Butterfly communities in a coffee-growing landscape: A study in the Western Ghats

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Declaration

I declare that the thesis entitled "Butterfly communities in a coffee-growing landscape: a study in the Western Ghats" comprises research work done by me under the guidance of Dr. Soubadra Devy and co-guidance of Dr. R. Ganesan and Dr. Aravind N.A. The work is original and has not been done earlier by anyone else. Part of this work, which is related to or similar to work done by other researchers, has been referred to in this thesis at appropriate places. The results presented in this thesis have not been submitted previously to this or any other University for an M.Sc. or any other degree.

Signature of the Guide
(Dr. Soubadra Devy)

Signature of the Candidate
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Certificate

I declare that this thesis entitled "Butterfly communities in a coffee-growing landscape: a study in the Western Ghats" comprises research work carried out by Jignasu Dolia at the Centre for Wildlife Studies under my guidance and the co-guidance of Dr. R. Ganesan and Dr. Aravind N.A. during the period 2005-2006 for the Degree of Master of Science in Wildlife Biology & Conservation of the Manipal Academy of Higher Education (MAHE). The results presented in this thesis have not been submitted previously to this or any other University for M.Sc. or any other degree.

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Summary

Throughout the world, agricultural practices have caused significant loss in forest cover. Such practices, resulting in large-scale modifications of the landscape, have proved to be detrimental to wildlife. Some forms of land use may cause less damage to wildlife than others. For instance, tea plantations generally form a hostile matrix, whereas coffee plantations can serve as suitable habitat for various taxa.

Western Ghats, a biodiversity haven, has approximately ten percent of its area under protection. The major land use in the moist-deciduous and evergreen forests of the Western Ghats has been plantations such as tea and coffee. Often, the importance of conservation outside protected areas is undermined. It is critical to identify what biodiversity already exists outside these areas, as this is important to maintain healthy ecosystem services. Areas such as coffee plantations could thus be important in supporting biodiversity outside protected areas.

This study looked at butterfly communities in coffee plantations situated in the Chikmagalur district of Karnataka. Twenty-five belt transects that varied in shade type and distance from Bhadra Wildlife Sanctuary (BWS), along with fruit bait traps, were used to sample butterflies. A control site consisting of two transects was situated in BWS. Microclimatic variables such as temperature, relative humidity and light intensity were measured for each transect. Several other habitat variables such as canopy cover, basal area, leaf-litter depth and coffee density were also measured. Vegetation sampling was carried out to record trees, shrubs and herbs. Each transect was assigned to a distance class and shade category based on its distance from BWS and the percentage of *Grevillea robusta* (silver oak) present in it.

A total of 88 species, including six previously not documented from BWS, were recorded. Mean abundance, species richness and diversity did not differ significantly among the shade

categories. However, significant differences for the above were found among different distance classes. A decrease in the mean abundance of fruit feeders was noticed with increasing distance from forest. Many butterflies that were found in these plantations were ones that have a large geographical range and are multiple habitat users. This study shows that it is difficult to unravel the effect of distance from that of shade at the butterfly community level. Many of the shade trees found in these plantations are not attractive to butterflies either as adult resource or as larval food plants. Further long-term studies would give us a better picture on the determinants of habitat usage by butterflies.

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Last, but not the least, I would like to thank my two colleagues Anand and Archana for all their help. They were my biggest support and without them this dissertation would not have been half as much fun.

Contents

Introduction

Western Ghats, a biodiversity hotspot (Myers et al. 2000), has approximately ten percent of its area under protection (Rodgers and Panwar 1998). A large proportion of its landscape, especially the moist-deciduous and evergreen forests is mainly comprised of tea and coffee plantations, which have resulted in the severe fragmentation of its forests (Menon and Bawa 1997). While forests in this region are at various stages of degradation, opportunities to keep large tracts of native habitats intact are rapidly dwindling. In the highly populated and diverse tropics, conserving biodiversity only by protecting large areas would not be sufficient (Janzen 1998). Therefore, efforts to preserve it in fragmented habitats and within the agricultural matrix, and to understand the ecological processes in these systems, are extremely important (Saunders et al. 1991, Daily et al. 2003). It is also being realized how imperative biodiversity conservation within the agricultural landscape is in order to retain some of the critical ecosystem services provided by it (Jackson et al. 2005). Tea plantations, largely because of the absence of shade, are not favourable to wildlife. However, coffee plantations retain some sort of shade that may still be conducive to various taxa such as insects (Perfecto et al. 1996), birds (Greenberg et al. 1997, Wunderle and Latta 1998) and mammals (Gallina et al. 1996).

Studies regarding coffee and its biodiversity values are largely restricted to Central and South America. The focal group of most of these studies has been birds (Wunderle and Latta 1996, Greenberg et al. 1997, Calvo and Blake 1998). However, there have been a few studies that have looked at butterfly communities in coffee agro-ecosystems (Perfecto et al. 2003, Horner-Devine et al. 2003, Mas and Dietsch, 2003).

Mas and Dietsch (2003) found that butterfly species richness between traditionally managed coffee plantations and the neighboring forest reserve were not significantly different. Species richness declined as management intensity increased, thus corroborating the importance of preserving traditional shade coffee for the conservation of biodiversity. In another study, Horner-Devine and colleagues (2003) compared butterfly diversity between native forest and coffee farms with and without contiguous forest patches. They found that farms adjacent to forests had higher diversity than forest sites as well as farms without adjacent forest. Butterfly assemblages in farms close to forest were more similar in composition to forest. These results suggest the importance of small forest patches in a landscape dominated by coffee.

Perfecto et al. (2003) compared the species richness of fruit-feeding butterflies along a coffee intensification gradient represented by a reduction in the number of species of shade trees and percentage of shade. They found that plantations with higher number of tree species as well as with more shade maintained species richness most similar to the forest. Most of these studies have focused on the frugivorous guild of butterflies primarily because they are easy to sample.

Coffee in the Western Ghats is mainly grown around mid-elevation, moist-deciduous and evergreen forests. Incidentally, such forests have also been identified as harboring rich butterfly diversity (Larsen 1987, Kunte 2000). Hill slopes with such forests are most appropriate for growing coffee and thus, large-scale destruction and fragmentation of forests have occurred in this region. Butterflies are widely recognized as potentially important indicators of the environment (Kremen 1992, Pearson 1995). Larval dependence on specific host plants, combined with the adult’s role as pollinator for other plants, link butterflies intimately to the diversity and health of their habitats (Ehrlich and Raven 1986). They are extremely sensitive to changes in humidity, temperature and light-levels, all of which are typically affected by habitat disturbance (Murphy et al. 1990).

In the Western Ghats, coffee covers an area of approximately 3300 km^2 (Coffee Board of India, 2005). Traditionally, the native tree composition was largely left intact, while only the understorey plants were replaced by coffee. In recent times, however, farmers have replaced native shade trees with fast growing exotic tree species, especially *Grevillea robusta* (silver oak) primarily for economic benefits. The commercial exploitation of non-native tree species for timber serves as an additional source of income, especially during times of low coffee prices (Perfecto et al. 1996). However, the replacement of natural trees with exotic species has been a gradual process, resulting in a matrix with varying levels of native and exotic trees.

Western Ghats supports about 22 percent of the 1500 species of Indian butterflies. A few studies in the Western Ghats have addressed the effect of disturbance on butterflies (Davidar et al. 1996, Kunte et al. 1999, Devy and Davidar 2001, Aravind et al. 2001). However, the impact of coffee plantations on butterfly communities remains unexplored in India.

This study focused on butterfly communities in a coffee-growing landscape in the Western Ghats with varying shade types and proximity to forest, to address the following questions:

1. Does species richness, abundance and composition of butterflies vary among coffee plantations under different shade categories?
2. Does proximity to forests help to determine butterfly assemblages found within coffee plantations?

3. Do some guilds get affected disproportionately more than others?
4. What are the key factors that may be driving such changes?

Methods

Study area

Butterfly sampling was carried out between January and May 2006 in coffee plantations located in the Chikmagalur district of Karnataka, situated in the southern Western Ghats between 13˚18’ N and 13˚21’ N and 75˚31’ E and 75˚48’ (Plate 1). It receives the southwest monsoon, which is normally active from June to September. The annual rainfall ranges from 1000 mm to 4500 mm and is highly variable due to the topography of the landscape (Coffee Board of India 2005). Temperature ranges from a minimum of 15^0 C to a maximum of 30^0 C (Badrinarayanan 2001).

Coffee cultivation in India originated in Chikmagalur during the early 17th century. At present, it is the largest coffee producing region in India, accounting for approximately 25 per cent of its total production (Coffee Board of India 2005). This region is famous for its *arabica* variety of coffee, which is more shade tolerant than the *robusta*. Silver oak is the most common tree species in these coffee plantations. Another lower canopy shade tree, *Erythrina lithosperma* is also abundant in the plantations. Other popular permanent shade trees include *Ficus glomerata*, *Albizia lebek* and *Artocarpus heterophylla*. Twelve coffee estates that varied in shade-type and distance to Bhadra Wildlife Sanctuary (BWS) were identified based on Survey of India toposheets and reconnaissance surveys (Plate 2).

All estates, except for one, had two 300 m long transects that were separated by a minimum distance of 200 m. GPS locations of each transect were recorded. In *Bettadamalali* estate, there was only one transect, resulting in a total of 25 transects spread over 12 estates and one control site (forest).

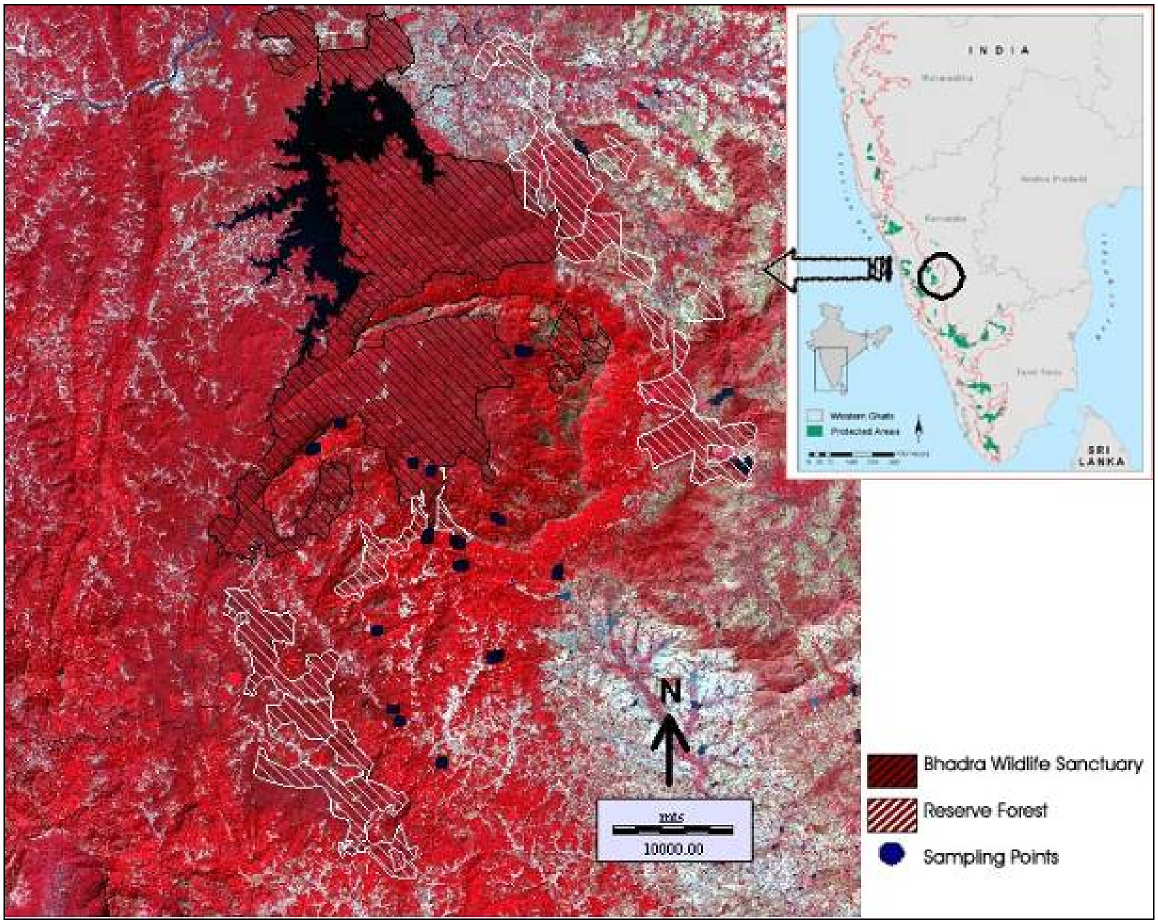
The forest site had two transects located in the Muthodi Range of the Bhadra Wildlife Sanctuary. The vegetation is predominantly moist-deciduous and is spread over an area of approximately 492 km^2. Some of the dominant tree species that form the overstorey are: *Tectona grandis*, *Terminalia alata*, *T. paniculata*, *Grewia tilaefolia* and *Lagerstroemia lanceolata* (Madhusudan 2000). The northern and southern parts of the Bhadra Wildlife Sanctuary are separated by the Bababudan hill range, which reaches an altitude of about 1800 metres above sea level.

The twelve coffee estates that contained 23 transects ranged in area from 44 ha to 160 ha (Table 1). The closest transect was 319 m away from Bhadra forest while the furthest one was 18,619 m. The altitude of these transects ranged from 792 m to 1265 m above sea level, with a mean of 1097.72 m (±27.32).

Table 1. Characteristics of the 25 transects selected for the study

Transect	Location		Area (Ha)	Altitude (m)	Minimum distance from Bhadra forest (in m)	Minimum distance from nearest forest (in m)
	Latitude	Longitude				
Bettadamalali I	13.32398	75.61043	160	1161	8346	2903
Chinanhalli I	13.37155	75.66998	128	1199	3711	3711
Chinanhalli II	13.37131	75.67481	128	1261	3834	3834
Gangegiri I	13.45568	75.56256	100	1218	755	755
Gangegiri II	13.45687	75.56364	100	1192	808	808
Ginimao I	13.39386	75.64747	72	1019	320	320
Ginimao II	13.39103	75.64796	72	1026	545	545
Hosamane I	13.40408	75.70210	45	1265	3067	775
Hosamane II	13.40587	75.69755	45	1167	2704	2885
Kendalhaklu I	13.26687	75.61981	90	870	14433	3840
Kendalhaklu II	13.25892	75.62723	90	967	15348	3886
Kesvinmane I	13.52555	75.72053	80	983	1484	1484
Kesvinmane II	13.52744	75.71571	80	946	985	985
Kondadkan I	13.46598	75.57627	140	1145	894	894
Kondadkan II	13.47385	75.58278	140	968	430	414
Mylemoney I	13.30341	75.69477	94	1200	11420	9141
Mylemoney II	13.30608	75.69928	94	1226	11533	9174
Shivgange I	13.3861	75.66949	132	1206	2389	2371
Shivgange II	13.38799	75.66684	132	1207	1911	1886
Vasanthcool I	13.36404	75.74375	88	1147	8990	8990
Vasanthcool II	13.36632	75.74325	88	1170	8813	8813
Yellikodige I	13.22705	75.65653	44	1140	18699	3811
Yellikodige II	13.22906	75.65678	44	1118	18484	4132
Forest I	13.43914	75.64918	49200	792	0	0
Forest II	13.44618	75.63664	49200	850	0	0

Plate 1: Map showing the location of study sites in Bhadra Wildlife Sanctuary



Sampling Methods

Butterfly sampling

a) Belt transects

To compare butterfly abundance, species richness and composition, butterflies were sampled using the transect walk method (Pollard and Yates 1993). Sampling was carried out in two rounds, one between January and March and the second between April and May. Twenty-five transects measuring 300 m each, were randomly marked for sampling. Each transect was surveyed four times, twice in each round. Since visibility in the coffee plantations as well as in the forest was good, all butterflies seen within twenty metres on either side of the transect were recorded. Transects were walked between 1000 hrs and 1300 hrs which corresponds to the peak activity period for most butterflies. The sampling duration for each transect lasted between 45 to 60 minutes. Most butterflies were identified to the species level using Gunathilagaraj et al. (1998) and Kunte (2000). Individual butterflies that could not be identified on flight, were caught using a butterfly net, identified and released. However, most butterflies belonging to the *Lycaenidae* and *Hesperiidae* families could only be identified to the genus or family level. Species belonging to these families were clubbed into two groups for analysis, as a result of which diversity and species richness could have been underestimated.

b) Bait traps

In addition to the transect walk method, five traps baited with rotten fruits, fermented sugarcane juice and rum were placed along each transect for monitoring fruit-feeding butterflies. These traps were custom made based on the Van-Someron-Rydon trap design (DeVries 1987). They were cylinders of green nylon netting (90 cm high and 30 cm in diameter) sewn onto a frame of two metal rings, closed at the top and open at the bottom. Each trap had a circular sheet of plywood (30 cm diameter) suspended approximately five centimetres below the open end of the trap. The plywood sheet, suspended to the metal ring with the help of three hooks, could be detached to release trapped butterflies. Approximately 100 grams of cooked fruit bait was placed in a circular fiber bowl (12 cm in diameter and 3 cm in depth) was placed in the center of the plywood sheet. The bait was prepared two to three days prior to use. The traps were installed in the evenings between 1600 hrs and 1800 hrs and were removed after approximately 24 hours. They were placed within ten metres on either side of each transect and the minimum distance between two traps was 60 m. Each trap was suspended roughly one metre above the ground. To increase the smell of the bait, approximately 30 ml of fermented sugarcane juice and 5 ml of rum were added to the semisolid bait prior to trap installation. The total number of individual of each species was recorded for each trap (Plate 2 and 3).

The following variables were measured for each transect to determine their effect on butterfly distribution.

Habitat variables

a) Microclimatic variables

Light intensity, temperature and relative humidity were measured for each transect. Light was measured every 30 m using a Var Tech MS6610 digital luxmeter. When light intensity fluctuated, a rough average of the minimum and maximum values was recorded. Temperature and relative humidity were measured at the start and end of each transect using a digital maximum/minimum thermo-hygrometer.

b) Vegetation characteristics

All trees greater than 30 cm diameter at breast height (dbh) within five metres on either side of the transect were recorded. Percentage canopy cover, canopy height, percentage herb cover, percentage leaf-litter cover, leaf-litter depth, flowering herb richness and coffee density were measured for each transect. Tree species richness, proportion of silver oak and mean basal area were calculated for each transect. To calculate the mean basal area, the dbh of each tree was measured. Canopy cover for each transect was measured every 30 m using a spherical densiometer. Four readings were taken at each point, one facing in each direction. Canopy height was measured every 30 m with the help of a range finder. Leaf-litter depth was measured every 50 m using a six-inch metal ruler. At each point, four readings were taken by placing the ruler randomly on the ground. Twelve 1x1 m plots (6 bordering the transect and 6 within 3 m on either side of it) were used to count flowering herb richness and to estimate the percentage herb and litter cover. The number of coffee stems in a 5x5 m plot was recorded every 50 m.

c) Distance from Bhadra Wildlife Sanctuary (BWS)

To measure distance from BWS, latitude and longitude for each transect was recorded at the start and end using a GPS. The distance of each point was obtained from satellite imagery using a GIS and image processing software IDRISI (Clark Labs 2003). A mean of both distances for each transect was calculated to arrive at a single value that was used for all subsequent analyses.

Analyses

Distance classes and shade categories

All transects were divided into distance classes and shade categories based on the minimum distance to BWS and the percentage of silver oak trees. Each transect was assigned to one of three distance classes- *Near* (0-2 km); *Intermediate* (>2- 9 km); and *Far* (>9km). There were nine transects in the ‘near’ class, eight in the ‘intermediate’ and six in the ‘far’. Similarly, each transect was assigned to one of the three shade categories based on the percentage of silver oak trees in that transect - *‘Natural’* (0- 25 %), *‘Mixed’* (>26-50 %) and *‘Silver-oak’* (>50 %). There were ten transects in the ‘natural’ category, five in the ‘mixed’ and eight in the ‘silver-oak’.

Plate 2: Pictures showing some of the study sites and bait trap used in the present study

 Control site at Bhadra Wildlife Sanctuary	 Setting up of bait trap in Bhadra
 Natural shade coffee estate	 Fruit bait used for butterfly trapping
 Silver oak dominated coffee estate	 Bait trap used in the study

Butterfly guilds

To test the effect of distance and shade type on different feeding guilds, butterflies were grouped into three feeding guilds based on literature and field observations. The three guilds were: *Nectar-feeders, Fruit-feeders* and *Omni-feeders.* Nectar-feeders primarily feed on floral nectar; fruit-feeders on rotting, alcohol-rich fruits and omni-feeders on both nectar and fruits, as well as on other resources such as animal and bird droppings, rotting carrion etc.

Common and rare species index

Butterfly species were categorized as ‘rare’, ‘uncommon’ and ‘common’ based on a ranking system that takes abundance and number of transects in which a species occurs into account (Davidar et al. 1996). All butterfly species recorded during the study were ranked in ascending order based on the number of transects in which each occurred. Butterflies recorded from transects 1 to 5 were assigned a rank of 1, 6 to 10 a rank of 2, 11 to 15 a rank of 3, 16 to 20 a rank of 4 and 21 to 25 a rank of 5. Similarly, each species was ranked in ascending order based on its abundance. Species with less than 10 individuals were given a rank of 0, 10 to 50 a rank of 1, 51 to 100 a rank of 2, 101 to 150 a rank of 3, 151 to 200 a rank of 4 and >200 a rank of 5. Individual ranks for each species were added to give a composite index ranging from 1 to 10. All species having a composite index of 1 or 2 were considered ‘rare’, those having an index of 3 or 4 considered ‘uncommon’ and those having an index of 5 and above considered ‘common’.

Statistical Analyses

Since there was no significant difference in butterfly abundance and richness between the two sampling rounds (*t test NS;* $p > 0.05$) all data collected was pooled for analysis. All variables were tested for normality using the one-sample Kolmogorov-Smirnov test computed using the software SPSS (Ver. 11.5, 2002). Since all variables were normally distributed, Pearson’s correlation coefficient (r) was used for all correlations. To obtain a correlation matrix of all variables that were measured during the study, 10^{-3} was added to each distance value before log-transforming it. All proportions were arcsine-transformed. The Shannon-Weiner diversity index (H’) was computed for butterfly and trees in each transect using Primer (Ver. 5, 2001). To compare the mean abundance, species richness and diversity between different distance classes and shade categories, a one-way analysis of variance (ANOVA) test was performed using the software SPSS (Ver. 11.5, 2002). A chi-square contingency table was used to generate expected values for butterfly abundance and richness in response to distance classes and shade categories. The Bray-Curtis index of similarity was used for cluster analysis using Primer (Ver. 5, 2001). For similarity between distance classes and shade categories, the Morisita-Horn index was computed using EstimateS (Ver. 7.5, Colwell 2005). To determine which factors had a strong influence on butterfly distribution, step-wise multiple regression was done using Statistica (Ver. 4.5, 1998). A t-test was used to check for significant differences for butterflies found in transects as well as in bait-traps.

Results

Vegetation characteristics

A total of 2478 trees belonging to 107 species were recorded from 25 vegetation plots. The number of trees per transect ranged from 35 to 203, with a mean of 99.12 trees (±47.52) (Table 2). Observed tree species richness per transect ranged from 11 to 21 with a mean of 15.80 (±3.19). Among all coffee transects, *Vasantcool II* had the highest richness with 21 species. The two control transects in Bhadra forest had 20 and 21 species respectively.

Table 2. Vegetation characteristics for 25 transects. Values in parentheses indicate ± 1SE.

Transects	**Number of tree species**	**Number of trees**	**% Silver oak trees**	**Mean basal area (cm^2)**
Bettadamalali I	12	132	57.58	863.05 (96.05)
Chinanhalli I	15	131	76.34	1615.12 (299.19)
Chinanhalli II	13	135	48.89	1997.09 (401.26)
Gangegiri I	16	56	12.50	2627.52 9 (788.76)
Gangegiri II	11	35	11.43	2459.69 (436.04)
Ginimao I	15	53	37.74	3527.92 (1085.72)
Ginimao II	14	51	21.57	3619.48 (583.33)
Hosamane I	13	149	71.81	1004.47 (288.82)
Hosamane II	20	123	55.28	879.43 (159.75)
Kendalhaklu I	16	91	13.19	1666.60 (309.55)
Kendalhaklu II	11	128	66.41	1165.45 (176.43)
Kesvinmane I	12	84	5.95	1326.42 (128.44)
Kesvinmane II	20	203	51.23	585.25 (44.53)
Kondadkan I	14	50	20.00	2856.46 (403.77)
Kondadkan II	18	51	41.18	1336.29 (150.74)
Mylemoney I	17	84	21.43	2886.58 (585.33)
Mylemoney II	16	135	48.89	2080.68 (485.97)
Shivgange I	14	97	24.74	2137.12 (408.43)
Shivgange II	14	96	50.00	2730.33 (739.14)
Vasanthcool I	20	142	64.79	1064.57 (67.89)
Vasanthcool II	21	203	57.64	831.12 (78.63)
Yellikodige I	18	47	4.26	4944.50 (1731.15)
Yellikodige II	14	46	13.04	5460.03 (1047.08)
Forest I	21	85	0.00	2363.94 (277.11)
Forest II	20	71	0.00	1408.44 (160.96)

Silver oak was the most abundant species representing 43.14% of trees sampled. In coffee estates, the proportion of silver oak ranged from 4.26% to 76.34%. Overall, the mean proportion of silver oak per transect was 38.08% (±22.94). ‘Natural’ shade transects had a mean of 16.11% (±9.65), ‘mixed’ had a mean of 42.74 % (±10.66) and ‘silver-oak’ had a mean of 62.63% (±8.66) silver oak trees. The forest site had no silver oak trees.

The rank abundance curves for trees in different distance classes and shade categories show that very few species dominate the community (Figure 1 and 2). For all shade categories, silver oak is the most dominant species with 59, 225 and 425 individuals for ‘natural’, ‘mixed’ and ‘silver-oak’ respectively. The other dominant trees were *Artocarpus heterophylla*, *Ficus* sp. *Erythrina indica* and *Bischofia javanica* in both distance and shade categories.

Figure 1. Rank abundance curve for trees in different shade categories.

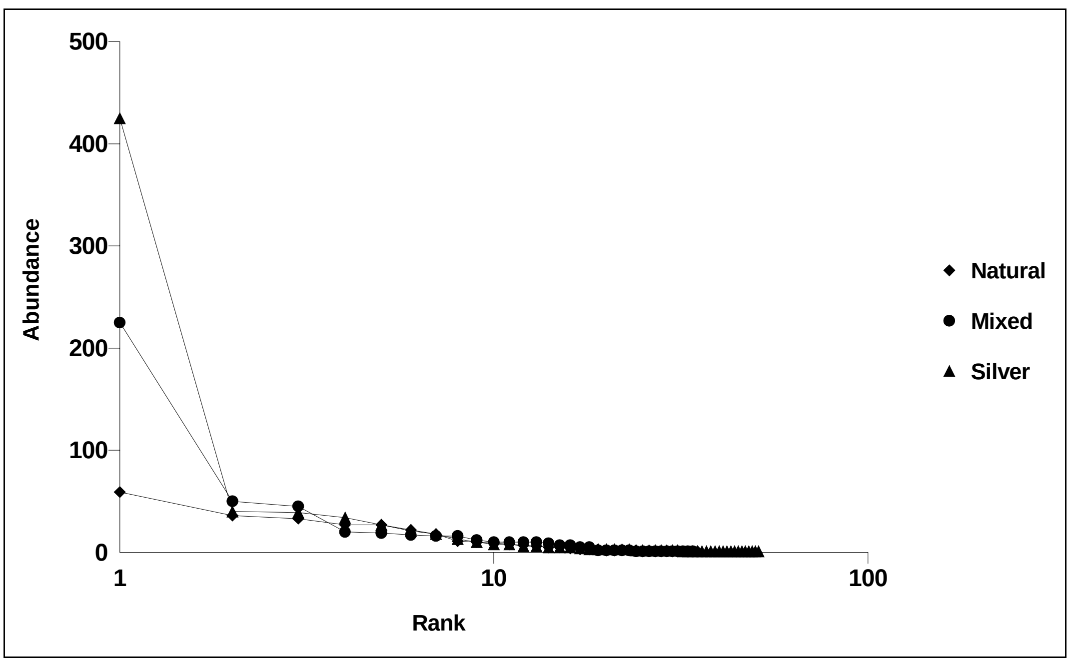
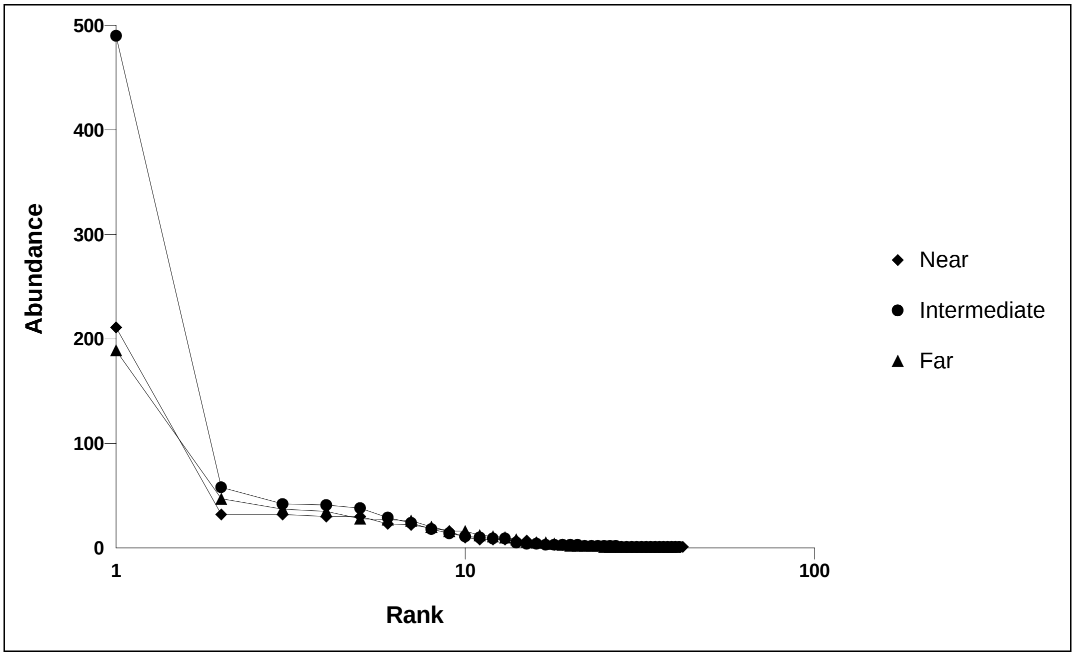


Figure 2. Rank abundance curve for trees in different distance classes



Habitat characteristics

Microclimatic variables

Relative humidity and ambient temperature were similar across the shade gradient. Light intensity was found to be higher in the silver-oak shade category (Table 3). However, ANOVA showed no significant differences across the shade gradient for any of the three variables (light: $F=1.43$; $p=0.26$; temperature: $F=0.31$; $p=0.74$ and humidity: $F=0.04$; $p=0.96$).

Table 3. Mean light intensity, temperature and humidity for each shade category (Values in parentheses indicate ± 1SE)

Microclimatic variables	**Natural**	**Mixed**	**Silver oak**
Light intensity (x100 lux)	280.4 (27.07)	315.85 (51.79)	352.02 (26.92)
Temperature (^{0}C)	27.77 (0.39)	28.00 (0.31)	28.23 (0.52)

Relative humidity (%)	51.05 (1.52)	50.80 (1.57)	50.19 (3.45)

Other habitat variables

In addition to vegetation characteristics, other habitat variables such as canopy cover, canopy height, leaf-litter depth, coffee density and flowering herb richness were measured for each transect. Canopy cover ranged from 53.05% to 90.50% with a mean of 81.04% (±1.71). Canopy height ranged from 13.41 m to 35.23 m with a mean of 21.07 m (±0.93). Leaf litter depth ranged from 1.71 to 5.29 with a mean of 3.76 (±0.17), and coffee density from 0 to 10 with a mean of 5.32 stems (±0.47) per 5m^2. Flowering herb richness ranged from 1 to 7 with a mean of 3.32 (±0.30).

Mean values for these were computed across different shade categories (Table 4). Of all these variables, only basal area ($F= 11.99; p<0.001$); number of trees ($F=23.73; p<0.001$); and tree diversity ($F=21.63; p<0.001$) were significantly different across the shade gradient.

Table 4. Habitat parameters for different shade categories (Values in parentheses indicate ± 1 SE)

Habitat parameters	**Natural**	**Mixed**	**Silver oak**
Number of trees	59.7 (6.10)	102.8 (15.55)	151.4 (11.60)
Tree species richness	14.7 (0.68)	15. (0.89)	16.5 (1.48)
Tree diversity	2.23 (0.06)	1.95 (0.08)	1.5 (0.11)
Basal area (cm^2)	3137.52 (412.97)	2056.3 (221.74)	1001.06 (107.22)
Canopy cover (%)	78.75(3.50)	83.07 (3.12)	82.42 (2.56)
Canopy height (m)	19.71(1.43)	19.66 (0.77)	23.36 (2.12)
Leaf-litter depth (cm)	3.86(0.35)	3.93 (0.21)	3.54 (0.29)
Coffee density (per 5 m^2)	6.1(0.66)	6.2 (0.73)	5.13 (0.52)
Flowering herb species richness	3.5(0.58)	3.6 (0.40)	3.13 (0.52)

Butterfly assemblages in the coffee landscape

A total of 5176 individuals belonging to 88 species were encountered during the study. Eighty-two species were identified up to the species level, five to morpho-species and one to the family level (*Lycaenidae*). Butterfly abundance per transect ranged from 46 to 453 with a mean of 207.04 (±22.69). Species richness ranged from 14 to 43 with a mean of 28.48 (±1.53) and Shannon-Weiner diversity index ranged from 2.14 to 3.04 with a mean of 2.68 (±0.05).

Bait-traps vs. Transects

Transects accounted for 82.88 % of the total number of butterflies sampled, while the remaining 17.12 % were captured in bait-traps. Eighty-three species were recorded in transects as compared to 23 in bait-traps. Six species were exclusively recorded in bait traps- *Lethe europa*, *Polyura athamas*, *Tanaecia lepidea*, *Zipoetis saitis*, *Mycalesis* spp. and *Melanitis* spp. Seventeen species were recorded both in transects as well as in bait-traps. Abundances of each species encountered in the two methods were compared for these 17 species and a t-test used to check for significance. Eleven of these 17 species showed significant differences (Table 5).

Table 5. Species found in both bait-traps and transects. Values in bold are significant at α= 0.05 (two-tailed)

Species	Bait	Transect	t value	p value
Ariadne ariadne	5	33	2.16	**0.036**
Apatura parisatis	1	1	0.00	1.000
Kallima horsfieldii	6	4	-0.49	0.626
Precis iphita	7	248	4.40	**0.001**
Mycalesis perseus	244	14	-4.25	**0.001**
Ariadne merione	22	22	-1.65	0.105
Melanitis leda	537	67	-7.99	**0.001**
Ypthima huebneri	6	362	4.01	**0.001**
Elymnias hypermenstra	2	1	-0.59	0.562
Neptis hylas	1	119	5.27	**<0.001**
Lethe rohria	30	2	-2.45	**0.018**
Hypolimnas misippus	1	23	3.88	**0.001**
Mycalesis patnia	29	21	-0.39	0.696
Hypolimnas bolina	1	35	3.46	**0.001**
Junonia lemonias	1	296	3.84	**<0.001**
Neptis columella	1	19	2.86	**0.006**
Mycalesis anaxias	9	4	-1.02	0.313

Forward stepwise multiple linear regression shows that canopy cover was the most significant habitat variable in determining butterfly abundance and richness (Table 6 and 7).

Table 6. Stepwise multiple linear regression for butterfly abundance

	Beta	SE of Beta	B	SE of B	t(20)	p-level	N
Intercept			553.769	131.051	4.226	0.000	
Average canopy cover	-0.678	0.160	-565.18	133.686	-4.228	0.000	25
Tree species richness	0.266	0.178	9.478	6.321	1.499	0.149	25
Num of non Silver oak	0.287	0.193	1.705	1.145	1.490	0.152	25
Tree abundance	-0.226	0.178	-0.539	0.424	-1.270	0.219	25
R= 0.747; R^2= 0.558; Adjusted R^2= 0.470; F(4, 20) =6.3161 p<0.002; SE of estimate: 82.624							

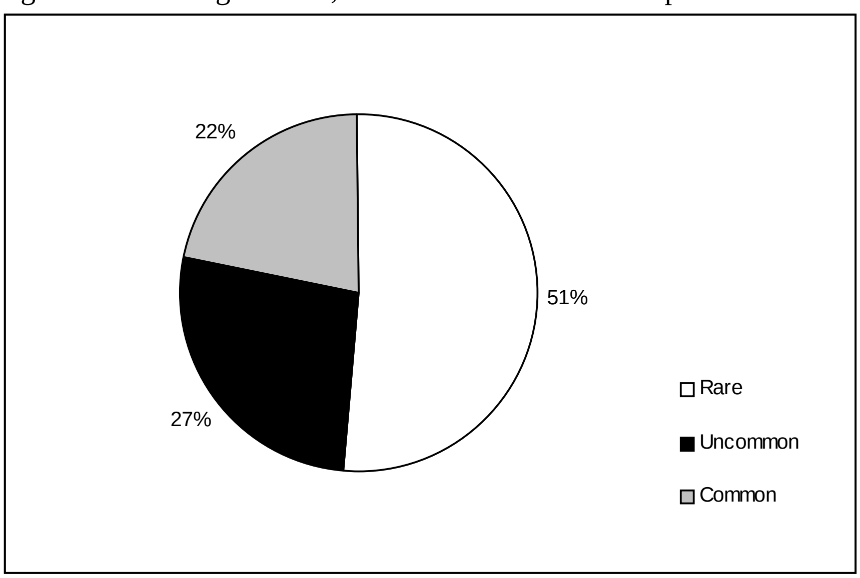
Table 7. Stepwise multiple linear regression for butterflies species richness

	Beta	**SE of Beta**	**B**	**SE of B**	**t(20)**	**p-level**	**N**
Intercept			54.889	9.872	5.560	$1.37x10^{-05}$	
Average canopy cover	-0.569	0.176	-31.965	9.909	-3.226	0.004	25
Num of non Silver oak	0.182	0.176	0.073	0.071	1.032	0.313	25
R= 0.573; R^2= 0.328; Adjusted R^2= 0.267; F(2, 22)=5.381; p<0.013; SE of estimate: 6.5423							

Common and rare species

Approximately 51 percent of species encountered were ‘rare’, 27 percent ‘uncommon’ and 22 percent ‘common’ (Figure 3). Out of the total number of individual butterflies encountered during the study 86 % were ‘common’, 1 % ‘uncommon’ and 3 % ‘rare’.

Figure 3. Percentage of rare, uncommon and common species.

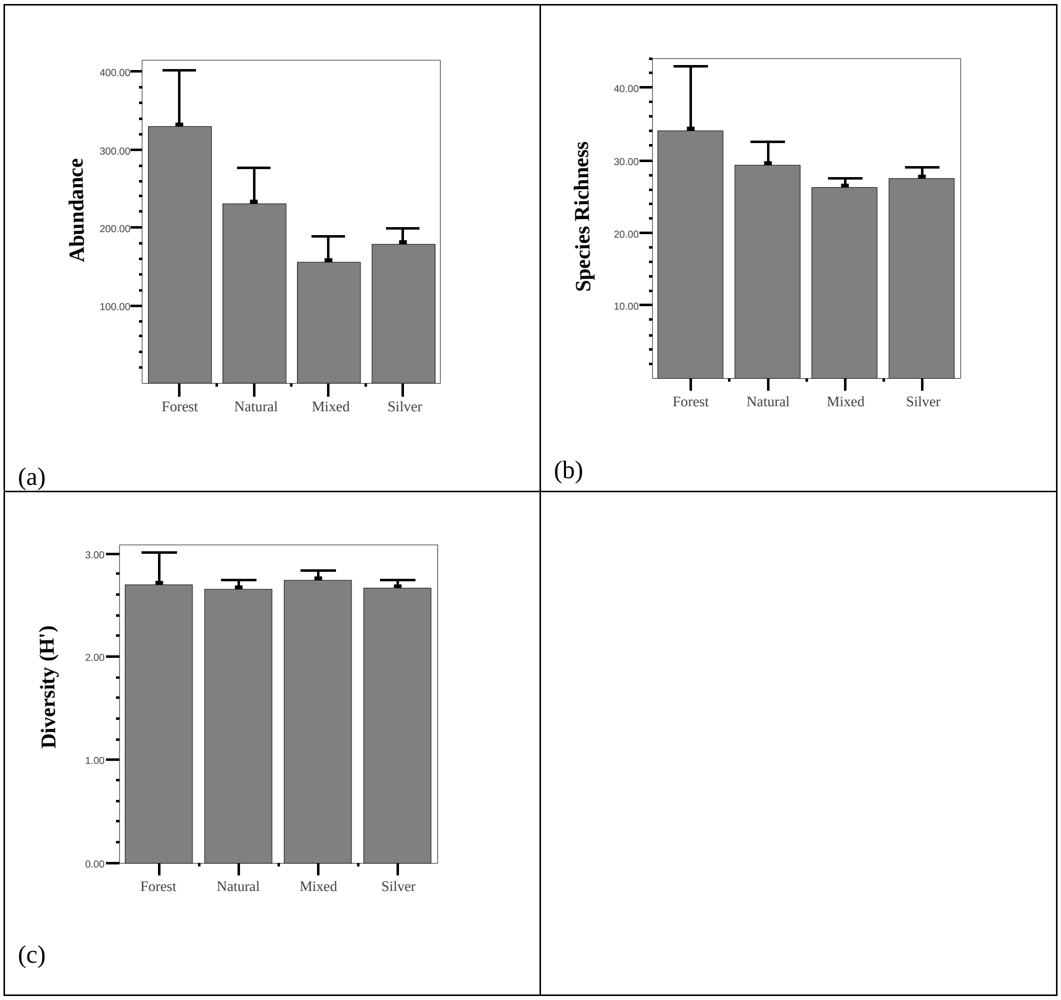


Influence of shade- type on butterfly assemblages

Overall pattern

The mean abundance, species richness and diversity of butterflies within each shade category were compared (Figure 4). Mean abundance of butterflies was highest for ‘natural’ shade with 230 (±47.33) individuals. ‘Silver-oak’ shade had 179.38 (±19.39) individuals whereas ‘mixed’ had 156 (±32.56) individuals. However, the forest site had highest mean abundance with 330.5 (±71.5) individuals. A similar pattern was found for mean species richness where ‘natural’ shade had 29.3 (±3.28) species, ‘silver-oak’ had 27.5 (±1.56), ‘mixed’ had 26.2 (±1.32) and ‘forest’ 34 (±9.00) species. Shannon-Weiner diversity was highest for ‘mixed’ shade with a value of 2.74 (±0.07), followed by 2.67 (±0.07) for ‘silver-oak’ and 2.65 (±0.09) for ‘natural’. The mean diversity for forest was 2.69 (±0.32). However, no significant differences were found for mean abundance ($F=0.893; p=0.425$), species richness ($F=0.308; p=0.738$) and diversity ($F=0.230; p=0.797$) across the shade gradient.

Figure 4. Graphs showing influence of shade type on mean +1SE for (a) abundance (b) species richness (c) diversity.



Response of guilds

One-way ANOVA of guild-wise comparison of species richness in each shade category shows that for neither guild, (a) nectar-feeders (*F=0.368; p=0.697*); (b) fruit-feeders (*F=0.817; p=0.456*) or (c) omni-feeders (*F=0.354; p=0.706*) there is any significant difference in mean species richness (Figure 5).

Similarly, ANOVA for the mean abundance of the three guilds shows that for neither guild, (a) nectar-feeders (*F=0.311; p=0.736*); (b) fruit-feeders (*F=0.2484; p=0.109*) or (c) omni-feeders (*F=1.836; p=0.185*) there is any significant difference (Figure 6). Based on the observed abundance of every guild in each shade type, expected abundances were computed and found to be significantly different ($\chi^2 = 96.71$; $p<0.0001$; Table 8). In 'natural' shade there is a five percent increase in omni-feeders from the expected value, and in 'silver-oak' shade an eight percent decrease in omni-feeders from the expected value.

Table 8. Observed and expected values for guilds in various shade categories

Shade category		**Nectar-feeders**	**Fruit-feeders**	**Omni-feeders**
Natural	Observed	1146	383	758
	Expected	1207.5	439.53	639.97
Mixed	Observed	449	98	227
	Expected	408.66	148.75	216.59
Silver	Observed	805	331	290
	Expected	752.9	274.06	399.04
Forest	Observed	317	177	165
	Expected	347.94	126.65	184.41

Figure 5. Graphs showing influence of shade type on mean species richness +1SE for (a) nectar-feeders (b) fruit-feeders (c) omni-feeders.

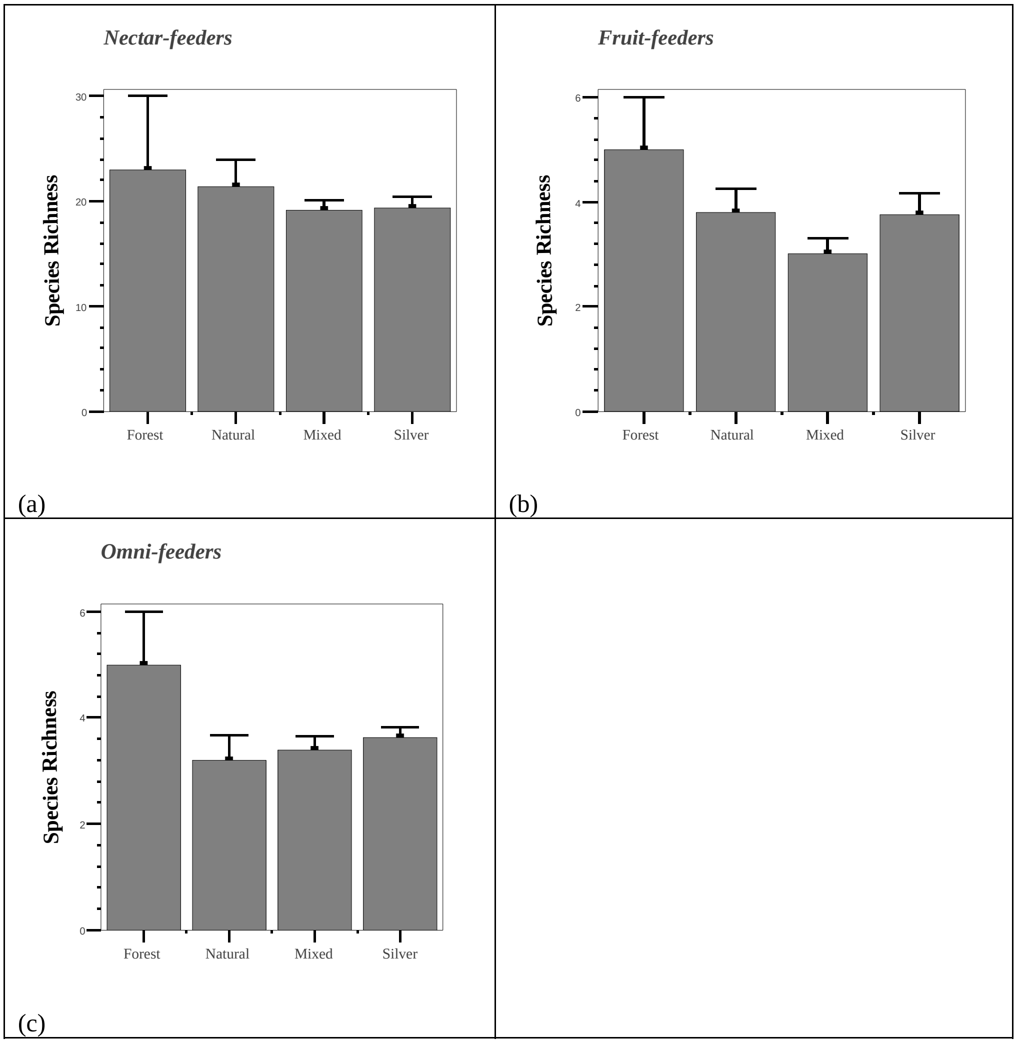
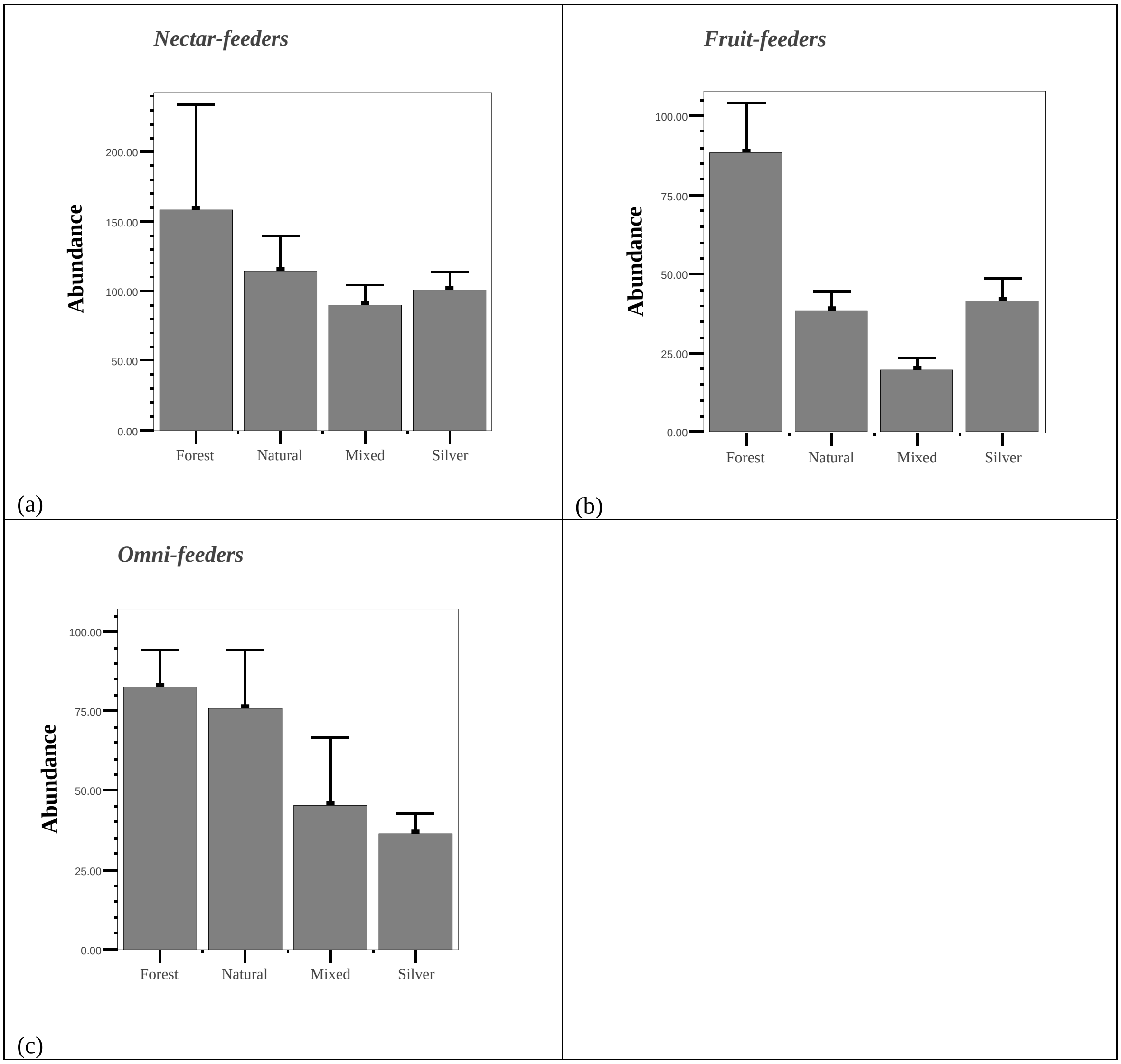


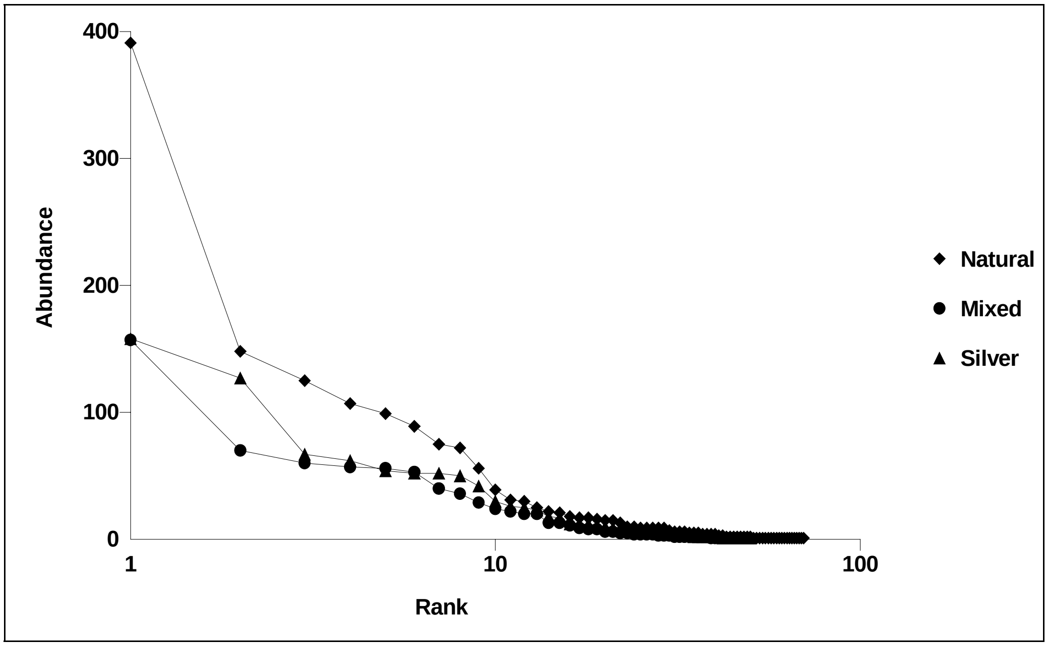
Figure 6. Graphs showing influence of shade type on mean abundance +1SE for (a) nectar-feeders (b) fruit-feeders (c) omni-feeders.



Community composition

A rank abundance curve plotted for butterflies in different shade categories shows that in ‘natural’ shade *lycaenids* (n=391) dominated the community (Figure 7). *Euploea core* (*n=148*) and *Melanitis leda* (*n=125*) were the other two dominant species in ‘natural’ shade. In ‘silver-oak’ shade, *Melanitis leda* (*n=158*), *Euploea core* (*n=127*) and *Junonia lemonias* (*n=67*) were the three most dominant species.

Figure 7. Rank abundance curve for the three shade categories.



The Bray-Curtis similarity in butterfly composition for each shade category was computed. One-way ANOVA showed that, on the whole, there is a significant difference in mean similarity in each shade type (similarity within a shade type is greater than similarity between shade types, $F=9.955;\ p<0.001$). The Morisita-Horn's index of similarity was used to calculate similarity in butterfly composition between different shade types (Table 9) Similarity between any two shade-types was greater than 70 percent for all shade categories.

Table 9. Morisita-Horn's similarity index for different shade categories

	Forest	**Natural**	**Mixed**	**Silver oak**
Forest	1			
Natural	0.81	1		
Mixed	0.81	0.96	1	
Silver oak	0.76	0.75	0.73	1

Influence of distance from forest on butterfly assemblages

Overall pattern

The mean abundance, species richness and diversity of butterflies within each distance class were compared. Among coffee transects, the mean abundance of butterflies was highest for 'near' transects with 280.33 (±40.21) individuals. 'Intermediate' transects had 164.75 (±17.7.) individuals, and 'far' transects had 112.33 (±24.30) individuals. A similar pattern was found for mean species richness where 'near' transects had a mean of 34.22 (±2.13), 'intermediate' had 26.63 (±1.10) and 'far' had 20.5 (±1.63). The mean Shannon-Weiner diversity was highest for 'near' transects with a value of 2.78 (±0.07), followed by 2.71 (±0.07) for 'intermediate' and 2.48 (±0.09) for 'far'. ANOVA showed that there were significant differences in mean (a) abundance ($F=7.497$; $p=0.004$); (b) species richness ($F=14.824$; $p<0.001$) and (c) diversity ($F=3.841$; $p=0.039$) between different distance classes (Figure 8).

Distance to forest

The effect of distance on the 15 most abundant species shows that only four species, *Mycalesis perseus* ($r=-0.40$, $p<0.05$), *Cupha erymanthis* ($r=-0.41$, $p<0.05$), *Delias eucharis* ($r= -0.41$, $p<0.05$) and *Parantica aglea* ($r=- 0.43$, $p<0.05$) had significant negative correlation with distance to nearest forest.

For the same 15 species, the general pattern observed was for abundance to decrease as distance to BWS increased. However, only five species- *Lycaenids* (*r=-0.40, p<0.05*), *Mycalesis perseus* (*r=-0.46, p<0.05*), *Tirumala limniace* (*r=-0.59, p<0.05*), *Neptis hylas* (*r=-0.40, p<0.05*) and *Cupha erymanthis* (*r=-0.40, p<0.05*), showed significant negative correlation with distance to BWS (Figure 9).

Figure 8. Graphs showing influence of distance on mean +1SE on (a) abundance (b) species richness (c) diversity.

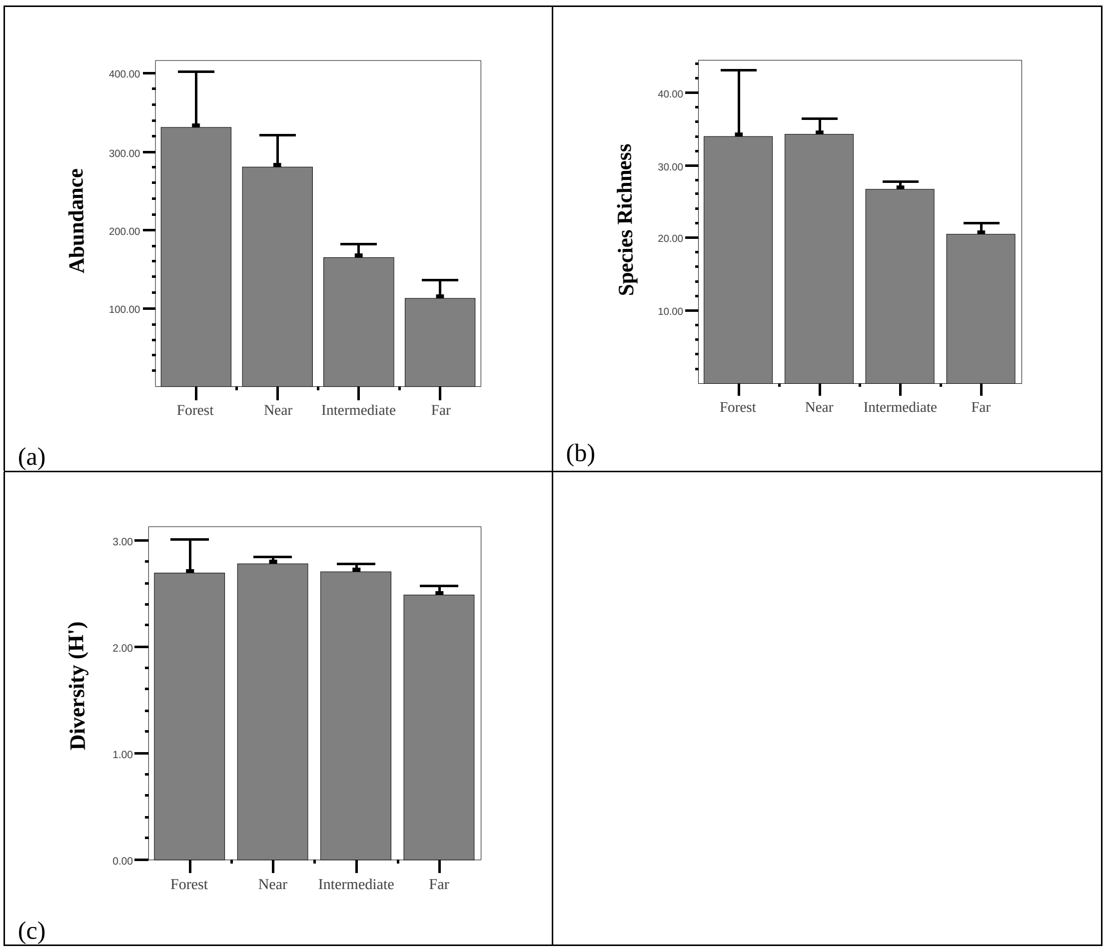
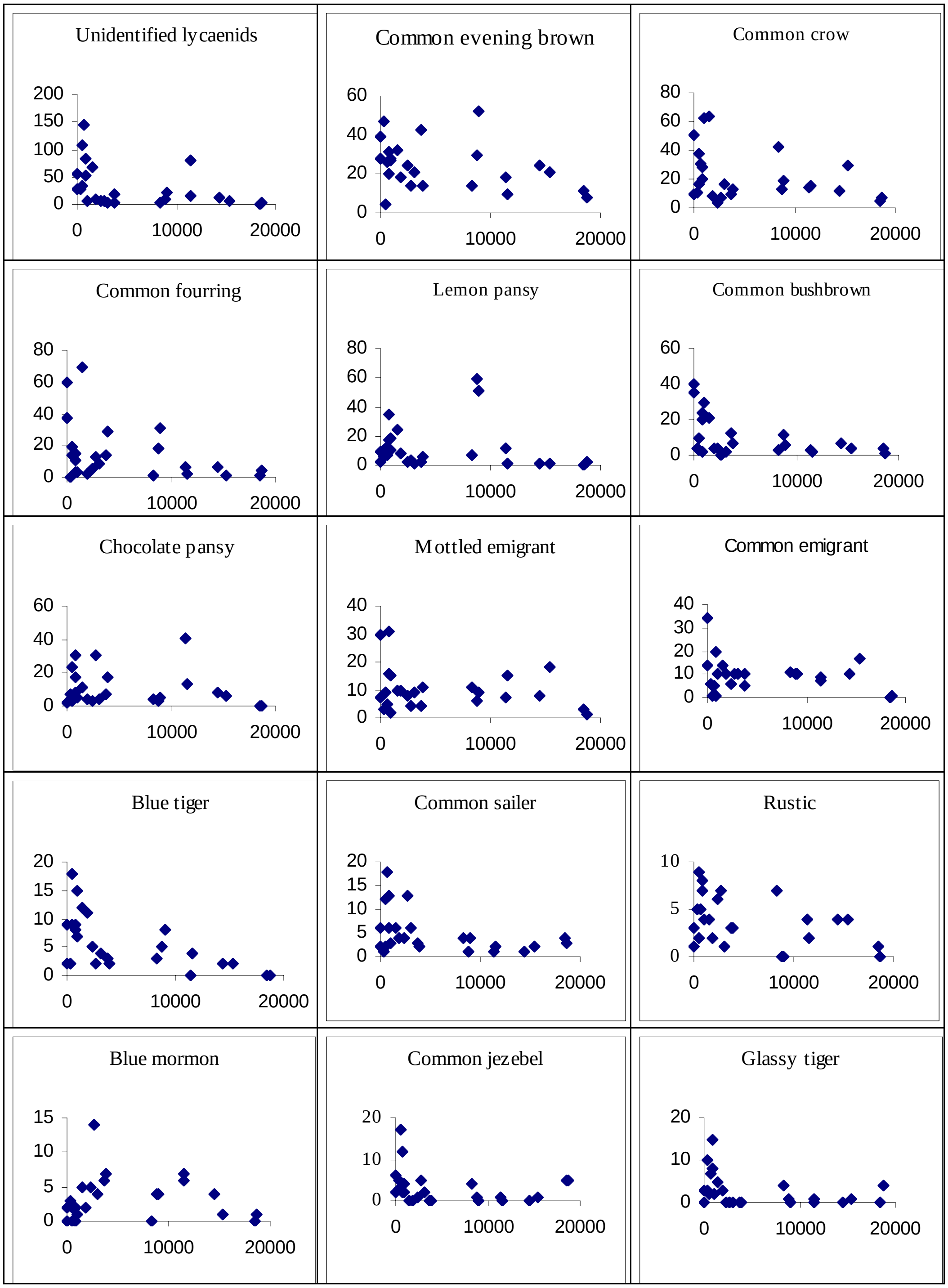


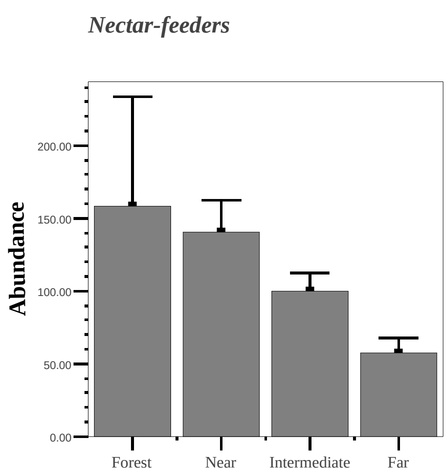
Figure 9. Scatter- plots for the 15 most abundant species. The x-axis represents distance to Bhadra wildlife sanctuary (in m) and the y-axis represents abundance.



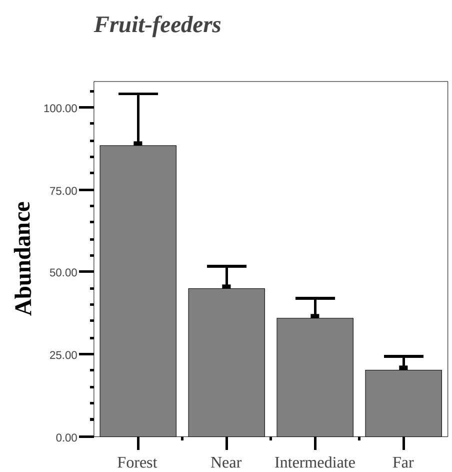
Response of guilds

ANOVA shows that there are significant differences in mean abundance for (a) nectar-feeders (*F=5.184; p=0.015*); (b) fruit-feeders (*F=3.721; p=0.042*) and (c) omni-feeders (*F=7.899; p=0.003*) between different distance classes (Figure 10). Significant differences in mean species richness were found only for (a) nectar-feeders (*F=16.204; p<0.001*) and (b) fruit-feeders (*F=4.755; p=0.02*).

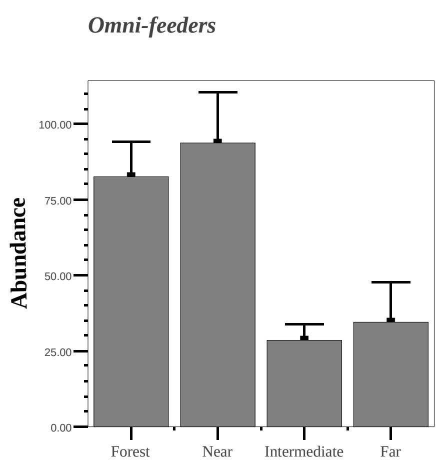
Figure 10. Graphs showing influence of distance on mean abundance +1SE for (a) nectar-feeders (b) fruit-feeders (c) omni-feeders



(a)



(b)



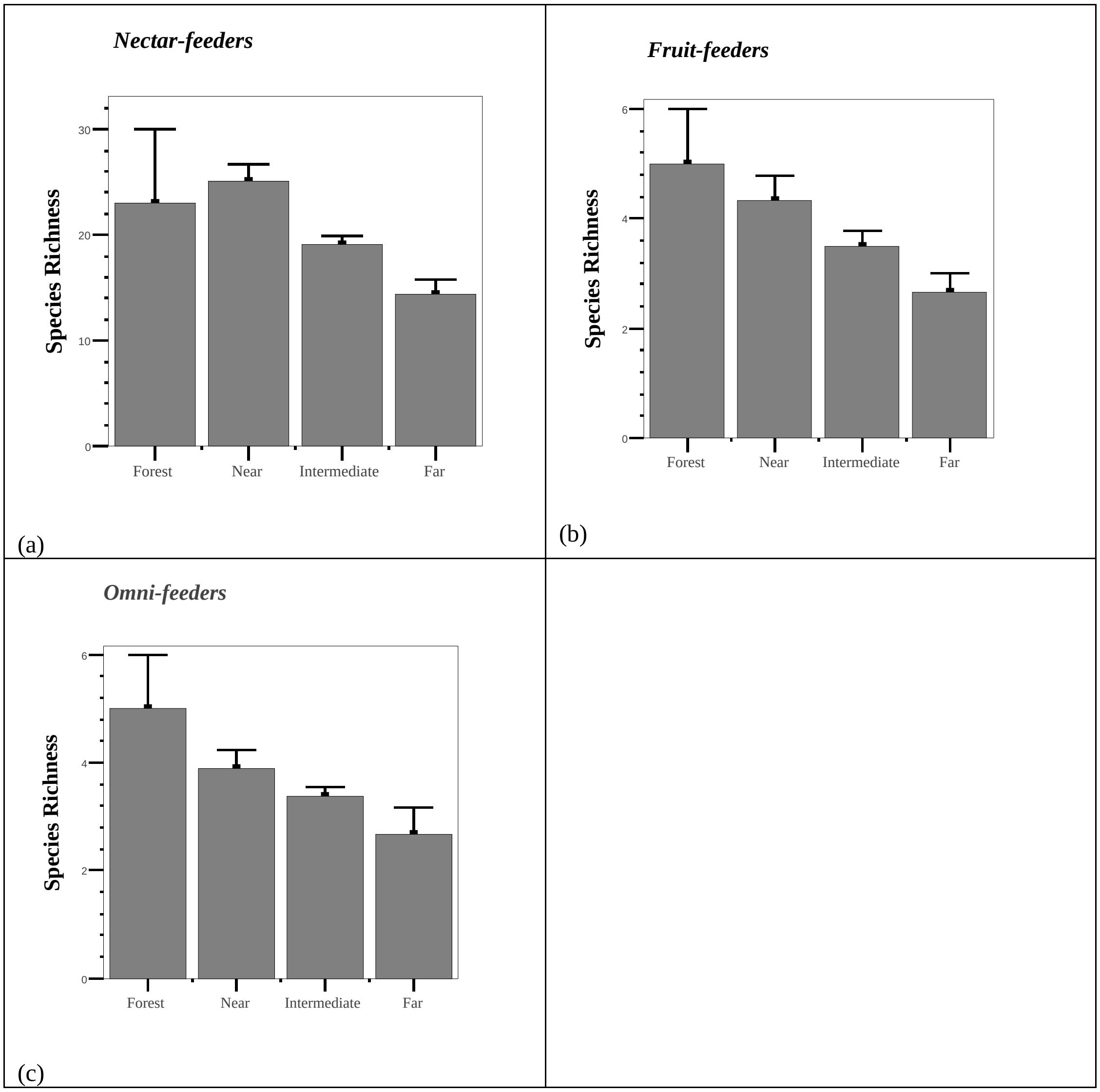
(c)

Based on the observed abundance of the three guilds in each distance class, expected abundances for the same were computed and found to be significantly different ($\chi^2 = 116.19$; $p < 0.001$; Table 10). In the 'intermediate' class there was an 8% percent increase of nectar-feeders and 11% decrease of omni-feeders from the expected values. In the 'forest' site, there was an eight percent increase in the abundance of fruit-feeders (Figure 11).

Table 10. Observed and expected values for different feeding guilds of butterflies in three distance classes.

Distance classes		**Nectar-feeders**	**Fruit-feeders**	**Omni-feeders**
Near	Observed	1261	404	842
	Expected	1323.65	481.82	701.53
Intermediate	Observed	797	287	227
	Expected	692.19	251.96	366.85
Far	Observed	342	121	206
	Expected	353.22	128.57	187.21
Forest	Observed	317	177	165
	Expected	347.94	126.65	184.41

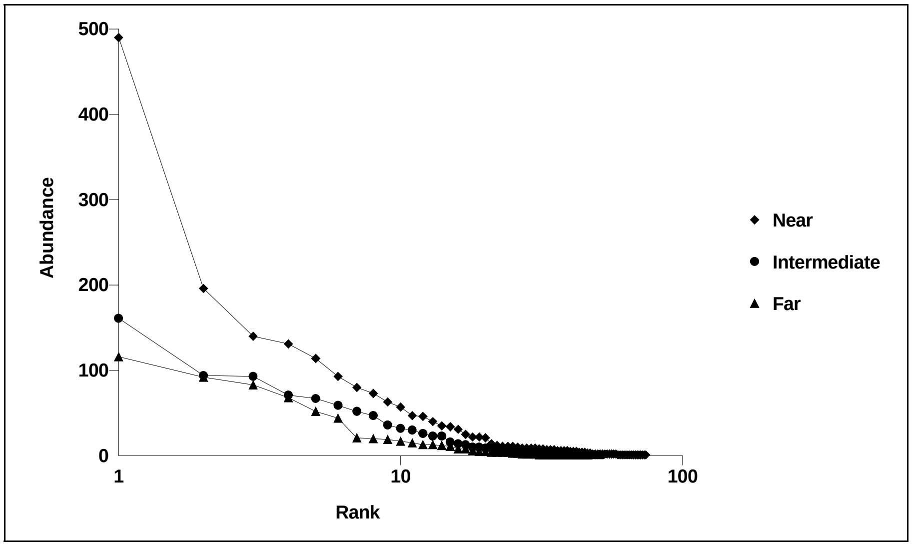
Figure 11. Graphs showing influence of distance on mean species richness +1SE for (a) nectar-feeders (b) fruit-feeders (c) omni-feeders



Community composition

A rank abundance curve for butterfly species found in each distance class shows that *Lycaenids* (n=490), *Euploea core* (n=196) and *Melanitis leda* (n=140) were the three most dominant species in the 'near' class. *Melanitis leda* (n=161), *Euploea core* (n=94) and *Ypthima huebneri* (n=93) were the dominant ones in the 'intermediate' class. In the 'far' class, *Lycaenids* (n=116), *Melanitis leda* (n=92) and *Euploea core* (n=83) were the dominant species (Figure 12).

Figure 12. Rank abundance curve for the three distance classes



The Bray-Curtis similarity in butterfly composition for each distance class was computed and ANOVA showed that, on the whole, there is a significant difference in mean similarity in each distance class (similarity within a distance class is greater than similarity between distance classes, *F=6.616; p=0.002*). The Morisita-Horn's index of similarity shows that similarity in butterfly composition between any two distance classes is greater than 75 percent. 'Near' transects were most similar to forest, whereas the 'intermediate' and 'far' ones were equally similar to forest. 'Near' and 'far' transects had high similarity, suggesting that the community in these distance classes were highly similar (Table 11).

Table 11. Morisita-Horn's similarity index for different distance classes

	Forest	**Near**	**Intermediate**	**Far**
Forest	1			
Near	0.82	1		
Intermediate	0.78	0.76	1	
Far	0.78	0.92	0.82	1

The percentage of ‘rare’ species was highest for ‘natural’ shade (45.6 %). ‘Mixed’ and ‘silver’ shade had 26.5 % and 26.3 % respectively (Figure 13). On the other hand an opposite trend was observed for the percentage of ‘uncommon’ species with ‘silver-oak’ having 40.4 % and ‘natural’ having 30.4%. However, observed values were not significantly different from the expected ones ($\chi^2=8.05$; $p=0.09$; Table 12). Similarly, the expected values for the number of ‘rare’, ‘uncommon’ and ‘common’ species in each distance class were computed (Table 13). The general trend observed was that the percentage of ‘rare’ species decreased as distance to forest increased, while that of ‘common’ species increased with distance to forest (Figure 14). However, observed values were not significantly different from the expected ones ($\chi^2=8.03$; $p=0.09$). It seems evident from figure 15 that no clear clustering can be seen based on either shade category or distance class. An interactive effect of shade and distance might be affecting butterflies. Further analysis is required to differentiate between the relative effect of each factor.

Table 12. Observed and expected values for rare, uncommon and common species in different shade categories.

Shade categories		**Rare**	**Uncommon**	**Common**
Natural	Observed	36	24	19
	Expected	27.33	27.33	24.34
Mixed	Observed	13	17	19
	Expected	16.95	16.95	15.10
Silver	Observed	15	23	19
	Expected	19.72	19.72	17.56

Table 13. Observed and expected values for rare, uncommon and common species in different distance classes.

Distance classes		**Rare**	**Uncommon**	**Common**
Near	Observed	33	24	19
	Expected	24.76	26.90	24.34
Intermediate	Observed	15	22	19
	Expected	18.25	19.82	17.93
Far	Observed	10	17	19
	Expected	14.99	16.28	14.73

Figure 13. Percentage of common, uncommon and rare species in different shade categories

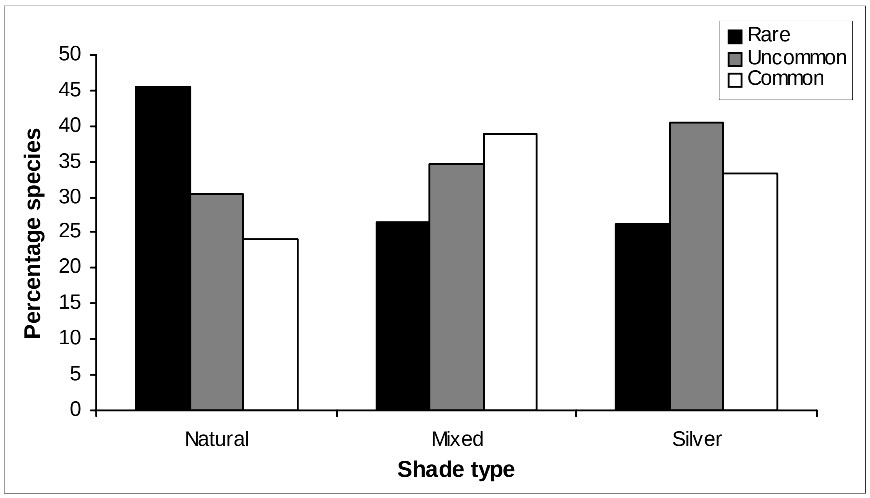


Figure 14. Percentage of common, uncommon and rare species in different distance classes.

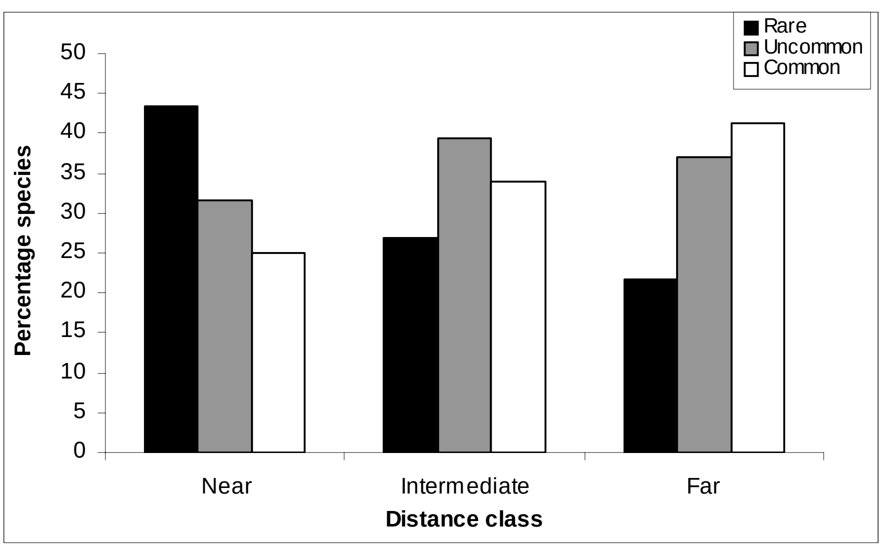
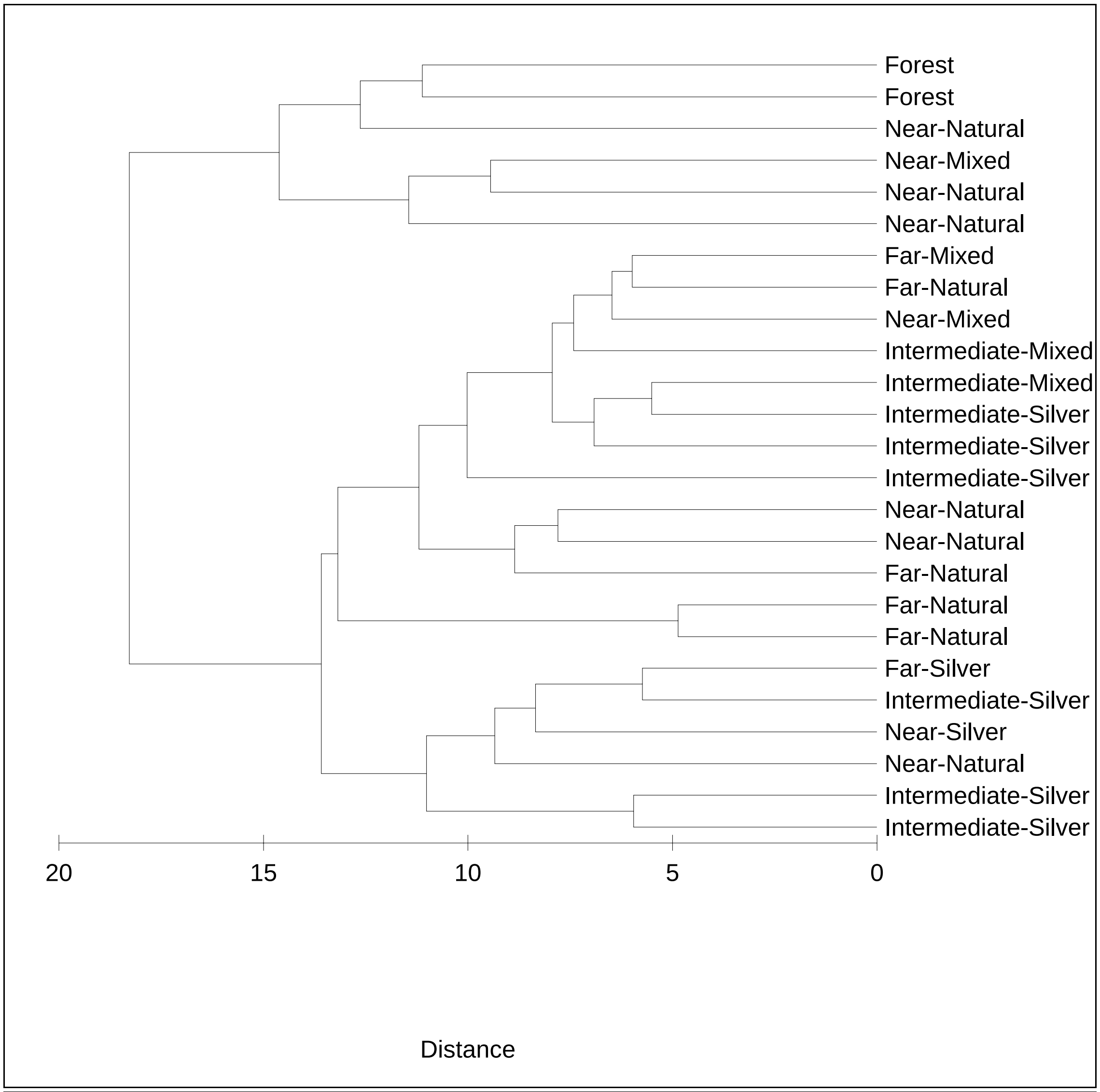


Figure 15. Dendrogram of similarity in butterfly composition with distance classes and shade categories combined, based on Euclidean distance (complete linkage).



Discussion

A total of 88 species were recorded from sites in coffee estates as well as in forest. Sampling seemed quite substantial as most of the species recorded for BWS during earlier surveys were encountered in this study. Species such as *Kallima horsfieldii* and *Apatura parisatis* that were encountered in bait traps, and *Tagiades japetus*, *Vindula erota*, *Udaspes folus* and *Papilio Buddha* that were encountered in transects, were previously not recorded for BWS (Sahyadri Pathangam 2005). Overall, mean species richness, abundance and diversity of butterflies in coffee under different shade categories did not show significant differences. This is in contrast to what was found for butterflies in Mexico, where species richness in coffee plantations decreased as management intensity increased (Mas and Dietsch 2003).

Butterflies are known to be sensitive to changes in microclimate. Contrary to expectation, this study showed that none of the microclimatic variables had a major influence on butterflies. Previous studies (Hill et al. 2001, Hamer et al. 2003) have shown that changes in light intensity can affect the diversity and composition of butterflies. Among the various habitat characteristics, canopy cover emerged as a major determinant of species richness and abundance. However, this could not be related to shade categories because canopy cover was not significantly different among them. The observed results may hold good only for the dry season because microclimatic conditions and food-plant availability among shade types may change after the monsoon. Most butterfly species appear to be tolerant of habitat changes associated with different shade types. However, this result should be viewed with caution, as some estates were contiguous to forest. Irrespective of shade type, the coffee matrix retains a continuous canopy, unlike tea or paddy. Because of this property, butterflies may be using coffee plantations as corridors between forest fragments.

Species' response to different shade types could vary across taxa. For example, Badrinarayanan's (2001) study on litter-insects showed that diversity was highest for natural shade coffee and lowest for the silver oak dominated one. She also found compositional differences in litter-insects between different shade types. This could possibly be attributed to the lower mobility of litter-insects. In case of butterflies, compositional uniformity across the shade gradient could be due to higher vagility. A study on birds in the Pulney hills showed that there was a reduction of insectivores in coffee plantations when compared to forest However, there were differences in bird composition between coffee and the adjoining forest (Shahabuddin 1997). A study on mammals in the Chikmagalur region showed that species richness was negatively correlated to distance from BWS. Distance, rather than the vegetation characteristics, seemed to have a greater influence on mammal species richness (Bali 2006).

There is a differential response of various butterfly species to shade type. Lemon pansy, for instance, was one of the three dominant species in the silver oak shade category. This could be attributed to the greater availability of its larval food plant, *Sida rhombifolia*, a herb that grows better in open and disturbed areas. There were only 42 individuals of the *Lycaenidae* family in the 'silver-oak' shade as compared to 157 for 'mixed' and 391 for 'natural'. This could possibly be explained by the greater diversity of larval food-plants in the 'natural' category. However, since larval food plants were not considered in this study, this remains a mere conjecture.

Most species that were found in coffee estates were common and widespread (Wynther-Blyth 1953). Rare species primarily occurred in forest or near-natural sites (e.g., *Kallima horsfieldii*, *Tanaecia lepidea*, *Zipoetis saitis*, *Parthenos sylvia*, *Papilio paris*, *Papilio Buddha* and *Graphium nomius*). This may be linked to their intrinsic biological requirements such as food and habitat specificity that may be absent in other shade types. Most of the food plants for butterflies are either understorey shrubs or herbs (Kunte 2000). These estates had low herb species richness, with coffee bushes dominating the shrub layer. Therefore, common species found in all shade types and at varying distance from forest, could actually be straddling opportunistically between coffee and forest. They could be feeding on adult resources in coffee plantations, but using the forest and near- natural sites for larval food plants.

This study showed that there were no significant differences for guild-wise abundance and richness between different shade types. The bird study by Anand (2006) shows that response to shade type varied from one guild to another. Insectivores were more abundant in the forest than in coffee plantations. However, within coffee plantations, insectivores had similar abundances in ‘natural’ and ‘silver-oak’ shade. The abundance of frugivorous birds, however, was highest in ‘natural’ shade. This result could probably be due to an increase in the abundance of *Ficus* trees in coffee plantations. A few butterflies such as *Melanitis leda* and *Mycalesis perseus* feed on the fruits of *Ficus glomerata* (*personal observation*). Also, the larval host plants of species such as *Cyrestis thyodamas* and *Euploea core* belong to the *Ficus* genus. However, *Ficus* trees may not be as beneficial to butterflies as they are to birds.

Proximity to the sanctuary emerges as a major factor influencing butterfly abundance and richness. This is similar to what Rickett’s et al. (2001) found for moths in a fragmented landscape in Costa Rica, where sites close to the forest fragment had higher abundance and richness than ones further away from it. However, distance may not affect all species of butterflies equally. Resources, rather than distance, may be driving the distribution of some butterflies. For instance, many individuals of *Troides minos* were found feeding on a single flowering tree in *Yellikodige* estate, which is approximately 18 km from BWS. *Papilio paris* and *Papilio buddha*, two forest-dependent species as well, were recorded in this estate. *Yellikodige* estate was about four kilometers away from a forest fragment. This fragment could be serving as a source for coffee estates. However, in order to test this, further sampling is required.

The results of this study suggest that the response of butterflies to shade and distance might be species-specific. Distance might be affecting the distribution and abundance of some species, whereas shade type might be critical for others. However, it seems quite likely that there is an interactive effect of both factors, which needs further investigation.

Conclusion

Many of the butterflies that were found in coffee plantations have broad geographic ranges and are multiple habitat users. At the community level, it seems difficult to differentiate the distance effect from that of shade. Even in the ‘natural’ shade category, there seems to be a low diversity of shade trees and planters seem to be favoring only a few species such as *Bischofia javanica*, *Artocarpus heterophylla* and *Ficus spp*. Many of the shade tree species found in these plantations do not attract butterflies, neither as adult food resource nor as larval food plants. *Ficus* can support only a few species of fruit-feeding butterflies. Even the high density of *Ficus* in the plantation does not result in increase in fruit-feeding butterflies. This is evident from the decrease in the abundance of fruit feeders as the distance from the forest increases. Also, coffee has replaced the diverse understorey plant community of natural forests. Coffee flowers are known to attract bees, but seldom attract butterflies (*personal observation*). This leaves little scope for nectar feeders. The natural shade regime of coffee plantations in India may not be comparable to that of South American ones, due to the reduced diversity of shade trees. Perhaps, plantations need to be enriched with tree species attractive to butterflies, in order to make the coffee landscape more conducive for butterfly conservation in Western Ghats.

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Plate 3: Some butterflies encountered during the study

 Common Mormon	 Blue Admiral
 Common Evening Brown	 Blue Oakleaf
 Grey Count	 Tamil Yeoman
 Common Sailer	 Mottled Emigrant feeding on coffee flower

Plate 4:Some butterflies encountered during the study (Contd.)

 Black Prince (Female)	 Common Cerulean
 Glad-eye Bush-brown	 Angled Pierrot
 White-bar Bush-brown	 Water Snow Flat
 Tamil Catseye	 Restricted Demon

Appendix 1

A list of butterfly species recorded during the study

Common Name	**Scientific Name**
Angled castor	*Ariadne ariadne*
Angled pierrot	*Caleta caleta*
Bamboo treebrown	*Lethe europa*
Black prince	*Apatura parisatis*
Blue mormon	*Papilio polymnestor*
Blue oakleaf	*Kallima horsfieldii*
Blue tiger	*Tirumala limniace*
Brown awl	*Badamia exclamationis*
Chestnut bob	*Iambrix salsala*
Chocolate pansy	*Precis iphita*
Clipper	*Parthenos sylvia*
Club beak	*Libythea myrrha*
Common baron	*Euthalia aconthea*
Common bluebottle	*Graphium sarpedon*
Common bushbrown	*Mycalesis perseus*
Common castor	*Ariadne merione*
Common cerulean	*Jamides celeno*
Common crow	*Euploea core*
Crow sp.	*Euploea sp.*
Common emigrant	*Catopsilia pomona*
Common evening brown	*Melanitis leda*
Common fivering	*Ypthima baldus*
Common fourring	*Ypthima huebneri*
Common grass yellow	*Eurema hecabe*
Common gull	*Cepora nerissa*
Common jezebel	*Delias eucharis*
Common lascar	*Pantoporia hordonia*
Common leopard	*Phalanta phalantha*
Common map	*Cyrestis thyodamas*
Common mime	*Papilio clytia*
Common mormon	*Papilio polytes*
Common nawab	*Polyura athamas*
Common palmfly	*Elymnias hypermenstra*
Common pierrot	*Castalius rosimon*
Common rose	*Pachliopta aristolochiae*
Common sailer	*Neptis hylas*
Common sergeant	*Athyma perius*
Common small flat	*Tagiades japetus*
Common treebrown	*Lethe rohria*
Crimson rose	*Pachliopta hector*
Cruiser	*Vindula erota*
Danaid eggfly	*Hypolimnas misippus*

Dark blue tiger	*Tirumala septentrionis*
Dark palm dart	*Telicota ancilla*
Fulvous pied flat	*Pseudocoladenia dan*
Gladeye bushbrown	*Mycalesis patina*
Glassy tiger	*Parantica aglea*
Grass demon	*Udaspes folus*
Great eggfly	*Hypolimnas bolina*
Great orangetip	*Hebomoea glaucippe*
Grey count	*Tanaecia lepidea*
Grey pansy	*Junonia atlites*
Lemon pansy	*Junonia lemonias*
Lime butterfly	*Papilio demoleus*
Malabar banded peacock	*Papilio Buddha*
Mottled emigrant	*Catopsilia pyranthe*
Nilgiri tiger	*Parantica nilgiriensis*
Paris peacock	*Papilio paris*
Pea blue	*Lampides boeticus*
Peacock pansy	*Junonia almana*
Peacock royal	*Tajuria cippus*
Pioneer	*Anaphaeis aurota*
Plain tiger	*Danaus chrysippus*
Plum judy	*Abisara echerius*
Psyche	*Leptosia nina*
Red helen	*Papilio helenus*
Rice swift	*Borbo cinnara*
Rustic	*Cupha erymanthis*
Short-banded sailer	*Neptis columella*
Southern birdwing	*Troides minos*
Spot swordtail	*Graphium nomius*
Striped tiger	*Danaus genutia*
Tailed jay	*Graphium Agamemnon*
Tamil catseye	*Zipoetis saitis*
Tamil yeoman	*Cirrochroa thais*
Tawny coster	*Acraea violae*
Bushbrown	*Mycalesis sp.*
Evening brown	*Melanitis sp.*
Unidentified flat	*Celaenorrhinus sp.*
Unidentified hesperids	Family: Hesperiidae
Unidentified lycaenids	Family: Lycaenidae
Unidentified ring	*Ypthima sp.*
Water snow flat	*Tagiades litigiosa*
White fourring	*Ypthima ceylonica*
White orangetip	*Ixias marianne*
Whitebar bushbrown	*Mycalesis anaxias*
Yellow orangetip	*Ixias pyrene*
Yellow pansy	*Junonia hierta*

Appendix 2

Microclimatic variables for each transect

Transect	**Light Intensity (x100 lux)**	**Temperature (^{0}C)**	**Relative Humidity (%)**
Bettadamallali I	409.12	27.51	44.63
Chinnenahali I	401.30	27.39	54.13
Chinnenahali II	441.51	27.04	56.00
Gangegiri I	294.91	26.21	47.50
Gangegiri II	444.88	26.90	47.00
Ginimao I	312.95	28.04	51.63
Ginimao II	283.43	28.46	46.75
Hosamane I	236.50	27.38	64.75
Hosamane II	263.56	26.08	63.38
Kendalhaklu I	210.86	29.63	56.75
Kendalhaklu II	406.70	30.80	47.63
Kesavinamne I	350.00	29.15	44.50
Kesavinamne II	378.98	28.28	47.50
Kondadkan I	320.38	27.43	52.86
Kondadkan II	325.54	28.20	51.14
Mylemane I	250.70	28.86	49.38
Mylemane II	223.84	28.88	51.25
Shivgange I	175.12	27.60	49.25
Shivgange II	413.26	28.28	46.38
Vasant Cool I	430.34	29.04	40.75
Vasant Cool II	289.67	29.36	38.75
Yellikodige I	176.32	26.77	55.50
Yellikodige II	159.56	26.23	58.67
Forest I	250.60	28.03	60.00
Forest II	237.69	26.70	66.25

Appendix 3

Habitat parameters measured for each transect

Transect	**Canopy cover (%)**	**Canopy height (m)**	**Leaf-litter depth (cm)**	**Coffee density (5m^{-2})**
Bettadamallali I	71.84	19.32	2.52	7
Chinnenahali I	85.68	35.23	3.17	5
Chinnenahali II	75.36	21.50	3.38	6
Gangegiri I	66.10	13.64	3.73	8
Gangegiri II	53.05	13.41	1.71	4
Ginimao I	83.75	23.86	3.35	5
Ginimao II	83.82	15.23	3.67	6
Hosamane I	90.20	24.77	4.06	7
Hosamane II	87.39	22.50	4.1	4
Kendalhaklu I	85.05	22.95	5.29	4
Kendalhaklu II	79.98	28.41	5.09	6
Kesavinamne I	75.84	18.50	3.4	4
Kesavinamne II	73.32	18.50	3.17	4
Kondadkan I	81.08	25.68	4.85	10
Kondadkan II	77.05	18.41	4.48	9
Mylemane I	88.30	23.86	2.98	5
Mylemane II	90.30	21.14	4.15	6
Shivgange I	89.91	19.77	3.5	5
Shivgange II	82.75	17.50	4.13	5
Vasant Cool I	80.43	20.68	2.85	5
Vasant Cool II	90.50	17.50	3.33	3
Yellikodige I	86.32	21.59	5.1	8
Yellikodige II	84.25	18.41	4.54	7
Forest I	81.03	22.27	3.83	0
Forest II	82.63	22.05	3.71	0