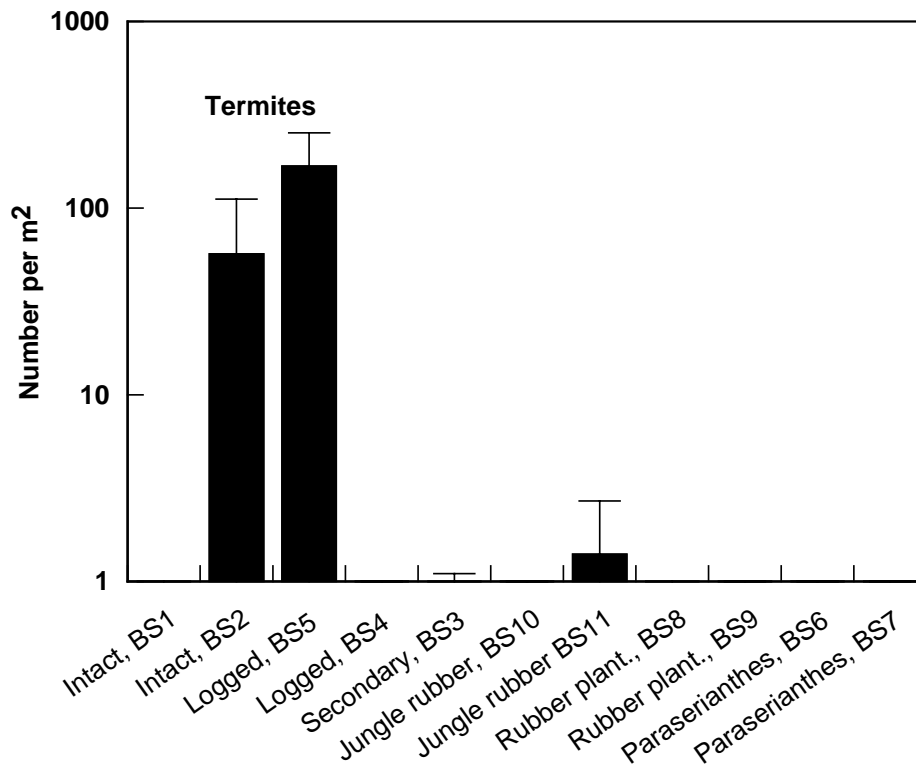


Figure 3 (above) and 4 (below): mean abundance of termites and Coleoptera, respectively, assessed by canopy fogging in the Pasir Mayang ar Jambi, Sumatra, November 1997.

**Figures 6.3 & 6.4**

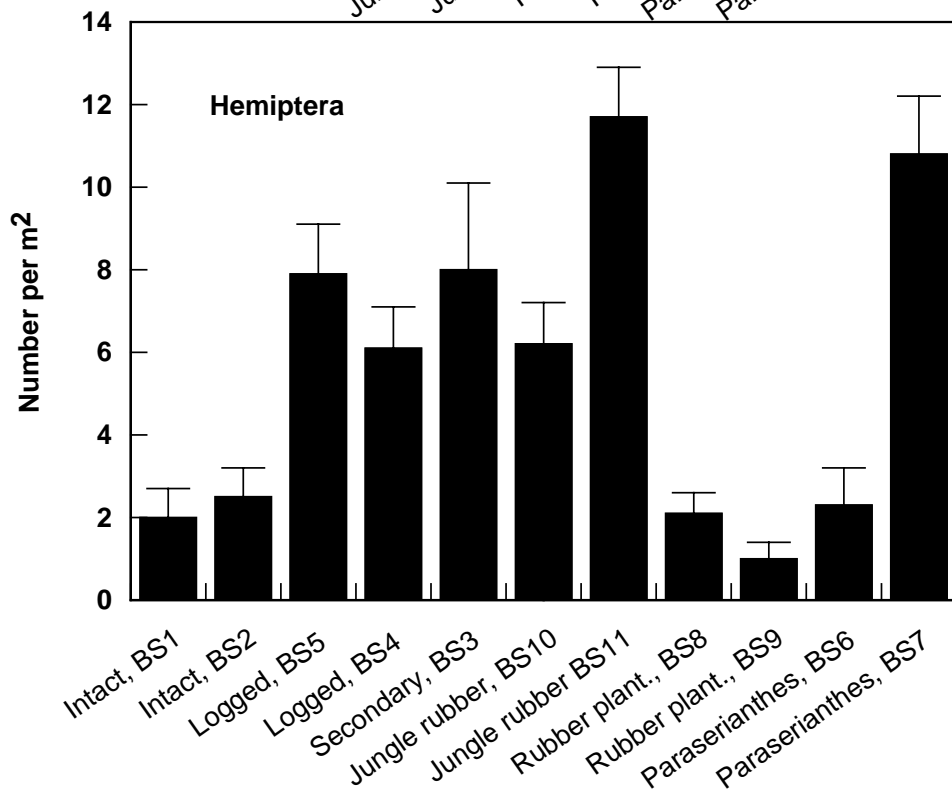
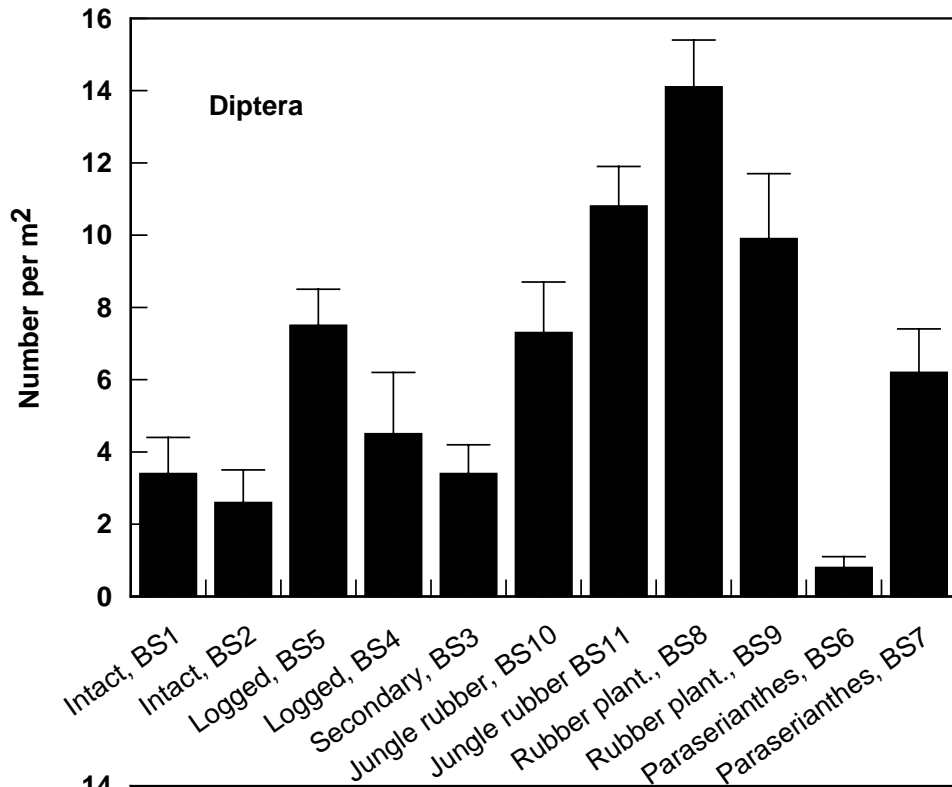


Figure 5 (above) and 6 (below): mean abundance of Diptera and Hemiptera, respectively, assessed by canopy fogging in the Pasir Mayang ar Jambi, Sumatra, November 1997.

**Figures 6.5 & 6.6**

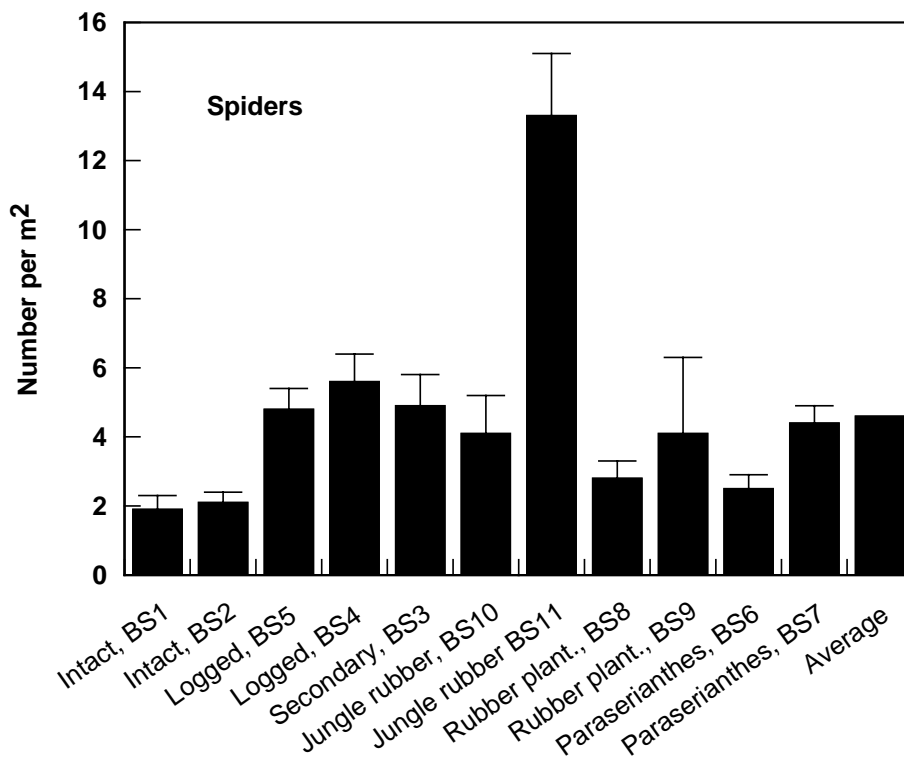
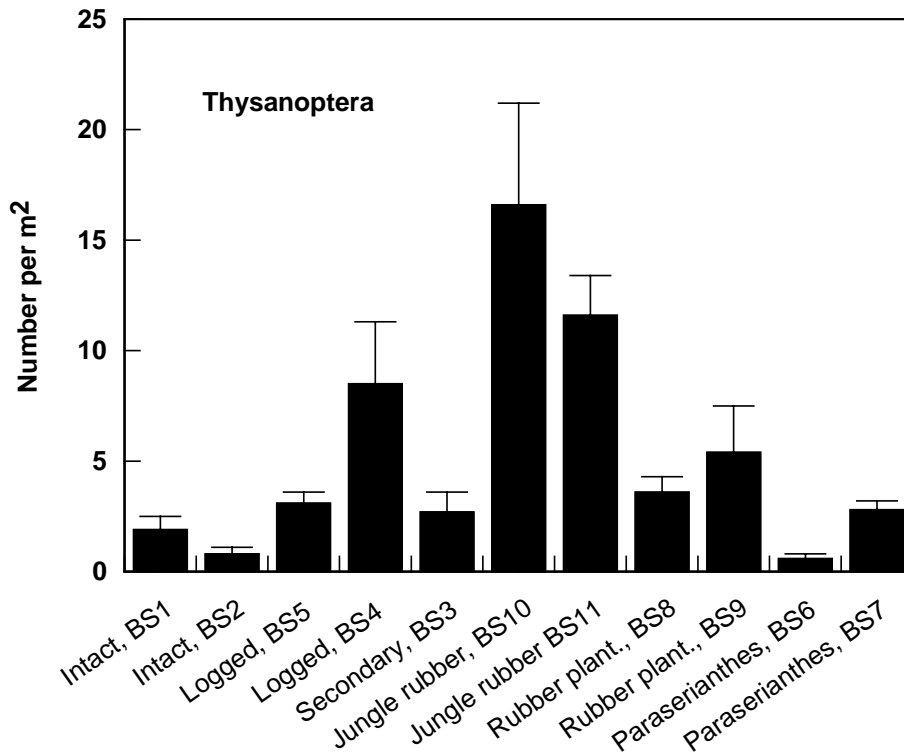


Figure 7 (above) and 8 (below): mean abundance of Thysanoptera and spiders, respectively, assessed by canopy fogging in the Pasir Mayang area, Jambi, Sumatra, November 1997.

**Figures 6.7 & 6.8**

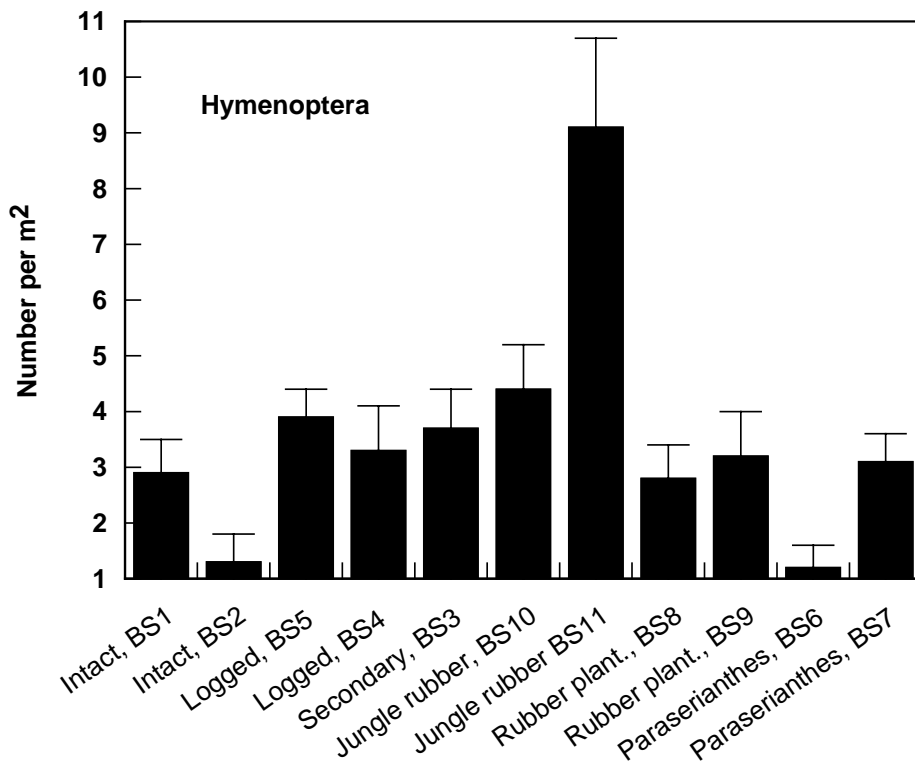
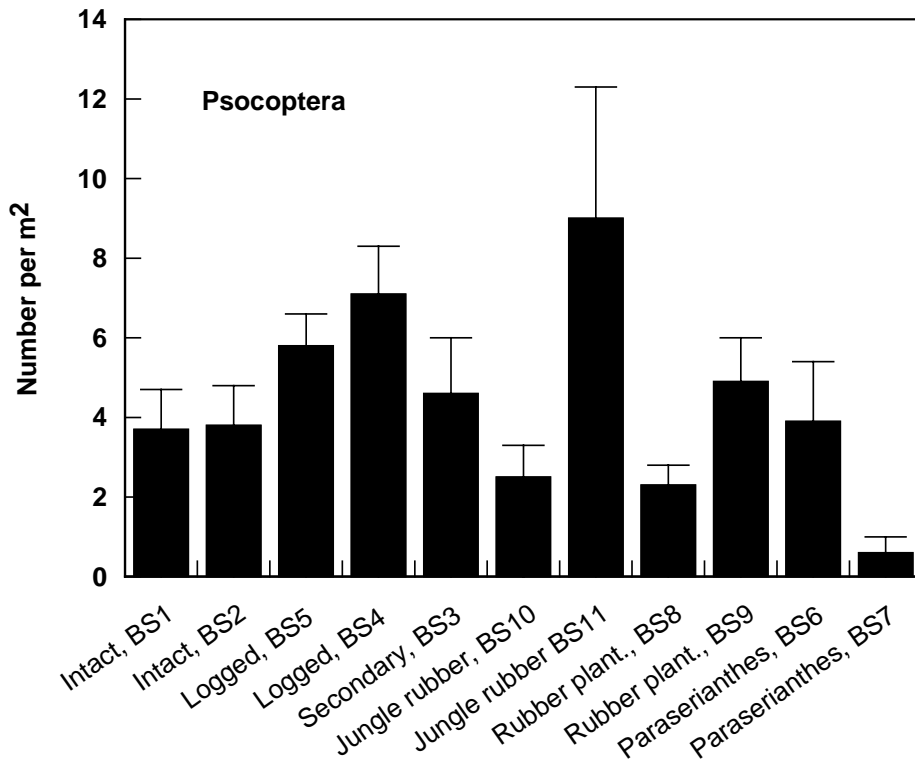


Figure 9 (above) and 10 (below): mean abundance of Psocoptera and Hymenoptera, respectively, assessed by canopy fogging in the Pasir Mayang area, Jambi, Sumatra, November 1997.

**Figures 6.9 & 6.10**

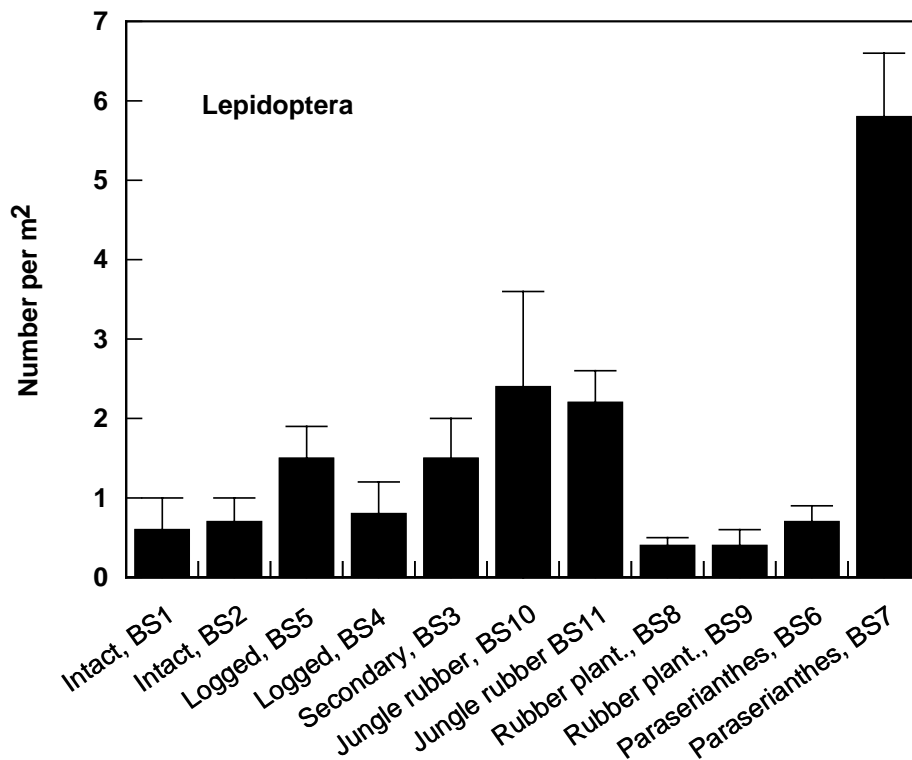
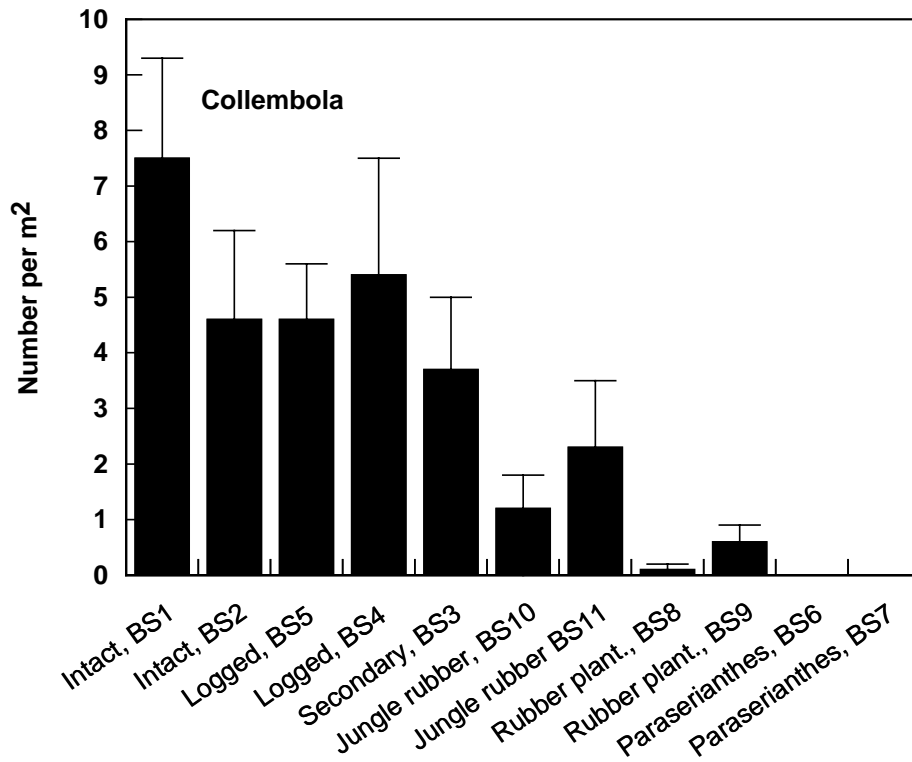


Figure 11 (above) and 12 (below): mean abundance of Collembola and Lepidoptera, respectively, assessed by canopy fogging in the Pasir Mayang area, Jambi, Sumatra, November 1997.

**Figures 6.11 & 6.12**

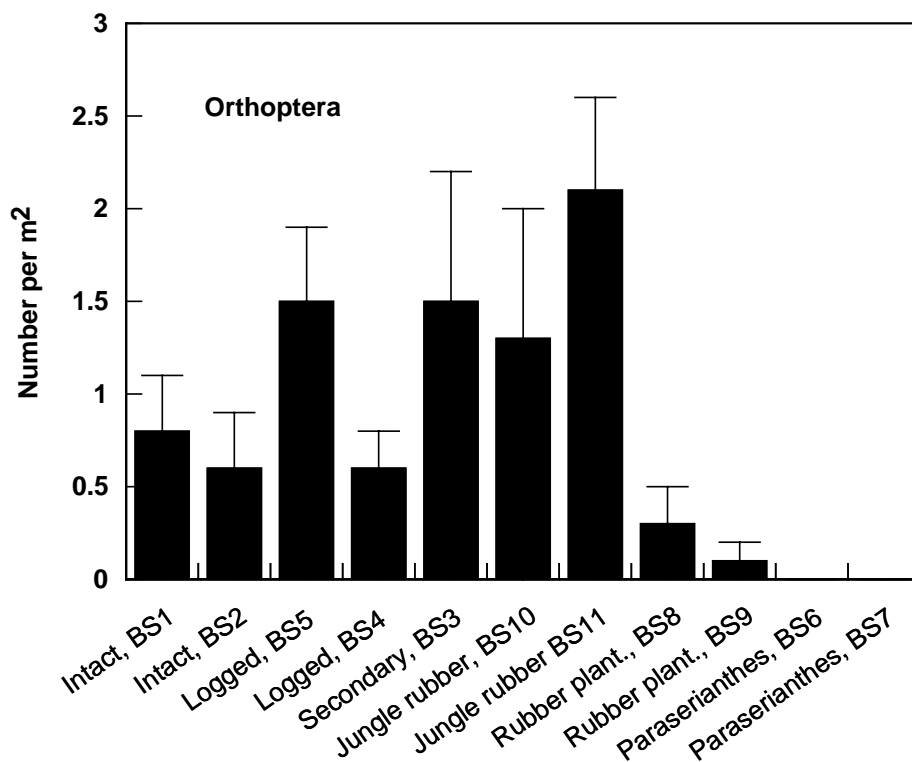
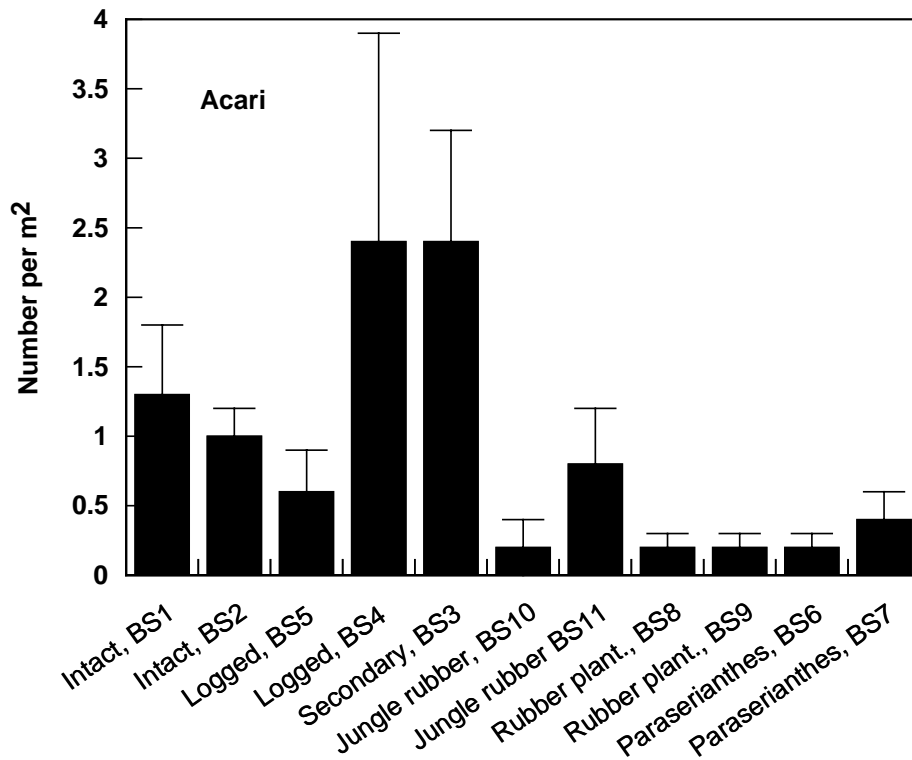


Figure 13 (above) and 14 (below): mean abundance of Acari and Orthoptera, respectively, assessed by canopy fogging in the Pasir Mayang area, Jambi, Sumatra, November 1997.

**Figures 6.13 & 6.14**

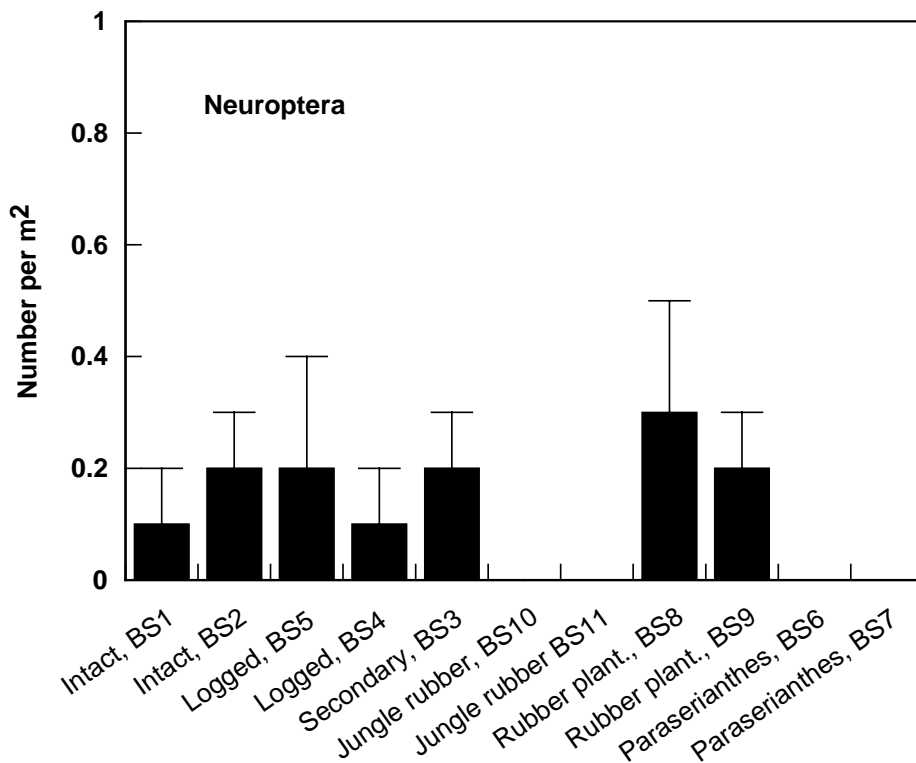
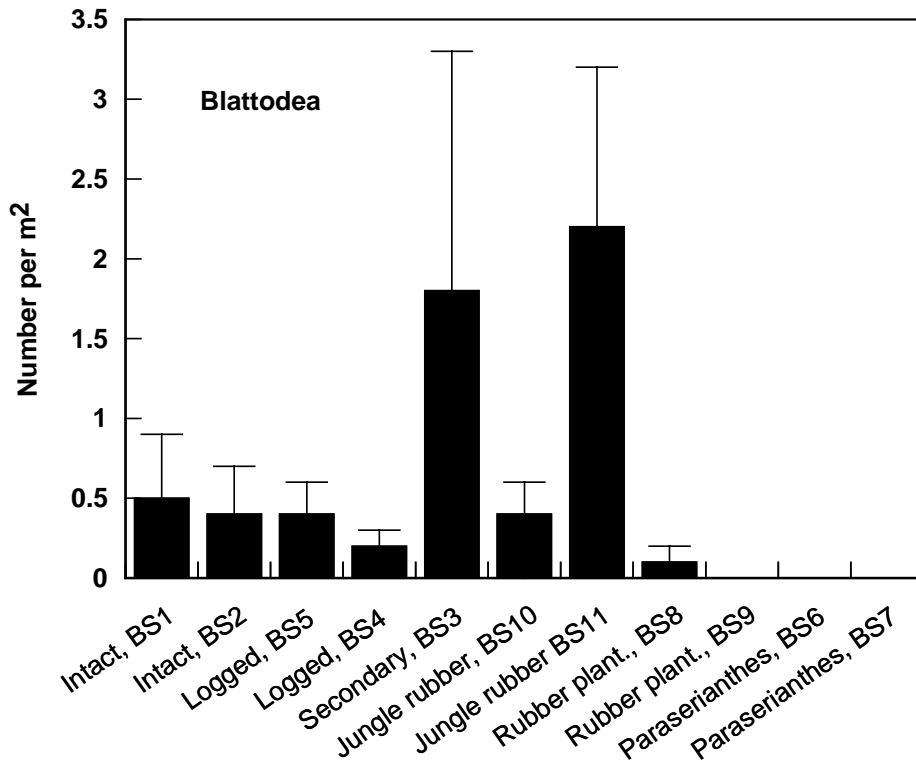


Figure 15 (above) and 16 (below): mean abundance of Blattodea and Neuroptera, respectively, assessed by canopy fogging in the Pasir Mayang area, Jambi, Sumatra, November 1997.

**Figures 6.15 & 6.17**

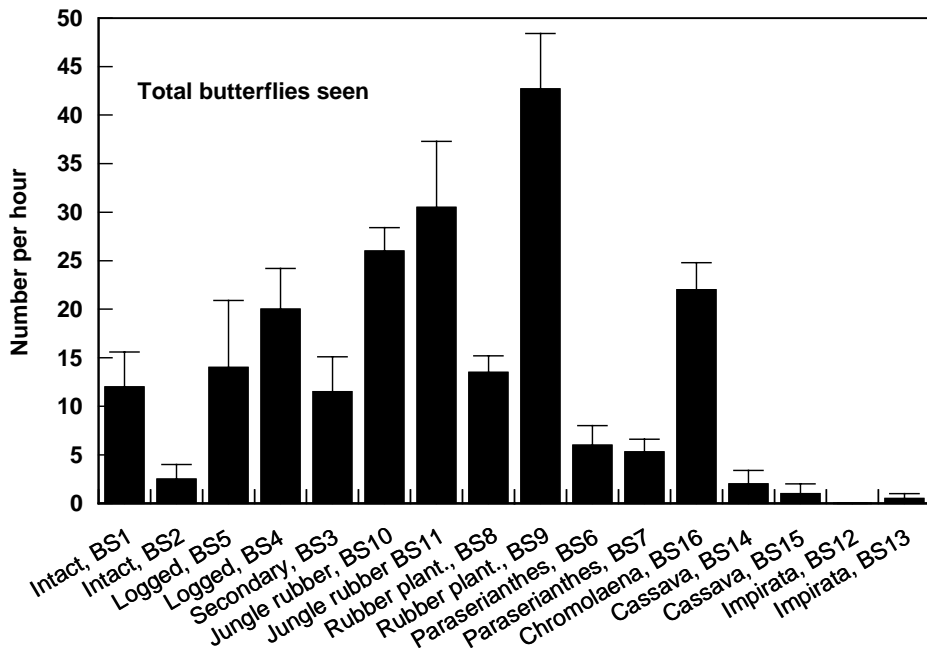
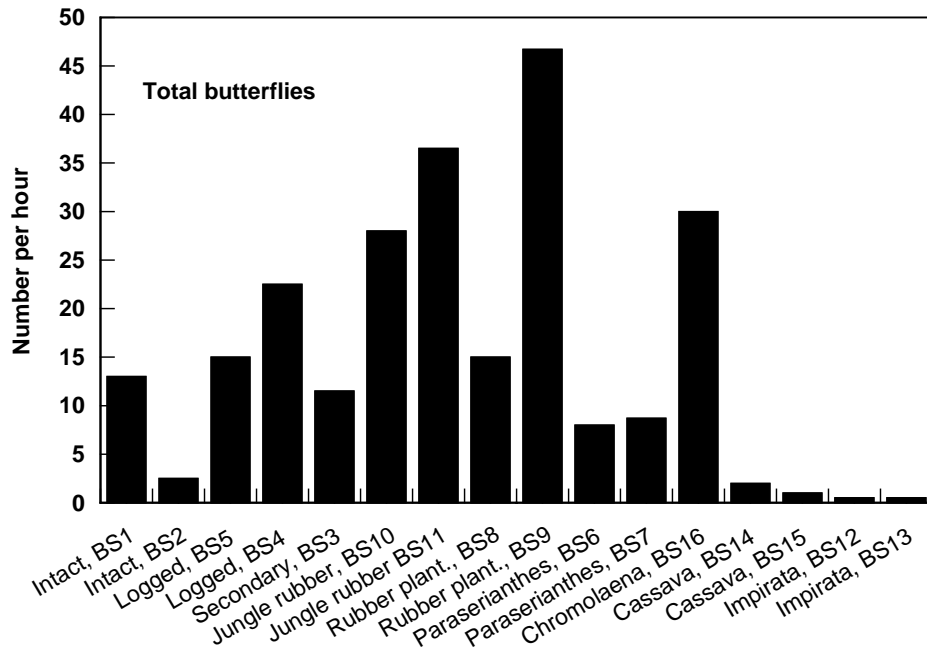


Figure 17 (above) and 18 (below): mean abundance of butterflies seen and caught and seen only, respectively, assessed by transect counts in the Pasir Mayang area, Jambi, Sumatra, November 1997.

**Figures 6.17 & 6.18**

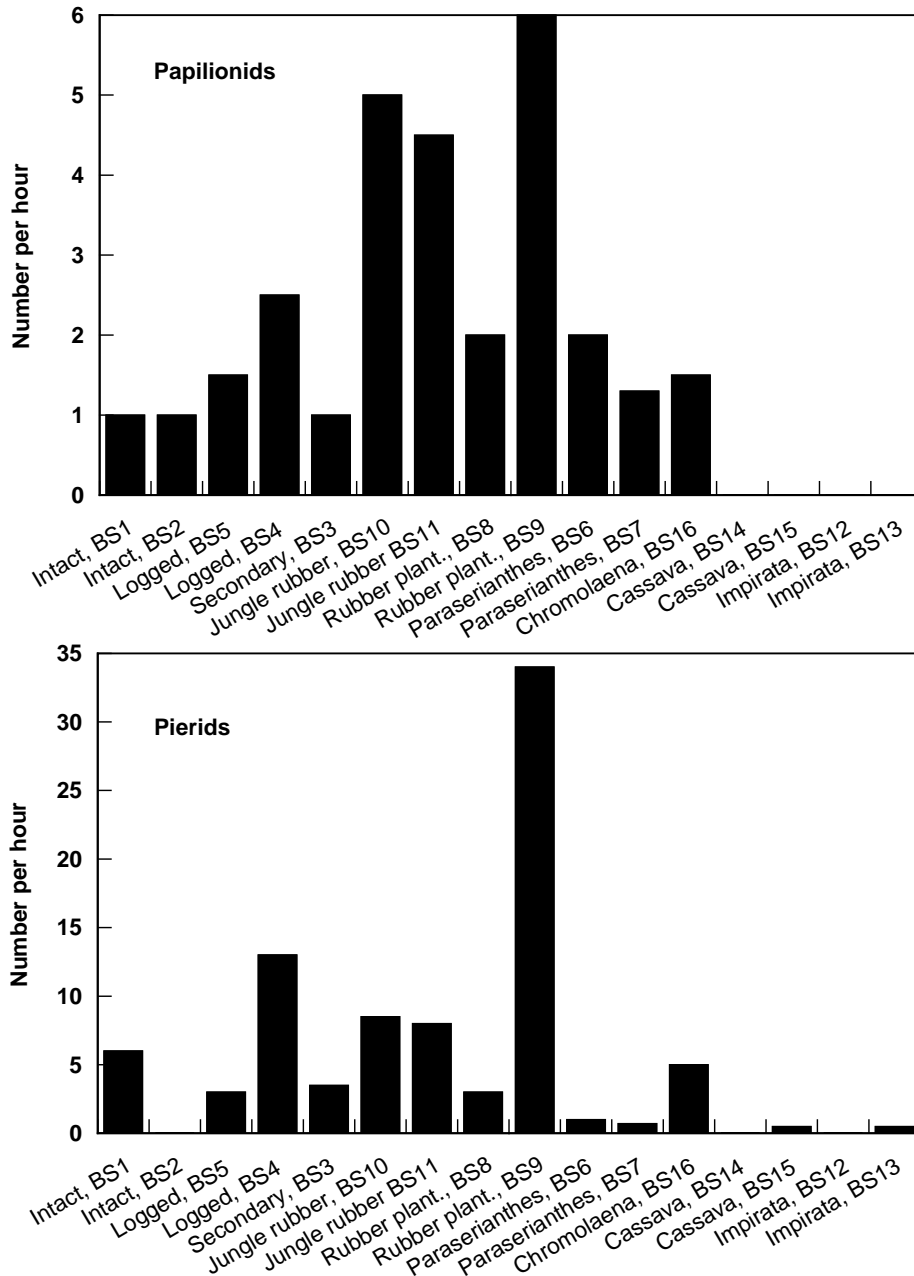


Figure 19 (above) and 20 (below): mean abundance of papilionids and pierids, respectively, assessed by transect counts in the Pasir Mayang area, Jambi, Sumatra, November 1997.

**Figures 6.19 & 6.20**

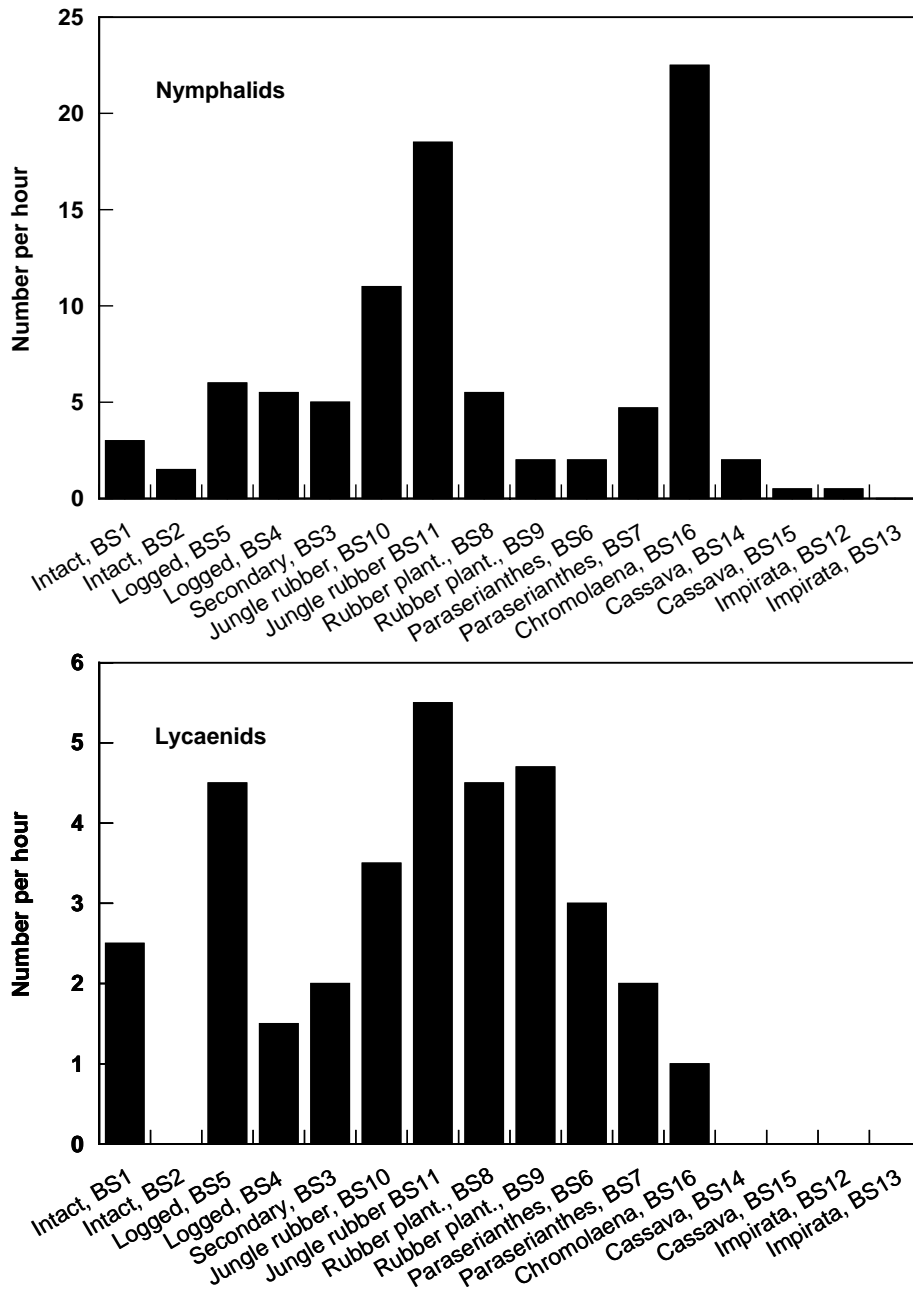


Figure 19 (above) and 20 (below): mean abundance of nymphalids and lycaenids, respectively, assessed by transect counts in the Pasir Mayang area, Jambi, Sumatra, November 1997.

**Figures 6.21 & 6.22**