# Response of wet forest butterflies to selective logging in Kalakad–Mundanthurai Tiger Reserve: Implications for conservation

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**The butterfly fauna of an unlogged wet evergreen site in Kalakad–Mundanthurai Tiger Reserve was compared with that of an adjoining 30-year-old selectively logged site. Comparison of the vegetation structure of both sites showed that the canopy was less contiguous and the ground cover was higher in the logged site. Species richness, abundance, and diversity of butterflies were higher in the selectively logged site. Species abundance in both forests types fitted log series distribution, which indicates that only a small portion of the assemblage occur in high abundance. Examination of habitat usage by the butterflies showed that the logged forest harbored a greater number of ubiquitous species along with the wet forest assemblage. Few species like *Idea malabarica* showed restraint in logged site, while there was a release of few other species in logged site. Implications of these results for butterfly conservation are discussed.**

THE mid-elevation wet forests of southern Western Ghats harbour a high diversity of plant species compared to the other forest types in the region[1,2]. These forests have also suffered large scale disturbances in the form of selective logging and clear felling to raise plantations of coffee and tea[3,4]. In comparison to clear-felled sites, selectively logged ones are relatively less impacted forests where only a portion of the commercially valued tree species is removed. In some cases, establishment of protected areas in the Western Ghats prevented further disturbance to these selectively logged sites[5,6].

The status of plant species assemblage, composition, and structure of these regenerating forests in the Western Ghats have been dealt with to some extent by Pomeroy and Primack (R. Ganesan, in prep.). However, the status of insects in logged sites has not received the attention it deserves. Insects are well known to be good indicators of habitat quality and contribute disproportionately to forest biodiversity[7]. Earlier studies suggest that impacts of logging on insect diversity could be negligible if the amplitude of disturbance is low[8], and in some cases an increase in the diversity has been observed[9–11]. However mere species numbers may not be an ideal assessment of the impacts of forest modifications. In addition, one time survey of insects give a snap-shot view of the actual fauna, and may not include rare species; besides, species assemblage of insects, and butterflies in particular, are known to replace one another through seasons[12]. In Western Ghats, studies on butterflies have so far been restricted to brief periods[13–16].

Kakachi, a mid-elevation wet forest site in KMTR, has not been explored for butterfly fauna[17–19]. This site has also vast selectively logged areas, which have been protected for almost 30 years now[5]. This study compares the butterfly assemblage in the unlogged wet forest with adjacent selectively logged sites in Kakachi recorded over a year. Implications of the results to butterfly conservation in logged and unlogged forests are also discussed.

## Study site

This study was conducted from January to December 1991 in the wet forests of Kakachi (8°40′N and 77°30′E) in the Kalakad–Mundanthurai Tiger Reserve. Kakachi located at 1250 m, receives an annual rainfall of over 3500 mm from both the south-west and north-east monsoons.

The vegetation is broadly classified as mid-elevation tropical wet evergreen forest[1] and has been described in detail elsewhere[20]. Kakachi is contiguous with the deciduous and the thorn forests in the lower elevations. About 5 km$^2$ in Kakachi was selectively logged for establishment of cardamom plantation but the crops were not raised due to failure in the nearby sites (R. Ganesan, unpublished). These areas have not suffered any intermittent disturbance after the initial selective removal of trees[21]. Over 77 species of butterflies have been recorded in the Kakachi area including two species endemic to wet forests of South Western Ghats[19].

## Methods

### *Vegetation structure*

To compare the vegetation structure in the logged and unlogged sites, circular plots of 5 m radius were laid

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around trees selected randomly in the forest. Plants above 10 cm diameter at breast height (DBH) were enumerated and their heights estimated. Twenty such plots were laid in the logged and unlogged forest. The percentage visibility of the sky and ground cover were estimated from two halves within the circular plots.

### *Butterflies*

An area of 30 $km^2$ was sampled by laying transects of 500 m × 10 m along existing forest trails and walking them at fortnightly intervals for a period of one year. Five transects in unlogged and another five transects in the adjacent logged sites were laid. These transects covered all the microhabitats such as gaps, marshes and stream beds in the forest.

Transect walks were carried at a constant pace and all the species encountered within 5 m on either side were recorded. About one hour was spent in each of these transects. Transect walks were restricted to 1000–1200 h which happened to be the ideal flight period of butterflies. Walks were abandoned during cloudy and rainy conditions and repeated on the closest sunny day. Efforts were made to sample all transects equally. For certain genera like *Eurema* in which all species appear similar, many individuals were collected and released after their identities were confirmed. Apart from the transect walks, tree rafts were erected to record the canopy butterflies at suitable points inside the forest. Grasslands and swamps in the forests were visited regularly and specimens were collected. Encounters from these were excluded from the analysis. A reference collection of almost all the butterfly species was made before the study was initiated.

As the primary and logged sites were close together and represented the same vegetation type, indices of alpha diversity were calculated for both forest types. To examine the community structure, the log series and log normal distributions were fitted to the data.

## Results

### *Vegetation structure*

There was no significant difference between logged and unlogged forests in terms of diversity and stem density (Table 1). The mean DBH and height of trees in the logged forest was significantly lower from those in the unlogged forest. The percentage ground cover and the sky visibility were higher in logged forest (Table 1). The dominant tree species in the two forests differed. The logged site was dominated by *Epiprinus mallotiformis*, which was an understorey species, followed by canopy species such as *Holigarna nigra* and *Cullenia exarillata*. The unlogged site was dominated by canopy species like *Palaquium ellipticum*, *Cullenia exarillata* and *Myristica dactyloides*.

### *Butterfly abundance and diversity*

A total of 110 transects were walked in each habitat type over a period of 12 months. Fortnightly sampling could not be carried out during June and December due to rainy conditions, therefore all the transects were walked only once in each month during this period. About 807 individuals were recorded in the unlogged forest while 1144 were recorded in the logged areas. In all, 60 species were recorded and a great number of them encountered by May in both the unlogged and logged forest (Figure 1). All the species that were recorded in the canopy were also encountered at the ground level during the transect walks.

### *Butterfly assemblage in logged and unlogged forest*

The abundance of each species was plotted on a logarithmic scale against the species rank in the order of most abundant to least abundant species in both the forest types. Both the forests were represented by a small frac-

**Table 1.** Vegetation structure in unlogged and selectively logged site

| | Logged | Unlogged | | | |
|---|---|---|---|---|---|
| No. of tree species | 82 | 92 | | | |
| Dominant species | *Epiprinus mallotiformis*<br>*Holigarna nigra*<br>*Cullenia exarillata* | *Palaquium ellipticum*<br>*Cullenia exarillata*<br>*Myristica dactyloides* | | | |
| | (Mean ± SD) | (Mean ± SD) | Statistic | *df* or *n* | *P* |
| Margalef index | 6.58 | 6.19 | – | – | – |
| Height | 20.19 ± 7.6 | 23.19 ± 5.43 | *t* = – 2.98 | 172 | < 0.01 |
| DBH | 26.15 ± 10.56 | 31.56 ± 9.4 | *t* = – 0.34 | 172 | < 0.05 |
| Stem density | 8.5 ± 2.42 | 9.5 ± 3.27 | *t* = – 1.10 | 38 | ns |
| Ground cover | 0.62 ± 0.36 | 0.40 ± 0.22 | *U* = 524.0 | 40 | < 0.01 |
| Sky visibility | 0.60 ± 0.35 | 0.30 ± 0.24 | *U* = 435.5 | 40 | < 0.01 |

*t* = *t* test, *U* = Mann–Whitney test (one-tailed).

tion of abundant species (Figure 2). Only 6 (20%) in the unlogged and 8 (13%) in the logged forest were encountered on more than 50 occasions during the survey. The log series model was found to be the best fit for both data sets (unlogged: $c^2 = 9.38$, $df = 8$, ns; logged $c^2 = 3.2$, $df = 8$, ns). However, the unlogged site also fitted the log normal distribution but only in its truncated form (unlogged: $c^2 = 4.9$, $df = 5$, $p < 0.05$; logged: $c^2 = 15.56$, $df = 5$, ns). Therefore, only log series diversity index (alpha) was employed for comparing the two sites[22]. However, Margalef's index for species richness and Berger–Parker index of dominance, which were not based on the species abundance distribution pattern, were used for comparisons of subsets of these data.

Calculation of diversity indices indicates that the logged forest had a more diverse butterfly assemblage compared to the unlogged forest. Species richness in the unlogged forest was almost half of that recorded in the logged sites. Twenty-nine species were recorded exclusively in the logged site, whereas only two species were recorded exclusively in the unlogged forests.

### Habitat specialists

We ranked all the species in terms of their habitat specialization from published work[23–28] and from our own observations in the altitudinal transects established in the area (M. S. Devy, unpublished). Wet evergreen specialists were assigned high ranking (R1). Rank 2 (R2) was assigned to species that occupy one more habitat besides the wet forest. Rank 3 (R3) included species that occupied two more habitats other than the wet forest. The relative abundance of these species in the two forests types was plotted in Figure 3 *a*, *b*. The lowest ranking species (R3) that exhibit wide habitat usage from thorn forests to dry deciduous were distinctly absent in the unlogged forest, although R2 which use two habitats, were well represented in them (Figure 3 *a*, *b*).

The assemblages of high ranking (R1) species in both the logged and unlogged forests were compared. Diversity index showed that R1 assemblage was not very different in both the forest types (Table 1). Comparison of abundance pattern also showed that there was no significant difference in R1 species of both the forest types (Mann–Whitney $U = 105$, $n = 60$, ns). However, the 609 individuals of R1 in unlogged forest represented almost 75% of the total species recorded, while 606 individuals in the logged site represented only 52% of the total recorded (R1 vs R2 and R3 in logged and unlogged forest: $c^2 = 103.45$, $df = 1$, $p = 0.01$). While the R2 in logged forests formed more diverse assemblage, many R2 species were not recorded in the unlogged site; R3 species, which have a wide amplitude, were very distinctly absent in the primary forest (Table 1). Examination of individual R1 species response showed that logging had positive impact on two species, *Parantica nilgiriensis* and *Ypthima ypthimoides*, whose densities showed 2- and 8-fold increase in logged sites, respectively. Three species, *Celatoxia albi-*

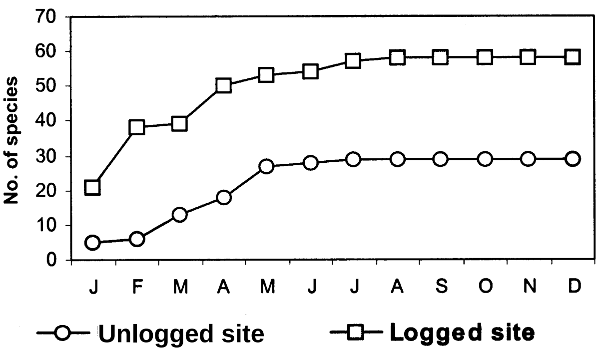


**Figure 1.** Species accumulation curve in the unlogged and logged forest.

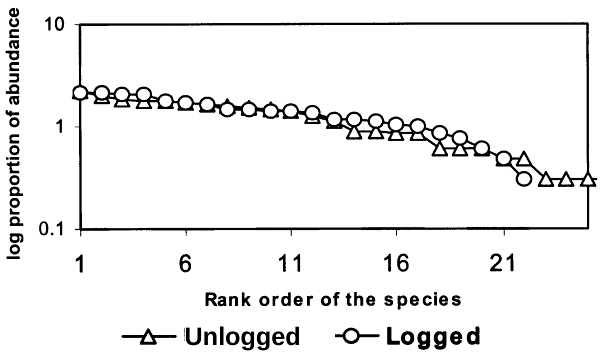


**Figure 2.** Species rank/log abundance of species recorded in the unlogged and logged forest.

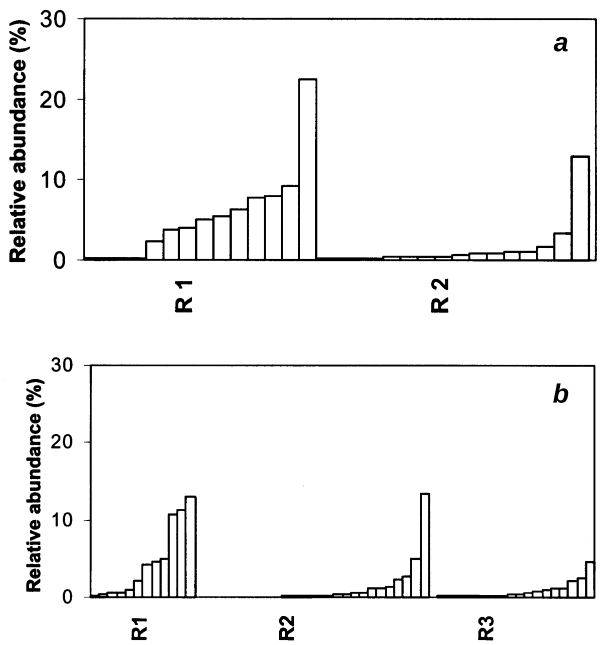


**Figure 3** ***a*, *b*.** Relative abundance of Rank 1, 2 and 3 species in unlogged and logged sites. Bars indicate species.

*disca*, *Melanitis phedima* and *Idea malabarica*, were not frequently encountered in the logged forests (Mann–Whitney $U = 9$, $n = 3$, $p < 0.05$). Two other species *Pachliopta pandiyana* and *Discophora lepida* were recorded twice during the transect walks only in the unlogged forest. The remaining R1 species showed almost equal abundances in the both the logged and unlogged sites (Appendix 1).

## Discussion

Species richness, abundance and diversity of the butterflies in Kakachi were found to be higher in the logged site than in unlogged forests (Table 2). Encountering more species in the logged site was not due to the better visibility but because of canopy openness. More species were also observed from the canopy rafts in the logged site compared to unlogged site. Such increase in the diversity in the secondary areas has been attributed to the increase of microhabitat and vegetation associated with disturbance[29,30]. However, Hill *et al*.[31] who sampled butterflies of a site which was logged five years prior to their study in Indonesia had contrasting results. They detected erosion in diversity and encountered only half the number of individuals recorded from the unlogged forest.

However, when habitat specialists were considered separately, certain inherent patterns were evident between the two forest types in Kakachi. The unlogged forest was represented by two types of butterfly assemblages, one set of species which were typical of wet forests and the other which are more common in the deciduous forest found contiguous to the wet forests of Kakachi. Analysis of Lepidoptera fauna over a range of altitudes in Malaysia also showed a sequence of association with the vegetation type present in various altitudes, with some overlap with the adjacent habitat[11]. Interestingly, in the logged forest of Kakachi, there was a ‘leap’ by common species from low altitude dry thorn forests, a habitat that was not contiguous with wet forests. A study of birds in Guianan rain forests showed a similar trend where species of broad ecological amplitude were found to colonize deforested areas[32]. Such fugitive or vagile species are known to colonize any newly disturbed patches whenever available and thereby persist at a regional level[33]. Similarly, ubiquitous butterfly species are also known to invade the gaps and canopy of unlogged tropical wet forest sites[30,16]. Such invasions, however, were not observed in the unlogged site at Kakachi.

**Table 2.** Diversity indices for the butterfly communities in logged and unlogged site

| | Unlogged | Logged |
|---|---|---|
| All species | | |
| No. of species | 29 | 58 |
| No. of individuals | 807 | 1144 |
| Berger–Parker | 4.40 | 7.43 |
| Margalef | 4.19 | 8.09 |
| Alpha | 5.30 | 12.80 |
| Rank 1 species | | |
| No. of species | 14 | 12 |
| No. of individuals | 609 | 606 |
| Berger–Parker | 3.34 | 4.09 |
| Margalef | 2.02 | 1.71 |
| Rank 2 species | | |
| No. of species | 16 | 27 |
| No. of individuals | 198 | 354 |
| Berger–Parker | 1.90 | 2.20 |
| Margalef | 2.80 | 4.20 |
| Rank 3 species | | |
| No. of species | 0 | 19 |
| No. of individuals | 0 | 184 |
| Berger–Parker | 0 | 3.50 |
| Margalef | 0 | 3.40 |

Invasion of selectively logged site by low ranking ubiquitous species could be due to the altered vegetation structure in these sites. The selectively logged site in Kakachi after 30 years of protection has undergone changes in terms of vegetation structure. Gap invading species and saplings of plants have established themselves in these sites reducing the gaps caused due to the removal of trees, therefore increasing the ground cover (Table 1). However, the canopy cover remains sparse, therefore illumination of these forests is still high compared to unlogged forests making it suitable for butterflies of warmer regimes. Earlier, with more gaps and less ground cover, the logged sites may have supported even larger number of ubiquitous species, which may have been slowly eliminated from the area with the progress of succession. A previous study in Kakachi by Davidar *et al*.[34] showed that secondary forests were richer in nectar resources than unlogged forests. Many of the R3 species were encountered during March–April in Kakachi (personal observations). These were probably taking advantage of the resource abundance in secondary forests to escape adverse dry conditions, which prevail in the dry forests at lower elevations around that time. However, the consequence of such invasions on the original fauna even if it is seasonal could prove detrimental. For instance, Lovejoy *et al*.[35] who studied the impacts of forest fragmentation on butterflies found many forest interior species facing interference from the edge species in smaller fragments.

Almost all wet forest specialists now use the logged site in Kakachi. Only three species showed reduced abundance in the logged site, of which *Idea malabarica*, a milkweed butterfly, was very distinct. Incidentally, the Southern Western Ghats has been identified as critical zone for *Idea malabarica*[36]. The wet forests of KMTR has been identified as the most intact zone in the Southern Western Ghats[2], therefore this region is probably one of the least disturbed sites in its entire range. On the contrary, two species, *Ypthima ypthimoides and Parantica nilgirensis*, showed release in the logged forest. These are generally the occupants of gaps surrounded by matrix of mature forest in unlogged sites (M. S. Devy, personal observations). Thomas[37] also found that butterfly species that use naturally occurring gaps in unlogged forest adapt readily to secondary forests due to the availability of large expanse of suitable habitats. However, these unlike the R2 and R3 species, were seldom encountered in the deciduous forests at lower elevations (M. S. Devy, unpublished).

The results of this study should be treated with caution, as the logged sites in Kakachi are contiguous with unlogged forests. The butterflies typical to the wet forest may not persist in isolated secondary forests and their presence in Kakachi may be a consequence of a mosaic containing the whole range of their required habitats (also see Bowman *et al.*[29]). Besides, regular recolonization even now could be occurring from the unlogged forests. Therefore, these sites cannot be viewed as alternatives to unlogged forest. However, if the present protection is continued over a long period a total convergence of fauna of logged site with the unlogged forest is likely with the progression of succession.

**Appendix 1.** Butterfly species recorded in the transects, with habitats and abundance

| Species | Unlogged site | Logged site | No. of habitats occupied |
|---|---|---|---|
| Papilionidae | | | |
| *Pachliopta pandiyana* Moore | 2 | 0 | 1 |
| *Papilio helenus Moore* | 51 | 47 | 1 |
| *Graphium agamemnon* Felder & Felder | 7 | 6 | 2 |
| *Graphium sarpendon* Felder & Felder | 27 | 56 | 2 |
| *Papilio polymnestor* (Cramer) | 13 | 13 | 2 |
| *Troides minos* Cramer | 4 | 31 | 2 |
| *Pachliopta aristolochaie* (Fabricius) | 0 | 14 | 3 |
| *Papilio demoleus* Linnaeus | 0 | 4 | 3 |
| *Papilio polytes stichus* (Hubner) | 0 | 2 | 3 |
| Pieridae | | | |
| *Appias indra* Moore | 44 | 52 | 1 |
| *Appias lalage* Doubleday | 182 | 123 | 1 |
| *Catopsilia pyranthe* (Linnaeus) | 0 | 2 | 3 |
| *Delias eucharis* (Drury) | 0 | 2 | 3 |
| *Catopsilia pomona* (Fabricius) | 0 | 4 | 3 |
| *Eurema hecabe* Moore | 0 | 52 | 3 |
| Nymphalidae | | | |
| *Cyrestis thyodamas* Boisduval | 2 | 4 | 1 |
| *Discophora lepida* Moore | 2 | 0 | 1 |
| *Idea malabarica* (Moore) | 41 | 11 | 1 |
| *Melanitis phedima* Stoll | 74 | 7 | 1 |
| *Mycalesis anaxias* Hewitson | 32 | 23 | 1 |
| *Mycalesis oculus* (Marshall) | 63 | 56 | 1 |
| *Parantica nilgiriensis* Moore | 64 | 129 | 1 |
| *Ypthima ypthimoides* Moore | 18 | 148 | 1 |
| *Zipoetis saitis* (Hewitson) | 2 | 2 | 1 |
| *Cirrochroa thais* (Fabricius) | 8 | 2 | 2 |
| *Cupha erymanthis* Drury | 2 | 15 | 2 |
| *Dophla evelina* Stoll | 0 | 1 | 2 |
| *Hypolimnas bolina* (Linnaeus) | 2 | 2 | 2 |
| *Kaniska canace* Evans | 4 | 1 | 2 |
| *Lethe drypetis* Hewitson | 4 | 1 | 2 |
| *Lethe europa* (Fruhstorfer) | 8 | 1 | 2 |
| *Neptis hylas* (Moore) | 0 | 27 | 2 |
| *Neptis soma* Moore | 0 | 3 | 2 |
| *Parantica aglea* Cramer | 0 | 14 | 2 |
| *Parthenos sylvia* (Cramer) | 0 | 2 | 2 |
| *Tanaecia lepidea* Frushstorher | 0 | 2 | 2 |
| *Vanessa cardui* (Linnaeus) | 0 | 1 | 2 |
| *Vanessa indica* (Herbst) | 0 | 1 | 2 |
| *Vindula erota* (Swinhoe) | 1 | 1 | 2 |
| *Ypthima baldus* Hewitson | 3 | 154 | 2 |
| *Ypthima huebrneri* (Kirby) | 0 | 7 | 2 |
| *Acraea terpsicore* (Linnaeus) | 0 | 2 | 3 |
| *Ariadne merione* Cramer | 2 | 6 | 3 |
| *Danaus chrysippus* (Linnaeus) | 0 | 2 | 3 |

| Species | Unlogged site | Logged site | No. of habitats occupied |
|---|---|---|---|
| *Danaus genutia* (Cramer) | 0 | 3 | 3 |
| *Elymnias hypermnestra* Butler | 0 | 6 | 3 |
| *Euploea core* (Cramer) | 0 | 13 | 3 |
| *Melanitis leda* (Drury) | 104 | 4 | 3 |
| *Mycalesis perseus* Fruhstorfer | 0 | 1 | 3 |
| *Precis lemonias* (Linnaeus) | 0 | 10 | 3 |
| *Precis atlites* (Linnaeus) | 0 | 3 | 3 |
| *Precis hierta* (Fabricius) | 0 | 3 | 3 |
| *Precis iphita* (Cramer) | 0 | 25 | 3 |
| *Libythea myrrha* Godart | 3 | 1 | 2 |
| Lycaenidae | | | |
| *Celatoxia albidisca* Moore | 30 | 6 | 1 |
| *Jamides celeno* Fabricius | 1 | 2 | 2 |
| *Talicada nyseus* Guréin-Méneville | 0 | 1 | 2 |
| *Abisara echerius* Stoll | 7 | 4 | 2 |
| *Castalius rosimon* (Fabricius) | 0 | 28 | 3 |
| Hesperiidae | | | |
| *Tagaides gana* Evans | 0 | 1 | 2 |

Species are arranged in the order of decreasing habitat specialization within each family and the classification follows Larsen[24–27] and Gunathilakaraj *et al*.[28].


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