ENTOMON 28(2): 105–114 (2000)
Article No. ent.28206

Impact of forest fire on insect species diversity—A study in the Silent Valley National Park, Kerala, India

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ABSTRACT: The impact of forest fire on insect species diversity was studied in representative plots in the Silent Valley National Park in the Kerala part of Western Ghats. The plots were laid out in such a way that forest patches representing both disturbed and undisturbed areas were covered. Shannon-Weiner diversity indices for insects and plants were determined separately for disturbed and undisturbed ares. The fire affected areas showed reduction in species diversity both in flora and fauna. The similarity index calculated for the various sites indicated that there was considerable difference between the sites and that each area was specialised with respect to its faunal elements. The undisturbed areas had good representation of primary plant species such as *Palaquium ellipticum*, *Myristica dactyloides* and *Vateria indica* whereas, in the disturbed area, there was a reduction in the number of primary species and invasion by secondary species like *Macaranga peltata*, *Zizyphus rugosa* and *Celtis* sp. and weeds such as *Lantana camara*, *Chromolaena odorata* and *Clerodendrum viscosum*. With regard to insects, the disturbed areas had more of herbaceous feeding forms belonging to the families, Noctuidae, Pyralidae, Chrysomelidae etc. whereas the undisturbed areas were rich in arboreal feeding insects belonging to the families, Cossidae, Geometridae and Saturnidae. The impact of disturbance on biodiversity was evident from the diversity values as well as the floral and faunal elements of the disturbed and undisturbed areas. Altogether, 578 species of insects belonging to 13 orders were collected, of which 275 species have been identified. Maximum number of species collected belonged to the Orders Lepidoptera and Coleoptera. The most dominant families were Pyralidae, Noctuidae and Geometridae (Lepidoptera) and Chrysomelidae, Cerambycidae and Tenebrionidae (Coleoptera). Based on the 'collector's curve' and 'distribution model', the study revealed that the area contained more species than could be collected in the present investigation indicating the need for further studies.

KEYWORDS: Forest insect diversity, effect of fire, Silent Valley

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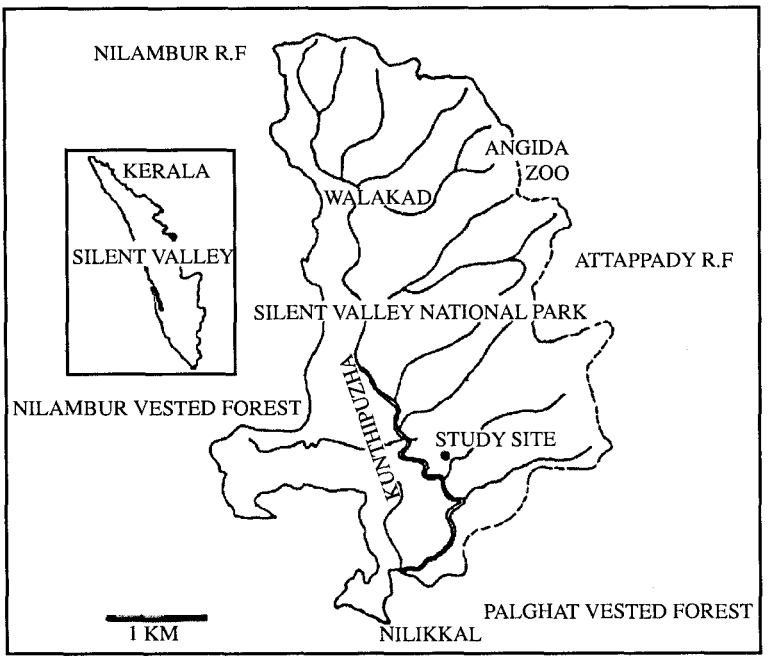

FIGURE 1. Map of Silent Valley National Park showing the study site.

INTRODUCTION

The Silent Valley National Park, one of the core zones of the Nilgiri Biosphere Reserve, is situated in the Palghat District of Kerala, between latitudes 11 °3′ and 11 °15′ N and longitudes 76 °23′ and 76 °30′ E (Fig. 1). The area, which was declared as a National Park in 1984, falls under the Malabar Rainforest Realm (Udvardy, 1975). Covering an area of about 90 km^2, this Reserve is situated more or less on a plateau at about 1000 m elevation. The Nilambur Forest Division and parts of Nilgiris in the north, the Vested Forest of Palghat and Nilambur in the south and the west and the Attappady Reserve Forests in the east, form its boundaries. The river Kunthipuzha that is a tributary of Bharathapuzha, takes its origin among the hillocks in this region. Heavy summer rains characterize this region. The mean annual rainfall is about 4400 mm spread over both southwest and northeast monsoons. The mean annual temperature is 20 °C. April and May are the hottest months of the year when the mean temperature goes up to 23.5 °C. December, January and February are the coolest months when the mean temperature is around 18 °C. From June to December the relative humidity is consistently high and is often around 95%.

Accessibility to this area is restricted due to the steep slopes on all sides and this has contributed to the area remaining more or less undisturbed. The adjacent Attappady Reserve, which lies to the east of Silent Valley, is more accessible and has suffered severe disturbance in its eastern portion. The forests of Silent Valley exhibit considerable variations in floristic composition, physiognomy and life forms

due to climatic, edaphic and altitudinal variations (KFRI, 1990). The types of forests recognized are west-coast tropical evergreen forest, subtropical broad-leaved hill forests, montane wet temperate forests and grasslands—low and high level.

The present study was carried out in a wet evergreen forest patch (Fig. 1). This type of forest is commonly encountered between 600 to 1100 m. The trees are about 45 m high and at least three strata of vegetation can be recognized. The trees of the top canopy have a spreading of umbrella-shaped crown. The middle stratum is candle-shaped and the lower is characteristically conical. *Artocarpus heterophyllus*, *Calophyllum elatum*, *Canarium strictum*, *Cullenia exarillata*, *Dysoxylum malabaricum*, *Elaeocarpus tuberculatus*, *Holigarna spp.*, *Mesua ferrea*, *Palaquium ellipticum*, *Persea macrantha* and *Poeciloneuron ellipticum* are the common tree species found in this forest.

The major disturbance is due to fire, which frequently occurs during the summer season in the grasslands and spreads to the adjacent natural forests. Although the grasslands contain fire hardly species, which may sprout with the rains, fire in the evergreen forests will affect the delicate ecosystem characteristic of such habitats leading to the disappearance of many evergreen species. The gaps formed in the forest due to burning subsequently get colonised by various secondary species that are found in the adjacent moist deciduous forests and grasslands.

MATERIALS AND METHODS

The study was carried out in representative plots selected in the disturbed (fire affected) and undisturbed forest patches. Eight plots were laid out at fixed intervals along a transect in such as way that four plots are in the disturbed zone and the remaining in the undisturbed zone. The plot size was fixed at 625 m^2 and the distance between plots was 25 m. Data on vegetation and insects were collected from all the eight plots in each locality and from this, the indices of diversity, dominance, evenness, species richness etc. of plants and insects were computed separately for the disturbed areas were pooled for deriving the overall values for each locality. Details of methodology followed for studies on vegetation and insect community are described below.

Sampling methods

Vegetation was studied with a view to generate base line data on the floral elements in order to understand the relationship between the vegetation and insect community. Plants above 2 cm diameter were enumerated in all the study plots. The diameter of small plants was measured at about 6 cm from ground. In the case of tall plants, girth at breast-height (gbh) was recorded. Based on girth, the tall plants were classified into different categories *viz.*, mature trees (individuals with gbh more than 30 cm), saplings (individuals with gbh <10.1–30 cm), seedlings, shrubs, herbs and climbers (individuals with girth <10 cm) (Chandrashekara and Ramakrishnan, 1994).

Sampling of insects was done using a battery operated light trap specially fitted with a switching device to facilitate self operation at specified hours (Mathew, 1996).

In order to avoid the influence of lunar phase on insect catches, the trap was operated alternately between plots in the disturbed and undisturbed areas i.e. if the trap was operated initially in plot 1 in the disturbed area, on the next day, it was operated in plot 1 of the undisturbed area and then in plot 2 of the disturbed area and so on. In addition to trap catches, collections were also made during daytime (8 am to 1 pm) using hand nets. At each location, collections were made for a period of one year. The insects collected were sorted out to species and the number of individuals for each species was recorded on data sheets. As it was not possible to identify all the species readily, code numbers were assigned to the various species. The insects were later identified by comparison with national collections at IARI, New Delhi and ZSI, Calcutta.

Analysis of data

Density: Density was estimated for various plant categories such as trees, saplings, seedlings, shrubs, herbs and climbers in each locality for disturbed and undisturbed sites and the pooled values were also calculated separately.

Diversity index: Shannon–Weiner diversity index was calculated as given in Margalef (1968). In order to find out whether any significant difference existed in the insect diversity of the disturbed and undisturbed areas, a 't' test was done (Magurran, 1988).

Distribution models: This is another way of describing diversity in a community (Fisher *et al.*, 1943). A species-abundance model utilises all the information gathered in a community and is the most complete mathematical description of the data (Magurran, 1988). The frequency distribution of insects per collected species was studied and the data were described using truncated log-normal distribution (Pielou, 1975), which will indicate whether the locality contain any rare species or not and also, the number of species which had not been possibly included in the sample collection.

Similarity measures: The similarity between disturbed and undistrubed areas was studied by calculating the modified Sorensen's coefficient of similarity.

Dominance index: The dominance index was calculated for studying the patterns of relative abundance of each insect Order in the study site. The following formula was used:

Dominance index $= n_i \times 100/N$, where n_i = number of insects in the ith order, and N = the total number of insects in all the orders collected during the study period.

Evenness or equitability index: This index, which measures the evenness of species abundance is complimentary to the diversity index concept and it indicates how the individuals of various species are distributed in the community. For estimating evenness, Shannon's evenness index was calculated (Pielou, 1975, 1977).

TABLE 1. Characteristic of the vegetation in the undisturbed and disturbed[1] sites at Silent Valley

Community parameters	Plant categories							
	Category	Mature trees	Tree saplings	Tree seedlings	Shrubs	Herbs	Climbers	Total
No. of species	UD	35	48	46	9	4	9	81
	D	33	48	50	18	11	16	109
No. of individuals	UD	191	488	575	262	44	48	1608
	D	116	493	668	711	208	147	2343
Diversity	UD	2.99	3.22	3.29	1.67	1.15	1.84	3.66
	D	2.93	2.54	3.04	1.93	1.32	2.19	3.55
Richness	UD	2.53	2.17	1.92	0.56	0.60	1.30	2.02
	D	3.06	2.16	1.93	0.68	0.76	1.32	2.25
Evenness	UD	0.84	0.83	0.86	0.76	0.83	0.84	0.83
	D	0.84	0.66	0.78	0.67	0.55	0.79	0.76

UD: Undisturbed; D: Disturbed; Plot size: 25 × 25 m; Replicates: 4 plots per habitat

Species richness: In the ecological literature, the number of species at a site, in a region or in a collection is called species richness, which is the simplest and most useful measure of species diversity. In this study, the total number of insect species collected in each month from each locality was considered as species richness.

Species richness index: The index of species richness was calculated using the formula given by Menhinick (1964).

RESULTS

Vegetation studies

In the undisturbed area, out of 81 plant species recorded, 48 were represented as saplings, 46 as seedlings and 35 as mature trees (Table 1). Herbs, shrubs and climbers were sparse. *Palaquium ellipticum, Aglaia* sp., *Myristica dactyloides, Mesua ferrea, Cullenia exarillata, Dimocarpus longan, Drypetes oblongifolia, Holigarna arnottiana, Casearia bourdilonii, Garcinia morella, Litsea floribunda, Persea macrantha, Syzygium cumini* and *Artocarpus heterophyllus* were the common tree species in this area. Tree seedlings showed higher species diversity followed by tree saplings, mature trees, climbers, shrubs and herbs (Table 1). With regard to density, highest values obtained were for tree seedlings (575) followed by tree saplings (488). The index of species richness was higher for mature trees (2.53) followed by tree saplings (2.17). Evenness index was found to be higher for tree seedlings.

In the disturbed area, out of 109 species recorded, 33 were present as mature trees, 48 as tree saplings and 50 as tree seedlings (Table 1). Shrubs, herbs and climbers were sparse. The tree diversity was lower than in the undisturbed are although species such as *Cullenia exarillata, Dimocarpus longan* and *Casearia bourdilloni*, were present. In addition to these, secondary species like *Olea dioica, Scolopia crenata, Clerodendrum*

TABLE 2. No. of species collected from Silent Valley National Park in different months

Category	No. of species collected												
	1995							1996					
	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Total
Undisturbed area	42	48	112	136	125	94	37	155	88	38	161	218	449
Disturbed area	52	74	91	131	56	73	34	122	68	66	166	207	417

Plot size: 25 × 25 m; Replicates: 4 plots per habitat.

viscosum, *Macaranga peltata* and *Zizyphus rugosa* were also present. Tree seedlings showed higher species diversity compared to all other categories. Species diversity values were low for herbs and shrubs. Highest density obtained was for shrubs followed by seedlings. The index of species richness was found to be higher for mature trees followed by tree saplings. Evenness index was also found to be higher for mature trees.

Insect community

Altogether 578 species belonging to 13 orders and 67 families were collected. Of these, 449 species were from the undisturbed and 417 species from the disturbed areas. In the former, the insects collected belonged to 13 orders and 61 families and in the latter to 12 orders and 60 families. The number of species collected from the disturbed and undisturbed areas in each month are shown in Table 2.

Species richness

In both the areas, maximum collection was during May and least in December. During June–July 1995, there was a slight reduction in the catches from the undisturbed area, compared to the disturbed area. Significant difference was found in the number of species collected in various months from the undisturbed ($\chi^2 = 347.89$) and disturbed areas ($\chi^2 = 307.47$).

Species richness index

The values for the undisturbed and disturbed areas were 5.91 and 6.10, respectively. The index was found to be high for the disturbed area, which indicates that the total number of individuals and species occurring in this area is high. This increase in species richness in the disturbed area could be due to two reasons: (1) the disturbance was mild, confined to relatively smaller patches and of recent origin and (2) the colonisation of the disturbed patches might have provided more habitats leading to diversified insect communities.

Dominance index

The dominance index for insects collected from Silent Valley is given in Table 3.

TABLE 3. Dominance indices for insect groups at Silent Valley.

Order	Percentage of species		Dominance index	
	Undisturbed	Disturbed	Undisturbed	Disturbed
Coleoptera	22.27	24.22	14.75	16.13
Dermaptera	0.45	0.24	0.64	0.54
Dictyoptera	1.11	1.44	1.31	0.73
Diptera	9 13	8.39	30.84	32.87
Ephemeroptera	0.45	0.48	0.09	0.19
Isoptera	0.45	0.96	0.99	3.66
Hemiptera	7.79	9.84	6.08	3.61
Hymenoptera	3.56	3.8	15.01	12.90
Lepidoptera	49.67	46.28	25.25	23.59
Mecoptera	0.22	0.24	0.02	0.02
Neuroptera	0.22	—	—	0.04
Orthoptera	0.89	0.96	0.51	0.34
Trichoptera	3.79	3.12	4.52	5.39

TABLE 4. Monthly collection of insects from the study areas in Silent Valley

Category	1995							1996					Total
	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	
Undisturbed area	73	152	406	923	428	314	73	760	269	109	877	1398	5781
Disturbed area	102	230	326	472	149	167	63	467	175	215	1057	1248	4670

The dominant insect orders with respect to number of species, in both the areas at Silent Valley were Diptera and Lepidoptera followed by Coleoptera and Hymenoptera. The dominance indices were more or less similar for both localities (disturbed and undisturbed) and showed only slight differences. Maximum number of species collected belonged to Lepidoptera in both the undisturbed (49.67%) and the disturbed areas (46.28%) followed by Coleoptera (22.27% in the undisturbed and 24.2% in the disturbed areas) (Table 3).

Species abundance

The number of insects collected during the various months ranged from 73 to 1398 in the disturbed area and from 63 to 1248 in the disturbed area. The number of individuals collected was less during June and December 1995 and high in April–May 1996 in the undisturbed area (Table 4).

The Chi-squre test showed significant difference in the number of insects in various months for the undisturbed ($\chi^2 = 4009.78$) and disturbed ($\chi^2 = 4105.99$) areas.

TABLE 5. Species diversity indices recorded for insects at Silent Valley

	Shannon's index of diversity												
	1995							1996					
Area	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Pooled
Undisturbed area	3.51	3.48	4.08	3.41	4.26	3.98	3.35	4.03	3.89	3.13	4.11	4.15	4.76
Disturbed area	3.50	3.68	3.83	4.22	3.46	3.71	3.34	3.80	3.58	3.52	4.11	3.92	4.65

Species diversity

Even though species abundance model provides full description of diversity, it cannot be used for comparison of diversity. For this, the Shannon's index of diversity was calculated which is a measure of diversity. Monthly variations in Shannon's index of diversity in the undisturbed and disturbed areas are presented in Table 5.

The diversity index remained more or less in the same range throughout the period of study although there was a slight reduction in the undisturbed area during December 1995 and March 1996. In the disturbed area, diversity was low in December 1995. A t-test was done to determine the significant difference between the disturbed and undisturbed areas in terms of species diversity. The t-value was found to be highly significant (2.29), which shows that the species present in the undisturbed area is more diverse than those in the disturbed area.

Distribution model

The observed and expected number of species at Silent Valley was compared using χ^2 goodness of fit test. The test showed no significant difference between the observed and expected distribution ($\chi^2 = 11.47$), which indicates that the distribution pattern of species is following truncated log-normal distribution. While the log-normal distribution is a symmetrical 'normal' bell-shaped curve, in the case of truncated log-normal distribution, the left hand portion of the curve called veil line (representing the rare/unsampled species) will be obscured (Magurran, 1988). The number of species which comes behind this line denotes the rare or unsampled species.

In the present study at Silent Valley, there were 202 species that belonging to this category (Table 6) which indicates the need for further sampling to arrive at a more realistic account of species occurring in this area.

Evenness or equitability indices

The evenness indices obtained for the undisturbed area was 0.78 and for the disturbed area it was 0.77 indicating that the undisturbed are contained more species and that they are uniformly distributed. The evenness index is complementary to the diversity index concept and it indicates how the individuals of various species are distributed in the community.

TABLE 6. Truncated log-normal distribution at Silent Valley

Classes	Upper class boundary	Observed species	Expected species	χ^2
Behind veil line	0.5	—	202.17	—
1	2.5	248	236.58	0.55
2	4.5	88	86.81	0.02
3	8.5	73	81.54	0.89
4	16.5	57	66.72	1.42
5	32.5	49	47.34	0.06
6	64.5	25	29.60	0.71
7	128.5	25	16.18	4.81
8	256.5	5	7.89	1.06
9	512.5	6	3.42	1.95
10		2	1.92	0.003
Total		578	780.17	11.47

Similarity measures

Similarity index was calculated using modified Sorenson's formula and the value obtained was 0.65. It indicates that there is 65% similarity between the undisturbed and disturbed areas.

DISCUSSION

The patterns of species diversity showed interesting trends with the fire affected areas showing differences in the floral and faunal elements besides reduction in diversity. The disturbed area in Silent Valley contained 2343 plants belonging to 109 species compared to 1608 plants belonging to 81 species in the undisturbed area. The undisturbed areas had good representation of primary plant species such as *Palaquium ellipticum*, *Myristica dactyloides* and *Vateria indica* whereas, in the disturbed area, there was a reduction in the number of primary species and invasion by secondary species like *Macaranga peltata*, *Zizyphus rugosa* and *Celtis* sp. and weeds such as *Lantana camara*, *Chromolaena odorata* and *Clerodendrum* sp. With regard to the occurrence of various plant categories, the disturbed area had more of shrubs, herbs, climbers, tree seedlings and saplings indicating good colonisation. The plant diversity index for the undisturbed area was 3.66 and for the disturbed area, it was 3.55.

With regard to the insects, 5781 individuals belonging to 449 species were recorded from the undisturbed area and 4670 insects belonging to 417 species from the disturbed area. The disturbed areas had more of herbaceous feeding forms belonging to the families, Noctuidae, Pyralidae, Chrysomelidae etc. whereas the undisturbed areas were rich in arboreal feeding insects belonging to the families, Cossidae, Geometridae and Saturnidae. The insect diversity index of the undisturbed area was high (4.76) compared to the disturbed area (4.65). The impact of disturbance on biodiversity was

evident from the diversity values was well as the floral and faunal elements of the disturbed and undisturbed areas. Similar trend was observed at other locations such as Sholayar, Nelliyampathy and Parambikulam (Mathew *et al.*, 1998). The similarity index calculated for the various sites indicated that there was considerable difference between the sites and that each area was specialised with respect to its faunal elements. Altogether, 578 species of insects belonging to 13 Orders were collected, of which 275 species have been identified. Isolation of forest habitats at Silent Valley and relatively low exposure to forest disturbance on account of greater protection might have lead to greater stability to the forest ecosystem in the area leading to greater diversity of the disturbed habitats. Based on the 'collector's curve' and 'distribution model' (log-normal distribution), the study has also shown that the area contains more species than could be collected in the present investigation indicating the need for further studies.

ACKNOWLEDGEMENTS

Thanks are due to Shri. Thomas Mathew, former Director, Biodiversity Hotspots Conservation Programme of WWF—India for the award of a research project to GM under which this study was carried out. Thanks are also due to Drs. A. R. K Sastry, N. G. Nair and Sudipto Chatterjee (WWF-India), for their whole hearted co-operation throughout this study. We also wish to place on record our gratitude to Dr. K. S. S. Nair (former Director) and Dr. J. K. Sharma (Director) of KFRI for their interest and encouragement to implement this study.

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(Received on 24 June 2003; accepted on 12 August 2003)