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Diversity of butterflies in different habitats from Tamilnadu part of Western Ghats (Lepidoptera: Rhopalocera)

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ABSTRACT

The present study was conducted in southern Western Ghats of Tamilnadu, India. It is one of the global biodiversity hotspots that includes Nilgiri biosphere and Kodaikanal Wildlife Sanctuary (proposed). We studied the Diversity, Dominance and Evenness of butterflies in three different habitats (forest area, river bank, and crop area) during the period January 2011 to December 2011. A total of 92 species, from 65 genera and 5 families were recorded. Species diversity and abundance were maximum in the months of March-May and dropped to the minimum in the months of December-January. Forest area habitat had greater species diversity, while river bank habitat had greater number of individuals; crop area had the least diversity and abundance among the studied habitats. We have also recorded the endemism and flight period of some butterflies and their distribution within the habitats with their nectar source plants. Analyses were done to emphasize the importance of butterflies and the need for their conservation.

Introduction

Butterflies (Lepidoptera: Rhopalocera) are one of the most plant dependent group of insects when compared to the other megadiverse insect groups. (Kristensen *et al.,* 1999) Butterflies are beneficial as they serve as pollinators and indicators of environmental quality and are appreciated for their aesthetic value (Chakravarthy *et al.,* 1997). The holometabolous life history of butterflies reveals that Lepidoptera are exposed to a wide range of environmental influences and are highly sensitive to the climatic changes in temperature, humidity and light levels (Erhardt 1985; Warren *et al.,* 2001). Nearly 1500 butterflies (Smetacek 1992; Gay 1992) are identified from the Indian sub-continent, constituting 8.33% of the 18,000 known species of the world; most of the Indian butterflies are reported from the Himalayas and from the Western Ghats (Larsen 1987a; 1988). The population status of butterflies in any area would help us to understand the status of ecosystem as they are good indicator species (Karemen 1992). Nearly 300 species of butterflies were recorded in a detailed survey of Nilgiri Biosphere (Larsen 1987a; 1988). At present Nilgiri Biosphere is one among the 18 hot-spots of the World.

Butterflies are good indicators in terms of anthropogenic disturbance and habitat quality (Kocher *et al.,* 2000). Particularly in forest ecosystem when habitats are fragmented, butterflies that shift from one habitat to other have increased chance of exposure to predators and are vulnerable to disturbances associated with human activity. The effect of habitat lose can be seen clearly with the declining population of butterflies. Moreover, the butterflies that are displaced after habitat loss disappear subsequently.

Climatic changes impact the diversity of species and are expected to exacerbate the ecosystems (Scott *et al.,* 2005). The changes in parameters of temperature, rainfall patterns, and extreme weather conditions such as heat waves, prolonged drought or excessive rainfall, have to be taken into consideration. Depletion of nectar and desiccation of host plants cause direct mortality and induce migratory behaviour. Butterflies, being exothermal, are highly sensitive to climatic variation and a short generation time makes them an appropriate model organism to study.

Agricultural intensification is widely accepted as a cause of biodiversity decline. It is however a broad concept encompassing many factors, such as the loss of semi-natural habitat, fragmentation of ecosystem, use of heavy machinery and increased input of insecticides, pesticides and herbicides (Tilman *et al.,* 2001). Of these, chemical pesticides potentially affect development of butterfly larva and nectar producing plants which adversely affect adult butterfly diversity. Adult temperate butterflies feed primarily on nectar (Scoble 1992), supplemented to varying extents by mud, dung or carrion (Boggs *et al.,* 2004). Developments of agriculture field in forest ecosystem endanger many species throughout the world; at present extinction rates are estimated to be 100 to 1,000 times the natural rate, depending on the taxonomic group (Scriber *et al.,* 1995; Virtuosic *et al.,* 1997).

The diversity of butterfly communities has been studied in different habitat types in different parts of the world including Indian Great Himalayas Region. However, there are not many studies done on the diversity of butterfly communities in tropical forests within different habitat types from southern India especially Western Ghats. Lien van Vu (2009) reported forest edges have greater diversity of butterflies which has more exposure to the open. The gaps in the forest like the stream or river path have higher diversity of butterflies than the closed forest areas (Spitzer *et al.,* 1997; Lien van Vu *et al.,* 2011).

The present study was aimed to examine the diversity, dominance and evenness of butterflies across three different habitats, namely forest area, river bank, and crop area, located in different altitudes from the southern part of Western Ghats and to correlate with the anthropological activity, availability of host

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plants and their nectar source.

Methodology:

Transects and butterfly data

The field method is based on standardized "Pollard walk" method (Pollard 1977; Pollard *et al.*, 1993). We applied line transects of about 1000 meter in length which was divided into five segments of 200 meters. Each transect was observed 3 times and the number of individuals per species as recorded from all the five segments. The butterflies were observed within 2.5 meters to the left and right side and five meters in front of the observer. Unfamiliar species were collected for the identification and the voucher specimens were deposited at Entomology Research Institute, Loyola College, and Chennai-34. Details such as habitat of occurrence, endemism and mud puddling behavior were recorded. Also we examined the vegetation in the area of transect line.

Study period

The butterflies were collected using sweep net and the collection was done every month from January 2011 to December 2011 from 8.00 AM to 4 PM under appropriate weather conditions (temperature 18 ℃, (always >13˚C) cloudless or just a few clouds and wind speed\5 Beaufort (only leaves and thin branches moved by the wind).

Study area:

Our study has been conducted in two different regions of the Western Ghats, the Nilgiris Biosphere, and Kodaikanal Hills. Both are important biodiversity hot spots of our planet. The Nilgiris Biosphere Reserve (NBR) covers an area of 5520 sq. Km covering the states of Karnataka, Kerala and Tamilnadu; it lies between (11˚08″ to 11˚37″ N and 76˚ 27″ to 77˚40″ E). Kodaikanal Wildlife Sanctuary (proposed) lies in the geographical coordinates (10˚ 14.6″ N 77˚29.6″ E) covering a total area of 21.45 sq. Km. (Fig 1) Different climatic gradients with various habitat like evergreen forest, tropical moist deciduous forest, moist deciduous forest, rivers, reservoirs, grass lands have produced favourable conditions for greater diversity of insects in Western Ghats.

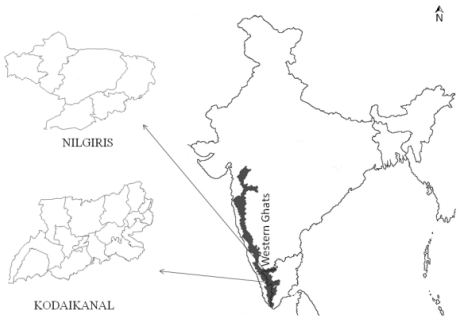

Fig. 1. The Map of Western Ghats in India shows biodiversity hotspots including Nilgiri biosphere and Kodaikanal hills

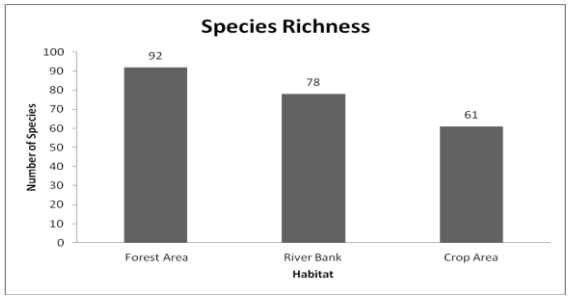

Fig. 2. Shows species richness found in the forest area when compare to riverbank and corp area

Western Ghats receives an average annual rainfall of 7600 mm; it receives much of its rain from the southwest monsoon during months of June-September; this region usually remains fairly dry for the rest of the year. Annual mean maximum and minimum temperatures range from 20.7˚C to 9.6˚C respectively. Annual relative humidity is 76.9% to 75.8%. A total of 21 transects (one transect per study site) were taken for the present study representing three different habitats types consisting the forest area, crop area (located within fragmented regions of the forest), and river bank.

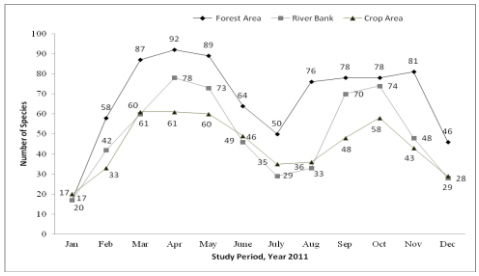

Fig. 3. Shows Species richness found in the forest area in the month of April followed by riverbank and crop area

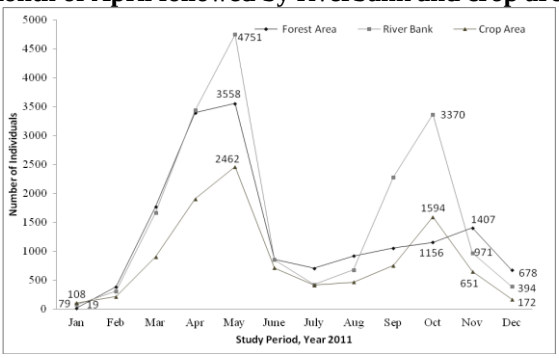

Fig. 4. Graph showing the two peaks of abundance of individuals recorded in the month of March-May followed by September-November

Forest Area:

Forest area is represented by thick canopy with almost shady ground and high relative humidity. Fourteen sites were observed in this habitat. namely Kumbakarai (10˚184883″ N 77.5157″ E Elevation 583m / 1925ft), Kallar garden (11°3442″ N 76°8784″ E Elevation 419m / 1370ft), Kombai (10°2945″ N 77°4370″ E Elevation 1020m / 3341ft), Vellagavi (10°1970″ N 77°4992″ E Elevation 1343m / 4408ft), Pethuparai (10˚2820″ N 77˚5303″ E Elevation 1369m / 4490ft), Katherina Falls (11°3835″ N 76°8581″ E Elevation 1470m / 4823ft), Perumalmalai (10˚2641″ N 77˚5375″ E Elevation 1563m / 5127ft), Matupatti (10°2742″ N 77°4554″ E Elevation 1680m / 5511ft), Coonoor (11°3392″ N 76°8018″ E Elevation 1686m / 5539ft) Shenbaganur (10°2317″ N 77°5030″ E Elevation 1798m / 5899ft), Bandichoolai (11°3720″ N 76°8194″ E Elevation 1979m / 6492ft), Vattakanal (10°2153″ N 77°4853″ E Elevation 2080m / 6825ft), Observatory (10°2292″ N 77°4625″ E Elevation 2295m / 7529ft), Doddabetta (11°4012″ N 76°7358″ E Elevation 2624m / 8607ft). Vegetation comprised of *Citrus aurantifolia, Calotropis gigantea, Musa paradisiaca, Ficus racemosa, Terminalia paniculata, Gloriosa superba, Malvastrum coromandelianum, Osbeckia octandra, O. chinensis, Crotalaria pallida, Triumfetta annua, Toddalia asiatica, Salvia coccinea, Eucalyptus globules, Bidens pilosa, Siegesbeckia orientalis, Erigeron karvinskianus, Dahlia imperialis, Helichrysum bracteatum, Anaphali sleptophylla, Leucas martinicensis, Physalis peruviana, Rubus ellipticus,*

Persicaria chinensis, *Spilanthes calva*, and *Acacia sinutata*.

River Bank:

Rivers create gaps in the forest; river bank that lies in the open area within the forest support a variety of fauna including many kinds of insects. They have a microclimate that is very different from the forest hence we have considered this area for our study. With a very thin vegetation of shrubs and grass, damp soil, the river bank was an ideal ground for many nectar plant. Two sites were considered in this habitat, one was along the banks of Bhavani River which is situated on the foothill of Nilgiri Biosphere, 10 Km from the Mettupalayam to the West and 40 Km from Coimbatore to the South. It has an approximate width of 21 meters at Kallar region. It is located over (11.3400″ N 76.8817″ E Elevation 388m / 1273ft). The second habitat was Elephant Valley Cascade (10˚3116″ N 77˚5205″ E Elevation 1148m / 3764 ft) located 20 Km from the Kodaikanal Hills. Elephant Valley Cascade is among the 25 most important biodiversity hotspots on the Planet. Dominant nectar source vegetations within the transect lines are *Helichrsysm bracteatum*, *Hibiscus vitifolius*, *Chromolaena odorata*, *Hibiscus rosasinensis*, *Capparis zeylanica*, *Asclepias curassavica*, *Datura stramonium*, *Hyptis sp.*, Plum, *Sarracen iaalata*, *Senna tora*, *Tecoma stans*, *Osbekia octandra*, *Asystasia sp*., *Gnidia glauca*.

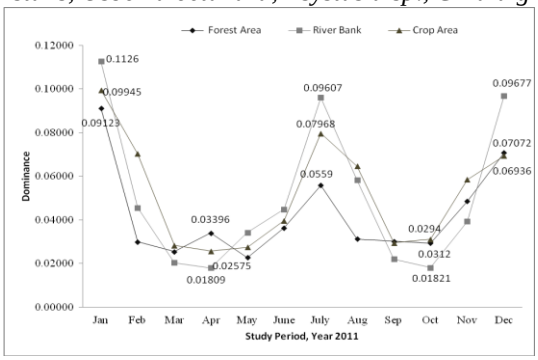

Fig. 5. Shows maximum dominance of Butterflies in river bank habitat than the other study area

Crop Area:

Various agricultural fields were chosen for the study to analyze the diversity of the butterflies among the fragmented area of the forest as well as to find the impact of insecticides and pesticides in their habitat. Transect has been fixed in following agriculture fields and the study was conducted in the following sites namely Ithalar (11°3428″ N 76°6357″ E Elevation 2112m / 6932ft), Porthy (11°3434″ N 76°6307″ E Elevation 2036m / 3689ft), Poombarai (10°2471″ N 77°4040″ E Elevation 1926m / 6320ft), Shenbaganur (10°2317″ N 77°5030″ E Elevation 1798m / 5899ft), Pallangi (10°2732″ N 77°4523″ E Elevation 1665m / 5461ft). Dominant nectar source plants were *Piper nigrum*, *Camellia sinensis*, *Coffea arabica*, *Solanum tuberosum*, *Daucus carota*, *Citrus sinensis*, *Brassica oleracea*, *Beta vulgaris*, *Persea americana*, *Phaseoius coccineus*, *pyrus sp*.

Results:

Diversity calculation:

The total number of individuals collected under each identified species in different habitats was recorded and diversity indices namely dominance index, Shannon's diversity indices (H′), and evenness index (e^H/S) were calculated using PAST software (PAST; version= 2.02).

Species composition:

A total of 45,528 individuals of 92 species of butterflies belonging to 65 genera and 5 families were observed during January 2011 to December 2011.

Species Richness:

There was a significant difference in number of species between different habitat types. Species Richness was greater in Forest Area (92) than in other two habitats, River Bank (78) and Crop Area (61). In all the three habitats the maximum richness was recorded in the month of April and the minimum richness was recorded in the month of December and January.

Species Abundance:

In the totally observed individuals from three different habitats Forest Area (15927), River Bank (19230) and Crop Area (10371), maximum abundance was noted in two seasons, ; March - May and September – November with the peak in April and October respectively. Maximum abundance within the habitats was observed in River Bank (4751) followed by Forest Area (3558) and Crop Area (2462). Minimum abundance was observed in the month of January (River Bank – 108, Crop Area – 79, Forest Area –19).

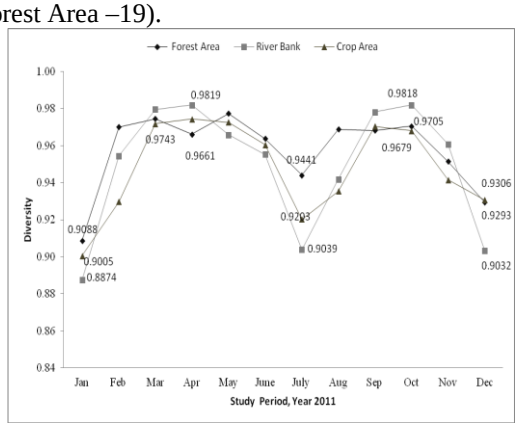

Fig. 6. Shows greater diversity of butterflies in forest area followed by river bank and crop area in the month of April

Dominance, Simpson Diversity and Evenness:

Dominance, Simpson Diversity and Evenness were studied using PAST version 2.0. Maximum dominance was recorded in River Bank (0.11260) in the month of January when compared to other two habitats, Forest Area (0.09945) and Crop Area (0.09123). In all the three habitats dominance showed similar kind of trend. Minimum dominance was recorded in the month of April followed by October. River Bank habitat showed greater dominance among all the three habitats.

Maximum Simpson diversity was recorded in River Bank (0.9743) in the month of April followed by Crop Area (0.9819) and Forest Area (0.9661). Simpson Diversity showed peaks in the months of April and October in all the three habitats. Minimum Simpson diversity was recorded in January for River Bank (0.9088), Crop Area (0.9005), and Forest Area (0.9088).

Trends in the Evenness showed that there was a considerable dominance by few species in all the three habitats. However in crop area evenness was least modified throughout the season. Forest Area had the minimum evenness with a higher degree of dominance particularly in the months of January (0.7792) and October (0.6128). Highest mean Evenness was found in River Bank (0.6954) habitat followed by Crop Area (0.6768) and Forest Area (0.6054).

Discussion:

Western Ghats is considered one among the 12 mega biodiversity hotspots of the world (Larsen 1987a,b,c.); its climatic conditions and tropical temperature with very high rainfall throughout the year (Larsen 1988) have made it favourable for the richness of species. Butterflies (Lepidoptera: Rhophalocera) are considered as ecological indicators

(McGeoch 1998; Rosenberg *et al.*, 1986; New *et al.*, 1995; Vu 2007). They help in pollination (Johnson *et al.*, 1994; Johnson *et al.*, 1995). In our study, butterflies from all the families were recorded; among them, family Nymphalidae outnumbered with the maximum species throughout the study period; this because of their ecological adaptation (Jiggins *et al.*, 1996), speciation and high dispersal ability (Adler *et al.*, 1994). Family Nymphalidae is the largest family representing nearly one-third of the known butterflies of the world. Family Nymphalidae was followed by Lycaenidae, Pieridae, Papilionidae, and Hesperiidae in the total number of species observed. Similar findings were reported by Mathew and Rahamathulla (1993) from Western Ghats.

Wynter- Blyth (1956) had identified two seasons, March-April and October as the peak periods in India for the species diversity and abundance. We also observed maximum species diversity and abundance in the months of March-May, and October-November (Fig 2&3); and there was a gradual increase during the early summer from the month of March and it reached maximum in the month of May; a second peak was recorded in the month of October and November. Butterflies in all the habitats have flight periods, and their abundance strongly correlates with their different flight periods (Leather 1984; Norris 1935). Almost all butterflies are abundant in short peak in particular seasons, and may or may not appear in other seasons.
Diversity and abundance of butterflies correlate with the flowering phenology of plants (Gutierrez *et al.*, 1995; Watt *et al.*, 1974; Kunte 2000). Some polyphagous species (Larsen 1988) like *Neptis hylas*, *Eurema heceba*, and *Catopsilia phomona*, were abundant throughout the year in all the habitats. Species like *Papilio crino* has only short flight period and are found only in the month of March in Bhavani river bank. *Papilio polymnester*, *Junonia almana*, and *Eupolio core* have long flight period. Species abundance and diversity declined in two seasons, one in December-January due to extreme cold and withering of flowers (nectar source) and again in late summer, June-July due to non-availability of nectar source, over heat, and scarcity of water. Among the habitats studied, less abundance was recorded in the crop area habitat of Western Ghats which could be due to non availability of host plant. This needs to be studied further.

Presence of butterfly species at a particular habitat depends on a wide range of factors; the availability of food and microclimate are considered most important (Janzen *et al.*, 1968). In our results, the river bank habitat has the greatest abundance of butterflies but lower species number than the forest and crop area habitats. The living environment of the river bank habitat is diversified with vegetation, rocks, sand, animal dung, mud, with water that attracts more butterflies (Janzen *et al.*, 1968), and thus the river bank habitat has the greatest abundance of butterflies. The river bank habitat is less diverse (78 species) than the forest habitat (91 species) probably due to the availability of host plant. Greater abundance (Fig 4) and less diversity (Fig 6) lead to the higher dominance (Fig 5) in the river bank habitat (0.1126) than the other habitats. *Catopsilia Pomona, Eurema hecabe, Graphiun Sarpedon*, and *Ypthima ceylonica* were observed throughout the year in the river bank habitat.

Evenness index ranged between 0.4237 to 0.8341 in three different habitats (Fig 7). Optimum Evenness was found between the months of June and July in our study, where diversity and dominance of butterflies were even. Low rainfall, moderate temperature and moderate availability of nectar source resulted in optimum evenness. High fluctuation in Evenness in crop area is because of different cultivable plants that have varied blooming period. In crop area Lycaenidae species (*Acytolepis pupsa, Amblypodia anita,)* were dominantly found, because of their varied feeding mechanism, ability to change their host plant, and symbiotic relationship with ant which increased their caterpillar survival rate.

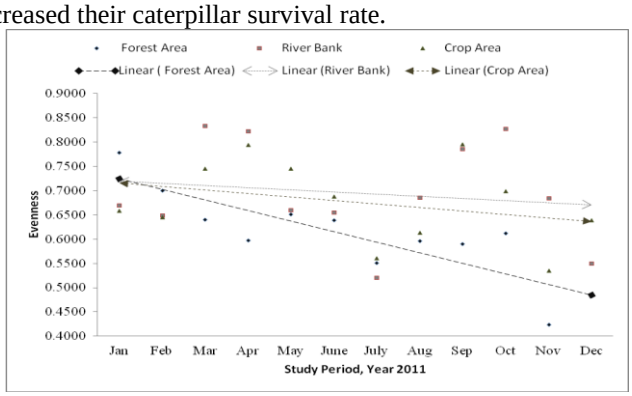

Fig. 7 shows high degree of Evenness fluctuation throughout our study period

Western Ghats is unique in endemism (Holloway 1974, Sudheendrakumar *et al.*, 2000); each habitat has a specific set of microenvironment suitable for endemic species (Holloway 1974). Seventeen endemic species of butterflies were recorded in the present study. Among them, ten species namely *Papilio polymnestor, Papilio helenus, Troides minos, Vanessa indica, Vanessa cardui, Cirrochroa thais, Cupha erymanthis, Colias nilagiriensis, Melanitis leda, Mycalesis anaxias, Orsotrioena medus, lethe rohria neelgiriensis, Tagiades litigiosa* and *Loxura atymnus* were observed in the forest habitat, and three other species were found such as *Phalanta phalantha, Hebomoia glaucippe, Papilio crino* from the river bank habitat. Maximum number of endemic species was found in undisturbed evergreen forest when compared to other habitats; this may be due to the availability of host plant and least disturbance. Significantly, we couldn't record any endemic species in the crop area habitat.

Conclusion

The statistical comparison of the results in three different habitats shows that the butterflies' diversity and abundance have significantly declined in the crop area habitats than the other two habitats, - river side and forest habitat. This is probably due to the destruction of host plant in crop area habitat, use of chemical pesticides, and human disturbance. Fragmentation of forest for crop area could certainly destroy the host plant and could greatly influence the biodiversity of butterflies. Biodiversity laws alone cannot create awareness and conserve butterflies. It is very important to understand the relation between host plant and the butterflies to protect them as they have co-evolved. Western Ghats being one of the biodiversity heritage sites, need more attention for effective conservation of butterflies.

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References

Adler GH, Dudley, R. Biogeography of Milkweed of Milk butterflies Nymphalidae Danainae and mimetic patterns on patterns on tropical pacific archipelagos. Biol. J. Linn. society. 1996; (57): 317-326.

Chakravarthy AK, Rajagopal D, Jagannatha R. Insect as a bioindicator of conservation in tropics. Zoos print. 1997 ;(12): 21-25.

Erhardt A. Diurnal Lepidoptera sensitive indicators of cultivated and abandoned grassland. J. Appl. Ecol. 1985 ;(22) 849-861.

Gay. Common Butterflies of India. WWF India and Oxford University Press Mumbai India. 1992.

Gutierrez D, Mendez R. Phenology of butterflies in a mountain area in northen Iberian Peninsual. Ecography. 1995;(18): 209–219.

Holloway JD. The biogeography of Indian butterflies. In: MS Mani (ed) Ecology and Biogeography in India. Dr. W. Junk. B.V. Publishers, The Hague, 1974; p. 473-499.

Janzen DH, Schoener TW. Difference in insect abundance and diversity between wetter and drier sites during a tropical dry season. Ecology. 1968;(49): 96–110.

Jiggins CD, McMillan WO, Neukirchen W, Mallet J. What can hybrid zones tell us about speciation? Biol. J. Linn. society. 1996;(59):221-242.

Johnson SD, and Bond WJ. Red flowers and butterfly pollination in the fynbos of South Africa. In: Arianoutsou, M., Groves, R.H. (eds), Plant-animal interactions in Mediterranean-type ecosystems. Kluwer Academic Press Dordrecht 1994; p .137-148.

Johnson and Steiner. Long-proboscid fly pollination of two orchids in the Cape Drakensberg Mountains South Africa. J. S. African Bot. Suppl. 1995;(195): 169-175.

Spitzer K, Lepš J, Soldan T. Butterfly communities and habitat of seminatural savana in southern Vietnam Papilionoidae Lepidoptera. Acta Entomologica Bohemoslovaca. 1987;(84): 200–208.

Kocher SD, Williams EH. The diversity and abundance of North American Butterflies Vary with habitat Disturbance and Geography. J. Biogegor. 2000;(27):785-794.

Kremen C. Assessing the indicator properties of species assemblages for natural areas monitoring. Ecological Applications. 1992;(2): 203-17.

Kristensen NP, Skalski AW. Phylogeny and palaeontology. In: Kristensen N.P. (ed), Evolution, systematics and biogeography. Handbook of Zoology Lepidoptera: moths and butterflies. 1999; (5): 7-25.

Kunte K. A lifescape of butterflies of peninsular India. University Press Hyderabad. 2000.

Larsen TB. The butterflies of Nilgiri Mountains of south India Lepidoptera Rhopalocera. J. Bombay Nat. hist. soc. 1988;(86): 39-46.

Larsen TB. The butterflies of the Nilgiri mountains of South India Lepidoptera Rhopalocera. J. Bombay Nat. hist. soc. 1987a ;(84): 26-43.

Larsen TB. The butterflies of the Nilgiri mountains of South India Lepidoptera Rhopalocera. J. Bombay Nat. hist. soc. 1987b;(84): 291-316.

Larsen TB. The butterflies of the Nilgiri mountains of South India Lepidoptera Rhopalocera. J. Bombay Nat. hist. soc. 1987c ;(84): 560-584.

Leather SR. The effect of adult feeding fecundity Wight loss and survival of the fine beauty moth panolis flammea. Oecologia. 1984 ;(81): 249-257.

Lien van Vu. Diversity and similarity of butterflies communities in five different habitat types at Tam Dao National Park Vietnam. J. of Zoology. 2009; (227): 15-22.

Lien van Vu, and con Quang. The differences of butterfly Lepidoptera Papilionoidea communities in habitats with various degrees of disturbance and altitudes in tropical forests of Vietnam. Biodivers. Conserv. 2011; (12): 1099–1111.

Mathew and Rahamathulla Studies on the butterflies silent valley National park. Entomon. (1993); (18): 185-192.

McGeoch M.A. The selection testing and application of terrestrial insects as bioindicators. Biological Review. 1998; (73): 181-201.

New TR, Pyle RM, Thomas JA, Thomas CD, Hammond PC. Butterfly conservation Management. Annual review of Entomology. 1985;(40): 57-83.

Norris MJ. A feeding experiment of adult pieris rapae. Entomol. 1935;(68):125-127.

Pollard E. A method for assessing changes in the abundance of butterflies. Biol. Conserv. 1977; (12): 115–153.

Pollard E, Yates TJ. Monitoring Butterflies for Ecology and Conservation. Chapman and Hall London. 1993.

Rosenberg DM, Danks HV and Lehmkuhl DM. Importance of insects in environmental impacts assessment. Environmental Management. 1986; (10): 773-783.

Scoble MJ. the Lepidoptera Form Function and Diversity. Oxford University Press, Oxford. 1992.

Scott D, Lemieux C. Climate change and protected area policy and planning in Canada. The Forestry Chronicle. 2005 ;(81): 696-703.

Scriber JM, Gage SH. Pollution and global climate change plant ecotones butterfly hybrid zones and Changes in biodiversity In: Scriber J.M., Tsubaki Y., Lederhouse R.C. (eds), Swallowtail Butterflies Their Ecology and Evolutionary Biology. Scientific Publishers. Gainesville. Florida. 1995; p.319–344.

Smetacek P. Record of Plebejus eversmanni (Stgr.) from India. J. Bombay Nat. hist. soc. 1992 ;(89): 385-386.

Spitzer K, Novotný V, Tonner M, Lepš J. Habitat preferences distribution and seasonality of the butterflies (Lepidoptera: Papilionidae) in a montane tropical rain forest Vietnam. J. of Biogeography. 1993;(20): 109-121.

Sudheendrakumar VV, Binoy CF, Suresh PV, Mathew G. Habitat associations of butterflies in the Parambikulam Wildlife Sanctuary Kerala India. J. Bombay Nat. hist. soc. 2000;(97): 193-201.

Tilman D, Fargione J, Wolff B, D'Antonio C, Dobson A, Howarth R. Forecasting agriculturally driven global environmental change. Science. 2001;(292): 281–284.

Vu V.L. Ecological indicator role of butterflies in Tam Dao National Park Vietnam. Russian Entomological J. 2007;(16): 473–480 .

Warren MS, Hill JK, Thomas JA, Asher J, Fox R. Rapid responses of British butterflies to opposing forces of climate and habitat change. Nature 2001;(414): 65–69.

Watt WB, Hoch PC, Mills SG. Nectar source use by *Colias* butterflies chemical and visual aspects. Oecologia. 1974; (14): 353-374.

Wynter-Blyth MA . Butterflies of the Indian Region. J. Bombay Nat. hist. soc. 1956; p.523.