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COMMUNICATION

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COMMUNICATION

Butterfly diversity in heterogeneous habitat of Bankura, West Bengal, India

Kalyan Mukherjee [1] & **Ayan Mondal** [2]

[1] State Animal Health Centre, P.O. Amta, Howrah District, West Bengal 711401, India.
[2] Ecology and Environmental Modelling Laboratory, Department of Environmental Science, The University of Burdwan, Burdwan, West Bengal 713104, India mondalayan.zoo@gmail.com
[2] Department of Zoology, G.G.D.C, Sialsai, Srirampur, Mohanpur, West Bengal 721436, India
[1] kalyan.govt2009@gmail.com, [2] mondalayan.zoo@gmail.com (corresponding author)

Abstract: Butterfly diversity was observed in different habitats of Bankura District, West Bengal, India. This district is located at the junction of Chotanagpur plateau and Gangetic plain; it contains a variety of transitional habitats. We found 117 butterfly species from our covered survey area. The highest species recorded in the present study belonged to family Lycaenidae (30.76%) and Nymphalidae (29.91%) followed by Hesperiidae (16.23%), Pieridae (13.67%), Papilionidae (8.54%), and Riodinidae (0.85%), respectively. Based on sighting we found that 12.82% of all the butterflies recorded were abundant in nature while 21.36% were very common, 41.88% were frequent, and 23.93% were rare. Cluster analysis and other diversity indices gives us an overall idea about environmental health. The pattern of diversity change from plain to plateau gradient gives important insight about ecological edge effect. High species number in relation with low individual numbers were found in forest habitat. This preliminary study showed that heterogeneous habitats could harbour many butterflies and need proper conservation efforts to sustain it.

Keywords: Chotanagpur plateau, diversity, heterogenous habitat, Lepidoptera, transitional habitats.

সারাংশ : পশ্চিমবঙ্গের বাঁকুড়া জেলায় প্রজাপতির বৈচিত্র পর্যবেক্ষণ করা হয়েছে। এই জেলাটি গাঙ্গেয় সমভূমি ও ছোটনাগপুর মালভূমির সংযোগস্থলে অবস্থিত, সুতরাং এটা বিভিন্ন পরিবর্তকালীন স্বাভাবিক আবাসস্থল ধারণ করে। আমরা মোট ১১৭ রকমের প্রজাপতি প্রজাতি পেয়েছি এই এলাকা থেকে। সবচেয়ে বেশি প্রজাতি পাওয়া গেছে লাইসিনাইডি (৩০.৭৬%) ও নিমফালাইডি (২৯.৯১%) পরিবারে, তার পরে যথাক্রমে হেস্পেরিডি (১৬.২৩%), পিয়েরাইডি (১৩.৬৭%), পাপিলোনিডি (৮.৫৪%) এবং রিওডিনিডি (০.৮৫%) পরিবারে। পর্যবেক্ষণ অনুসারে আমরা প্রচুর পরিমানে পেয়েছি ১২.৮২%, যথেষ্ট পরিমানে পেয়েছি ২১.৩৬%, মোটামুটি পরিমানে পেয়েছি ৪১.৮৮%, ও কম পরিমানে পেয়েছি ২৩.৯৩% প্রজাপতি। প্রজাতির বৈচিত্র সূচক ও গুচ্ছবদ্ধকরণ আমাদের স্থানীয় পরিবেশের স্বাস্থ্য সম্পর্কে ধারণা দেয়। সমভূমি থেকে মালভূমিতে প্রজাপতি বৈচিত্রের ক্রমপরিবর্তন বাস্তুতন্ত্রের প্রান্তিক প্রভাব সম্পর্কে গুরুত্বপূর্ণ তথ্য সরবরাহ করে। বেশি প্রজাতি পাওয়া গেছে জঙ্গলযুক্ত আবাসস্থলে। প্রাথমিক ভাবে এই গবেষণা মনে করছে নানাধর্মী আবাসস্থল অনেক বেশি পরিমানে প্রজাপতি প্রজাতি ধারণে সক্ষম ও তাদের যথাযত সংরক্ষণের প্রয়োজন।

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Author details: Kalyan Mukherjee is a Veterinary Pharmacist under Department of Animal Resources Development, Government of West Bengal by profession and associated with Green Plateau (NGO). He is also a content reviewer of butterflies of India website. His particular interest are on butterfly early stage and host plant interaction. Ayan Mondal is an Assistant Professor of Zoology, Department of Higher Education, Government of West Bengal. Currently he is working on ecological modelling of non-linear dynamics and stability analysis of ecosystem. Apart from this he is interested on spider taxonomy and systematics.

Author contribuion: KM collected all the field data and photographs. He also wrote primary draft of the manuscript. AM analysed the data and helped in manuscript improvement.

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INTRODUCTION

Butterflies are one of most important pollinators and herbivores in nature (Kunte 2000; Tiple et al. 2006) and they also have coevolved with plants (Ehrlich & Raven 1964). Mostly they live on nectar and in larval condition leaves of host plant. Larva of the member of Family Lycaenidae sometimes may associated with ants (Nimbalkar et al. 2011). They are also considered as good indicators of ecosystem health due to their sensitivity to environmental parameters (New 1991; Pollard et al. 1994; Kunte 2000; Thomas 2005; Bonebrake et al. 2010). Anthropogenic effects on habitat quality are well reflected by these organisms (Kocher & Williams 2000; Kunte 2000; Summerville & Crist 2001; Koh 2007). In general, species diversity and richness indices with special references to bioindicator group helps in better ecosystem management (Wilson et al. 2004).

In the present investigation we studied butterfly diversity of Bankura District of West Bengal, India, that contains some completely different types of habitat having unique geomorphological variations. Being a part of Chotanagpur plateau the present study sites contained undulating landscape, some hills as well alluvial plain, and the probability of harbouring many new species too (Mirza & Mondal 2018). So, this less explored area might shed light upon how butterfly diversity could have changed across the geomorphological gradient in relation to ecosystem health. Major outcome of this study might help in conservation of this least explored area of West Bengal, India.

MATERIALS AND METHODS

Study site

Bankura District is situated in the western part of southern West Bengal (Figure 1). It contains both plains of Bengal and plateau of Chotanagpur. Eastern to north-eastern site of this land are low-lying alluvial plains while on other side western zone gradually rises altitude, and fringed region of plateau starts; characterized by rocky undulating landscape. Numerous small monadnocks are interspersed in this area which are locally known as 'Tila' along with two major hills, namely: Susunia (448m) and Biharinath (451m). They are mainly made up of igneous rocks of the Archaean era as well as coal-bearing mudstone and quartzite rocks of Carboniferous period. The district also contains several rivers like Damodar, Dwarakeswar, Shilabati, Kangsabati, Sali, Gandheswari, Kukhra, Birai, Jaypanda and Bhairabbanki. Climatic condition of the characterized by an overbearingly hot summer, high humidity nearly all the year around and well distributed rainfall (1,303.7mm) during the monsoon months. The cold weather starts from about middle of November and lasts till the end of February. Summer months extends from March to May. We had chosen six area (Image 1) to conduct our survey along the geomorphological and altitudinal gradient to cover almost every type landscape and habitat of this district (Table 1).

Site A Deciduous Sal forest and red, laterite soil covers a major portion of this district. Taldangra, Simlapal, Onda, Joypur, Bishnupur, Beliator represents this region. Average altitudinal variation ranges 75–150 m. Moisture content of soil is relatively low compared to Vindhya alluvial soil and also vegetation type majorly differs from it.

Site B Raipur, Sarenga, Pali are situated beside Kangasabati River. Numerous 'tila' can be found dispersed throughout the region which are locally called "Masaker Pahar". Poor ferruginous soil and hard bed laterite are the characteristic soil types. Vegetation is mainly characterized by scrub jungles. Actually, this is located at the fringed region of Chotanagpur plateau.

Site C The rarh region in this district is represented by the region between Damodar and Dwarakeswar rivers, especially areas like Raibaghini, Kotulpur, Indas, and Patrasayer. Average altitudinal variation is 5–100 m and soil profile is characterized by Vindhya alluvial soil type. Actualy, almost 37% of this district contain this type of soil.

Site D This study site was mostly associated with dry agricultural land. Kadamdeuli and its surroundings constituted an excellent wetland as well as riparian ecosystem that harboured a rich butterfly diversity. Kadamdeuli reservoir is situated on Silabati River near Hatirampur.

Site E Susunia one of two hill situated in this district. This arid region contains a special type of island like habitat in the midst of agricultural land. Tropical dry deciduous type forest dominated by Sal tree (*Shorea robusta* Roth.). The hill is very rich in its plant resources including medicinal plants. Highest peak of this region is 442m.

Site F Jhilimili, Ranibandh, Sutan represents a dense dry deciduous forest mainly dominated by sal, nim, kendu tree. Average altitudinal variation is around 200m. Humus rich, friable gravelly soil with undulating perfect plateau landscape.

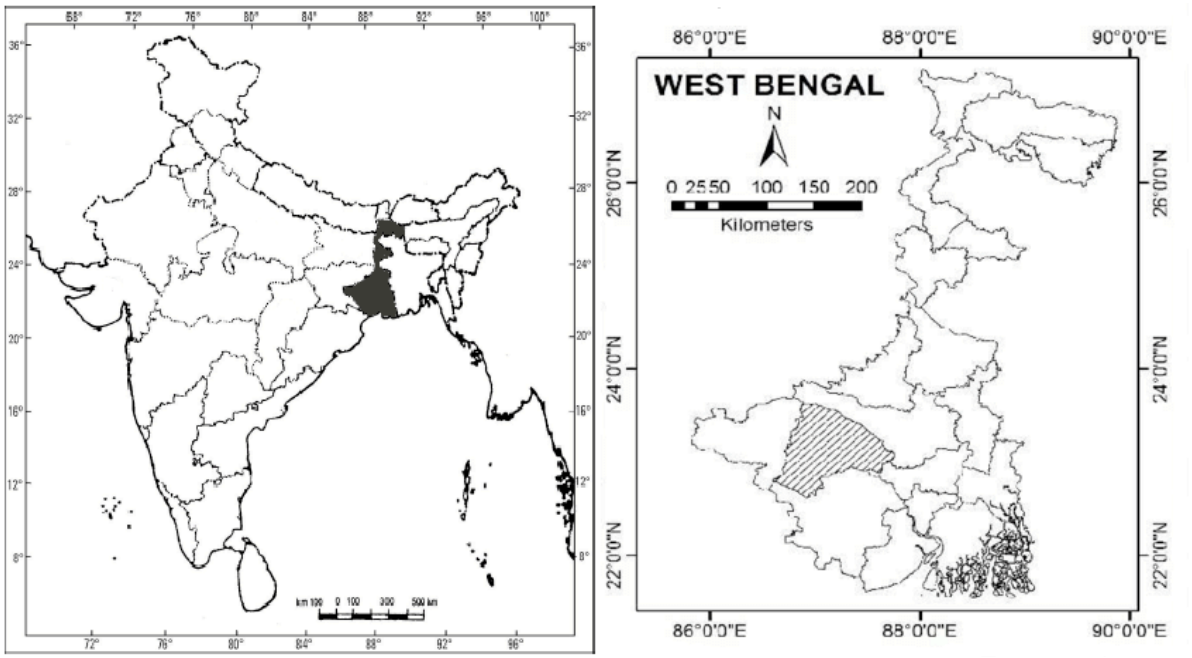

Figure 1. Location of Bankura District in West Bengal, India

Data Collection

The selected sites were surveyed from December 2012 to January 2019 to assess the diversity of butterflies. Yearly survey was categorized into three different seasons, viz., the Summer (March, April, May, and June), Winter (October, November, December, January, and February), Monsoon (July, August, and September). Pollard Walk Method (Pollard 1977) was followed for recording the butterflies while walking along surveyed paths along the areas. The observation width was limited to about 3m and at a stretch 150m on an average path covered. Flight periods, seasonality and abundance of butterfly species in different habitats were also recorded. Butterfly species were identified directly in the field or, in difficult cases, following capture or photography. As conservation policy, over collection was avoided and in fact specimens were collected only if doubts persisted in their specific identity. Rainfall and calm wind data were taken from India Meteorological Department and temperature, humidity data were taken by using a portable digital KTJ thermometer with humidity sensor.

Identification of the butterflies were primarily made directly in the field. In critical condition, specimens were collected only with handheld aerial sweep nets. Each specimen was placed in plastic bottles and was carried to the laboratory for further identification with the help field guide (Wynther-Blyth 1957; Kunte 2000) and butterfly taxonomist. The observed butterflies were grouped in five categories based on number of sighting in the field. The butterflies were categorized as Abundant (A>30%), Very Common (VC=10–30%), Frequent (F=5–10%), and Rare (R=1–5%) (Rajasekhar 1995).

Data Interpretation

Single factor ANOVA were done separately among sites and different season. Dominance_D, Simpson_1-D, Shannon_H, Evenness_e^H/S, Brillouin, Menhinick, Margalef, Equitability_J, indices were calculated. Individual rarefaction analysis was done among sites. Hierarchical classical clustering was performed using single linkage algorithm with Bray-Curtis similarity index and 10,000 bootstraps among sites. All the analysis was done in statistical software PAST Version 3.26 developed by Øyvind Hammer, Natural History Museum, University of Oslo.

RESULTS

During the course of study 117 species of butterflies, belonging to six families (Figure 2) were recorded. The highest number of butterflies was recorded belonging to the families Lycaenidae (36 species; Image 3), and Nymphalidae (35 species; Image 2), followed by Hesperiidae (19 species; Image 4), Pieridae (16 species; Image 5), Papilionidae (10 species; Image 6), and Riodinidae (1 Species; Image 7). Among them 15 were

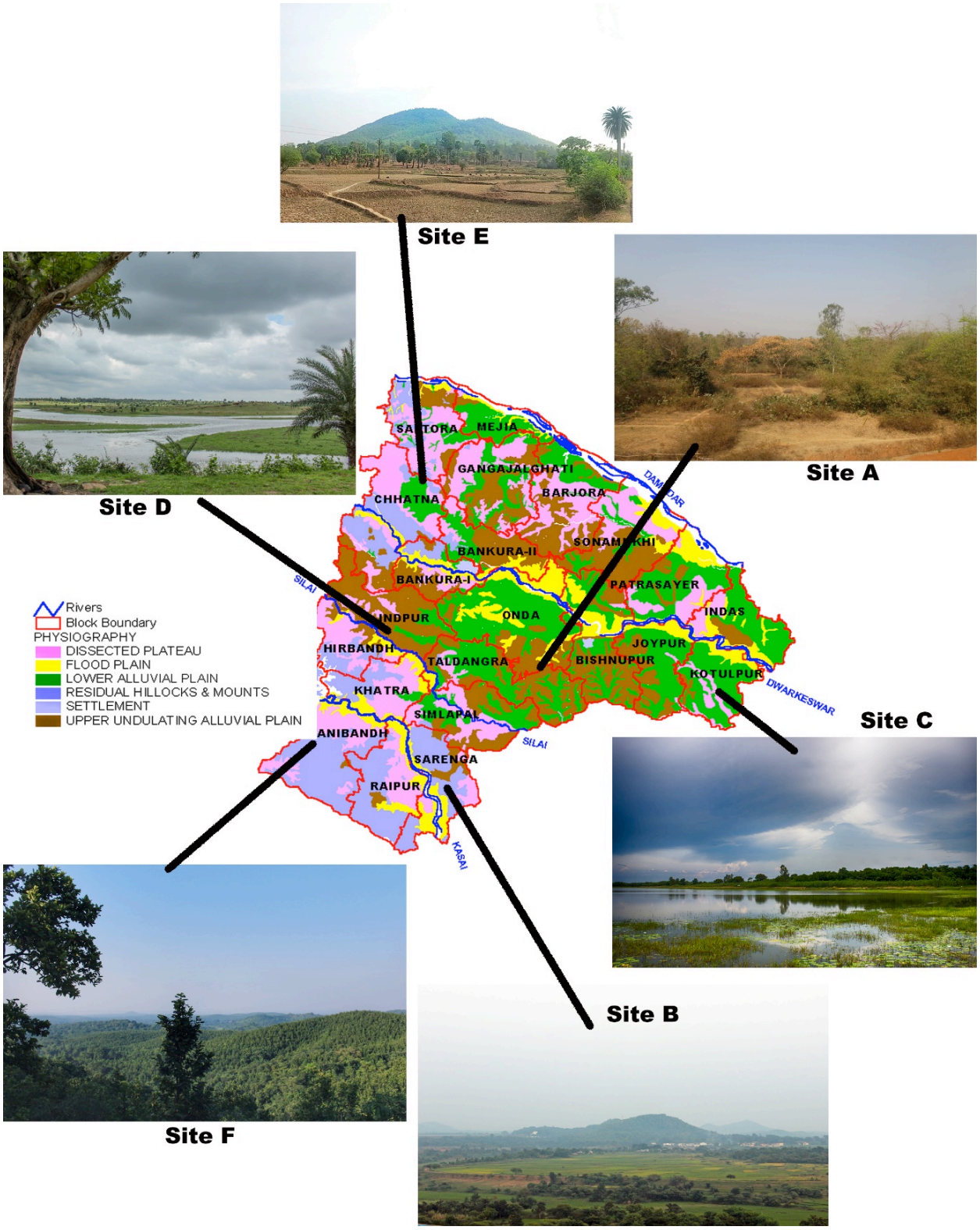

Image 1. Study sites and corresponding habitats.

Table 1. A brief description of the selected sites with habitat types (as per Champion & Seth 1968).

Site name	Habitat and forest type	Dominant larval host plants	Region (Latitude, Longitude), altitude
Site A	Tropical dry deciduous forest; Agricultural lands	*Soria robusta*, *Citrus limon*, *Citrus grandis*, *Citrus medica*, *Murraya koenigii*, *Sida rhombifolia*, *Portulaca oleracea*, *Cleome viscosa*, *Aristlochia indica*, *Aegle marme*, *Psidium guava*, *Glycosmis pentaphylla*, *Hygrophilia auriculata*, *Mangifera indica*, *Butea monosperma*, *Costus speciosus*	Taldangra (23.036°N, 87.126°E) 107m; Simlapal (22.946°N, 87.069°E) 96m; Onda (23.139°N, 87.208°E) 77m; Joypur (23.058°N, 87.429°E) 75m; Beliatore (23.314° N, 87.195°E) 106m; Bishnupur (23.039°N, 87.319°E) 94m
Site B	Tropical throny/scrub forests; Open grassland	*Aristlochia indica*, *Citrus grandis*, *Sida rhombifolia*, *Soria robusta*, *Tragia involucrate*, *Barleria cristata*, *Hygrophilia auriculata*, *Mangifera indica*, *Butea monosperma*, *Phoenix acaulis*	Raipur (22.805°N, 86.923°E) 104m; Sarenga (22.779°N, 87.041°E) 112m; Pali (22.780°N, 86.827°E) 131m
Site C	Agricultural lands and remnant of dry deciduous forest	*Citrus limon*, *Aristlochia indica*, *Mangifera indica*, *Phoenix acaulis*, *Ixora coccinea*, *Zingiber officinale*, *Laportea interrupta*, *Abrus precatorius*, *Polyalthia longifolia*, *Tamarindus indica*, *Bombax* sp., *Bauhinia acuminate*, *Flacourtia indica*, *Passiflora indica*, *Neolamarckia cadamba*, *Turnera ulmifolia*, *Ziziphus jujube*, *Glycosmis pentaphylla*	Raibaghini (23.029°N, 87.557°E) 37m; Indas (23.141°N, 87.614°E) 36m; Patrasayer (23.184°N, 87.540°E) 48m
Site D	Wetland and open grasslands	*Aristlochia indica*, *Mangifera indica*, *Phoenix acaulis*, *Tamarindus indica*, *Abrus precatorius*, *Hybanthus enneaspermus*, *Flacourtia indica*, *Cocos nucifera*, *Soria robusta*, *Butea monosperma*	Kadamdeuli (23.108°N, 86.867°E) 128m
Site E	Tropical dry deciduous forest	*Phoenix acaulis*, *Tamarindus indica*, *Soria robusta*, *Butea monosperma*, *Ziziphus jujuba*, *Ziziphus rugosa*, *Hygrophilia auriculata*, *Aristlochia indica*	Susunia (23.396°N, 86.988°E) 410m
Site F	Tropical Moist deciduous forest	*Aristlochia indica*, *Mangifera indica*, *Butea monosperma*, *Flacourtia indica*, *Terminalia elliptica*, *Ficus benghalensis*, *Terminalia bellirica*, *Abrus precatorius*, *Psidium guava*, *Glycosmis pentaphylla*, *Soria robusta*	Jhilimili (22.818°N, 86.633°E) 194m; Sutan (22.405°N, 86.739°E) 214m; Ranibandh (22.854°N, 86.779°E) 204m

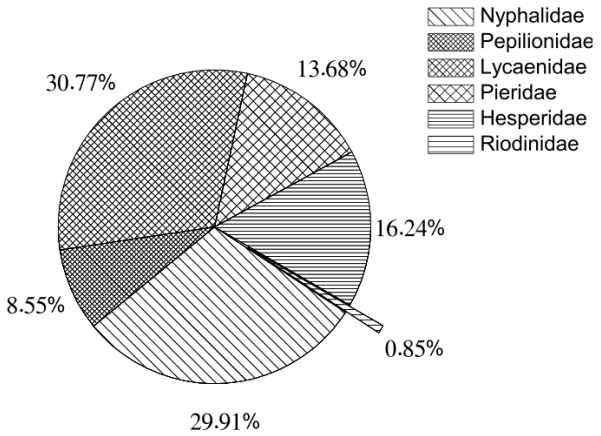

Figure 2. Relative number of species abundances among different family.

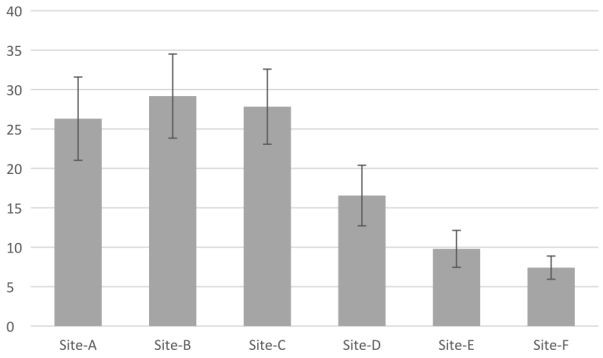

Figure 3. Site-wise average individual number per species.

abundant, 25 were very common, 49 were frequent, and 28 were rare (Table 2).

Ascending order of altitudinal heights of our sites are C < A < B < D < F < E (Table 1). Average individual number per species were highest in Site-B followed by C, A, D, E, and F (Figure 3). Single factor ANOVA among sites on the basis of individual number of different species showed significant difference ($p<0.001$). Number of butterfly species was highest in Site-C (91) followed by F (78), A (76), B (73), D (67), and E (65). Dominance index of all six sites ranges from 0.037 to 0.065 also Simpson 1-D index of all sites remains very close to 1. Berger-Parker index indicating single taxa dominance is relatively high in Site-D and E followed by F than A, B, C. But overall evenness and equitability show very little difference among sites. Shannon, Brillouin, Menhinick and Margalef index are also calculated (Table 3). There are significant differences ($p<0.05$) of butterfly diversity among different seasons. Individual rarefaction analysis of data when plotted in respect to 95 percent confidence of taxa in a conditional way showed probability of finding highest specimen in Site-B, followed by C, A, D, E, and F (Figure 4). Site-B and C are closely associated in terms

Table 2. List of butterflies with their local occurrence status: A—abundant (A>30%) | VC—very common (VC— 10–30%) | F—frequent (F—5–10%) | R—rare (R—1–5%) (Rajasekhar 1995)). Observed flight period (January—1 | February—2, March—3 | April—4 | May—5 | June—6 | July—7 | August—8 | September—9 | October—10 | November—11 | December—12).

Common name	Scientific name	Index of abundance	Flying period
Lycaenidae			
Common Pierrot	*Castalius rosimon*	A	1–12
Striped/Rounded Pierrot	*Tarucus nara*	VC	1–12
Lime Blue	*Chilades lajus*	VC	1–12
Tiny Grass Blue	*Zizula hylax*	F	3–7
Pale Grass Blue	*Pseudozizeeria maha*	VC	2–9
Dark Grass Blue	*Zizeeria karsandra*	A	1–12
Lesser Grass Blue	*Zizina otis sangra*	VC	1–12
Zebra Blue	*Leptotes plinius*	F	2–10
Gram Blue	*Euchrysops cnejus*	F	3–11
Common Line Blue	*Prosotas nora*	F	3–7
Large Oak Blue	*Arhopala amantes*	F	1–5,7–10
Indian Oak Blue	*Arhopala atrax*	F	2–7
Common Guava Blue	*Virachola Isocrates*	F	1–12
Pea Blue	*Lampides boeticus*	F	1–6
Leaf Blue	*Amblypodia anita*	F	4–7
Forget Me not	*Catochrysops strabo strabo*	VC	1–12
Common Cerulean	*Jamides celeno aelianus*	F	4–10
Dark Cerulean	*Jamides bochus*	F	10–7
Plains Blue Royal	*Pratapa deva deva*	R	4
The Quaker	*Neopithecops zalmora*	A	1–12
Common Red Flash	*Rapala airbus*	F	11–4
Indigo Flash	*Rapala varuna*	F	2–9
Slate Falsh	*Rapala manea*	F	12–7
Apefly	*Spalgis epeus*	F	11–3
Grass Jewel	*Freyeria trochylus*	F	10–4
Silver Streak Blue	*Iraota timoleon*	F	12–6
Monkey Puzzle	*Rathinda amor*	F	1–12
Yamfly	*Loxura atymnus*	F	3–11
Common Silverline	*Spindasis vulcanus*	F	1–12
Scarce Shot Silverline	*Spindasis elima*	R	6
Common Shot Silverline	*Spindasis ictis*	R	3–6
Tailless Lineblue	*Prosotas dubiosa*	R	3–8
Pointed Ciliate Blue	*Anthene lycaenina*	F	1–12
Indian Sunbeam	*Curetis thetis*	VC	8–1
Angled Sunbeam	*Curetis acuta*	R	12
Bright Babul Blue	*Azanus ubaldus*	R	6–7
Riodinidae			
Double Banded Judy	*Abisara bifasciata*	F	10–3

Common name	Scientific name	Index of abundance	Flying period
Nymphalidae			
Tawny Coster	*Acraea violae*	A	1–12
Angled Castor	*Ariadne ariadne*	A	1–12
Common Castor	*Ariadne merione*	VC	1–12
Great Eggfly	*Hypolimnas bolina*	VC	1–12
Danied Eggfly	*Hypolimnas misippus*	F	8–3
Common Leopard	*Phalanta phalantha*	A	1–12
Chocolate Pansy	*Junonia iphita*	F	1–12
Yellow Pansy	*Junonia hierta*	VC	5–9
Grey Pansy	*Junonia atlites*	VC	1–12
Blue Pansy	*Junonia orithiya*	VC	12–6
Lemon Pansy	*Junonia lemonias*	VC	1–12
Peacock Pansy	*Junonia almana*	VC	1–12
Baronet	*Euthalia nais*	VC	6–1
Gaudy Baron	*Euthalia lubentina indica*	R	4–6
Common Baron	*Euthalia aconthea*	A	1–12
Chestnut Streaked Sailer	*Neptis jumbah jumbah*	F	12–4
Common Sailer	*Neptis hylas*	F	12–4
Common Bushbrown	*Mycalesis perseus*	VC	1–12
Common Evening Brown	*Melanitis leda*	VC	1–12
Common Palmfly	*Elymnias hypermenstra*	VC	1–12
Plain Tiger	*Danaus chrysippus*	A	1–12
Striped/Common Tiger	*Danaus genutia*	F	9–2
Blue Tiger	*Tirumala limniace*	F	2–11
Common Crow	*Euploea core core*	A	1–12
Bamboo Tree Brown	*Lethe europa*	F	4–11
Commander	*Moduza procris*	F	2–11
Painted Lady	*Vanessa cardui*	R	3–6
Common Four Ring	*Ypthima huebneri*	F	1–12
Double Branded Crow	*Euploea sylvester*	R	1–12
Common Five Ring	*Ypthima baldus*	R	1–12
Black Rajah	*Charaxes solon*	R	3–9
Brown King Crow	*Euploea klugii*	F	1–12
Dark Branded Bushbrown	*Mycalesis mineus*	R	8–12
Common Nawab	*Charaxes athamas*	R	10–1
Tawny Rajah	*Charaxes bernardus*	R	4–10
Papilionidae			
Common Mormon	*Papilio polytes*	A	1–12
Blue Mormon	*Papilio polymnestor*	F	1–12

Common name	Scientific name	Index of abundance	Flying period
Common Rose	*Pachliopta aristolochiae*	VC	1–12
Tailed Jay	*Graphium agamemnon*	F	1–12
Common Jay	*Graphium doson*	F	1–12
The Lime	*Papilio demoleus*	A	1–12
Common Mime	*Papilio clytia*	F	1–12
Red Helen	*Papilio helenus*	R	8
Spot Swordtail	*Graphium nomius*	F	4–6
Common Banded Peacock	*Papilio crino*	R	2–11
Pieridae			
Common Jezebel	*Delias eucharis*	F	1–12
Psyche	*Leptosia nina nina*	A	1–12
Pioneer or Cape White	*Belenois aurota aurota*	F	1–12
Striped Albatross	*Appias olferna*	VC	1–12
Yellow Orange Tip	*Ixias pyrene*	VC	9–2
White Orange Tip	*Ixais marianne*	VC	9–2
Common Gull	*Cepora nerissa*	A	1–12
Common Emigrant	*Catopsilia pomona*	A	1–12
Mottled Emigrant	*Catopsilia pyranthe*	A	1–12
Common Grass Yellow	*Eurema hecabe*	VC	1–12
Three Spot Grass Yellow	*Eurema blanda*	F	1–12
Spotless Grass Yellow	*Eurema laeta*	R	1–12
Common Albatross	*Appias alpina*	R	2–6
One Spot Grass Yellow	*Eurema brigitta*	F	1–12
Indian Cabbage White	*Pieris canidia*	R	1
Chocolate Albatross	*Appias lyncida*	R	6–7
Hesperiidae			
Indian Skipper	*Spialia galba*	VC	1–12
Chestnut Bob	*Iambrix salsala*	F	3–11
Indian Palm Bob	*Suastus gremius*	F	1–12
Common Redeye	*Gangara thyrsis*	VC	1–12
Dark Palm Dart	*Telicota bambusae*	F	2–8
Rice Swift	*Borbo cinnara*	F	1–12
Brown Awl	*Badamia exclamationis*	F	2–11
Grass Demon	*Udaspes folus*	VC	5–10
Common Small Flat	*Sarangesa dasahara*	R	8–10
Common Grass Dart	*Taractrocera maevius*	R	6
Complete Paint-brush Swift	*Baoris farri*	F	3–8
Common Banded Awl	*Hasora chromus*	R	12–4
Tree Flitter	*Hyarotis adrastus*	R	10
Golden Angle	*Caprona ransonnettii*	R	10
Small-banded Swift	*Pelopidas mathias*	F	8–10
Obscure Branded Swift	*Pelopidas agna*	F	7–11
Water Snow Flat	*Tagiades litigiosa*	R	6
Tricolor Pied Flat	*Coladenia indrani*	R	7–8
Bush Hopper	*Ampittia dioscorides*	R	3–10

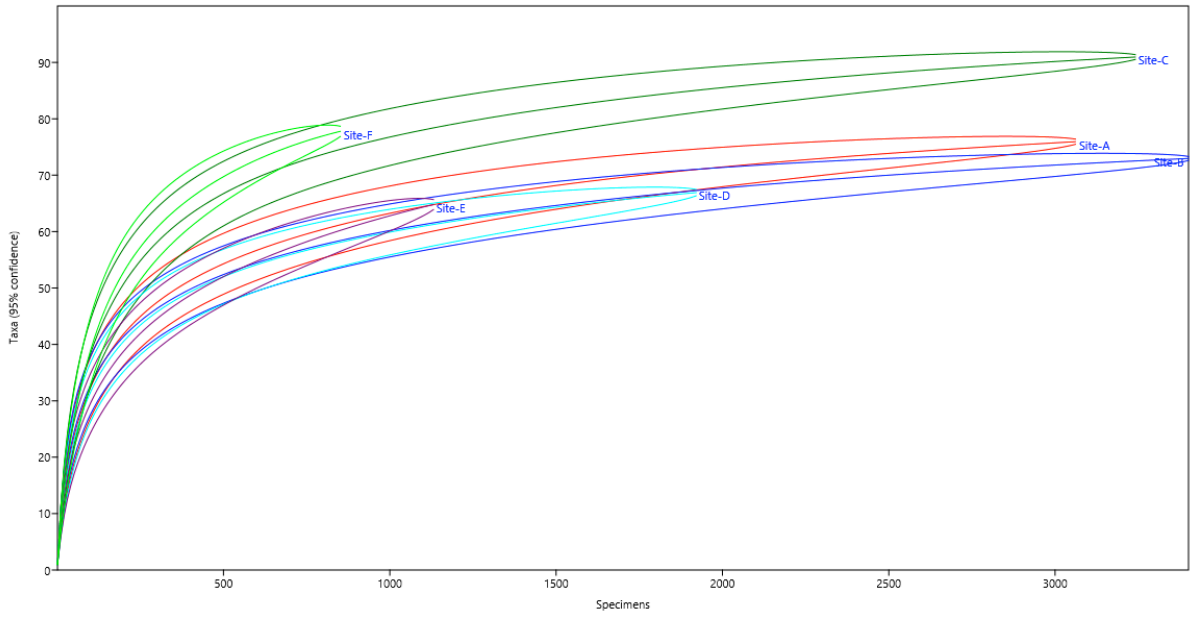

Figure 4. Individual rarefaction analysis plot.

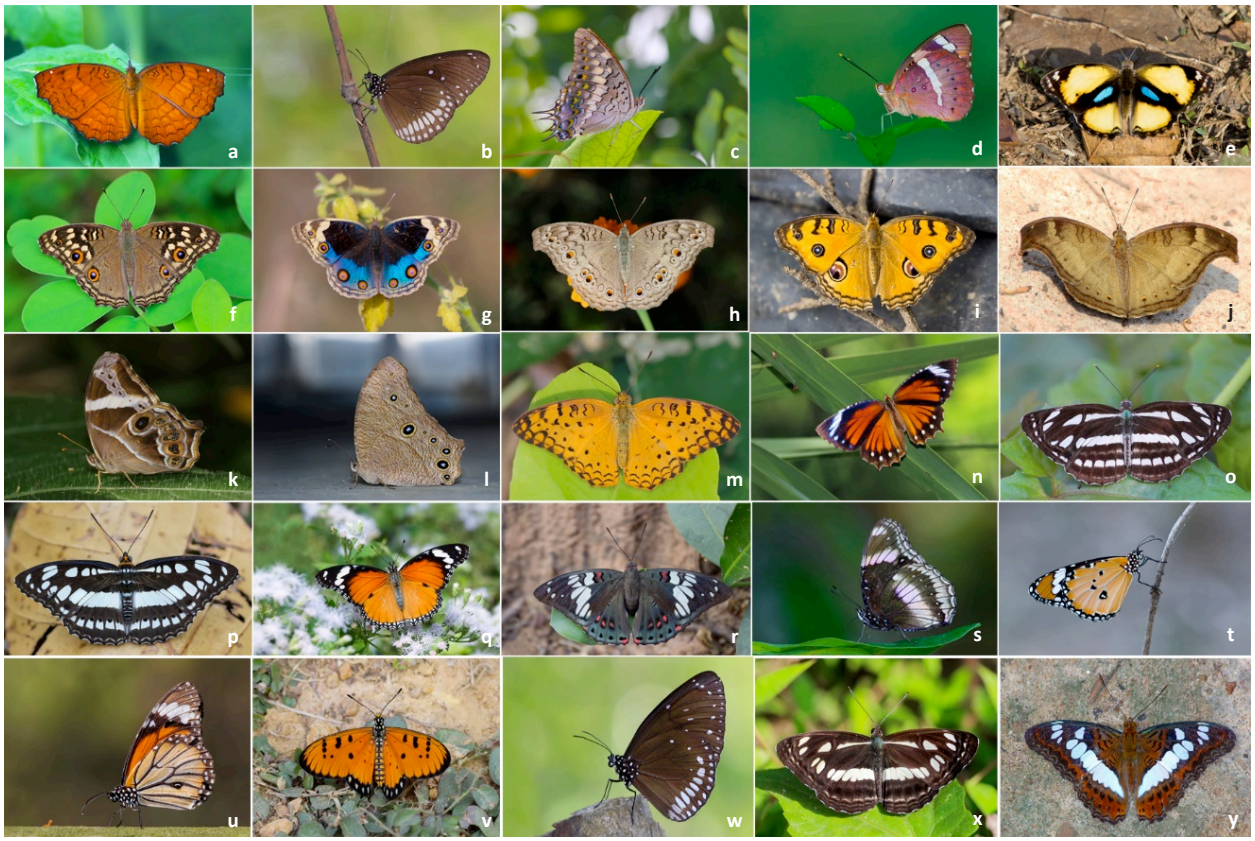

Image 2. Nymphalidae butterflies: a—Angled Castor | b—Common Crow | c—Black Rajah | d—Baronet | e—Yellow Pansy | f—Lemon Pansy | g—Blue Pansy | h—Grey Pansy | i—Peacock Pansy | j—Chocolate Pansy | k—Bamboo Tree Brown | l—Common Evening Brown | m—Common Leopard | n—Common Palmfly | o—Common Sailer | p—Common Sergeant | q—Danaid Eggfly | r—Gaudy Baron | s—Great Eggfly | t—Plain Tiger | u—Common Tiger | v—Tawny Coster | w—Brown King Crow | x—Chestnut Streaked Sailer | y—Commander. © Kalyan Mukherjee.

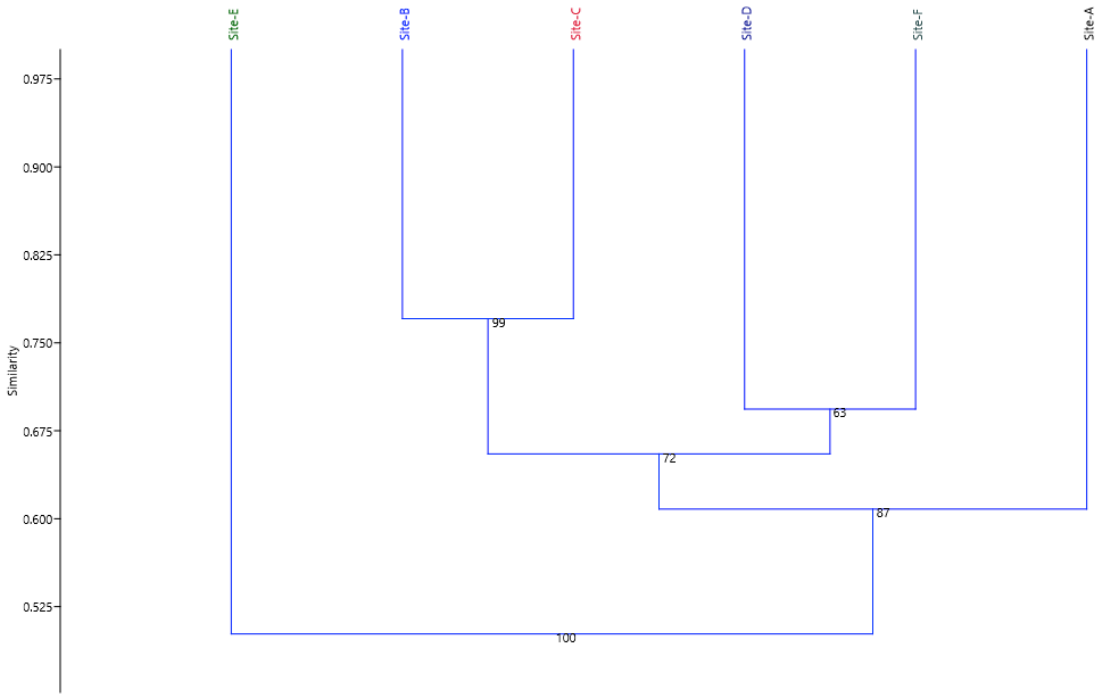

Figure 5. Hierarchical clustering using Bray-Curtis similarity index of studied sites.

Image 3. Lycaenidae butterflies: a—Plains Cupid | b—Red Flash | c—Silverstreak Blue | d—Slate Flash | e—Quaker | f—Zebra Blue | g—Tiny Grass Blue | h—Pale Grass Blue | i—Pea Blue | j—Pointed Ciliate Blue | k—Dark Grass Blue | l—Forget Me Not | m—Indian Sunbeam | n—Grass Jewel | o—Gram Blue | p—Bright Babul Blue | q—Guava Blue | r—Common Lineblue | s—Common Pierrot | t—Dark Cerulean | u—Apefly | v—Tailless Lineblue | w—Yamfly | x—Common Cerulean | y—Common Silverline. © Kalyan Mukherjee.

Table 3. Site-wise diversity and evenness indices.

	Site A	Site B	Site C	Site D	Site E	Site F
Taxa_S	91	76	73	65	78	67
Individuals	3256	3078	3413	1146	867	1937
Dominance_D	0.03756	0.0485	0.04168	0.06532	0.04768	0.06198
Simpson_1-D	0.9624	0.9515	0.9583	0.9347	0.9523	0.938
Shannon_H	3.698	3.419	3.479	3.217	3.595	3.303
Evenness_e^H/S	0.4435	0.4018	0.4442	0.384	0.4671	0.4059
Brillouin	3.638	3.367	3.432	3.118	3.441	3.234
Menhinick	1.595	1.37	1.25	1.92	2.649	1.522
Margalef	11.13	9.338	8.85	9.086	11.38	8.72
Equitability_J	0.8198	0.7894	0.8109	0.7707	0.8253	0.7856
Berger-Parker	0.09214	0.09942	0.07559	0.1745	0.1153	0.1719

of associated species composition after then D and F, these two-cluster associated with each other 73 percent similarity. Conjugated cluster of Site-B, C, D, and F are linked with A and E shows low level of similarity with rest of the cluster (Figure 5).

DISCUSSION

Butterfly diversity in different sites of this district helps to visualize the habitat heterogeneity; that indicates spatial distribution of host plant and nectaring plant along the landscape (Harrington & Stork 1995; Öckinger

Image 4. Hesperiidae butterflies: a—Brown Awl | b—Chestnut Bob | c—Tree Flitter | d—Indian Skipper | e—Complete Paint Brush swift | f—Common Red Eye | g—Common Grass Dart | h—Common Small Flat | i—Dark Palm Dart | j—Pale Palm Dart | k—Golden Angle | l—Grass Demon. © Kalyan Mukherjee.

Table 4. Correlation matrix among butterfly families and environmental factors.

	Nyphalidae	Papilionidae	Lycaenidae	Pieridae	Hesperiidae	Temp.	Humidity	Clam Wind	Rainfall
Nyphalidae	1.00								
Papilionidae	0.85	1.00							
Lycaenidae	0.88	0.83	1.00						
Pieridae	0.62	0.61	0.79	1.00					
Hesperiidae	0.69	0.59	0.83	0.80	1.00				
Temparature	0.01	-0.03	0.13	-0.02	0.08	1.00			
Humidity	-0.84	-0.72	-0.66	-0.35	-0.43	0.05	1.00		
Clam Wind	-0.23	-0.01	-0.15	0.11	-0.08	-0.65	0.24	1.00	
Rainfall	-0.55	-0.54	-0.49	-0.32	-0.38	0.43	0.68	-0.32	1.00

& Smith 2006; Öckinger et al. 2006, 2009; Mukherjee & Ghosh 2018). Being a good indicator of the health of an ecosystem (Stefanescu et al. 2004), richness of data of some distinct species found in different geographical area will help us to get an overview about the habitat of concerned locality. Generally, we can say among six studied sites, equitability index shows a similar pattern while Simpson 1-D and dominance index state that very few dominant species were present. Besides that, Shannon, Brillouin, and Menhinnick indices show little variability in those sites. High diversity of nymphalids and lycaenids in our data is consistent with other study on butterfly diversity (Dronamraju 1960; Roy et al 2012; Harsh 2014; Mukherjee et al 2015). Number of species and average individual number shows most ambiguous result in case of Site F. But this could be easily explained by the habitat characteristics of that site. This site mostly covered by dense forest. Probably we found lowest number of individuals per species here due to visual barrier in dense forest; but comparatively species number were higher due to presence of various types of host plant in forested area. Among 28 rare species Red

Image 5. Pieridae butterflies: a—Chocolate Albatross | b—White Orange Tip | c—Yellow Orange Tip | d—Pioneer | e—Striped Albatross (Male) | f—Striped Albatross (Female) | g—Common Gull | h—Common Grass yellow | i—Indian Jezebal | j—Common Wanderer (Male) | k—Common Wanderer Female | l—Mottled Emigrant (Male) | m—Psyche | n—Spotless Grass Yellow | o—Common Emigrant | p—Mottled Emigrant (Female). © Kalyan Mukherjee.

Image 6. Papilionidae butterflies: a—Blue Mormon | b—Common Banded Peacock | c—Common Jay | d—Common Mime | e—Common Mormon | f—Tailed Jay | g—Lime | h—Common Rose | i—Red Helen. © Kalyan Mukherjee.

Image 7. Riodinidae butterfly: Double Banded Judy.

Helen *Papilio helenus* and Chocolate Albatross *Appias lyncida* were just seen for couple of times.

Result of individual rarefaction analysis indicates that highest number of taxa could be found in Site C that contains a mixed habitat and landscape (Table 1). In contrast site B required more specimen than other sites to cover all the found taxa. Significant seasonal and site wise variation in species assemblage number were seen during the study period. Cluster analysis result shows hill region Site E is much distinct than other sites. Site-D and F were in plateau region, also clustered with 63% similarity; this is due to differences in habitat quality and type. It is indicating that altitude and landscape are not only determines species assemblage similarity, but habitat type and quality also effect on it. Site-B and C are representative of fringe region of plateau and makes a cluster with highest level of similarity. These two-cluster linked with each other with 72% similarity and the joined cluster linked with Site A, that is plains with totally different types of habitat. Family Nymphalidae, Papilionidae, and Lycaenidae negatively correlated with humidity. No noteworthy correlation found with temperature and clam wind; families Nymphalidae and Papilionidae shows moderately correlated with rainfall.

CONCLUSION

Butterfly diversity significantly changes throughout habitat and landscape type change. The rich diversity of butterflies, especially the nymphalids and lycaenids in the study area indicates a varied assemblage of floral species. Many rare species also indicating that some preferred habitat is in peril. Probability of getting high individual in fringe region of plateau as well as junction of two different landscape plain and plateau ecologically that can be stated as ecotone clearly shows the edge effect that is consistent with robust ecological theoretical concept. Plain, fringe region, plateau and hill region showing sharp differences among species richness and habitat quality through cluster analysis. Forested habitat shows high species with low number of individual, so it may harbour much more unexplored species. Being potential pollinating agents of their nectar plants as well as indicators of the health and quality of their host plants and the ecosystem as a whole, exploration of butterfly fauna thus becomes important in identifying and preserving various habitats under threat.

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