IMPACTS OF LAND USE CHANGE ON FOREST BUTTERFLY COMMUNITIES IN THE WESTERN GHATS OF SOUTHERN INDIA

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SHAHABUDDIN, G. & ALI, R. 2001. **Impacts of land use change on forest butterfly communities in the Western Ghats of southern India.** We studied the role of plantation agriculture as a refuge for the butterflies of deciduous forest habitat in the Western Ghats of southern India. Abundance, diversity and species composition of the butterflies of forest habitat were compared with those of adjoining lime plantations. Butterfly communities were studied using visual censusing techniques along eleven line transects in forest habitat and five line transects in plantation habitat. Observed butterfly densities were not significantly different in forest (478 ± 378) and plantation transects (401 ± 167). Observed species richness was higher in plantations (38 ± 5) compared to forest habitat (34 ± 8) but this difference was not statistically significant. However, ordination analysis revealed that species composition differed between the two types of habitat with forest specialists being replaced by edge and secondary growth species in plantations. Faunal similarity between plantation and forest transects was low, with only 33.7%. The study indicated that although butterfly abundance and species richness of plantations were comparable with those of forest, species composition varied significantly between the two types of habitat.

Key words: Butterfly - plantation - deciduous forest - diversity - species composition - Western Ghats - Palni Hills

SHAHABUDDIN, G. & ALI, R. 2001. **Kesan perubahan penggunaan tanah terhadap komuniti kupu-kupu hutan di Ghats Barat di selatan India.** Kami mengkaji peranan pertanian ladang sebagai perlindungan bagi kupu-kupu daripada habitat hutan daun luruh di Ghats Barat di selatan India. Kelimpahan, kepelbagaian dan komposisi spesies kupu-kupu daripada habitat hutan dibandingkan dengan kupu-kupu daripada ladang limau nipis yang bersebelahan. Komuniti kupu-kupu dikaji menggunakan teknik bancian secara penglihatan di sepanjang sebelas transek garis di habitat hutan dan lima transek garis di habitat ladang. Kepadatan kupu-kupu yang dicerap adalah tidak

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berbeza dengan bererti di transek hutan (478 ± 378) dan transek ladang (401±167). Kekayaan spesies yang dicerap lebih tinggi di ladang (38 ± 5) berbanding habitat hutan (34± 8) tetapi dari segi statistik, perbezaan ini tidak bererti. Bagaimanapun, analisis pengordinatan menunjukkan bahawa komposisi spesies berbeza antara dua jenis habitat tersebut, dengan spesies khusus hutan digantikan dengan spesies tepi dan spesies sekunder di ladang. Persamaan fauna antara transek ladang dan transek hutan adalah rendah, iaitu hanya 33.7%. Kajian menunjukkan bahawa walaupun kelimpahan kupu-kupu dan kekayaan spesies di ladang dan hutan dapat dibandingkan, komposisi spesies berbeza dengan bererti antara kedua-dua jenis habitat itu.

Introduction

Rapid deforestation all over the globe has caused unprecedented loss of bio-diversity in recent decades (Skole & Tucker 1993). Much of this deforestation is due to the expansion of agricultural activities into previously uninhabited forest areas, resulting in the formation of a habitat mosaic in which forest fragments are located in an agricultural land use matrix (Wilcove *et al.* 1986, Ranta *et al.* 1998).

In the current situation, it is necessary to evaluate the role of various types of agricultural land use as habitat for forest-dwelling animal and plant species (Vandermeer & Perfecto 1997).Types of land use, that provide foraging and breeding habitat for forest fauna or corridors for animal movement, can be used to maintain continuity between forest fragments (Salafsky 1993), which is essential for the maintenance of biodiversity (Taylor *et al.* 1993). Butterflies are a useful taxon to study in this context as they are sensitive indicators of changes in vegetation structure, composition and microclimatic conditions that inevitably occur when forests are converted into agricultural land (Kremen 1994, Sparrow *et al.* 1994).

In the Palni Hills, located in the Western Ghats mountain system of southern India, deciduous forest between 500 and 1500 m asl is rapidly being converted into various types of plantations including those of banana, lime and coffee. In this study, we evaluated the use of lime plantations as habitat for forest butterflies in this area through comparison of butterfly communities of plantations with those of adjoining forest fragments. The major questions addressed in this study were: (1) What was the effect of forest conversion on the abundance and species diversity of local butterfly fauna? (2) Was the butterfly species composition of lime plantations significantly different from that of adjoining natural forest?

Materials and methods

Study area and vegetation characteristics

The Western Ghats are a mountain chain running south-north close to the western coast of India and covering an altitudinal range of 500 to 2500 m asl. The study was carried out at Siruvattukadu Kombei (SVK), a valley covering about 80 km^2 in the Palni Hills of the Western Ghats. The Palni Hills are located within the state of Tamil Nadu between 10° 21' to 10° 25' N and 77° 36' and 77° 44' E (Figure 1).

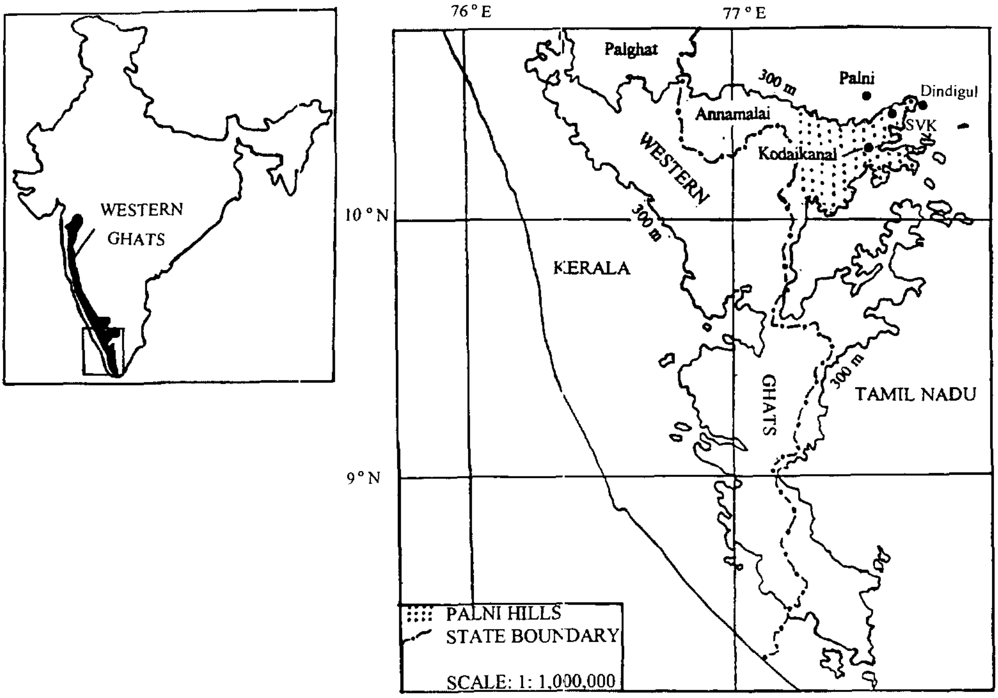

Figure 1 Location of the study site, Siruvattukadu Kombei, in the Palni Hills of the Western Ghats

The mean altitude of the valley is 750 m asl. SVK receives an average of 1000 mm of rainfall every year, most of which occurs between October and December.

The forest vegetation in SVK consists of a mix of moist and dry deciduous associations, with an evergreen understorey layer in many places. Dominant tree species in the area include *Miterophera heyneana, Alphonsea sclerocarpa, Celtis wightii, Sapindus emarginata* and *Diospyros melanoxylon* in the canopy as well as *Murraya paniculata, Tarenna asiatica* and *Canthium parviflora* in the understorey. *Mangifera indica, Terminalia arjuna* and *Pongamia pinnata* dominate the riparian forest. Nectar sources were rare and scattered in this habitat during the period of study. Canopy trees such as *T. arjuna*, understorey trees including *Gardenia obtusa* and riparian trees like *Asclepias curassavica* were the important sources of nectar for forest butterflies during the study period.

Mixed lime plantations are one of the dominant agricultural land uses in the area. In this type of land use, 1–4 m tall lime trees (*Citrus aurantifolia*) were grown in rows, mixed with useful tree species including silk-cotton (*Bombax ceiba*), jackfruit (*Artocarpus heterophylla*) and banana (*Musa sapientum*). Most plantations harboured a high density of herbaceous weeds such as *Stachytarpheta indica, Acanthospermum hispidum* and *Tridax procumbens* which were flowering throughout the period of study. Along with *Lantana camara*, an invasive shrub of South American origin, the weeds presented important sources of nectar for butterflies during the period of study.

In addition to differences in plant species composition, plantation and forest habitat differ in vegetation structure. In general, plantations have fewer vegetation strata, more open canopy and greater density of flowers compared with forest habitat (Shahabuddin 1993). Average density of trees (> 20 cm gbh) along the plantation transects is low, namely, 1.2 per 100 m^2 compared to that along forest transects, with 4.2 per100 m^2 (Shahabuddin 1993). Average density of shrubs and saplings (all plants > 1 m in height but < 20 cm gbh) is also lower in plantations (0.3 per 100 m^2) compared to that measured along forest transects (215 per 100 m^2) (Shahabuddin 1993).

Data collection

Butterfly densities were estimated in forest and plantation habitats using the line transect method following Pollard and Yates (1993). Five 200-m-long line transects were laid in the plantation habitat (P1 to P5) while eleven were established in the forest (F1 to F11). The transects were established in three different plantations but in widely separated portions of the same forest continuum. Transects were laid in a variety of terrain including slopes and streamsides so that the maximum range of variation was captured in each of the two types of habitat. The F5, F6, F7 and P5 transects were located along streamside while the remaining transects were established along valley slopes and bottom. However, all the transects were located at approximately the same elevation, namely, 750 m asl. Table 1 gives an overview of the locational and vegetational attributes of each transect.

Table 1 Attributes of vegetation along study transects in Siruvattukadu Kombei

Habitat/ transect	Location	Canopy cover	Sapling and shrub density ($\times$ 100 m^{-2})	Tree density ($\times$ 100 m^{-2})
Forest				
F1	Valley	H	25	2.67
F2	Valley	M	31	4
F3	Valley	M	49	6
F4	Valley	M	34	5.67
F5	Streamside	H	15.33	1
F6	Streamside	M	8	2
F7	Streamside	M	4.33	2.33
F8	Valley	H	15	4
F9	Valley	H	7.33	3.67
F10	Valley	M	7.67	5.67
F11	Valley	M	18.33	9.67
Plantation				
P1	Valley	L	0.67	5.67
P2	Valley	L	0.67	0
P3	Valley	M	0	0
P4	Valley	L	0.33	0.33
P5	Streamside	L	n.m.	0

Source: Shahabuddin (1993).
H = high, M = medium and L = low.
n.m. = not measured

Before the transect counts started, a reference collection of butterflies was built up. Specimens were identified (Evans (1911), Wynter-Blyth (1957), Ugarte & Rodericks (1960), Satyamurti (1966)). Most butterflies could be identified during the transect counts. A few butterflies that could not be identified immediately were captured for later identification.

A total of 20 counts was carried out along each of the 16 transects on different days. Thus, a total of 320 counts were undertaken during the study. In each transect, counts were spaced evenly through the three-month study period (24 March–17 June 1992). For a single count, we walked the transect slowly for 15–25 minutes. During that time, the vegetation on either side was scanned continuously for butterflies up to a distance of 5 m. The species and number of all butterflies seen during these counts were recorded. Counts were made during sunny weather between 9 a.m. and 3 p.m . The total number of butterflies of a given species, seen during all the 20 counts along a particular study transect, was used as an indicator of its population density; an assumption that was proven to be viable by Pollard and Yates (1993).

Statistical analysis

Species richness was calculated for each study transect (Magurran 1988). Species richness and total abundance were compared between forest and plantation transects using the Kruskal-Wallis test, a non-parametric analysis of variance test which accounts for unequal sample sizes (Sokal & Rohlf 1981). The abundance of each species was compared between forest and plantation habitats, also using the Kruskal-Wallis tests. In order to study the effects of various physical variables upon butterfly abundance and species richness, linear regressions were carried out using canopy cover, understorey density and tree density (Table 1). Species composition of communities in different habitats was compared using detrended correspondence analysis (DCA), a technique which assumes normal response functions of species to environmental gradients (Jongman *et al.* 1995). The assumption of normal response functions of species to environmental gradients is one that is considered biologically robust (Jongman *et al.* 1995). DCA was carried out using the ordination package PC-ORD (Multivariate Analysis of Ecological Data 1997, Version 3). In addition, a Fortran program called GDIS (Landscape Ecology Laboratory, Duke University) was used to compare species composition of the two types of habitat.

Results and discussion

Butterfly abundance and species richness

A total of 8628 butterflies belonging to 94 species in 5 families was sighted during the surveys. In addition, eight species were recorded before the counts began but were not seen subsequently. A classified list of the butterfly species seen during the study is given in Appendix 1. Of the 8628 individuals, 1224 individuals (14%)

could be identified only to family level and were therefore excluded from the analysis. A total of 34 species was seen 10 times or less across all transects. These species were also excluded from the analysis to avoid erroneous results associated with low sample size. Finally, 7263 individuals belonging to 59 species were used for the present analysis. The total number of butterflies for each species seen along each transect during the 20 counts is given in Table 2.

Observed butterfly densities were not significantly different in forest (478 ± 378) and plantation transects (401 ± 167) (Kruskal-Wallis test statistic (H) = 0.03, df = 1, $p < 0.87$). Plantations harboured a greater number of butterfly species compared to forest habitat (plantations: 38 ± 5 and forests: 34 ± 8) but this difference was not statistically significant (H = 1.57, df = 1, $p < 0.21$).

Overall, the results indicate that butterfly densities and species do not differ significantly between forest and plantation habitats. The effects of habitat disturbances such as fragmentation (Brown & Hutchings 1997), selective logging (Hill *et al.* 1995) and plantation agriculture (Watt *et al.* 1997) on butterfly diversity are varied and complex. However, it appears that small-scale or low level forest disturbances as seen in coffee plantations, creation of small tree fall gaps and partial forest clearing, often result in increased local butterfly diversity (Janzen 1987, Spitzer *et al.* 1997, Watt *et al.* 1997, Wood & Gillman 1998). Small-scale disturbances encourage light penetration and create a locally heterogeneous environment suitable for butterfly activity, even encouraging the growth of certain larval host plants and increasing the local abundance of flowers. However, more severe disturbance such as large-scale logging or clear felling may result in local loss of diversity even after a period of regeneration (Hill *et al.* 1995). At SVK, lime plantations were typically small (up to a hectare), located close to the forest and therefore might be considered to be small-scale disturbances that did not have significant effects upon net local diversity.

In particular, floral diversity could be a major reason for the high diversity of butterflies recorded inside the plantations. The variety of herbaceous weeds that were flowering during the study period attracted numerous butterflies for feeding, including some from forest habitat. In contrast, forest habitat had isolated and sparse flowering sources. The nectar sources utilised by butterfly species in the different habitat types were described in detail by Shahabuddin (1997b).

Vegetation structure and butterfly abundance

Linear regressions indicated that observed butterfly abundance along transects was not related to any of the variables related to forest structure such as canopy cover ($r^2 = 0.049$, F = 0.67, $p < 0.43$, df = 1,13), understorey density ($r^2 = 0.0387$, F = 0.52, $p < 0.48$, df = 1,13) or tree density ($r^2 = 0.108$, F = 1.58, $p < 0.23$, df = 1,13). However, transect location (streamside or interior forest) was a strong determinant of butterfly abundance ($r^2 = 0.5514$, F = 15.98, $p < 0.001$). Similarly, transect location had a significant effect upon species richness ($r^2 = 0.5992$, F = 19.44, $p < 0.0007$) but there was no indication that butterfly species richness was determined by any of the measured variables related to vegetation structure (canopy cover: $r^2 = 0.0160$,

Table 2 Ranked scores of butterfly species on first and second DCA axes (in increasing order)

Axis 1		Axis 2	
Species	Score	Species	Score
Mycalesis patnia	-131	*Hypolimnas missipus*	-108
Dophla evelina	-115	*Neptis jumbah*	-82
Mycalesis mineus	-103	*Euploca core*	-61
Leptosia nina	-95	*Euthalia aconthea*	-60
Euthalia aconthea	-85	*Tirumala limniace*	-54
Arhopala bazaloides	-83	*Pantoporia hordonia*	-52
Neptis jumbah	-82	*Tagiades jepetes*	-38
Ypthima philomela	-82	*Arhopala bazaloides*	-29
Melanitis leda	-77	*Graphium doson*	-20
Tagiades jepetes	-66	*Catopsilia pyranthe*	-5
Papilio polymnestor	-54	*Celatoxia albidisca*	0
Pantoporia hordonia	-53	*Libythea lepita*	2
Neptis hylas	-42	*Phalanta phalantha*	12
Amblypodia anita	-41	*Hypolimnas bolina*	21
Libythea lepita	-34	*Catochrysops strabo*	29
Iambrix salsala	-32	*Papilio demoleus*	35
Pachliopta aristolochiae	-30	*Lampides boeticus*	35
Papilio crino	-3	*Chilades laius*	40
Jamides bochus	-1	*Danaus septentrionis*	42
Junonia iphita	9	*Spialia galba*	42
Euploea core	37	*Junonia hierta*	42
Parantica aglea	38	*Jamides celeno*	44
Graphium doson	56	*Acraea violae*	44
Graphium agamemnon	58	*Junonia lemonias*	47
Hypolimnas missipus	68	*Neptis hylas*	56
Jamides celeno	97	*Junonia orithya*	62
Pachliopta hector	98	*Junonia iphita*	66
Papilio polytes	134	*Euripus consimilis*	68
Ypthima ceylonica	139	*Chilades putli*	68
Celatoxia albidisca	143	*Ariadne merione*	75
Tirumala limniace	143	*Zizina otis*	75
Catopsilia pyranthe	152	*Leptotes plinius*	83
Danaus genutia	168	*Catopsilia pomona*	90
Eurema hecabe	168	*Melanitis leda*	100
Castalius rosimon	169	*Papilio polymnestor*	103
Hebomoia glaucippe	169	*Cepora nerissa*	103
Phalanta phalantha	190	*Zizula hylax*	108
Hypolimnas bolina	202	*Graphium agamemnon*	115
Leptotes plinius	208	*Castalius rosimon*	117
Danaus septentrionis	209	*Mycalesis mineus*	117
Halpe homolea	210	*Halpe homolea*	136
Cepora nerissa	219	*Danaus chrysippus*	144
Chilades laius	220	*Papilio crino*	148
Catopsilia pomona	242	*Ypthima philomela*	157
Danaus chrysippus	246	*Parantica aglea*	159
Euripus consimilis	251	*Eurema hecabe*	160
Zizula hylax	255	*Papilio polytes*	164
Ariadne merione	262	*Hebomoia glaucippe*	167
Catochrysops strabo	274	*Mycalesis patnia*	191
Zizina otis	274	*Amblypodio anita*	209
Junonia lemonias	277	*Jamides bochus*	217
Papilio demoleus	290	*Ypthima ceylonica*	217
Spialia galba	296	*Dophla evelina*	221
Junonia hierta	298	*Danaus genutia*	236
Acraea violae	301	*Pachliopta hector*	247
Lampides boeticus	310	*Iambrix salsala*	289
Junonia orithya	315	*Pachliopta aristolochiae*	293
Chilades putli	319	*Leptosia nina*	425

$F = 0.21$, $p < 0.65$, df = 1,13; understorey density: $r^2 = 0.0612$, $F = 0.85$, $p < 0.37$, df=1,13; tree density: $r^2 = 0.309$, $F = 5.81$, $p < 0.03$, df = 1,13). Thus the results of regression suggest that the presence of water is perhaps the most important factor affecting local species richness and abundance of butterflies. Earlier analysis also indicated that a high proportion (79%) of the species recorded in SVK is observed in streamside habitat (Shahabuddin 1997b). High species richness and butterfly abundance in streamside habitat could be attributed to the need for mud-puddling among most butterfly species which intensify during the dry season.

Species distribution

Of the 60 species, 28 (47%) showed no significant difference in abundance between forest and plantation transects. It was observed that 15 (25%) species were significantly more abundant in plantation habitat while 17 (29%) were more abundant in forest habitat (Appendix 1). Species such as *Kallima horsfieldi, Papilio polymnestor, Mycalesis patnia, Cyrestis thyodamas* and *Parantica aglea* were more abundant along forest transects. On the other hand, certain species such as *Junonia hierta, Danaus chrysippus* and *Chilades laius* preferred open agricultural areas and were generally restricted to them. However, nearly half the recorded species, including *Pachliopta hector* and *Eurema hecabe,* did not show significant variation in abundance between plantation and forest habitats.

The restriction of butterfly species to certain habitats could be explained by one or a combination of three important factors: the local abundance of their larval host plants (Gaonkar, pers. comm.), adult feeding sites and their preference for a certain level of canopy shade to which they are physiologically adapted. Highest densities of most butterfly species were generally seen where these conditions overlapped. For example, the abundance of *Papilio demoleus* in plantation habitat was possibly due to both its attraction for lime shrubs (on which it oviposited) and its tendency to fly in open areas. Similarly, *Talicada nyseus* was only seen close to its larval food plant, *Kalanchoe* spp., found growing in a few spots on the sandy banks of the stream. Exact reasons for the habitat preferences of individual species can be found out only by detailed study of their biological and movement patterns.

Species composition

DCA revealed a clear separation of plantation and forest transects along the first axis (Figure 2). The first DCA axis accounted for 42.3% of the variation in butterfly community composition, indicating that forest and plantation transects differed substantially from each other. An examination of first axis DCA scores showed that species reportedly restricted to forest habitat, such as *Cupha erymanthis, Dophla evelina* and *Mycalesis patnia* (Larsen 1987c), were replaced by species that were characteristic to more open areas, such as Chilades putli, Lampides boeticus, *Papilio demoleus* and *Junonia hierta* (Larsen 1987a, b, c; Table 3). The second axis in Figure 2 accounted for an additional 16.9% of variation in species composition among the study transects. The clustering of transects F5, F6, F7 and

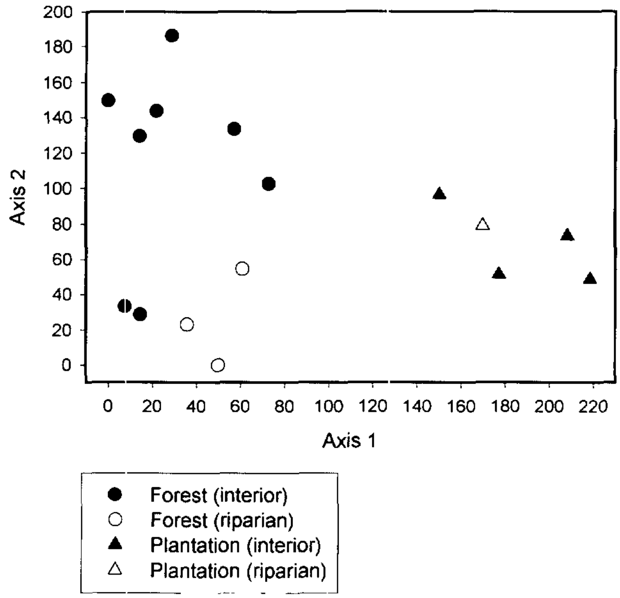

Figure 2 Results of detrended correspondence analysis (DCA) of the 16 study transects based on butterfly species composition

P5 along the second DCA axis indicated that the variation in species composition along the second axis may be related to the presence of flowing water as these were the transects located along the streamside. Table 2 confirms that several species are much more common along streamside forest transects than non-stream forest transects. These species include *Graphium doson, Neptis hylas, Jamides bochus* and *Jamides celeno.*

Community similarity analysis using GDIS indicated that the mean within group similarity among forest transects was 52% while that among plantation transects was 55.4%. The mean between group similarity in species composition (using all transects) was much lower with 33.7%. Randomisation tests showed that within group similarities were significantly greater than between group similarities (p = 0), thereby indicating that there was a significant difference in overall species composition between forest and plantation habitats.

Plantation agriculture and biodiversity

Plantation agriculture has been considered to be one of the agricultural land uses that are relatively hospitable to forest faunaand useful as buffer zone vegetation, providing both primary and secondary habitats for animal species. For example, shade coffee plantations in India (Shahabuddin 1997a), shifting cultivation plots in the Amazonian rain forest (Dufour 1990) and forest gardens in Indonesia (Salafsky 1993) have been recorded to harbour a significant proportion of the native vertebrate fauna of surrounding forests. However, an equal number of studies have recorded impoverished faunas in plantations in comparison with natural forests, including traditional agroforests in Indonesia (Thiollay 1995) and coffee plantations in Guatemala (Greenberg *et al.* 1997). It appears that the faunal similarity of between human modified habitat and natural forest depends primarily upon the corresponding degree of similarity in vegetation structure, plant species composition and diversity. For example, the maintenance of a diverse tree composition, presence of canopy shade and a multi-layered vegetation structure in coffee plantations improved the suitability of plantation agriculture for native fauna (Perfecto *et al.* 1996). However, the few studies that had extended such investigations to arthropod communities showed that effects of habitat conversion on these animals may be more dramatic than those observed for mammals and birds (Didham 1997, Watt *et al.* 1997). The greater sensitivity of insects to changes in habitat variables can be attributed to their narrower specialisation on plant species and dependence on a variety of different micro-habitats in their life cycle. Insects are also more vulnerable to changes in microclimate than vertebrates due to their poikilothermic nature and therefore are more affected by changes in forest structure including canopy cover and understorey density (Greatorex-Davies *et al.* 1993, Thomas 1994). The present study confirmed previous observations that the conversion of forest to plantation agriculture may result in drastic alterations in the composition of arthropod communities, although net diversity may not be significantly reduced.

Sampling design

Certain problems with sampling design need to be considered while interpreting the results of the study. For example, it is questionable whether we can consider the forest transects as true controls for comparison with plantation habitat. The forest habitat in SVK was degraded in some places and exposed to moderate levels of human disturbance, importantly, those caused by firewood and fodder extraction. In several places, herbs and shrubs that are indicative of disturbance in moist deciduous forest habitat were seen. For example, *Lantana camara* and *Scutia* spp. (from drier scrub habitats) were found scattered throughout the forest. Such sampling problems are unavoidable when studying the effects of human disturbance due to the pervasive influence of human activity in any area (Freese 1997).

Seasonal variation in butterfly movement patterns also needs to be considered when interpreting the results of the present study. Studies in seasonally dry areas indicate that movement patterns of butterflies may change on a seasonal basis (Braby 1995). For example, in the dry season, several species are known to aggregate in sheltered riparian areas to avoid dessication (De Vries 1987). Dry season aggregation may affect the results of the present study; more individuals are likely to be recorded inside forests than would be during other times of the year. In the wet season, reproductive needs of butterflies may restrict their distribution to areas with relatively higher densities of their host plants and other plants on which they oviposit. Temporal trends in floral density and distribution are also likely to alter butterfly diversity and abundance, given the scarcity of nectar sources in forest habitat and the high degree of mobility of most species while seeking nectar. Long-term studies covering an entire annual cycle are required to completely investigate habitat selection among butterfly species.

Conclusion

Despite its limitations, our study shows that butterfly communities of mixed lime plantations differ considerably from those of deciduous forests. The extension of such agricultural practices in the Palni Hills may have deleterious effects upon the local biodiversity of insects. We, therefore, recommend that other types of agricultural land use be investigated with regard to their conservation value so that more diversity-friendly land use can be propagated in this part of the Western Ghats.

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Appendix 1 Abundance of butterfly species along the study transects

Taxon	Common name	Total number of butterfly: Forest habitat											Plantation habitat					Habitat preference
		F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	P1	P2	P3	P4	P5	
Papilionidae: Papilioninae																		
Pachliopta hector	Crimson rose	28	37	15	31	2	10	11	21	28	10	15	13	13	13	10	16	0
Pachliopta aristolachiae	Common rose	20	8	1	9	1	4	4	16	7	9	6	1	2	3	2	1	F
Troides minos	Western Ghats birdwing	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	-
Papilio crino	Common banded peacock	0	1	4	1	1	3	1	0	0	0	0	0	0	0	0	0	F
Papilio demoleus	Lime swallowtail	0	0	0	0	9	10	0	0	0	0	0	3	52	21	29	7	P
Papilio polytes	Common mormon	6	10	36	9	18	13	15	14	2	6	2	10	8	14	7	8	0
Papilio polymnestor	Blue mormon	2	10	4	5	20	40	21	18	25	21	23	2	0	3	1	5	F
Papilio clytia	Common mime	*																-
Papilio helenus	Red Helen	0	0	0	0	1	1	0	1	1	1	0	0	0	0	0	0	-
Graphium doson	Common jay	1	6	6	4	106	132	18	2	1	14	17	1	8	3	5	22	0
Graphium agamemnon	Tailed jay	0	0	1	0	4	2	1	1	3	1	0	0	0	0	0	3	0
Graphium sarpedon	Common bluebottle	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	-
Graphium nomius	Spot swordtail	0	0	0	0	2	1	0	0	0	0	0	0	1	0	0	0	-
Pieridae: Coliadinae																		
Catopsilia pomona	Common emigrant	0	1	0	0	3	18	3	0	0	0	0	0	6	7	7	86	P
Catopsilia pyranthe	Mottled emigrant	0	0	0	1	32	10	3	2	1	2	1	0	5	0	6	9	0
Eurema hecabe	Common grass yellow	12	23	18	30	40	45	27	22	19	11	8	31	20	41	33	26	0
Pieridae: Pierinae																		
Cepora nadina	Lesser gull	0	0	0	0	7	1	0	0	0	0	0	0	0	0	0	0	-
Cepora nerissa	Common gull	0	0	0	1	4	3	0	0	3	0	1	3	1	6	3	11	P
Leptosia nina	Psyche	7	0	0	3	2	0	0	2	3	0	0	0	0	0	0	0	0
Delias eucharis	Common jezebel	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	-
Appias albina	Common albatros	0	0	0	1	1	1	1	0	0	0	0	0	1	0	0	0	-
Colotis etrida	Little orangetip	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	-
Colotis eucharis	Plain orangetip	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	-
Colotis danae	Crimson tip	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	-
Ixias pyrene	Yellow orangetip	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	-
Pareronia valeria	Common wanderer	*																-
Hebomoia glaucippe	Great orangetip	1	0	0	2	1	1	2	0	0	1	0	0	1	1	1	1	0

* = Seen outside of count hours, P = more abundant in plantation habitat, F = more abundant in forest habitat.
0 = No difference between forest and plantation habitats, - = not analysed because of insufficient samples.

(Continued)

Appendix 1 - continued

Taxon	Common name	Total number of butterfly: Forest habitat F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	Plantation habitat P1	P2	P3	P4	P5	Habitat preference
Nymphalidae: Satyrinae																		
Melanitis leda	Common evening brown	1	1	1	1	0	0	4	3	1	4	6	0	0	0	0	2	F
Ypthima ceylonica	White fourring	0	3	6	16	3	2	2	0	5	3	0	3	1	11	0	0	0
Ypthima philomela	Baby fivering	2	23	3	37	31	15	15	15	18	30	30	2	0	2	0	1	F
Orsotriaena medus	Nigger	*																0
Lethe drypetis	Tamil treebrown	1	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	-
Mycalesis patnia	Glad-eye bushbrown	11	32	10	18	3	11	2	38	8	28	56	0	0	0	0	0	F
Mycalesis mineus	Dark-brand bushbrown	5	3	2	2	2	3	7	9	4	14	17	0	0	2	0	1	F
Nymphalidae: Heliconiinae																		
Acraea violae	Tawny coster	0	0	2	2	0	0	0	0	0	0	0	1	31	32	2	0	P
Cupha erymanthis	Southern indian rustic	0	9	0	0	0	1	2	0	1	1	0	0	0	0	0	0	0
Phalanta phalantha	Common leopard	0	1	0	1	11	15	1	0	0	1	0	0	5	5	4	5	0
Nymphalidae: Apaturinae																		
Euripus consimilis	Painted courtesan	0	0	1	0	1	0	0	0	0	0	0	1	1	3	1	4	P
Nymphalidae: Limenitinae																		
Neptis hylas	Common sailer	2	7	5	9	23	19	11	9	3	13	24	0	0	3	1	4	F
Neptis jumbah	Chesnut-streaked sailer	0	1	1	1	20	6	7	0	0	5	8	0	0	0	0	0	F
Pantoporia hordonia	Common lascar	0	0	0	0	14	7	5	2	0	3	3	0	0	0	0	1	0
Athyma selenophora	Staff sergeant	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	-
Limenitis procris	Commander	*																-
Polyura athamas	Common nawab	0	1	0	2	1	2	1	0	1	0	0	0	0	0	0	0	-
Euthalia aconthea	Baron	0	4	0	0	17	2	2	0	0	2	4	0	0	0	0	0	F
Dophla evelina	Redspot duke	0	2	0	2	0	2	1	2	6	1	3	0	0	0	0	0	F
Ariadne merione	Common castor	0	0	0	0	1	0	1	0	0	0	0	8	1	3	9	5	P
Cyrestis thyodamas	Common map	0	0	0	0	0	7	0	0	1	0	0	0	0	0	0	0	-
Nymphalidae: Libytheinae																		
Libythea lepita	Common beak	2	0	2	2	25	4	4	0	0	0	2	0	0	0	0	1	F
Nymphalidae: Nymphalinae																		
Hypolimnas bolina	Great eggfly	0	0	1	0	1	2	0	0	0	1	1	4	1	1	0	4	0

* = Seen outside of count hours, P = more abundant in plantation habitat, F = more abundant in forest habitat.
0 = No difference between forest and plantation habitats, - = not analysed because of insufficient samples.

(Continued)

Appendix 1 - continued

Taxon	Common name	Total number of butterfly: Forest habitat F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	Plantation habitat P1	P2	P3	P4	P5	Habitat preference
Nymphalidae: Nymphalinae																		
Hypolimnas bolina	Great eggfly	0	0	1	0	1	2	0	0	0	1	1	4	1	1	0	4	0
Hypolimnas missipus	Danaid eggfly	0	0	0	0	2	1	3	0	0	4	1	1	1	1	0	0	0
Junonia hierta	Yellow pansy	0	0	0	0	1	2	0	0	0	0	0	0	19	16	8	7	P
Junonia almana	Peacock pansy	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	-
Junonia iphita	Chocolate pansy	5	35	18	40	114	147	92	26	34	54	21	2	10	15	9	21	F
Junonia orithya	Blue pansy	0	0	0	0	0	0	0	0	0	0	0	0	15	4	7	6	P
Junonia lemonias	Lime pansy	1	2	4	2	5	6	3	0	0	1	0	4	49	54	14	10	P
Kallima horsfieldi	Blue oakleaf	1	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	-
Nymphalidae: Danainae																		
Danaus chrysippus	Plain tiger	0	1	0	14	4	7	1	1	0	1	0	8	11	26	20	22	P
Danaus genutia	Common tiger	5	0	3	25	9	9	2	0	0	0	0	3	4	9	5	3	0
Danaus septentrionis	Dark blue tiger	1	0	2	7	17	11	0	2	3	1	18	0	27	24	5	2	0
Parantica aglea	Glassy tiger	4	9	11	6	10	0	5	8	3	9	10	3	2	8	1	1	F
Tirumala limniace	Blue glassy tiger	1	0	1	1	41	3	16	0	0	7	26	4	6	19	9	5	0
Euploea core	Common crow	14	28	36	38	724	87	227	8	11	230	200	24	62	127	23	30	0
Lycaenidae: Polyommatinae																		
Castalius rosimon	Common pierrot	0	1	3	1	0	6	0	0	0	0	0	0	0	5	0	0	0
Discolampa ethion	Banded blue pierrot	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	-
Zizina otis	Lesser grass blue	0	0	1	0	0	4	0	0	0	0	0	4	13	4	5	17	P
Catochrysops strabo	Forget-me-not	0	0	0	0	2	5	0	0	0	0	0	1	15	9	1	7	P
Celatoxia albidsca	White-disc hedge blue	0	0	0	0	10	3	0	1	0	0	0	0	1	0	1	3	0
Caleta caleta	Angled pierrot	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	-
Azanus jesous	African babul blue	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	-
Leptotes plinius	Zebra blue	0	2	1	0	1	4	0	0	0	0	0	1	0	5	1	4	0
Celastrina lavendularis	Common hedge blue	*																-
Zizula hylax	Tiny grass blue	1	0	1	3	6	1	0	0	0	0	0	5	10	15	6	35	P
Chilades laius	Lime blue	0	0	0	0	24	9	1	0	2	0	0	11	3	13	8	43	P
Chilades putli	Southern grass jewel	0	0	0	0	0	0	0	0	0	0	0	0	18	11	23	1	P
Anthene lycaenina	Pointed ciliate blue	*																-

* = Seen outside of count hours, P = more abundant in plantation habitat, F = more abundant in forest habitat.
0 = No difference between forest and plantation habitats, - = not analysed because of insufficient samples.

(Continued)

Appendix 1 - continued

Taxon	Common name	Total number of butterfly																Habitat preference
		Forest habitat											Plantation habitat					
		F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	P1	P2	P3	P4	P5	
Lampides boeticus	Peablue	0	0	0	0	1	1	0	0	0	0	0	3	47	36	18	2	P
Jamides bochus	Dark cearulean	33	4	2	4	53	24	5	10	18	3	1	4	0	0	0	15	0
Jamides celeno	Common cearulean	3	1	6	0	34	35	18	2	12	7	0	7	0	0	1	28	0
Talicada nyseus	Red pierrot	0	0	0	1	7	0	0	0	0	0	0	0	0	0	0	0	-
Lycaenidae: Theclinae																		
Arhopala bazaloides	Tamil Oakblue	0	4	0	0	9	8	7	1	0	1	6	0	0	0	0	0	F
Amblypodia anita	Leaf Blue	1	0	1	0	6	0	0	3	2	0	0	0	0	0	0	1	0
Laxura atymnus	Yamfly	0	0	5	0	1	1	0	0	0	0	0	0	0	0	0	0	-
Spindasis vulcanus	Common Silverline	0	0	0	0	0	0	0	0	0	0	0	0	0	6	1	0	-
Rathinda amor	Monkey Puzzle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	-
Deudorix epijarbas	Cornellian	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	-
Tajuria cippus	Peacock Royal	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	1	-
Lycaenidae: Curetinae																		
Curetis thetis	Indian Sunbeam	0	0	0	0	0	2	2	0	1	0	0	0	0	0	0	2	-
Hesperidae: Pyrginae																		
Celanorrhinus leucocera	Common Spotted Flat	1	0	1	0	0	0	1	0	1	1	0	0	0	0	0	0	-
Celanorrhinus ambareesa	Malabar Flat	*																-
Coladenia indrani	Tricolor Pied Flat	1	0	0	2	0	0	0	0	0	0	0	0	0	1	0	0	-
Tagiades litigiosa	Water Snow Flat	0	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	-
Tagiades jepetes	Suffused Snow Flat	0	0	0	0	2	5	5	0	1	0	2	0	0	0	0	0	0
Spialia galba	Indian Skipper	0	0	0	0	0	0	0	0	0	0	0	0	1	7	3	0	P
Hesperidae: Hesperiinae																		
Iambrix salsala	Chesnut Bob	4	2	0	1	1	0	2	0	3	1	0	0	1	0	0	0	0
Matapa aria	Common Redeye	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	-
Halpe homolea	Ceylon Ace	2	1	1	0	5	2	0	0	0	0	0	1	3	1	4	2	0
Telicota ancilla	Dark Palm Dart	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	-
Odontoptilum ransonneti	Golden Angle	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	-
Psolos fuligo	Coon	1	0	2	0	0	3	0	0	1	0	2	0	0	0	0	0	-
Gangara thyrsis	Giant Redeye	*																-

* = Seen outside of count hours, P = more abundant in plantation habitat, F = more abundant in forest habitat.
0 = No difference between forest and plantation habitats, - = not analysed because of insufficient samples.