PATTERNS OF DIVERSITY AND DISTRIBUTION OF BUTTERFLIES IN HETEROGENEOUS LANDSCAPES OF THE WESTERN GHATS, INDIA

Geetha Nayak[1], Subramanian, K.A[2], Madhav Gadgil[3]
Achar, K.P[4], Acharya[5], Anand Padhye[6], Deviprasad[7],
Goplakrishna Bhatta[8], Hemant Ghate[9], Murugan[10],
Prakash Pandit[11], Shaju Thomas[12]
and Winfred Thomas[13]

ENVIS TECHNICAL REPORT No.18

Centre for Ecological Sciences
Indian Institute of Science
Bangalore-560 012
Email: ceslib@ces.iisc.ernet.in

December 2004

Acknowledgement

This study was carried out as part of the Western Ghats Biodiversity monitoring programme sponsored by the Department of Biotechnology (DBT), Govt. of India. We acknowledge the DBT for the financial support. We also thank the forest departments of Maharastra, Karnataka, Tamil Nadu and Kerala for their valuable support during field studies. The students and local villagers were the backbone of this whole exercise, who enthusiastically participated and supported this programme.

Geetha Nayak[1], Subramanian, K.A[2], Madhav Gadgil[3]
Achar, K.P[4], Acharya[5], Anand Padhye[6], Deviprasad[7], Goplakrishna Bhatta[8], Hemant Ghate[9], Murugan[10], Prakash Pandit[11], Shaju Thomas[12] and Winfred Thomas[13]

1. Salim Ali School of Ecology, Pondicherry University, Pondicherry
2. National Centre for Biological Sciences, GKVK Campus, Bangalore-65
3. Centre for Ecological Sciences, IISc, Bangalore
4. Mathrukripa, Thellar road, Karkala, Udupi-
5. BSGN, Nasik
6. Dept. of Zoology, Abasaheb Garware College, Pune
7. Nehru Memorial P.U. College, Aranthodu, Sullia
8. Dept. of Zoology, Bhandarkar College, Kuntapur
9. Dept. of Zoology, Modern College Pune
10. Dept. of Botany, University College, Trivandrum
11. Dept. of Zoology, A.V. Baliga College, Kumta
12. Dept. of Zoology, Nirmala College, Muvattupuzha
13. Dept. of Botany, American College, Madurai

Abstract

Eight localities in various parts of the Western Ghats were surveyed for pattern of butterfly diversity, distribution and abundance Each site had heterogeneous habitat matrices, which varied from natural habitats to modified habitats like plantations and agricultural fields. The sampling was done by the belt transects approximately 500m in length with 5 m on either side traversed in one hour in each habitat type. A total of 168 species were recorded in 8 localities The diversity of butterfly species was high in natural habitats than the modified ones Further analysis on commonness and rarity of butterfly species showed the rare butterflies were recorded only in natural habitats. The presence of natural habitats in the heterogeneous matrix influenced the species encountered in modified habitats. The data presented here is entirely collected by undergraduate students and teachers in Western Ghats Biodiversity Monitoring programme

Key words: Butterfly diversity, distribution, heterogeneous landscapes, Western Ghats

Table of Contents

Introduction

Butterflies (Order Lepidoptera) are sensitive biota which gets severely affected by the environmental variations and changes in the forest structure as they are closely dependent on plants (Pollard 1991 and Blair, 1999). They also react quickly to any kind of disturbance and changes in the habitat quality making a good indicator to study changes in the habitat and landscape structure variations (Blair 1999) Here an attempt is made to understand how the distribution and variation in butterfly diversity changes in heterogeneous habitats in various sites in the Western Ghats. The data was collected by undergraduate teachers and students in Biodiversity Monitoring Network. As part of the Western Ghats Biodiversity Monitoring programme a network of experts, undergraduate students, teachers, NGO's and local people is being developed since 1994. Fifteen study sites along the Western Ghats covering major landscape features and vegetation types were mapped and important flora and fauna documented. The available data from 8 localities was analyzed with following objectives to see if

1. there is variation in the butterfly community across various sites.
2. butterfly diversity changes in heterogeneous landscapes
3. seasonal variations in the butterfly diversity.
4. changes in the butterfly diversity in natural, semi-natural and man-made ecosystem.

Materials and Methods

The sampling and monitoring of butterflies was carried out localities along the Western Ghats The present work is based on butterflies communities sampled at 8 different localities in the Maharashtra, Karnataka, Kerala and Tamil Nadu states (Table-1). Monitoring selected biological taxa involving teachers and students was initiated in 1994 by Prof. Madhav Gadgil. Where, he formed a network of over 20 undergraduate colleges collaborating with ecologists at Centre for Ecological Sciences, Indian Institute of Science The data analyzed here was collected entirely by students and teachers of the network.

Study Sites and Sampling design

Following are the study sites located in various parts of Western Ghats along with LSE types sampled in the study sites.

1. ***Muvattpuzha:*** Semi-evergreen, moist deciduous, scrub, teak plantation, coconut, and mixed vegetation.
2. ***Alagarkoil:*** Riparian, mixed cultivation.
3. ***Dhoni:*** Evergreen, semi-evergreen, moist deciduous, dry deciduous, riparian, coconut, rubber, unknown1, disturbed semievergreen, unknown 2.
4. ***Sullia:*** Disturbed evergreen, moist deciduous, riparian, bamboo, areca, paddy, and human habitation.
5. ***Mala:*** Evergreen, semievergreen, scrub, riparian, human habitation, mixed areca coconut, rubber.
6. ***Sringeri:*** Evergreen, Ticket, Grassland, paddy, orchards, and plantations.
7. ***Kumta:*** Semi-evergreen, scrub, acacia, teak, paddy and orchards.
8. ***Nasik:*** moist deciduous, dry deciduous
9. ***Tamini:*** Mixed mosaic.

A standard methodology was given by CES team to all participating group, which involved sampling a LSE type in a line transect approximately 500m length with 5 m on either side covered in an hour walking at a constant pace. All the butterflies on the line as well as 5 m on either side were recorded with time, number of individuals seen. Other parameters such as weather condition, habitat mosaic, LSE type within a site were also recorded. Few of the initial samplings were done along with CES team until participants were familiar with the methodology and identification of some common butterflies. All the identification was done in the field without collecting the specimens. Some of the field guides were referred for identification. Most of the sampling was done from 8-30 to 11-00 hrs when butterflies were most active.

Data Analyses

(a) Comparison of sampling done by Teachers and students with data collected by experts: The data on butterfly diversity in various states published by Harish Gaonkar (1996) was used to compare the butterfly diversity by college teachers and students. The data in various sites belonging to 4 different states i.e. Kerala, Karnataka, Tamil Nadu and Maharastra were pooled together and each species was assigned to the family and comparison was done Percentage of butterflies recorded under each family was calculated in comparison with data collected by experts.

(b) Variations in butterfly community across habitats in Western Ghats: The transects data of each habitat (irrespective of what site it is from) were pooled to and rarefaction models or expected number of species for minimum sample size was done to construct rarefaction curve for all LSE types and find out which habitat supported more number butterfly species A distributional pattern of butterfly species and analysis of rare and common butterfly was done using the abundance and frequency of occurrence data.

The number of habitats a species was found and its abundance was used to analyze the status of each species. The butterfly species recorded on all LSE types were ranked in ascending order based on the number of habitats it was recorded These were transformed into an index of 1-5. Butterflies recorded in 1-6 habitats were ranked 1 (6 habitats constitutes the 25% of the number of habitats identified) Then 7-12 rank 2, 13-18 ranks 3 19-24 rank 4 and more than 24 rank 5 Then based on abundance each species was ranked from least abundant to most abundant species. Species with less then 10 sightings were given a value of 0,10-50 sightings a rank 1,51-100 a rank of 2 101-150 rank of 3 151-200 rank of 4 and 200+ rank of 5 Then each species was assigned to families. (Davidar *et al* 1996)

(c) Butterfly diversity and heterogeneous landscape: The transect data from various LSE types of within the site was used to calculate rarefied species richness using minimum common sample size (i.e. minimum number of individuals in each LSE type). Cluster analysis was done using Jaccard's

dissimilarity index for each site containing various LSE types, and dendrogram was plotted for each site. The data on various sites were analyzed for butterfly diversity, evenness, uniqueness, and rarity, endemic species to identify the LSE type important for butterfly species.

(d) Seasonality variations in butterfly in heterogeneous landscapes

The data from each sites was classified into premonsoon, monsoon and postmonsoon (irrespective of which LSE type it is from) based on the month of sampling. Sampling in February-May was considered as Pre-monsoon, June-September as Monsoon, and October-January as post monsoon. Rarefaction was done using minimum number of individuals recorded in particular season

(e) Endemictiy across LSE types in various sites: Endemic butterflies were noted in each LSE types and percentage of endemic species found in each was calculated in comparison with the total endemic in Western Ghats and Srilanka.

(f) Butterfly diversity in natural, semi-natural and man-made ecosystem: Each LSE types were assigned into natural (like evergreen, semievergreen, deciduous etc) Semi-natural (scrub, thicket, grassland, woodland) and man-made or human impacted ecosystems (plantations, human habitations etc.) diversity and average abundance in each of these categories was tested for difference.

Results and Discussion

This study recorded a total of 8860 individuals of 168 butterfly species belonging to five families recorded during 6392 detection and 226 hours of sampling in 8 sites of the Western Ghats

(a) Comparison of sampling done by Teachers and students with data collected by experts:

This study recorded 51% of butterflies, which were known to occur in Western Ghats. All the papilonids and 73% of nymphalids, 75% of pierids were recorded whereas, Families Lycaenidae and Hesperidae had lower recording with only 31% and 28% respectively (Figs.1, 2, 3, 4 and 5). The reason for recording all species

in the Family Papiliondae can be attributed to their size and conspicuousness. On the other hand, the families Hesperidae and Lycaenidae had poor recording as investigators tend to miss out due to its small size and difficulty in identification without collection. The reason for low recording in Tamil Nadu was due to presence of only one study site and comparatively small data set (Alagarkoil), which represent only 8% of the total number of species.

It is a commendable effort by teachers and students involved in the monitoring project without any prior experience in natural history of butterflies to record 51% of butterflies. It is important to note that these study sites were mostly between altitudes 50-750 m (whereas here the comparison is done with whole Western Ghats butterfly pool which also includes the higher altitudes) and moreover, the sampling done here was without collecting the specimens

(b) Variations in butterfly community across habitats in Western Ghats:

From the results it is evident that natural habitat supported more number of species. On the whole semievergreen forests, scrub and evergreen forests had higher butterfly species diversity than those of the semi-natural, monoculture plantation area (fig-16). The results of this can be compared to the study done by Kunte (1999) showing similar results, with high diversity in natural habitats compared to human impacted areas in the Western Ghats areas.

The ranking results showed that species with broad distributional range (regional) are also most abundant. About 57% butterflies were in rare category, which was recorded in 1 to 6 habitats, which also had low abundance, and only 8% of butterflies were distributed in more than 19-27 habitats. When abundance is considered about 38% species were recorded in less than 10 individuals and 7% of butterfly species were recorded being more than 200 individuals. The families, Papilionidae and Pieridae were found almost in all habitats with even distributions. Members of the families Hesperidae and Lycaenidae had restricted distributions they were recorded in 18 LSE types (total number of LSE types in this study was 27). Of the 7% butterflies present in rank 5 category of the abundance which included species like Common Indian Crow, Common Emigrant, Rustic, Chocolate Pansy etc. Species turn over or beta diversity across LSE types analyzed by

jaccard's index. The dendrogram plotted by clustering the jaccard's similarity shows distinctly grouping of the natural habitat, from human impacted and plantations. Overall there was 42% species were common to all the LSE types

(c) Butterfly Diversity and heterogeneous landscape:

All the study sites had various habitats from natural forests to agricultural lands and the butterfly diversity varied in all these habitats. The pattern of this variation was different in these 8 sites, in some the human impacted LSE types has similar species composition as natural LSE types. The species richness (observed and rarefied), diversity indices, evenness, number endemic and unique species for various LSE types in all study sites are listed in Table 3,4,5,6,7, 8 9 and 10. Species accumulation curve for various sites sampled given in Figure 14 There were no adequate sampling efforts in some sites. Family wise classification of butterfly recorded for various sites given in Figure 15.The Family Nymphalidae was dominant among the butterflies recorded in all the area, followed by Family Papilionidae some and Pieridae in other sites.

1. **Nasik:** Dry deciduous and moist deciduous forests are two sampled LSE types, and a total of 42 species are recorded in this site. Shannon's and Simpson's diversity indices showed higher value in dry deciduous forest. There was 3 endemic and 21 unique species recorded in dry deciduous forest whereas in moist deciduous there was 4 unique species and no endemic species recorded (Table 3)
2. **Kumta:** Semi evergreen forests and scrubs showed higher Shannon and Simpson indices values A total of 45 species was recorded in this site. There was no unique species to any LSE type in this site. The overlap of species between the LSE types was about 10%. Semi evergreen forest and scrub had 6 endemic species, lowest being in Paddy fields (3) and Acacia plantation (4). (table 4 and figure 8).
3. **Alagarkoil:** Riparian and Mixed plantation is the two LSE types sampled in this site. Riparian forests had higher Shannon and Simpson's value. Riparian forests had 8 unique species whereas mixed plantations had 4.A total of 27 species was recorded in this site. The data set in this site was small (table 5).

4. **Sringeri:** A total of 74 species were recorded in 6 LSE type. The species overlap between the LSE types is 45%. Highest number of unique species was recorded in grasslands (7) and evergreen forests (6). The species were evenly distributed in all the habitats. The Shannon and Simpson diversity indices showed somewhat similar values for all the LSE types (table 6 and figure 9)
5. **Mala:** A total of 85 species were recorded in 12 LSE type. The species overlap between the LSE types if 68%. Semi-evergreen, evergreen forests, scrub, had high Shannon and Simpson's diversity values Semi evergreen forests had 8 endemic and 4 unique species whereas plantations had comparatively low diversity indices (table 7 and figure 10).
6. **Sullia:** The species overlap between the LSE types was 83%, even the species richness (observed and rarefied) did not vary much in LSE types (table 8. and figure 11). A total of 86 species was recorded in the site.
7. **Dhoni:** A total of 111 species were recorded in this site. The species overlap between LSE types being 64 %. Like in other sites the natural habitats Evergreen forests supported maximum number of species than other LSE types. The highest diversity was recorded in the natural habitats and lowest in plantations (table 9 and figure 12).
8. **Muvattpuzha:** A total of 79 species recorded in 6 LSE types, about 48% of species shared in these LSE types. Teak plantation had 15 unique species and 7 endemic species (table 10 and figure 13).

(d) Seasonality variation in number butterfly species in various sites: There was a fluctuation in number of butterfly species in various seasons. The changes in number of butterfly species varied for different sites (figure 7). In Nasik, Kumta, Mala, Dhoni, there was more number of species in premonsoon season than monsoon and postmonsoon. The study by Kunte (1997) in Northern Western Ghats showed the butterfly population starts building up in early monsoon and showed two peaks first in late monsoon and second in winter. Here only the number of species is considered in each site which shows, the peak was in premonsoon in most of the study sites. However, it is not possible have a concrete idea of population fluctuations of butterflies from this study as, in some sites data was not available for comparison in various seasons and moreover; rarefaction

test was done taking minimum number of individuals, as the sampling was not uniform in all localities.

Conclusions

It appears from the results of the study that the heterogeneous habitats with various LSE types tend to share more species. In this particular study there were 26 LSE types (from all sites), which shared 42% of butterfly species The species found are not specialized to any particular habitat. The natural habitats supported more number of species than human impacted plantations. When LSE types within a single site was considered similar trend could be observed. However, there was overlap in the species between LSE types, ranging from 48% to 86% and natural habitats showed more number of species. It is important to note that the study was done by undergraduate teachers and students without much expertise in butterfly taxonomy and also without any collection butterfly species for identification. There was poor recording of species belonging to the families Lycaenidae and Hesperidae. However, the results of this study is efficient in showing that the natural habitats in mosaic landscape within a locality had more butterfly species compared to human impacted ones. This finding has an important implication for developing conservation strategies for natural fragments in heterogeneous landscapes

REFERENCES

1 **Gadgil, M., 1996** Documenting diversity: An experiment. *Current Science*, Vol.70, No 1. 36-44

2. **Gaonkar, H. 1996.** Butterflies of the Western Ghats, India including Sri Lanka, A Biodiversity assessment of a threatened mountain system, Centre for ecological Sciences, IISc, Bangalore and the Natural History Museum, London.

3 **Daniels, R.J.R., Joshi, N.V., and Gadgil, M., 1990a.** Birds of man-made ecosystems: The plantations. *Proc Indian Acad Sci(Anim Sci.)* 90:79-89

4. **Daniels, R.J.R., Hegde, M., Joshi, N.V. and Gadgil, M., 1991.** Assigning conservation values: A case study from India. *Conserv Biol.*5:1-12

5. **Daniels, R.J.R., 1994.** A landscape approach to conservation birds. J Biosci 19:503-509

6. **Davidar, P., Yoganand, T.R.K., Ganesh,T., and Joshi,N.1996** An assessment of common and rare forest bird species of the Andaman islands. *Forktail* 12:135-142

7. **Devy, M.S., Ganesh,T., and Davidar, P., 1998.** Patterns of butterfly distribution in the Andaman Islands: implications for conservation. *Acta Oecologia* 19(6)527-534

8. **Kunte, K., Joglekar, A., Ghate, U. and Padmanabhan, P. 1999.** Patterns of butterfly, bird and tree diversity in the Western Ghats. Current Science, Vol 77. No.4, 25.

9. **Kunte, K., 1997.** Seasonal patterns in butterfly abundance and species diversity in four tropical habitats in northern Western Ghats. Journal of Bioscience. Vol22. Pp593-603

10 **Kunte. K., 1999.** Determinants of butterfly species diversity: Plant diversity, foliage height diversity and resource richness across vegetation types. MS thesis submitted to Wildlife Institute of India, Dehra Dun.

11. **Pollard, E. and Yates T. J., 1993.** Monitoring Butterflies for Ecology and Conservation (London: Chapman and Hall).

12. **Raman, T.R.S., and Sukumar, R. 2000** Responses of tropical rainforest birds to abandoned plantations, edges and logged forest in Western Ghats, India Animal Conservation 5, 201-206.

13. **Simonson, S.E., Opler, P.A., Stohlgren,T.J. and Chong, G.W., 2001** Rapid assessment of butterfly diversity in a montane landscape Biodiverstity and Conservation 10:1369-1386

14. **Yoganand, K., and Davidar, P., 2000.** Habitat preference and distributional status of some forest birds in Andaman Islands *Journal, Bombay Natural History Society*, 97(3) 375-380

Table-1. Study sites in the Western Ghats

State/Site	Latitude	Longitude	Altitude (m)	Rainfall (mm)
Kerala				
Muvattpuzha	10° 07' to 10°09'	76°40' to 76°45'	50-200	2500
Dhoni	10°51'38"	76°34'22"	200-450	2090
Karnataka				
Sullia	13°9'	75°4'	90-850	
Mala	13°9'	75°4'	90-1200	5500
Sringeri	13°23'38"	75°8'58"	700-750	5500
Kumta				
Tamil Nadu				
Alagarkoil	10°20'53"	78°12'40"	350-450	810
Maharastra				
Nasik	19°58'47"	73°25'9"	750	3000
Tamini	18°45'96"	73°44'14"	608	3500

Table-2. Distribution of transects across vegetation types in various localities in the Western Ghats.

Sites/habitats	*1*	*2*	*3*	*4*	*5*	*6*	*8*	*10*	*11*	*12*	*13*	*14*	*16*	*17*	*18*	*19*	*20*	*22*	*24*	*26*	*27*	*28*	*29*	*31*	*32*	*33*	
Nasik	0	0	0	3	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11
Kumta	0	0	3	0	0	0	0	2	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	2	0	0	10
Sringeri	11	0	0	0	0	0	0	0	13	7	0	0	0	0	0	0	0	0	13	0	0	0	0	1	3	0	48
Mala	2	0	6	0	0	2	0	6	6	0	0	1	4	0	3	0	3	0	3	1	0	0	0	0	0	3	40
Sullia	0	6	0	2	0	6	1	0	0	0	0	0	0	0	2	0	0	0	1	2	0	0	0	0	0	0	20
Dhoni	11	0	5	12	2	6	0	0	0	0	0	0	0	5	0	1	0	4	0	0	3	2	2	0	0	0	53
Alagarkoil	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3
Muvattpuzha	0	0	5	2	0	0	0	5	0	0	0	0	0	18	0	3	0	0	0	0	0	0	0	0	0	8	41
Total	24	6	19	19	10	15	1	13	19	7	1	1	4	24	5	4	3	4	18	3	3	2	2	3	3	13	226

1-Evergreen, 2- Evergreen disturbed, 3-Semi-evergreen, 4-Moist Deciduous, 5-Dry Deciduous, 6-Riparian, 8- Bamboo, 10-Scrub, 11-Thicket, 12-Grassland, 13-Acacia, 14-Casurina, 17-Teak, 18-Areca, 19-Coconut, 20-Cashew, 22-Rubber, 24-Paddy, 26-Human habitation, 27-Unknwon 1, 28-Disturbed semievergreen, 29-Unknown2, 31-Orchards 32 plantation, 33-mixed.

Natural- 1,3,4,5, and 6
Semi-natural-2,8,10,11, 12 and 28
Plantation, cultivation and human habitation-13,14,17,18,19,20,22,24,26,27,29,31 and 33

Table -3 Nasik

Habitat	Dry deciduous	Moist deciduous
Species richness (observed)	39	22
Rarefied species richness at 119	31	21
Endemic species	3	0
Unique species	21	4
Simpson's index	0 91	0.88
Shannon's index	2 92	2.41
Hill's N1	18.53	11.16
Hill's N2	11.29	8.11
Evenness	0.59	0.70

Table-4 Kumta

Habitat	Semi Evergreen	Scrub	Teak	Orchards	Paddy	Acacia
Species richness (observed)	44	45	24	37	24	35
Rarefied species richness at 63	35	34	23	30	22	30
Endemic species	6	6	5	5	3	4
Unique species	0	0	0	0	0	0
Simpson's index	0.97	0 97	0.96	0.97	0.94	0 97
Shannon's index	3 61	3.55	3.05	3.41	2.84	3 41
Hill N1	37.08	34.92	21.12	30 28	17 17	30.38
Hill's N2	35.53	30.15	23.52	30 52	15.38	35.92
Evenness	0 96	0.86	1.12	1.01	0.89	1.19

Table-5. Alagarkoil

Habitat	Riparian	Mixed
Species richness	16	14
Rarefied species richness	15	13
Endemic species	0	0
Unique species	21	4
Simpson's index	0.91	0 88
Shannon's index	2.92	2 41
Hill's N1	18 53	11.16
Hill's N2	11 29	8.11
Evenness	0.59	0 70

Table-6 Sringeri

Habitat	Evergreen	Thicket	Grassland	Paddy	Orchards	Plantation
Species richness (Observed)	46	54	36	44	9	20
Rarefied species richness at 16	14	13	12	13	9	10
Endemic species	5	7	2	3	1	2
Unique species	6	3	7	5	0	1
Simpson's index	0.93	0.91	0.89	0.93	0.91	0 82
Shannon's index	3.15	2.97	2.73	3.04	2.05	2 19
Hill's N1	23.32	19.56	15.35	20.98	7.74	8 92
Hill's N2	13.39	10 85	9.30	14.37	10.91	5.56
Evenness	0.56	0.53	0 58	0,67	1.47	0 58

Table-7 Mala

Habitat	Evergreen	Semi evergreen	Riparian	Scrub	Thicket	Casurina	Hopea	Areca	Cashew	Paddy	Human habitation	Mixed
Species richness	35	49	31	31	41	14	31	22	31	31	14	31
Rarefied species richness 30	19	19	17	19	19	13	20	15	18	18	13	19
Endemic species	4	8	4	3	5	2	4	2	5	4	2	3
Unique species	1	4	3	1	1	0	0	1	0	0	0	0
Simpson's index	0.94	0.92	0.91	0.94	0.92	0.91	0.95	0.91	0.92	0.91	0.86	0.94
Shannon's index	3.06	3.08	2.81	2.99	3.02	2.37	3.10	2.56	2.90	2.83	2.20	3.01
Hill N1	21.23	21.68	16.55	19.91	20.41	10.72	22.28	12.91	18.09	16.97	9.02	20.32
Hill's N2	16.23	13.05	11.28	15.76	12.60	11.45	20.00	10.62	12.98	11.06	7.26	16.71
Evenness	0.75	0.58	0.66	0.78	0.60	1.07	0.89	0.81	0.70	0.63	0.78	0.81

Table-8 Sullia

Habitat	Evergreen disturbed	Riparian	Moist deciduous	Bamboo	Areca	Paddy	Human habitation	Unknown1
Species richness	20	48	34	29	28	29	24	48
Rarefied at 110	20	31	30	22	26	26	23	35
Endemic species	2	4	2	5	6	2	1	5
Unique species	0	4	2	2	3	1	1	2
Simpson's index	0.93	0.92	0.92	0.69	0.93	0.86	0.91	0.92
Shannon's index	2.74	3.00	2.95	1.93	2.87	2.57	2.71	3.04
Hill's N1	15.52	20.06	19.12	6.86	17.66	13.02	15.02	20.98
Hill's N2	14.36	12.53	12.39	3.24	14.19	7.09	10.62	12.18
Evenness	0.92	0.61	0.63	0.38	0.79	0.51	0.69	0.56

Tabl- 9 Dhoni

Habitat	Evergreen	Semi-evergreen	Moist deciduous	Dry deciduous	Riparian	Teak	Coconut	Rubber	Unknown1	Unknown2
Species richness	81	52	50	24	49	42	15	31	23	13
Rarefied at 56	33	27	28	22	28	29	15	21	19	13
Endemic species	12	7	7	4	8	5	0	5	6	1
Unique species	6	2	0	2	0	1	0	2	0	0
Simpson's index	0.95	0.95	0.94	0.90	0.96	0.95	0.92	0.87	0.92	0.94
Shannon's index	3.43	3.23	3.11	2.75	3.27	3.12	2.69	2.51	2.58	3.08
Hill's N1	30.89	25.30	22.41	15.70	26.39	22.68	14.80	12.26	13.25	21.85
Hill's N2	19.61	18.94	15.79	10.43	22.22	21.54	12.08	7.41	12.18	17.05
Evenness	0.62	0.74	0.69	0.64	0.84	0.95	0.80	0.57	0.91	0.77

Table 10. Muvattpuzha

Habitat	Semi evergreen	Moist deciduous	Scrub	Teak	Coconut	Mixed
Species richness	41	24	23	62	9	46
Rarefied at 41	22	16	19	26	9	24
Endemic species	7	4	4	7	1	5
Unique species	1	1	1	15	0	7
Simpson's index	0.92	0.85	0.91	0.95	0.85	0.94
Shannon's index	3.00	2.37	2.67	3.44	1.95	3.21
Hill's N1	20.13	10.68	14.51	31.31	7.04	24.85
Hill's N2	12.06	6.80	11.34	19.96	6.51	17.09
Evenness	0.58	0.60	0.77	0.63	0.91	0.67

Table-11. Distributional patterns and abundance of Western Ghats Butterfly species in various families

Family			Number of habitats						Abundance			
Rank		1	2	3	4	5	0	1	2	3	4	5
		1-6	7-12	13-18	19-24	>24	<10	10-50	51-100	101-150	151-200	200+
Hesperidae	23	18	5	0	0	0	14	8	1	0	0	0
Lycaenidae	31	21	5	4	1	0	14	10	4	2	0	1
Nymphalidae	71	35	16	11	8	1	22	25	9	4	4	7
Papilionidae	19	9	2	7	1	0	6	4	2	3	2	2
Pieridae	24	12	8	2	2	0	8	8	3	2	0	3
Total	168	95	36	24	12	1	64	55	19	11	6	13

Figure 1. Butterfly species richness recorded by teachers and students in comparison with the Western Ghat pool

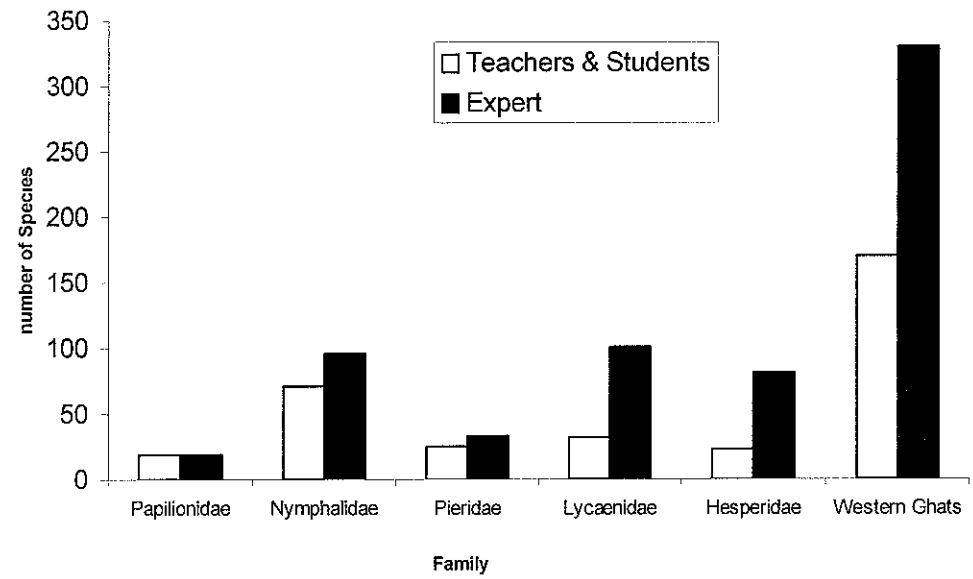


Figure 2. A comparison of Butterflies species recorded by investigators in Kerala with total species pool

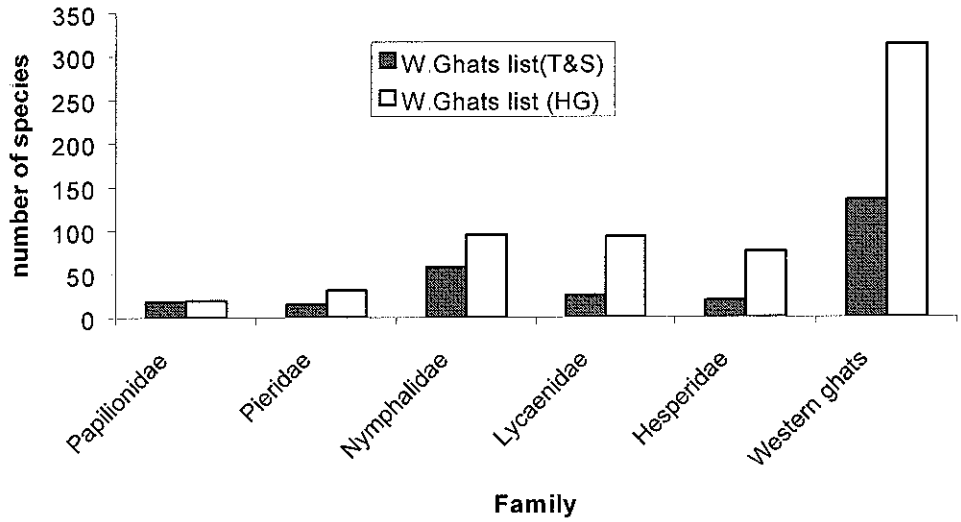


Figure 3. A comparison of Butterfly species richness recorded by investigators in Karnataka with total species pool

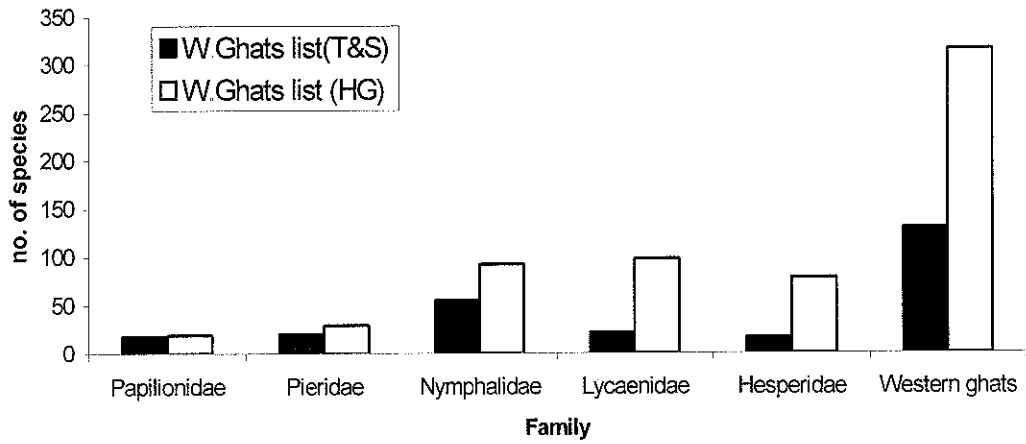


Figure 4. A comparison of Butterfly speices richness recorded by investigators in Tamil Nadu with total species pool

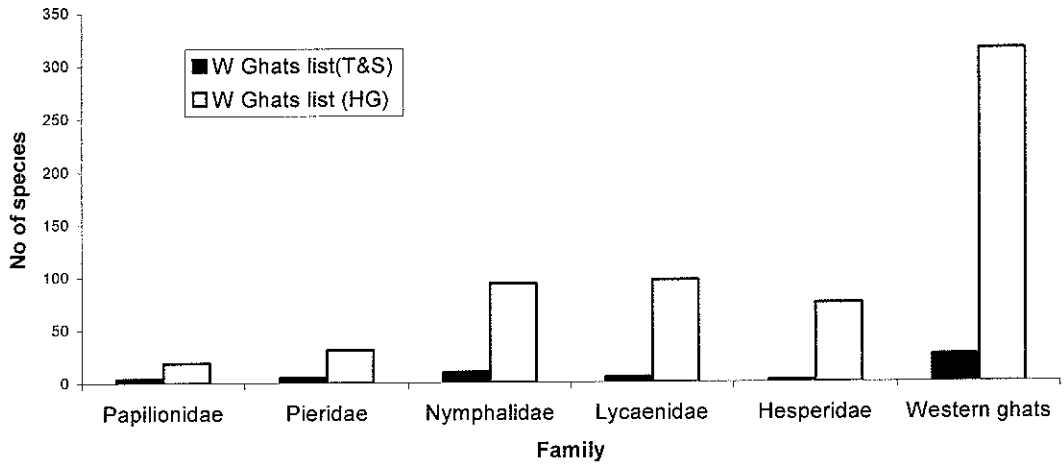
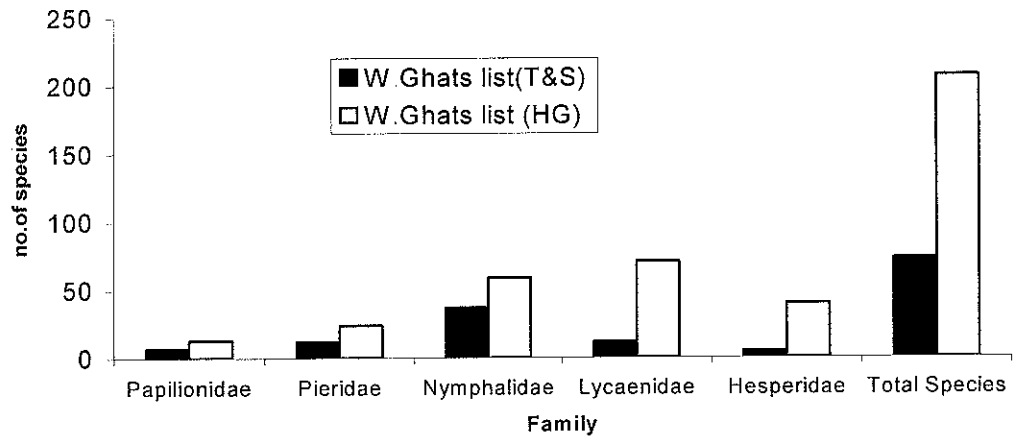


Figure 5. A comparison of Butterfly species richness recorded by investigators in Maharashtra with total species pool



Dendrogram showing similarity in butterfly composition across LSE types

Single Linkage

Jaccard's similarity

Figure 6

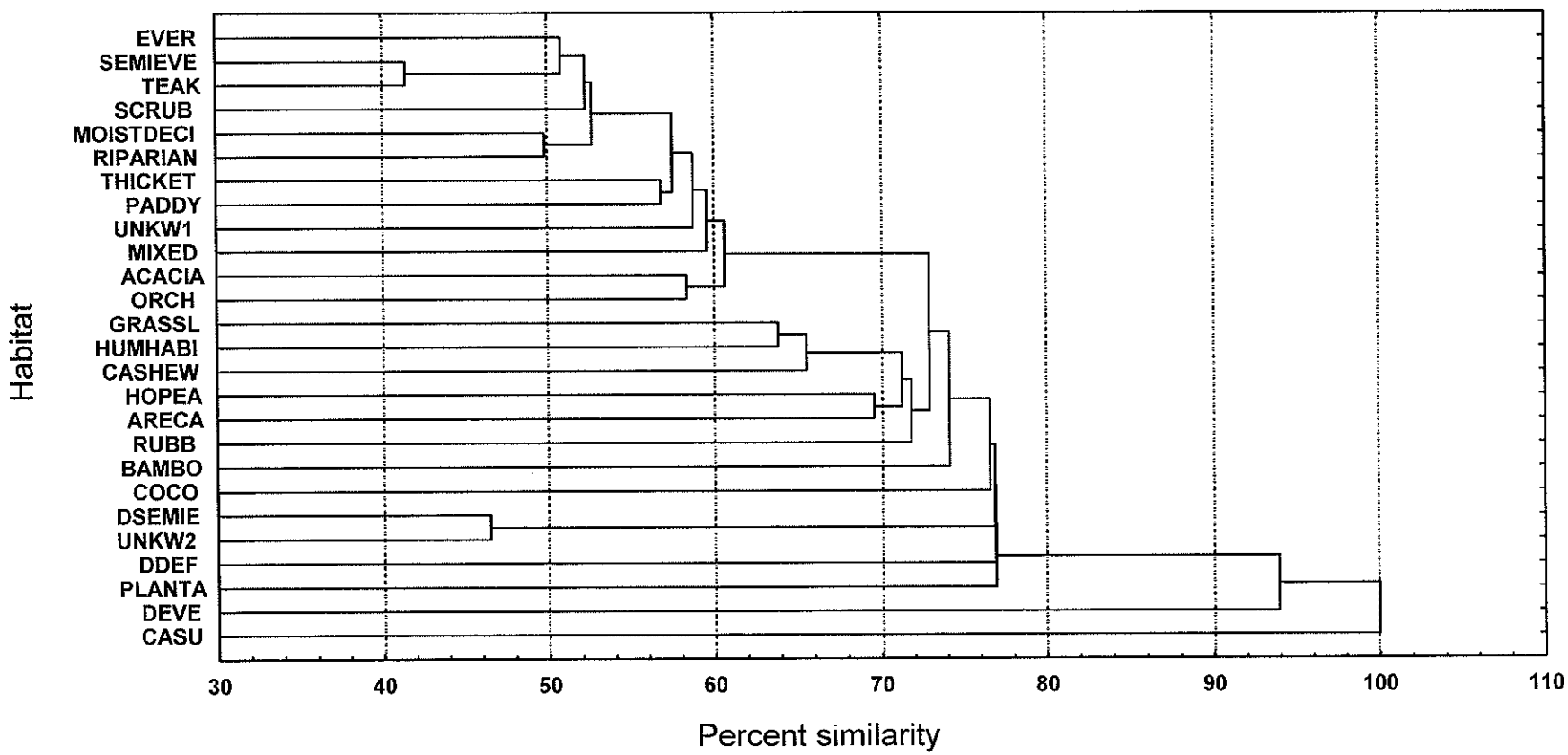
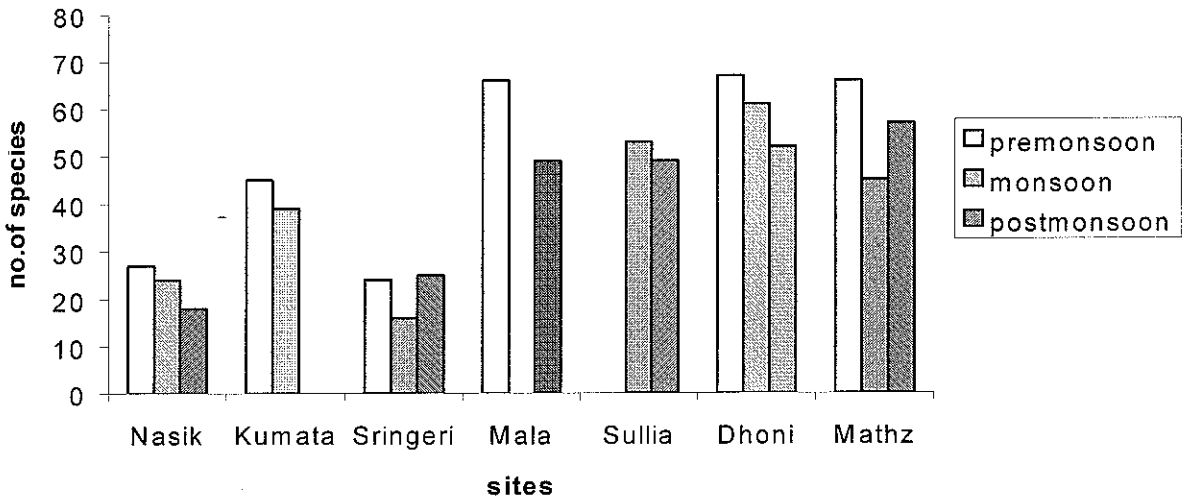
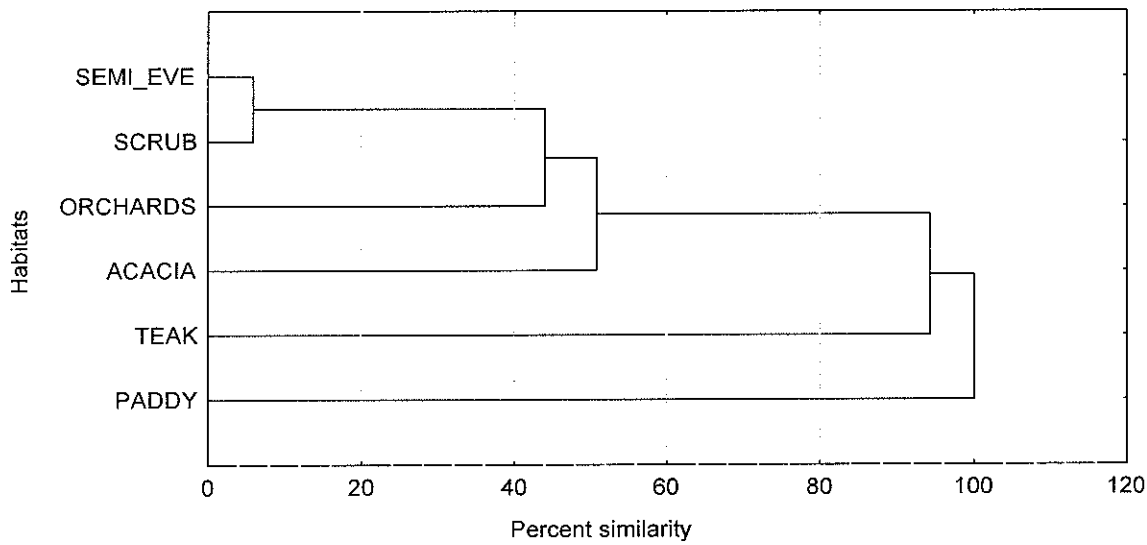


Figure 7. seasonality variations in butterfly species across various sites in Western Ghats



Dendrogram showing similarity in species composition across LSE types in Kumta
Single Linkage
Jaccard's similarity

Figure 8.

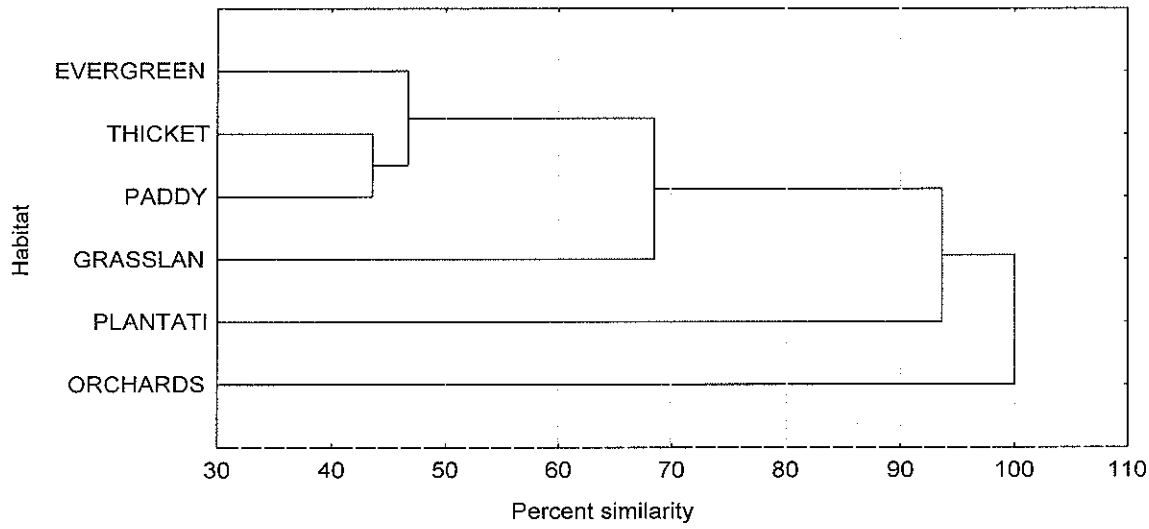


Dendrogram showing similarity in species composition across LSEtypes in Sringeri

Single Linkage

Jaccard's similarity

Figure 9.

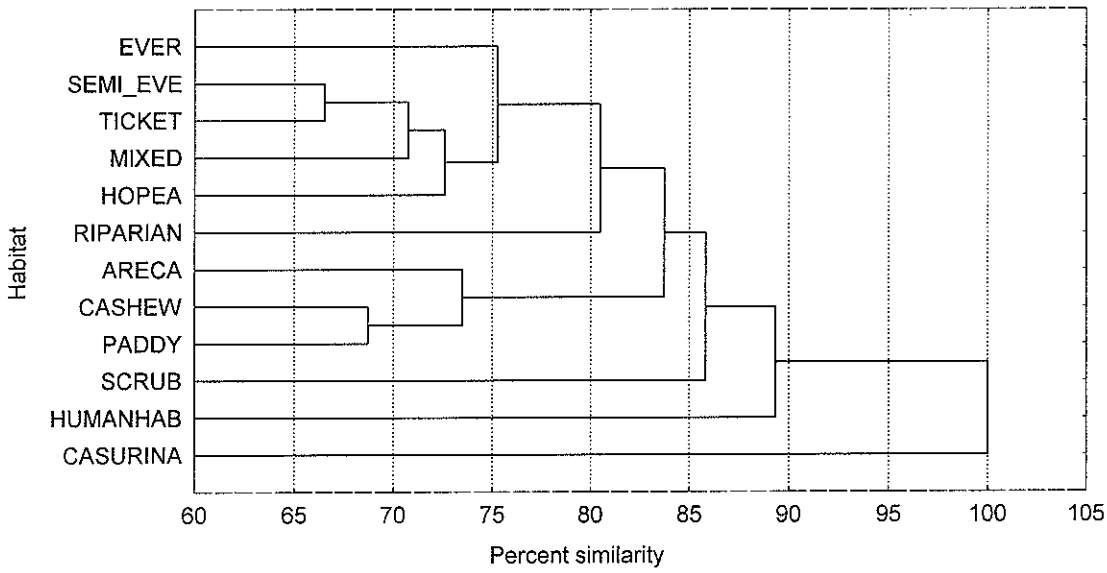


Dendrogram showing similarity in species composition across LSE types in Mala

Single Linkage

Jaccard's similarity

Figure. 10

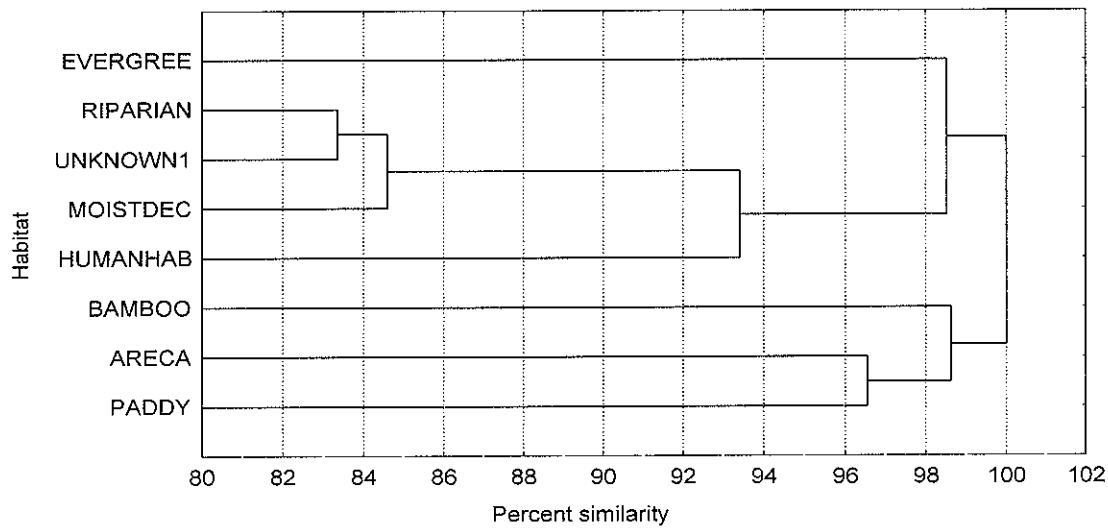


Dendrogram showing similarity in species composition across LSE types in Sullia

Single Linkage

Jaccard's similarity

Figure. 11

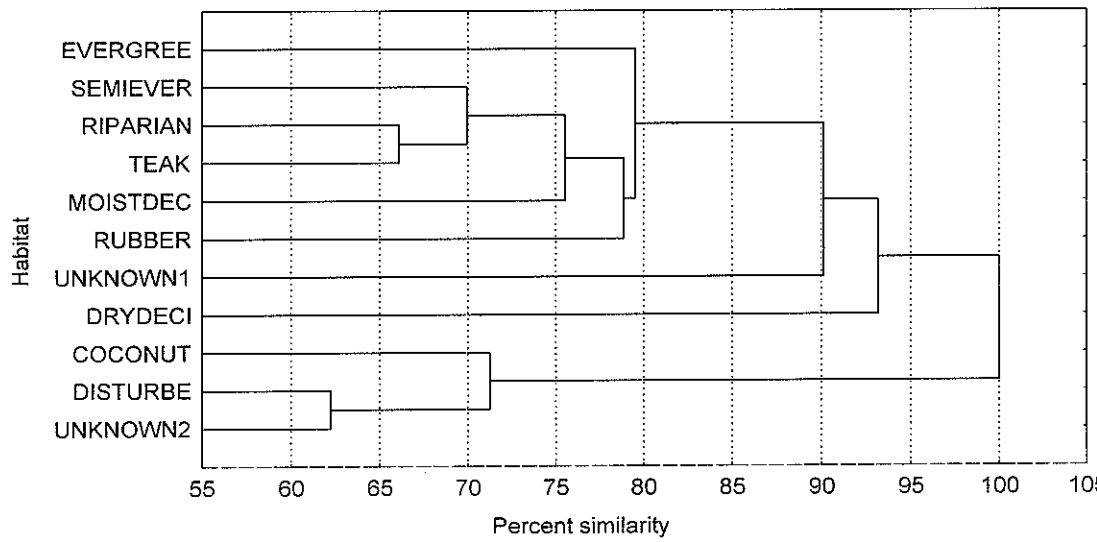


Dendrogram showing similarity in species composition acorss LSE types in Dhoni

Single Linkage

Jaccard's similarity

Figure. 12



Dendrogram showing similarity in species composition acorss LSE types in Muvattpuzha

Single Linkage

Jaccard's similarity

Figure. 13

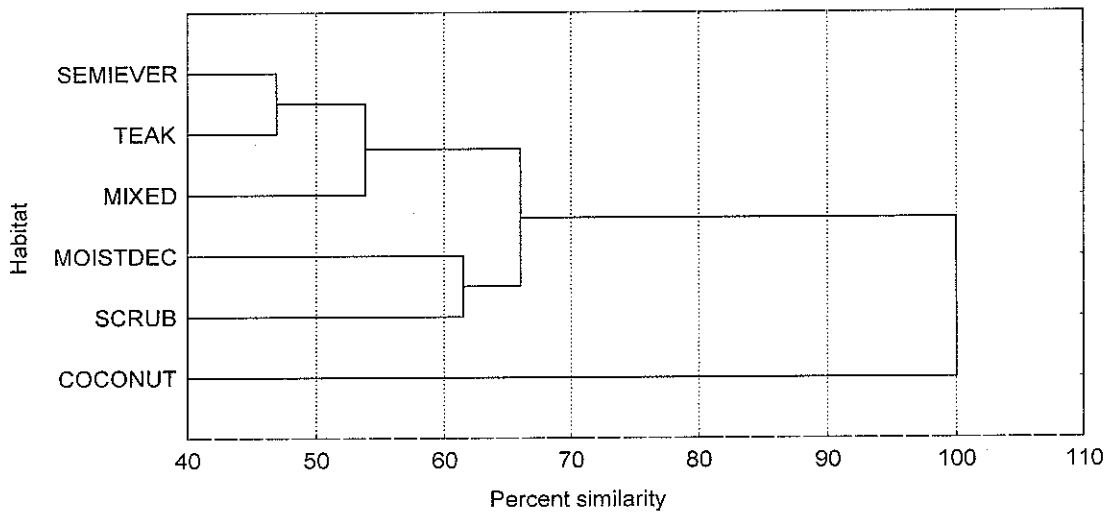


Figure 14. Species accumulation curve for various sites in the Westren Ghats

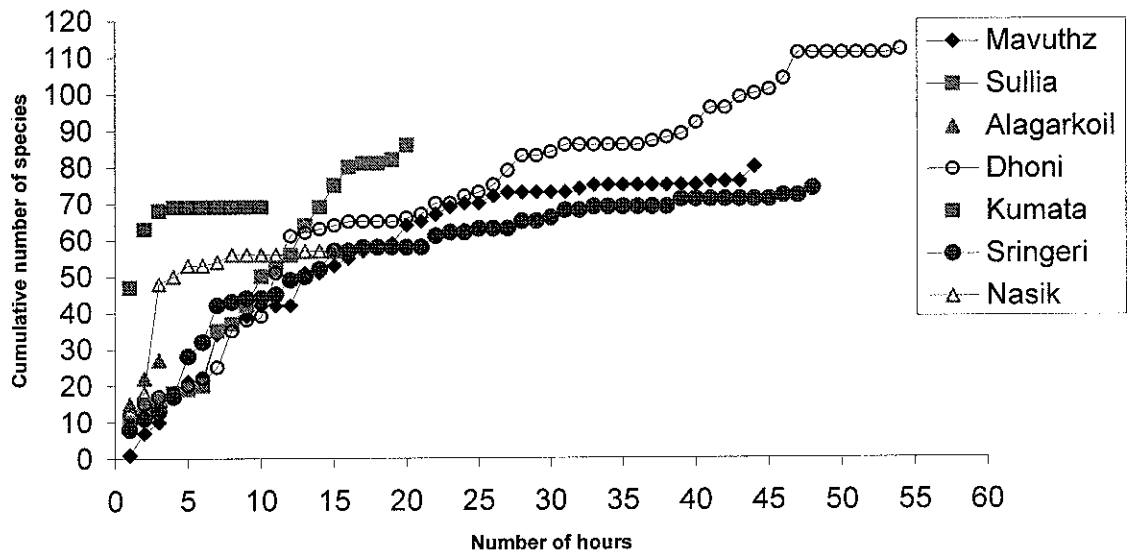


Figure 15. Familywise classification of butterfly species recorded in various sites in Western Ghats

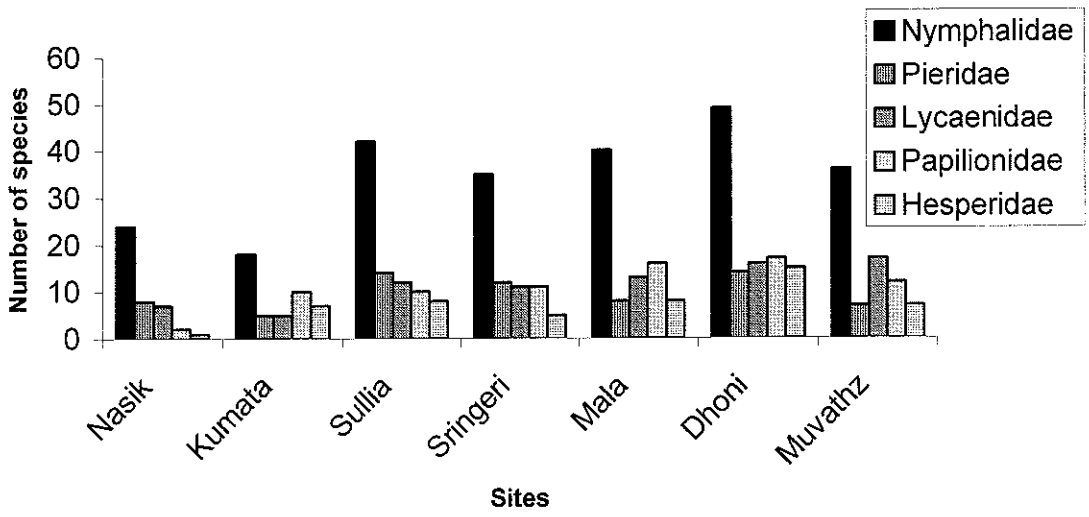
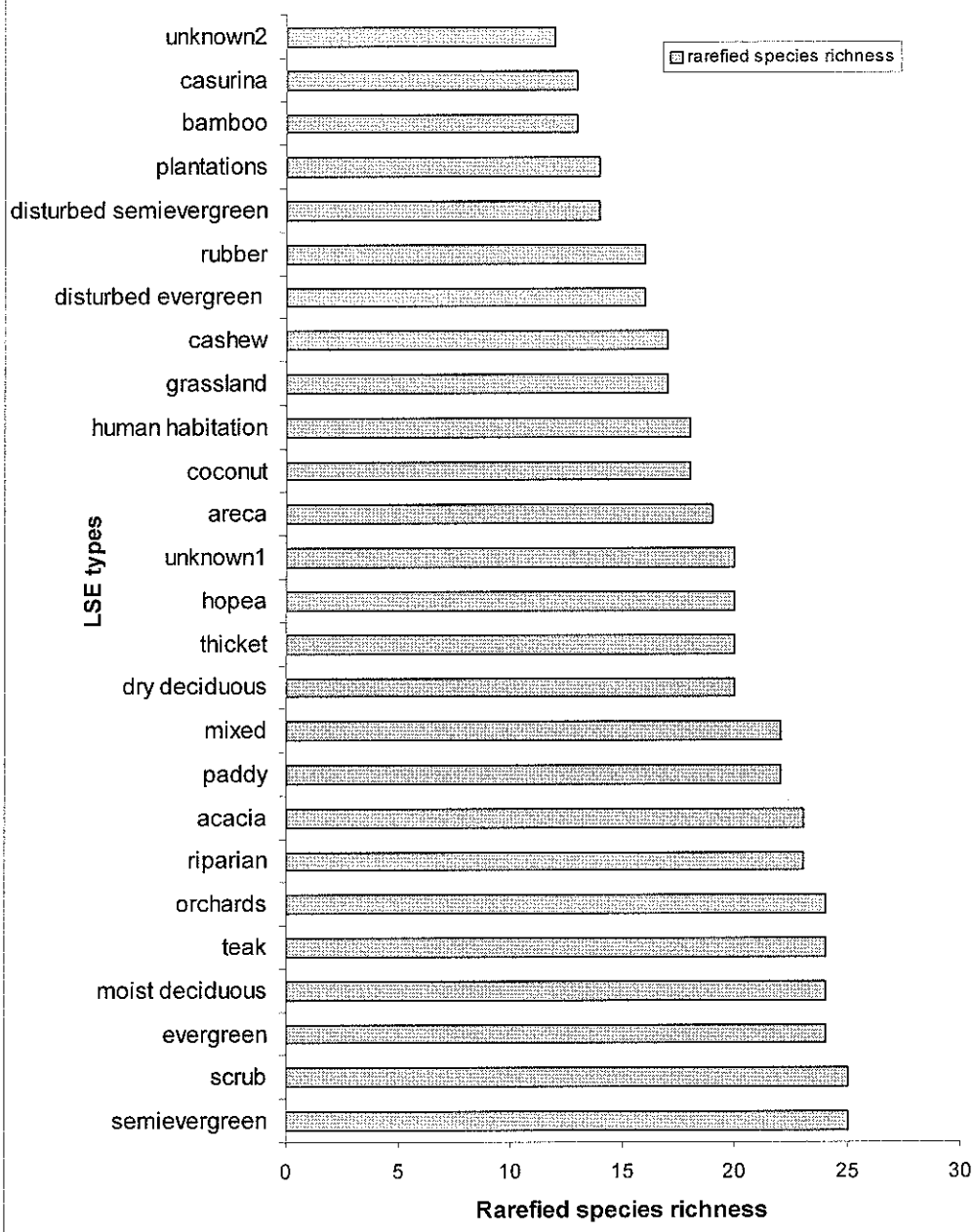


Fig A. Rarefied species richness of various LSE types in Western Ghats



CHECKLIST OF BUTTERFLY SPECIES RECORDED FROM VARIOUS SITES

SINo	FAMILY	NAME OF THE SPECIES/SITE	Scientific Name/SITE	1	2	3	4	5	6	7	8
I	**PAPILIONIDAE**										
1		TAILED JAY	*Graphium agamemnon*	-	+	-	+	+	+	+	+
2		FIVE-BAR SWORDTAIL	*Graphium antiphates*	-	-	-	+	+	+	-	+
3		COMMON JAY	*Graphium doson*	+	-	-	+	-	-	-	+
4		SPOT SWORDTAIL	*Graphium nomius*	-	-	+	-	-	-	+	-
5		COMMON BLUEBOTTLE	*Graphium sarpedon*	-	+	-	+	+	+	+	+
6		COMMON ROSE	*Pachliopta aristolochiae*	+	-	-	-	+	-	+	+
7		CRIMSON ROSE	*Pachliopta hector*	-	+	-	-	+	+	+	+
8		MALABAR OR CEYLON ROSE	*Pachliopta pandiyana*	-	+	-	+	+	-	+	+
9		MALABAR BANDED PEACOCK	*Papilio budha*	-	-	-	+	+	+	+	-
10		COMMON MIME	*Papilio clytia*	+	+	-	-	+	-	+	+
11		COMMON BANDED PEACOCK	*Papilio crino*	-	-	+	-	+	+	+	-
12		LIME	*Papilio demoleus*	-	+	+	+	+	+	+	-
13		MALABAR RAVEN	*Papilio dravidarum*	-	-	-	-	+	-	-	-
14		RED HELEN	*Papilio helenus*	-	+	-	+	+	+	+	+
15		MALABAR BANDED SWALLOWTAIL	*Papilio liomedon*	-	-	-	-	-	-	-	+
16		PARIS PEACOCK	*Papilio paris*	-	-	-	-	-	-	+	+
17		BLUE MORMON	*Papilio polymnestor*	-	+	-	+	+	+	+	+
18		COMMON MORMON	*Papilio polytes*	-	+	+	+	+	+	+	+
19		SOUTHERN BIRDWING	*Troides minos*	-	+	-	+	+	+	+	+
II	**PIERIDAE**										
20		PIONEER OR CAPER WHITE	*Anaphaeis aurota*	+	+	-	-	+	-	+	-
21		COMMON ALBATROSS	*Appias albina*	-	-	-	-	+	+	+	-
22		PLAIN PUFFIN	*Appias indra*	+	-	-	-	-	-	-	-
23		CHOCOLATE ALBATROSS	*Appias lyncida*	-	-	-	-	-	+	+	-
24		COMMON EMIGRANT	*Catopsilia pomona*	+	+	+	+	+	+	+	+

SINo	FAMILY	NAME OF THE SPECIES/SITE	Scientific Name/SITE	1	2	3	4	5	6	7	8
25	**PIERIDAE**	MOTTLED EMIGRANT	*Catopsilia pyranthe*	-	-	-	-	+	+	+	+
26		LESSER GULL	*Cepora nadina*	-	-	-	+	-	+	-	-
27		COMMON GULL	*Cepora nerissa*	+	-	+	+	-	-	-	+
28		NILGIRI CLOUDED YELLOW	*Colias nilgiriensis*	-	-	-	-	-	-	+	-
29		CRIMSON TIP	*Colotis danae*	-	+	-	+	-	+	+	-
30		SMALL ORANGE TIP	*Colotis etrida*	-	-	-	+	-	-	-	-
31		PLAIN ORANGE TIP	*Colotis eucharis*	-	-	-	-	-	-	+	-
32		COMMON JEZEBEL	*Delias eucharis*	-	-	-	+	+	+	+	+
33		ONE-SPOT GRASS YELLOW	*Eurema andersoni*	-	-	-	+	-	-	-	-
34		THREE-SPOT GRASS YELLOW	*Eurema blanda*	-	-	-	+	+	+	+	+
35		SMALL GRASS YELLOW	*Eurema brigitta*	+	-	-	-	-	-	-	-
36		COMMON GRASS YELLOW	*Eurema hecabe*	+	+	-	+	+	+	+	+
37		SPOTLESS GRASS YELLOW	*Eurema laeta*	+	-	-	-	-	-	-	-
38		GREAT ORANGE TIP	*Hebomoia glaucippe*	-	-	-	+	+	+	+	+
39		WHITE ORANGE TIP	*Ixias marianne*	-	+	-	-	-	-	-	-
40		YELLOW ORANGE TIP	*Ixias pyrene*	-	-	-	+	-	+	+	-
41		PSYCHE	*Leptosia nina*	+	-	-	-	+	+	+	+
42		COMMON WANDERER	*Pareronia valeria*	+	-	+	-	+	+	+	-
43		PAINTED SAWTOOTH	*Prioneris sita*	-	-	-	-	-	+	-	-
III	**NYMPHALIDAE**										
44		TAWNY COSTER	*Acraea violae*	-	+	+	+	+	-	+	+
45		INDIAN FRITILLARY	*Argyreus hyperbius*	-	+	-	-	-	-	-	-
46		ANGLED CASTOR	*Ariadne ariadne*	-	-	-	-	-	+	-	+
47		COMMON CASTOR	*Ariadne merione*	+	-	+	+	+	+	+	+
48		COMMON SERGEANT	*Athyma perius*	+	+	-	-	-	+	+	+
49		STAFF SERGEANT	*Athyma selenophora*	-	-	-	-	-	-	+	-
50		JOKER	*Byblia ilithyia*	-	-	+	-	+	+	+	-
51		TAMIL LACEWING	*Cethosia nietneri*	-	-	-	+	-	-	+	+
52		TAWNY RAJAH	*Charaxes bernardus*	-	-	-	-	+	-	+	-
53		BLACK RAJAH	*Charaxes solon*	+	-	-	-	-	-	-	-

SINo	FAMILY	NAME OF THE SPECIES/SITE	Scientific Name/SITE	1	2	3	4	5	6	7	8
54	**NYMPHALIDAE**	TAMIL YEOMAN	*Cirrochroa thais*	-	-	+	-	+	+	+	+
55		RUSTIC	*Cupha erymanthis*	-	+	-	+	+	+	+	+
56		PAINTED LADY	*Cynthia cardui*	+	-	-	-	-	+	+	-
57		COMMON MAP	*Cyrestis thyodamas*	-	+	-	-	-	-	-	-
58		PLAIN TIGER	*Danaus chrysippus*	+	+	-	+	+	+	+	-
59		STRIPED OR COMMON TIGER	*Danaus genutia*	+	-	-	+	+	+	+	+
60		REDSPOT DUKE	*Dolpha evelina*	-	-	-	-	-	-	+	-
61		COMMON PALMFLY	*Elymnias hypermenstra*	+	-	-	+	+	+	-	+
62		COMMON INDIAN CROW	*Euploea core*	+	+	-	+	+	+	+	+
63		DOUBLE-BRANDED CROW	*Euploea sylvester*	-	+	-	+	+	-	-	-
64		COMMON BARON	*Euthalia aconthea*	+	-	-	+	+	+	+	-
65		GAUDY BARON	*Euthalia lubentina*	-	+	-	-	-	-	-	-
66		BARONET OR RED BARON	*Euthalia nais*	+	+	-	-	-	+	-	-
67		GREAT EGGFLY	*Hypolimnas bolina*	-	-	-	+	+	+	+	+
68		DANAID EGGFLY	*Hypolimnas misippus*	-	+	-	-	+	+	+	+
69		MALABAR TREE NYMPH	*Idea malabarica*	-	+	-	+	+	+	+	-
70		PEACOCK PANSY	*Junonia almana*	-	+	-	+	+	-	-	-
71		GREY PANSY	*Junonia atlites*	-	+	-	+	+	+	+	+
72		YELLOW PANSY	*Junonia hierta*	+	-	+	+	-	+	+	+
73		CHOCOLATE PANSY	*Junonia iphita*	+	-	-	+	+	+	+	+
74		LEMON PANSY	*Junonia lemonias*	+	-	-	+	+	+	+	+
75		BLUE PANSY	*Junonia orithya*	+	+	-	+	+	-	+	-
76		INDIAN BLUE OAKLEAF	*Kallima horsfieldi*	+	+	-	-	-	+	+	-
77		BLUE ADMIRAL	*Kaniska canace*	-	+	-	-	-	-	+	-
78		COMMON TREEBROWN	*Lethe rohria*	+	-	-	-	-	-	+	-
79		COMMANDER	*Limenitis procris*	-	-	-	+	+	+	+	+
80		COMMON EVENING BROWN	*Melanitis leda*	+	-	+	+	+	+	+	+
81		DARK EVENING BROWN	*Melanitis pedima*	-	+	-	-	-	-	-	-
82		WHITEBAR BUSHBROWN	*Mycalesis anaxias*	-	-	-	-	-	-	+	-
83		DARK BRANDED BUSHBROWN	*Mycalesis mineus*	-	+	-	+	+	+	+	+
84		RED-DISK BUSHBROWN	*Mycalesis occulus*	-	-	-	-	-	-	+	-

SINo	FAMILY	NAME OF THE SPECIES/SITE	Scientific Name/SITE	1	2	3	4	5	6	7	8
85	**NYMPHALIDAE**	GLADEYE BUSHBROWN	*Mycalesis patnia*	+	+	-	-	-	-	-	-
86		COMMON BUSHBROWN	*Mycalesis perseus*	-	-	-	+	+	+	+	+
87		TAMIL BUSHBROWN	*Mycalesis subdita*	-	-	-	-	-	+	+	-
88		COMMON SAILOR	*Neptis hylas*	+	-	+	+	+	+	+	+
89		YELLOW JACK SAILOR	*Neptis viraja*	-	-	-	-	-	-	-	+
90		NIGGER	*Orsotrianea medus*	-	+	-	+	+	+	+	+
91		COMMON LASCAR	*Pantoporia hordonia*	+	-	-	-	-	+	-	+
92		GLASSY TIGER	*Parantica aglea*	+	+	-	+	+	+	+	+
93		CLIPPER	*Parthenos sylvia*	-	+	-	+	+	+	+	+
94		SMALL LEOPARD	*Phalanta alcippe*	-	-	-	-	+	+	+	-
95		COMMON LEOPARD	*Phalanta phalantha*	+	+	-	+	+	+	-	+
96		COMMON NAWAB	*Polyura athamas*	-	-	-	+	+	-	+	+
97		GREY COUNT	*Tanaecia lepidea*	+	+	-	+	+	+	+	+
98		BLUE TIGER	*Tirumala limniace*	+	+	+	+	+	+	+	+
99		DARK BLUE TIGER	*Tirumala septentrionis*	+	+	+	+	+	+	+	+
100		INDIAN RED ADMIRAL	*Vanessa indica*	-	+	-	-	-	-	+	-
101		CRUISER	*Vindula erota*	+	-	-	+	+	+	+	-
102		COMMON THREERING	*Ypthima asterope*	-	+	-	+	-	-	-	+
103		COMMON FIVERING	*Ypthima baldus*	-	-	-	-	+	-	+	+
104		WHITE OR CEYLON FOURRING	*Ypthima ceylonica*	-	-	-	+	-	+	-	-
105		COMMON FOURRING	*Ypthima huebneri*	+	-	-	+	+	+	+	+
106		BABY FIVERING	*Ypthima philomela*	-	-	-	-	+	-	-	-
107		TAMIL CATSEYE	*Zipoetis saitis*	-	+	-	-	-	-	-	-
IV	**LYCAENIDAE**										
108		PLUM JUDY	*Abiasara echerius*	+	-	-	+	+	-	+	+
109		HAMPSON'S HEDGE BLUE	*Actolepis lilacea*	-	-	-	-	-	+	-	-
110		COMMON HEDGE BLUE	*Actolepis puspa*	-	-	-	+	+	+	+	-
111		WESTERN CENTAUR OAKBLUE	*Arhopala pseudocentaurus*	-	-	-	-	-	-	+	-
112		COMMON PIERROT	*Castalius rosimon*	+	-	-	+	+	+	+	+
113		COMMON IMPERIAL	*Cheritra freja*	-	-	-	-	-	+	-	-

SINo	FAMILY	NAME OF THE SPECIES/SITE	Scientific Name/SITE	1	2	3	4	5	6	7	8
114	**LYCAENIDAE**	LIME BLUE	*Chilades laius*	-	-	+	-	-	-	-	-
115		INDIAN SUNBEAM	*Curetis thetis*	+	-	-	-	-	+	-	-
116		GRAM BLUE	*Euchrysops cnejus*	-	-	+	-	-	-	-	+
117		INDIAN CUPID	*Everes lacturnus*	-	+	+	+	-	+	+	-
118		GRASS JEWEL	*Freyeria trochylus*	+	-	-	+	-	-	-	-
119		METALLIC CERULEAN	*Jamides alecto*	-	-	-	-	-	-	+	-
120		DARK CERULEAN	*Jamides bochus*	+	-	-	-	+	+	-	+
121		ZEBRA BLUE	*Leptotes plinius*	-	-	-	-	+	-	+	-
122		YAMFLY	*Loxura atymnus*	-	-	-	+	+	-	-	+
123		MALAYAN	*Magisba malaya*	-	-	+	-	-	-	+	+
124		QUAKER	*Neopithecops zalmora*	-	-	-	-	-	-	-	+
125		COMMON LINE BLUE	*Prosotas nora*	-	-	-	+	+	-	+	-
126		PALE GRASS BLUE	*Psuedozizeeria maha*	-	-	-	+	+	+	-	+
127		MONKEY PUZZLE	*Rathinda amor*	-	+	-	-	-	-	+	-
128		COMMON SILVERLINE	*Spindasis vulcanus*	-	+	-	+	-	-	+	+
129		RED PIERROT	*Talicada nyseus*	-	+	-	+	+	+	+	-
130		DARK PIERROT	*Tarucus ananda*	-	-	-	+	-	+	-	-
131		MANY-TAILED OAK BLUE	*Thaduka multicaudata*	-	-	-	-	-	-	-	+
132		FLUFFY TIT	*Zeltus amasa*	-	+	-	-	-	-	-	-
133		TINY GRASS BLUE	*Zizula hylax*	-	-	-	-	-	-	+	-
V	**HESPERIIDAE**										
134		BUSH HOPPER	*Ampittia dioscorides*	-	+	-	-	-	+	+	-
135		BROWN AWL	*Badamia exclamationis*	-	-	-	-	-	-	+	-
136		BEVAN'S SWIFT	*Borbo bevani*	-	+	-	+	+	-	+	+
137		RICE SWIFT	*Borbo cinnara*	-	-	-	-	-	-	+	-
138		MALABAR SPOTTED FLAT	*Celaenorrhinus ambareesa*	-	-	-	-	-	-	+	-
139		COMMON SPOTTED FLAT	*Celaenorrhinus leucocera*	-	-	-	+	-	-	-	-
140		GIANT REDEYE	*Gangara thyrsis*	+	+	-	-	-	-	+	-
141		COMMON BANDED AWL	*Hasora chromus*	-	-	-	-	-	+	+	-
142		TREE FLITTER	*Hyarotis adrastus*	-	-	-	-	-	-	+	-

SINo	FAMILY	NAME OF THE SPECIES/SITE	Scientific Name/SITE	1	2	3	4	5	6	7	8
143	**HESPERIIDAE**	CHESTNUT BOB	*Iambrix salsala*	-	-	-	-	+	+	+	+
144		COMMON REDEYE	*Matapa aria*	-	-	-	-	+	-	-	-
145		RESTRICTED DEMON	*Notocrypta curvifascia*	-	-	-	-	-	-	+	-
146		CHESTNUT/BANDED ANGLE	*Odontoptilum angulata*	-	+	-	+	+	-	+	-
147		GOLDEN ANGLE	*Odontoptilum ransonnetti*	-	-	-	-	-	-	-	+
148		CONJOINED SWIFT OR GREAT SWIFT	*Pelopidas conjucta*	-	-	-	-	-	+	-	-
149		SMALL BRANDED SWIFT	*Pelopidas mathias*	-	-	-	-	+	+	-	-
150		COON	*Psolos fuligo*	+	-	+	-	+	+	+	-
151		FULVOUS PIED FLAT	*Psuedocoladenia dan*	-	+	-	-	-	-	-	-
152		COMMON SMALL FLAT	*Sarangesa dasahara*	-	-	-	+	-	-	-	-
153		INDIAN SKIPPER	*Spialia galba*	-	+	-	-	+	+	+	+
154		INDIAN PALM BOB	*Suastus gremius*	-	+	+	+	-	-	+	-
155		SUFFUSED SNOW FLAT	*Tagiades gana*	-	-	-	-	-	+	-	-
156		WATER SNOW FLAT	*Tagiades litigiosa*	-	-	-	-	-	-	-	+
157		DARK PALM DART	*Telicota ancilla*	-	+	-	-	+	+	-	+
158		GRASS DEMON	*Udaspes folus*	+	-	-	-	+	-	-	-

Site Code

1- NASIK
2- KUMTA
3- ALAGARKOIL
4- SRINGERI
5- MALA
6- SULLIA
7- DHONI
8- MUVATTPUZHA

Note: 10 species used for the data analysis were identified only up genus (crow, flat, swift etc.). These species are not listed above.