Article

An inventory of butterfly species in relation to food sources and climatic factors influencing their diversity and richness in a semi-evergreen forest of Bangladesh

Md. Ashraf Ul Hasan[1], **Sufia Akter Neha**[1], **Mohammad Abdul Baki**[1], **Mohammad Quamruzzaman Babu**[2]

[1]Department of Zoology, Jagannath University, Dhaka-1100, Bangladesh

[2]House-25, Road-18, Sector-11, Uttara-1230, Dhaka, Bangladesh

E-mail: sazzad.jnu403@gmail.com

Received 15 April 2018; *Accepted 28 May 2018*; *Published 1 September 2018*

Abstract

An inventory of butterfly species in relation to food sources and climatic factors influencing their diversity and richness was studied from March 2015 to February 2017 in Satchari National Park. We recorded 195 butterfly species representing 125 genera under 21 subfamilies and 6 families. Nymphalidae was the more dominant family contributed 32.8% of the total species followed by Lycaenidae (25.7%), Hesperiidae (24.6%), Pieridae (8.2%), Papilionidae (7.7%) and Riodinidae (1.0%). The highest species diversity and richness were reported from pre-monsoon. Out of 195 species identified in the Satchari National Park, 79 species (40.5%) were observed sipping out only nectar from different flower sources while others obtained their food from both floral and non-floral resources such as puddles, excreta, carrion, rotten fruit and blood of vertebrates. Highest number of butterflies were documented from *Lantana camara* (73) followed by *Chromolaena odorata* (60), *Leea indica* (30), *Tridax procumbens* (23) and *Mikania micrantha* (15) respectively. The butterflies were most frequently attracted to white flowers (52.2%) during nectar feeding. Temperature was positively correlated with the total number of species (r=0.417, p=0.04) whereas rainfall and humidity were negatively correlated with the total number of species (r=-0.43, p=0.03 and r=-0.50, p=0.01).

Keywords butterfly; diversity; richness; food sources; climatic factors; semi-evergreen forest.

Arthropods
ISSN 2224-4255
URL: http://www.iaees.org/publications/journals/arthropods/online-version.asp
RSS: http://www.iaees.org/publications/journals/arthropods/rss.xml
E-mail: arthropods@iaees.org
Editor-in-Chief: WenJun Zhang
Publisher: International Academy of Ecology and Environmental Sciences

1 Introduction

Butterflies are the scaly winged creatures under the Order Lepidoptera of the Class Insecta. There are about 15,000-16,000 species of butterflies found from all over the world (Perveen and Ahmad, 2012a), however, a total of 305 species of butterflies belonging to 10 families have been reported from Bangladesh (IUCN Bangladesh, 2015). They are the major key to biodiversity studies as well as taxonomy, geographic

distribution and the conservation status of butterfly species. Moreover, butterflies are the biological indicators of habitat feature along with the environmental health and beauty (Larsen, 1988; Kocher and Williams, 2000; Sawchik et al., 2005; Perveen and Fazal, 2013), as several species are strictly seasonal and favor only particular place of habitats (Kunte, 1997). Butterflies are significant benchmarks of an ecosystem, because they are diverse, can be easily observed, captured, identified, and manipulated by researchers (Mielke and Casagrande, 1997). Although they are aesthetically and economically important species (Perveen and Ahmad, 2012a), their larvae damages crops (Gardiner et al., 2005). Butterflies are recognized as effective pollinators and thereby contribute to forest regeneration (Perveen and Ahmad, 2012b). They are extant throughout the year, and exhibit rapid responses regarding environmental disturbances (Öckinger et al., 2006).

Butterflies are available in terrestrial natural ecosystems (Daniels et al., 2014). The butterfly fauna in northeastern part of Bangladesh is relatively rich and diverse in contrast to the other parts of butterfly occupying habitat due to elevational gradients and microclimatic regimes. Satchari National Park is a tropical semi-evergreen forest in the northeast Bangladesh that harbor 245 angiosperm species (Arefin et al., 2011), 9 amphibians, 45 reptiles, 212 birds and 49 mammals (Choudhury et al., 2004). Additionally, the forest is home to a number of endangered species including Hoolock Gibbon (*Hoolock hoolock*), Phayre's Leaf Monkey (*Trachypithecus phayrei*), Asian Black Bear (*Ursus thibetanus*) and Fishing Cat (*Prionailurus viverrinus*). The habitat of this forest confirms the favorable environment of butterfly diversity. However, there is a significant study gap on butterflies in this habitat due to lack of surveys.

The diversity of butterflies for particular habitat is strongly interlinked with the availability of food sources (Shihan and Kabir, 2015). The food sources may often be the crucial factor influencing the distribution, abundance and movement of animals (Nimbalkar et al., 2011). Butterflies are often considered as opportunistic foragers that obtain their nutrients from a wide variety of food sources like nectar plant, puddles, carrion and excreta (Norris, 1936; Dosa, 1999). However, their choice of visiting the food sources is not random and sometimes depends on the various factors including color, odor and relative abundance of the food (Porter et al., 1992).

Seasonal variations of butterflies are regulated by environmental factors like temperature, humidity, rainfall, availability of food sources, and types of vegetation such as herbs, shrubs and trees (Tiple et al., 2007; Anu et al., 2009; Shanthi et al., 2009). Butterflies have exhibited increased sensitivity and responses to climatic fluctuations, which demonstrate a strong and direct influence on their development, reproduction and survival (McLaughlin et al., 2002; Ward and Masters, 2007). The rapid changes of these climatic variables may affect the diversity and richness of butterflies. Few works have been done on the checklist of butterflies in different region of Bangladesh, such as Alam and Ullah (1995), Hossain et al. (2003), Khan and Islam (2001), Islam et al. (2011), Hossain (2014), and Khandokar et al. (2014). No work has been done on the impact of abiotic factors in butterfly species availability in Bangladesh except Islam et al. (2013), which makes the study concentrating on compiling the list of butterfly species and correlating with the environmental factors. Since the study period covered all three seasons (pre-monsoon, monsoon and post-monsoon), a distinct climatological differences was recorded which led to a correlational findings of different climatological aspects with the diversity and richness of different species of butterflies.

Therefore, the prime objectives of the present study was to annotate an inventory of butterfly population in the Satchari National Park; to study the food sources relative to the occurrence of butterflies; and to evaluate the relationship between different climatic factors and butterfly population in the park. The findings from the previous work along with our current study will definitely enrich the checklist of butterflies of Bangladesh and will pave the way to initiate conservation interventions. We hope that this work will provide a baseline information on the populations of butterflies that helps in documenting the rich biodiversity of Satchari

National Park.

2 Material and Methods

The study was carried out from March 2015 to February 2017. Data were collected based on monthly 5 days fieldworks but deviations from this plan did occur due to unavoidable reasons. The butterflies were monitored during sunny day hours (07:00-16:00 hr). The study period was categorized in three seasons, viz. pre-monsoon (March - June), monsoon (July - October) and post-monsoon (November - February).

2.1 Study site

Satchari National Park (24°7'25.65"N 91°27'5.43"E) is a tropical semi-evergreen forest situated in the northeastern part of Bangladesh. This national park contains a partial transition zone between the Indian sub-continent and Indo-Chinese ecological region (Sharma, 2006). The area of the park is about 243 hectares and is comprised of the Raghunandan Hills Reserve Forests within the Satchari Range. It is bordered on the north-western part by Raghunandan hill reserved forest and on the south by India; other adjoining areas are covered by tea gardens, oil palm trees, lemon gardens, rubber and agricultural fields. The soil texture in general is sandy loam to silty clay and more acidic than the adjacent ecological zones (Choudhury et al., 2004; Uddin et al., 2013). The altitude is generally low with hilltops reaching 104 m above sea level and increasing towards India with elevation reaching 144 m above sea level beyond the border (Uddin et al., 2013). The vegetation type of Satchari National Park is mixed evergreen, with several species of timber, bamboo, grasses, fruits and fodder species (Sultana, 2007). The majority of the smaller understory trees are evergreen and the large dominant trees are deciduous. The climate is generally warm and humid but is cool during the winter. There about 24 families of Tipra tribe are living in the forest. These tribal people used to practice jhum in the forests but this was banned in the early 1980s.

2.2 Data collection and identification of butterflies

The butterflies were observed using Pollard Walk method (Pollard, 1977; Pollard and Yates, 1993) while walking through the roads, streams, forest trails and along the village of the study area. The butterflies were recorded along the route on a regular basis under reasonable weather conditions. Transects were typically about 1-2 km long with a fixed width of 10 m. Transect routes were chosen randomly across all habitat types. Butterflies while collecting nectar and puddling on mud, excreta, carrion, and rotten fruits were also noted. Periodic flower production of the nectar plants or phenology in the study area were also studied in transects in each month.

Butterflies were identified with the help of field guides by Evans (1927) and Kehimkar (2008). Butterflies were photographed by Canon DSLR 600D and 55-250 mm lens for further identification. In some cases, butterflies were captured that could not be identified directly by using insect collecting net. All scientific names and common names follow Larsen (2004) and Kunte (2000). Classification of butterflies is after Wynter-Blyth (1957). Nectar plants were identified by Pasha and Uddin (2013), Arefin et al. (2011) and Mukul et al. (2007). Weather parameters (temperature, humidity and rainfall) of the study area were recorded using AcuRite 01098R Weather Station.

2.3 Data analysis

The diversity indices of butterfly abundance were analyzed seasonally.

2.3.1 Shannon-Weiner Index (H′)

This index (Shannon and Weiner, 1948; Magurran, 1988, 2004) addresses species diversity among different seasons during the study period.

$H' = - \sum pi \times \ln pi$

Where, Pi is the proportion of species records of the ith species in the total sample.

2.3.2 Pielou's Evenness Index (J′)

This evenness index (Pielou, 1969; Magurran, 1988, 2004) represents the relative abundance of species in the study area.

$J' = H'/\ln S$

Where, S is the number of species observed in different seasons. The J values are in the range from 0 to 1.

2.3.3 Simpson's Dominance Index (D)

This index (Simpson, 1949) determines the proportion of more dominant species in an area. As species richness and evenness increase, the diversity also increases.

$D=1- \{\sum n(n-1)/N(N-1)\}$

Where, n is the total number of individuals of a particular species and N is the total number of individuals of all species. This index ranges between 0 and 1 where, 1 constitutes infinite diversity and 0, no diversity.

2.3.4 Margalef's Species Richness (D_{Mg})

This index compares the species richness found in a sample across seasons (Magurran, 1988, 2004).

$D_{Mg} =(S-1)/ \ln N$

Where, S is the number of species recorded and N is the total number of individuals in the sample.

2.3.5 Pearson correlation coefficient

This correlation (Zhang and Li, 2015; Zhang, 2018) was calculated to test the relationship between monthly recorded species, mean temperature, humidity and rainfall.

The data were analyzed using Microsoft Excel (2013) and R statistical software [3.4.0, R Core Team 2017].

3 Results

3.1 Species composition

A total of 3138 individuals belonging to 195 species under 125 genera in 21 subfamilies and 6 families were recorded during the study period (Table 1). The Nymphalidae was the more dominant family contributed 32.8% (n=64) of the total species followed by Lycaenidae 25.7% (n=50), Hesperiidae 24.6% (n=48), Pieridae 8.2% (n=16), Papilionidae 7.7% (n=15) and Riodinidae 1.0% (n=2) (Table 1). Among 195 species, a large proportion of the butterflies (47.7%, n=93) were locally threatened (EN and VU) (Table 2).

Butterfly diversity was greatly influenced by seasons. Species diversity, dominance, richness and evenness varied between different seasons as shown in the Table 3. The diversity indices indicate that the moderate level of species diversity but appears to be much greater species richness with the highest peak in pre- monsoon and lowest in monsoon.

Table 1 Family wise composition of butterflies exhibiting the total number of genera, species and individuals.

No.	Family	Sub-family	Genus	Species	Total no. of individuals
1	Papilionidae	1	7	15	380
2	Pieridae	2	9	16	342
3	Lycaenidae	4	34	50	739
4	Hesperiidae	3	36	48	527
5	Nymphalidae	10	37	64	1068
6	Riodinidae	1	2	2	82
Total	6	21	125	195	3138

Table 2 A checklist of butterfly species recorded in Satchari National Park during March 2015 to February 2017 with their local status.

No.	Common Name	Scientific Name	Local Status
Family: Papilionidae			
Sub-family: Papilioninae			
1	Common Birdwing	*Troides helena* (Felder & Felder, 1865)	VU
2	Common Rose	*Pachliopta aristolochiae* (Fabricius, 1775)	LC
3	Common Mormon	*Papilio polytes* (Cramer, 1775)	LC
4	Blue Mormon	*Papilio polymnestor (Cramer, 1775)*	LC
5	Great Mormon	*Papilio memnon* (Linne, 1758)	LC
6	Common Batwing	*Atrophaneura varuna* (Westwood, 1842)	EN
7	Lesser Batwing	*Atrophaneura aidoneus* (Doubleday, 1845)	Not Evaluated
8	Red Helen	*Papilio helenus* (Linne, 1758)	VU
9	Yellow Helen	*Papilio chaon* (Westwood, 1845)	VU
10	Lime Butterfly	*Papilio demoleus* (Linne, 1758)	LC
11	Five-Bar Swordtail	*Pathysa antipathes* (Fabricius, 1787)	VU
12	Common Mime	*Chilasa clytia* (Linne, 1758)	LC
13	Common Bluebottle	*Graphium sarpedon* (Linne, 1758)	VU
14	Tailed Jay	*Graphium agamemnon* (Linne, 1758)	LC
15	Common jay	*Graphium doson* (Felder & Felder, 1864)	LC
Family: Pieridae			
Sub-family: Coliadinae			
16	Mottled Emigrant	*Catopsilia pyranthe* (Linne, 1758)	LC
17	Lemon Emigrant	*Catopsilia pomona* (Fabricius, 1775)	LC
18	Three-Spot Grass Yellow	*Eurema blanda* (Wallace, 1867)	LC
19	Common Grass Yellow	*Eurema hecabe* (Linne, 1758)	LC
20	One-spot Grass Yellow	*Eurema andersoni* (Corbet & Pendlebury, 1932)	LC
21	Tree Yellow	*Gandaca harina* (Moore, 1906)	EN
Sub-family: Pierinae			
22	Chocolate Albatross	*Appias lyncida* (Boisduval, 1836)	LC
23	Striped Albatross	*Appias olferna* (Swinhoe, 1890)	LC
24	Common Wanderer	*Pareronia hippia* (Fabricius, 1787)	VU
25	Giant Orange Tip	*Hebomoia glaucippe* (Linne, 1758)	Not Evaluated
26	Psyche	*Leptosia nina* (Fabricius, 1793)	LC
27	Common Jezebel	*Delias eucharis* (Drury, 1773)	LC
28	Painted Jezebel	*Delias hyparete* (Wallace, 1867)	LC
29	Red-Spot Jezebel	*Delias descombesi* (Boisduval, 1836)	LC
30	Red-Base Jezebel	*Delias pasithoe* (Linne, 1767)	LC
31	Common Gull	*Cepora nerissa* (Fabricius, 1775)	LC
Family: Lycaenidae			
Sub-family: Polyommatinae			
32	Dark Grass Blue	*Zizeeria karsandra* (Moore, 1865)	LC
33	Pale Grass Blue	*Pseudozizeeria maha* (Kollar, 1848)	LC
34	Tiny Grass Blue	*Zizula hylax* (Fabricius, 1775)	LC
35	Lesser Grass Blue	*Zizeeria otis* (Fabricius, 1787)	LC
36	Lime Blue	*Chilades lajus* (Stoll, 1870)	LC
37	Gram Blue	*Euchrysops cnejus* (Fabricius, 1798)	LC
38	Zebra Blue	*Leptotes plinius* (Fabricius, 1793)	LC
39	Plains Cupid	*Chilades pandava* (Horsfield, 1829)	LC
40	Tailless Lineblue	*Prosotas dubiosa* (Evans, 1925)	VU
41	Common Lineblue	*Prosotas nora* (Moore, 1875)	EN
42	Teesta Brown Lineblue	*Prosotas lutea* (Evans, 1910)	EN
43	Transparent Six-Lineblue	*Nacaduba kurava* (Fruhstorfer, 1916)	Not Evaluated
44	Pale Four-Lineblue	*Nacaduba hermus* (Fruhstorfer, 1916)	Not Evaluated

45	pointed Lineblue	*Ionolyce helicon* (Moore, 1884)	DD
46	Common Ciliate Blue	*Anthene emolus* (Godart, 1823)	VU
47	Pointed Ciliate Blue	*Anthene lycaenina* (Felder, 1868)	EN
48	Common Pierrot	*Castalius rosimon* (Fabricius, 1775)	LC
49	Angled Pierrot	*Caleta decidia* (Hewitson, 1876)	LC
50	Banded Blue Pierrot	*Discolampa ethion* (Westwood, 1851)	VU
51	Veined Pierrot	*Tarucus venosus* (Moore, 1882)	Not Evaluated
52	Dark Pierrot	*Tarucus nara* (de Niceville, 1884)	Not Evaluated
53	Common Cerulean	*Jamides celeno* (Cramer, 1775)	LC
54	Dark Cerulean	*Jamides bochus* (Stoll, 1782)	VU
55	Metallic Cerulean	*Jamides alecto* (Fruhstorfer, 1916)	LC
56	Malayan	*Megisba malaya* (Moore, 1884)	EN
57	Forget-Me-Not	*Catochrysops strabo* (Fabricius, 1793)	VU
58	Silver Forget-Me-Not	*catochrysops panormus* (Felder, 1860)	Not Evaluated
59	Purple Sapphire	*Heliophorus epicles* (Godart, 1823)	VU
60	Common Quaker	*Neopithecops zalmora* (Butler, 1870)	LC
Sub-family: Theclinae			
61	Yellowdisc Tailless Oakblue	*Arhopala perimuta* (Moore, 1858)	EN
62	Falcate Oakblue	*Mahathala ameria* (Hewitson, 1862)	VU
63	Common Acacia Blue	*Surendra quercetorum* (Moore, 1857)	EN
64	Silver Streaked Acacia Blue	*Zinaspa todara* (de Niceville, 1887)	Not Evaluated
65	Yamfly	*Loxura atymnus* (Fruhstorfer, 1911)	VU
66	Chocolate Royal	*Remelana jangala* (Moore, 1865)	VU
67	Common Tit	*Hypolycaena erylus* (Fruhstorfer, 1912)	VU
68	Orchid Tit	*Chliaria othona* (Hewitson, 1865)	VU
69	Cornelian	*Deudorix epijarbas* (Fruhstorfer, 1912)	Not Evaluated
70	Slate Flash	*Rapala manea* (Hewitson, 1863)	LC
71	Copper Flash	*Rapala pheretima* (Hewitson, 1863)	VU
72	Red Flash	*Rapala iarbus* (Kollar, 1848)	VU
73	Suffused Flash	*Rapala suffusa* (Moore, 1883)	Not Evaluated
74	Assam Flash	*Rapala tara* (de Niceville, 1888)	Not Evaluated
75	Common Tinsel	*Catapaecilma major* (Druce, 1895)	EN
76	Common Silverline	*Spindasis vulcanus* (Fabricius, 1775)	LC
77	Club Silverline	*Spindasis syama* (Horsfield, 1829)	VU
78	Long Banded Silverline	*Spindasis lohita* (Moore, 1884)	VU
Sub-family: Miletinae			
79	Common Mottle	*Miletus chinensis* (Doherty, 1891)	EN
80	Apefly	*Spalgis epeus* (Westwood, 1851)	EN
Sub-family: Curetinae			
81	Indian Sunbeam	*Curetis thetis* (Drury, 1773)	LC
Family: Hesperiidae			
Sub-family: Pyrginae			
82	Common Snow Flat	*Tagiades japetus* (Moore, 1865)	VU
83	Suffused Snow Flat	*Tagiades gana* (Plotz, 1884)	VU
84	Water Snow Flat	*Tagiades litigiosa* (Moschler, 1878)	EN
85	Common Small Flat	*Sarangesa dasahara* (Moore, 1865)	VU
86	Common Spotted Flat	*Celaenorrhinus leucocera* (Kollar, 1848)	Not Evaluated
87	Fulvous Pied Flat	*Pseudocoladenia dan* (Evans, 1949)	EN
88	Tricolor Pied Flat	*Coladenia indrani* (Moore, 1865)	Not Evaluated
89	Fulvous Dawnfly	*Capila phanaeus* (Evans, 1949)	Not Evaluated
90	Chestnut Angle	*Odontoptilum angulata* (Felder, 1862)	LC
Sub-family: Hesperiinae			
91	Chestnut Bob	*Iambrix salsala* (Moore, 1865)	LC
92	Grass Bob	*Suada swerga* (de Niceville, 1883)	Not Evaluated
93	Indian Palm Bob	*Suastus gremius* (Fabricius, 1798)	EN

94	Rice Swift	*Borbo cinnara* (Wallace, 1866)	LC
95	Straight Swift	*Parnara guttatus* (Moore, 1865)	LC
96	Ceylon Swift	*Parnara bada* (Moore, 1878)	EN
97	Conjoined Swift	*Pelopidas conjuncta* (Herrich- Schaffer, 1869)	LC
98	Bengal Swift	*Pelopidas agna* (Moore, 1865)	LC
99	Complete Paint-brush Swift	*Baoris farri* (Moore, 1878)	Not Evaluated
100	Black Paint-brush Swift	*Baoris unicolor* (Moore, 1883)	EN
101	Small Paint-brush Swift	*Baoris chapmani* (Evans, 1937)	VU
102	Banana Skipper	*Erionota thrax* (Linnaeus, 1767)	EN
103	Common Redeye	*Matapa aria* (Moore, 1865)	LC
104	Black-veined Branded Redeye	*Matapa sasivarna* (Moore, 1865)	VU
105	Giant Redeye	*Gangara thyrsis* (Fabricius, 1775)	VU
106	Common Dart	*Potanthus pseudomaesa* (Moore, 1881)	Not Evaluated
107	Common Grass Dart	*Taractrocera maevius* (Fabricius, 1793)	Not Evaluated
108	Wax Dart	*Cupitha purreea* (Moore, 1877)	EN
109	Pale Palm Dart	*Telicota colon* (Fabricius, 1775)	Not Evaluated
110	Dark Palm Dart	*Telicota bambusae* (Moore, 1878)	VU
111	Common Dartlet	*Oriens gola* (Mabille, 1883)	LC
112	Forest Hopper	*Astictopterus jama* (Moore, 1878)	LC
113	Pygmy Scrub Hopper	*Aeromachus pygmaeus* (Fabricius, 1775)	VU
114	Narrow-Banded Velvet Bob	*Koruthaialos rubecula* (Evans, 1949)	EN
115	Tree Flitter	*Hyarotis adrastus* (Moore, 1865)	VU
116	Common Wight	*Iton semamora* (Moore, 1866)	EN
117	Coon	*Sancus fuligo* (Moore, 1878)	EN
118	Grass Demon	*Udaspes folus* (Cramer, 1775)	LC
119	Restricted Demon	*Notocrypta curvifascia* (Felder, 1862)	EN
120	Spotted Demon	*Notocrypta feisthamelii* (Moore, 1865)	Not Evaluated
121	Common Banded Demon	*Notocrypta paralysos* (Fruhstorfer, 1911)	LC
122	Chocolate Demon	*Ancistroides nigrita* (Moore, 1865)	Not Evaluated
123	Moore's Ace	*Halpe porus* (Mabille, 1876)	VU
Sub-family: Coeliadinae			
124	Indian AwlKing	*Choaspes benjaminii* (Fruhstorfer, 1911)	EN
125	Small Green Awlet	*Bibasis amara* (Moore, 1865)	EN
126	Branded Orange Awlet	*Bibasis oedipodea* (Mabille, 1883)	Not Evaluated
127	Common Awl	*Hasora badra* (Moore, 1858)	VU
128	Common Banded Awl	*Hasora chromus* (Cramer, 1782)	EN
129	Brown Awl	*Badamia exclamationis* (Fabricius, 1775)	VU
Family: Nymphalidae			
Sub-family: Danainae			
130	Common Crow	*Euploea core* (Cramer, 1780)	LC
131	Blue-spotted Crow	*Euploea midamus* (Felder & Felder, 1865)	EN
132	Blue King Crow	*Euploea klugii* (Moore, 1858)	VU
133	Long-Branded Blue Crow	*Euploea algea* (Westwood, 1848)	EN
134	Striped Tiger	*Danaus genutia* (Cramer, 1779)	LC
135	Plain Tiger	*Danaus chrysippus* (Linnaeus, 1758)	LC
136	Blue Tiger	*Tirumala limniace* (Gmelin, 1790)	LC
137	Glassy Tiger	*Parantica aglea* (Moore, 1883)	VU
Sub-family: Satyrinae			
138	Common Palmfly	*Elymnias hypermnestra* (Drury, 1773)	LC
139	Spotted Palmfly	*Elymnias malelas* (Hewitson, 1865)	EN
140	Tiger Palmfly	*Elymnias nesaea* (Wallace, 1869)	EN
141	Common Four -Ring	*Ypthima huebneri* (Kirby, 1871)	LC
142	Common Five-Ring	*Ypthima baldus* (Fabricius, 1775)	VU
143	Common Bushbrown	*Mycalesis perseus* (Fabricius, 1798)	VU
144	Intermediate Bushbrown	*Mycalesis intermedia* (Moore, 1891)	Not Evaluated

145	Long-Brand Bushbrown	*Mycalesis visala* (Moore, 1857)	VU
146	Dark-Brand Bushbrown	*Mycalesis mineus* (Linne, 1767)	LC
147	Bamboo Treebrown	*Lethe europa* (Fruhstorfer, 1911)	VU
148	Oriental Medus Brown	*Orsotriaena medus* (Fabricius, 1775)	VU
149	Common Evening Brown	*Melanitis leda* (Linne, 1758)	LC
150	Dark Evening Brown	*Melanitis phedima* (Moore, 1857)	VU
151	Common Red Forester	*Lethe mekara* (Fruhstorfer, 1911)	EN
152	Tailed Red Forester	*Lethe sinorix* (Hewitson, 1863)	DD
Sub-family: Morphinae			
153	Common Duffer	*Discophora sondaica* (Westwood, 1851)	LC
Sub-family: Charaxinae			
154	Common Nawab	*Polyura athamas* (Drury, 1770)	LC
155	Jewelled Nawab	*Polyura delphis (Doubleday*, 1843*)*	EN
156	Black Rajah	*Charaxes solon* (Rothschild & Jordan, 1898)	VU
157	Tawny Rajah	*Charaxes psaphon* (Butler, 1870)	EN
Sub-family: Nymphalinae			
158	Common Jester	*Symbrenthia lilaea* (Moore, 1874)	EN
159	Orange Oakleaf	*Kallima inachus* (Boisduval, 1846)	EN
160	Great Eggfly	*Hypolimnas bolina* (Linne, 1758)	LC
161	Grey Pansy	*Junonia atlites* (Linne, 1763)	LC
162	Peacock Pansy	*Junonia almana* (Linne, 1758)	LC
163	Yellow Pansy	*Junonia hierta* (Fabricius, 1793)	LC
164	Blue pansy	*Junonia orithya* (Hubner, 1816)	VU
165	Chocolate Pansy	*Junonia iphita* (Cramer, 1779)	LC
166	Lemon Pansy	*Junonia lemonias* (Linne, 1758)	LC
Sub-family: Biblidinae			
167	Common Castor	*Ariadne merione* (Moore, 1884)	LC
168	Angled Castor	*Ariadne ariadne* (Fruhstorfer, 1899)	LC
Sub-family: Limenitidinae			
169	Common Earl	*Tanaecia julii* (Menetries, 1857)	VU
170	Plain Earl	*Tanaecia jahnu* (Moore, 1857)	EN
171	Grey Count	*Tanaecia lepidea* (Butler, 1868)	VU
172	Common Baron	*Euthalia aconthea* (Moore, 1857)	LC
173	Powered Baron	*Euthalia monina* (Moore, 1859)	EN
174	Clipper	*Parthenos sylvia* (Fabricius, 1787)	VU
175	Knight	*Lebadea martha* (Fabricius, 1778)	VU
176	Commander	*Moduza procris* (Cramer, 1777)	LC
177	Common Sergeant	*Athyma perius* (Linne, 1758)	LC
178	Blackvein Sergeant	*Athyma ranga* (Moore, 1857)	VU
179	Color Sergeant	*Athyma inara* (Westwood, 1850)	VU
180	Common Sailer	*Neptis hylas* (Moore, 1872)	LC
181	Chestnut Streaked Sailer	*Neptis jumbah* (Moore, 1857)	LC
182	Short-Banded Sailer	*Phaedyma columella* (Moore, 1872)	Not Evaluated
183	Perak Lascar	*Pantoporia paraka (Butler, 1879)*	EN
184	Common Lascar	*Pantoporia hordonia* (Stoll, 1790)	VU
Sub-family: Heliconiinae			
185	Common Leopard	*Phalanta phalantha* (Drury, 1770)	LC
186	Leopard Lacewing	*Cethosia cyane* (Drury, 1773)	LC
187	Tawny Coster	*Acraea violae* (Fabricius, 1775)	LC
188	Common Yeoman	*Cirrochroa tyche* (Moore, 1872)	EN
189	Rustic	*Cupha erymanthis* (Sulzer, 1776)	LC
190	Cruiser	*Vindula erota* (Fabricius, 1793)	EN
191	Vagrant	*Vagrans sinha* (Kollar, 1848)	VU
Sub-family: Cyrestinae			
192	Common Map	*Cyrestis thyodamas* (Boisduval, 1836)	EN

Sub-family: Apaturinae			
193	Courtesan	*Euripus nyctelius* (Doubleday, 1845)	EN
Family: Riodinidae			
Sub-family: Nemeobiinae			
194	Punchinello	*Zemeros flegyas* (Cramer, 1780)	LC
195	Plum Judy	*Abisara echerius* (Moore, 1882)	EN

Table 3 Diversity indices in different seasons at Satchari National Park (March 2015-February 2017).

Diversity Indices	Pre-monsoon	Monsoon	Post-monsoon	Annual
Shannon-Weiner Index (H′)	2.76	2.19	2.45	2.47
Pielou's Evenness Index (J′)	0.52	0.41	0.46	0.46
Simpson's Dominance Index (D)	0.09	0.18	0.14	0.13
Margalef's Species Richness (D_{Mg})	14.91	9.31	12.17	12.13

Table 4 Nectar food plants of butterflies with their floral characteristics recorded in Satchari National Park during the study period.

Food sources of butterfly	Plant Type	Flower Color	Flowering Period	No. of species observed
Family: Acanthaceae				
Thunbergia grandiflora	Vine	Bluish white	April-October	3
Family: Amaranthaceae				
Achyranthes aspera	Herb	Reddish green	Throughout the year	8
Family: Annonaceae				
Artabotrys hexapetalus	Shrub	Yellow	April-July	1
Family: Apocynaceae				
Catharanthus roseus	Herb	Pink	Throughout the year	4
Tabernaemontana coronaria	Shrub	White	April-October	3
Alstonia scholaris	Tree	Greenish white	September-November	6
Family: Asteraceae				
Chromolaena odorata	Shrub	Pale pink	December-April	60
Tridax procumbens	Herb	Yellowish white	May-December	23
Spilanthes acmella	Herb	Yellow	July-December	13
Emilia sonchifolia	Herb	Pink	January-May	10
Mikania micrantha	Vine	Greenish white	June-September	15
Ageratum conyzoides	Herb	Pale pink, white	January-May	10
Family: Boraginaceae				
Heliotropium indicum	Herb	Pale pink, white	Throughout the year	9
Family: Caesalpiniaceae				
Caesalpinia pulcherrima	Shrub	Yellow, orange	April-July	4
Family: Costaceae				
Costus speciosus	Herb	White	August-October	3
Family: Dioscoreaceae				
Dioscorea sp.	Vine	White	February-April	2
Family: Euphorbiaceae				
Jatropha integerrima	Shrub	Red	Throughout the year	5
Euphorbia hirta	Herb	Reddish green	Throughout the year	2
Family: Lamiaceae				
Leucas aspera	Herb	White	March-April	4
Leucas zeylanica	Herb	White	March-May	4
Family: Leeaceae				

Leea indica	Shrub	Greenish white	February-May	30
Family: Malvaceae				
Urena lobata	Shrub	Pink	June-November	10
Sida acuta	Herb	Yellow	March-August	4
Family: Meliaceae				
Chukrasia tabularis	Tree	Yellow	June-October	4
Family: Mimosaceae				
Acacia pennata	Shrub	Pale yellow	September-February	8
Mimosa pudica	Herb	Pink	February-October	5
Family: Myrtaceae				
Syzygium cumini	Tree	Pale yellow	May-July	3
Family: Rhamnaceae				
Ziziphus oenoplia	Shrub	Greenish yellow	July-November	3
Family: Rubiaceae				
Ixora coccinea	Shrub	Reddish orange	Throughout the year	3
Mussaenda glabrata	Shrub	Golden orange	April-November	14
Spermacoce articularis	Herb	Pinkish white	October-December	5
Family: Rutaceae				
Citrus aurantiifolia	Shrub	Greenish white	February-June	5
Micromelum pubescens	Tree	White	March-June	7
Glycosmis pentaphylla	Shrub	White	April-September	2
Family: Sapindaceae				
Allophylus cobbe	Shrub	Yellowish white	April-July	3
Lepisanthes rubiginosa	Tree	White	December-March	5
Sapindus saponaria	Tree	White	May-October	2
Family: Scrophulariaceae				
Lindernia ciliata	Herb	Purple, white	September-November	3
Family: Verbenaceae				
Clerodendrum viscosum	Shrub	Pinkish white	November-April	8
Lantana camara	Shrub	Red, Yellow, Orange, Pink	Throughout the year	73
Stachytarpheta jamaicensis	Herb	Pinkish white	April-August	9
Tectona grandis	Tree	White	May-November	4
Lippia alba	Shrub	Pinkish white	Throughout the year	9
Vitex peduncularis	Tree	Yellowish	February-April	4
Family: Vitaceae				
Cayratia trifolia	Vine	Greenish white	Throughout the year	5
Family: Zingiberaceae				
Curcuma zedoaria	Herb	Purple	June-October	3

3.2 Nectar food sources

Among 195 butterfly species identified, 79 species were observed sipping out only nectar from different flower sources while others obtained their food from both floral and non-floral sources. A total of 46 nectar plants under 24 families were used as food. The nectar plants comprised of 8 species of trees, 17 species of herbs, 17 species of shrubs and 4 species of vines (Table 4). Highest number of butterflies were recorded from *Lantana camara* (73) followed by *Chromolaena odorata* (60), *Leea indica* (30), *Tridax procumbens* (23) and *Mikania micrantha* (15). The color and size of flowers were also influenced the butterfly species with the highest attraction to white flowers (52.2%) followed by yellow (21.7%), pink (17.4%) and orange/red (8.7%). Due to patchiness of the forest, flowers were found available throughout the year in different plants, however, flower production is related significantly to monthly rainfall ($r=0.68$, $df=22$, $p=0.03$).

3.3 Non-floral food sources

Puddling behavior is a conspicuous feature of the family Papilionidae, Lycaenidae and Nymphalidae. Overall

111 species of butterflies were seen mud puddling on wet soil, 49 species on dung or excreta and 4 on rotten fruit. Moreover, *Burara amara* and *Prosotas dubiosa* were observed obtaining nutrients from carrions, while only *Prosotas dubiosa* was seen to feed from blood of *Sus scrofa*.

3.4 Effects of climatic factors on butterfly diversity

The results showed that there was significant relationship between weather conditions and the number of species sighted in each month. Butterflies have shown positive correlation with the monthly average temperature and the number of species (r=0.417, df=22, p=0.04). Both monthly average humidity (r=-0.50, df=22, p=0.01) and rainfall (r=-0.43, df=22, p=0.03) were negatively correlated with the number of species found in that month.

4 Discussion

The butterfly fauna of the study area are very rich when compared to the butterfly fauna of different protected areas of northeast region of Bangladesh (Feeroz et al., 2011: 34 species in Rema Kalenga Wildlife Sanctuary; Shihan and Prodhan, 2014: 74 species in Rema Kalenga Wildlife Sanctuary; Khandokar et al., 2014: 159 species in Lawachara National Park; This study: 195 species in Satchari National Park). The higher richness of butterflies in the study area might be the adequate distribution of larval host plants and nectar plants, and also for favorable abiotic factors as these factors are strongly correlated with the butterfly diversity and richness (Wright et al., 1993; Gutierrez and Mendez, 1995; Brown and Freitas, 2000; Forister and Shapiro, 2003; Barlow et al., 2007; Menendez et al., 2007;). The dominance of Nymphalidae family may be characteristic to their being polyphagous, that supports these butterflies to live in a wide variety of habitats, and also because they are active fliers; forage in larger areas (Majumder et al., 2013).

Seasonal changes influence butterfly diversity and richness that are crucial to the population of the species (Fordyce and Nice, 2003). Seasonal inconsistence of butterflies are controlled by climatic factors, such as temperature, humidity, rainfall and productivity of the food sources, types of vegetation, e.g. herbs, shrubs and trees (Tiple et al., 2007; Anu et al., 2009; Islam et al., 2013). Butterfly richness was reported higher in between the wet and dry season (Wynter-Blyth 1957; Emmel and Leck, 1970) which is compatible with the present study as butterfly richness were highest in pre-monsoon (March-June) which was the transition period in between the wet (monsoon) and dry (post-monsoon) season. Butterfly diversity and richness could be related to the availability of food sources because flowering of plants had greater influence on seasons (Gutierrez and Mendez, 1995; Poulin et al., 1999). The number of flowering nectar plants in this study area peaked in the pre-monsoon and post-monsoon, e.g. *Chromolaena odorata*, *Alstonia scholaris*, *Leea indica*, *Citrus aurantiifolia*, *Spilanthes acmella*, *Emilia sonchifolia*, *Ageratum conyzoides* and *Clerodendrum viscosum*. The shrubs explicitly *Urena lobata*, *Mussaenda glabrata* and vines *Mikania micrantha*, *Thunbergia grandiflora* concentered butterflies particularly during monsoon.

Puddling behavior (mud, excreta, carrion) of butterflies are essential for sodium extraction; males usually appear to benefit from the sodium uptake through mud-puddling which enhance in reproductive success (Arms et al., 1974; Pivnick and McNeil, 1987; Molleman et al., 2005; Molleman and Midgley, 2009). Furthermore, sodium is pivotal for egg production (Pivnick and McNeil, 1987). Puddling could be an alternative feeding strategy to minimize competition for nectar (Boggs and Jackson, 1991). In addition, puddles, excreta and carrion provides proteins and amino acids other than sodium could be nutritionally important (Mevi-Schutz and Erhardt, 2003; Boggs and Dau, 2004).

Butterflies are very sensitive to changing of climatic factors, e.g. temperature, humidity and rainfall (Sparrow et al., 1994; Brown and Freitas, 2000; Fordyce and Nice, 2003; Zhang and Chen, 2011; Ojianwuna, 2015; Kumar et al., 2017). Temperature was positively correlated to the total number of butterfly species

which is comparable with Ojianwuna (2015) and Kumar et al. (2017). Higher temperature might influence butterfly life cycle, distribution and abundance (Roy et al., 2001). It has also impact on the fitness, migration, reproduction and ultimate survival of butterflies (Roy and Sparks, 2000; Memmott et al., 2007). Humidity and rainfall have significantly negative correlation with the total number of species in many studies (Moss and Pollard, 1993; Pollard et al., 1993) which was also in line with the present study. This might be related that heavy rainfall often accelerate the mortality of adult butterflies (Young, 1982). Moreover, butterflies are more active in sunny weather (Heinrich, 1986; Nylin, 1989; Pollard et al., 1995; Van Strien et al., 1997), so this may be a rationale that the number of butterfly species are antagonistically correlated with the humidity.

Acknowledgements

The authors would like to thank Dr. Md. Saiful Islam, Professor, Department of Zoology, Jagannath University, Dhaka, who had been a source of inspiration and for his timely guidance in the conduct of the study. Authors are also grateful to Isaac Kehimkar for stretching his hands to butterfly identification. We express our deep sense of gratitude to Nadim Parves for his invaluable assistance during the field work. We are also indebted to Late Munir Ahmed Khan, Range Officer, Satchari National Park for his advice and generous support in running the research. Words are not enough to express our heartfelt appreciation to the Tipra people for their immense support. No field work relating to this study would have been possible without the permission, help and cooperation of Forest Department, Dhaka, Bangladesh.

References

Alam MS, Ullah GMR. 1995. A checklist of butterflies of Chittagong University. Bangladesh Journal of Zoology, 23(1): 111-112

Anu A, Sabu TK, Vineesh PJ. 2009. Seasonality of litter insects and relationship with rainfall in a wet evergreen forest in south Western Ghats. Journal of Insect Science, 9: 46

Arefin KM, Rahman MM, Uddin ZM, Hassan AM. 2011. Angiosperm flora of Satchari National Park, Habiganj, Bangladesh. Bangladesh Journal of Plant Taxonomy, 18(2): 117-140

Arms K, Feeny P, Lederhouse RC. 1974. Sodium: stimulus for puddling behaviour by tiger swallowtail butterflies, *Papilio glaucus*. Science, 185(4148): 372-374

Barlow J, Overal WL, Araujo IS, Gardner TA, Peres CA. 2007. The value of primary, secondary and plantation forests for fruit-feeding butterflies in the Brazilian Amazon. Ecology, 44(5): 1001-1012

Boggs CL, Dau B. 2004. Resource specialization in puddling Lepidoptera. Environmental Entomology, 33(4): 1020-1024

Boggs CL, Jackson LA. 1991. Mud puddling of butterflies is not a simple matter. Environmental Entomology, 16(1): 123-127

Brown KS, Freitas A. 2000. Atlantic forest butterflies: indicators for landscape conservation. Biotropica, 32(4b): 934-956

Choudhury JK, Biswas SR, Islam SM, Rahman O, Uddin SN. 2004. Biodiversity of shatchari reserved forest, Habiganj. 1-30, IUCN Bangladesh country office, Dhaka, Bangladesh

Daniels JC, Schaefer J, Huegel CN, Mazzotti FJ. 2014. Butterfly gardening in Florida. 1-23, Department of Agriculture, UF/IFAS Extension Service, University of Florida, Florida, USA

Dosa G. 1999. Flower visitation pattern of butterflies and burnet moths in the Aggtelek- Karst (Hungary).Nota Lepidopterologica, 22(1): 58-66

Emmel TC, Leck CF. 1970. Seasonal changes in organisation of tropical rainforest butterfly populations in

Panama. Journal of Research on the Lepidoptera, 8(4): 133-152

Evans WH. 1927. The Identification of Indian Butterflies. Journal of the Bombay Natural History Society, 16: 199-273

Feeroz MM, Hasan MK, Khan MMH. 2011. Biodiversity of protected areas of Bangladesh: Rema-kalenga wildlife Sanctuary. Vol. 1, Bio track, Arannayk Foundation, Dhaka, Bangladesh

Fordyce JA, Nice CC. 2003. Variation in butterfly egg adhesion: Adaptation to level host plant senescence characteristics? Ecological Letters, 6: 23-27

Forister ML, Shapiro AM. 2003. Climatic trends and advancing spring flight of butterflies in lowland California. Global Change Biology, 9(7): 1130–1135

Gardiner AJ, Reid RS, Kiema S. 2005. Impact of land-use on butterflies in southwestern Burkina Faso. African Entomology, 13(2): 201-212

Gutierrez D, Mendez R. 1995. Phenology of butterflies in a mountain area in northern Iberian Peninsula. Ecography, 18: 209–216

Heinrich B. 1986. Thermoregulation and flight activity of a Satyrine, *Coenonympha inornata* (Lepidoptera:Satyridae). Ecology, 67(3): 593-597

Hossain M. 2014. Checklist of butterflies of the Sundarbans mangrove forest. Bangladesh Journal of Entomology and Zoological Studies 2(1): 29-32

Hossain MM, Shaheduzzaman M, Howlader AJ, Chowdhury SH. 2003. Checklist of butterflies of Jahangirnagar University, Bangladesh. Bangladesh Journal of Life Science, 15(1): 83-86

Islam ATMF, Islam MH, Saifullah ASM, Endo K, Yamanaka A. 2011. New records of butterflies and their species diversity in four different areas of Savar, Dhaka, Bangladesh. University Journal of Zoology, Rajshahi University, 30: 9-15

Islam MA, Parven N, Islam MS, Bashar MA. 2013. Butterfly abundance in relation to abiotic-biotic factors of forest ecosystem of the butterfly research park, Gazipur. Bangladesh Journal of Zoology, 41(2): 247-255

IUCN Bangladesh (International Union for Conservation of Nature Bangladesh). 2015. Red List of Bangladesh. Vol. 7, IUCN, Bangladesh Country Office, Dhaka, Bangladesh

Kehimkar I. 2008.The Book of Indian Butterflies. 1-520, Bombay Natural History Society, Bombay, India

Khan MMH, Islam MA. 2001. Diversity of butterflies in Tangail, Bangladesh. In:Environment and agriculture: biodiversity, agriculture and pollution in South Asia (Eds. PK Jha, SR Baral, SB Karmacharya, HD Lekhak, P Lacoul and CB Baniya). 65-67, Kathmandu, Nepal

Khandokar F, Rashid M, Das DK, Hossain M. 2014. Species diversity and abundance of Butterflies in the Lawachara National Park, Bangladesh. Jahangirnagar University Journal of Biological Sciences, 2(2): 121-127

Kocher SD, Williams EH. 2000. The diversity and abundance of North American butterflies vary with habitat disturbance and geography.Journal of Biogeography, 27(4): 785-794

Kumar P, Ramarajan S, Murugesan AG. 2017. Diversity of butterflies in relation to climatic factors in environmental centre campus of Manonmaniam Sundaranar University, Tamil Nadu, India. Journal of Entomology and Zoological Studies, 5(2): 1125-1134

Kunte K. 1997. Seasonal patterns in butterfly abundance and species diversity in four tropical habitats in Northern Western Ghats.Journal of Biosciences, 22(5): 593-603

Kunte K. 2000. Butterflies of Peninsular India. 1-254, Universities Press (Hyderabad) and Indian Academy of Sciences, Bengaluru, India

Larsen TB. 1988. The butterflies of the Nilgiri mountains of the Southern India (Lepidoptera: Rhopalocera).

Journal of the Bombay Natural History Society, 85(1): 26-43

Larsen TB. 2004. Butterflies of Bangladesh: An Annotated Checklist. 1-158, IUCN, The World Conservation Union, Bangladesh Country Office, Bangladesh

Magurran AE. 1988. Ecological diversity and its measurement. 1-179, Chapman and Hall, London, UK

Magurran AE. 2004. Measuring Biological Diversity. 1-264, Blackwell Publishing Company, USA

Majumder J, Lodh R, Agarwala BK. 2013. Butterfly species richness and diversity in the Trishna Wildlife Sanctuary in South Asia. Journal of Insect Science, 13: 79

McLaughlin JF, Hellmann JJ, Boggs CL, Ehrlich PR. 2002. Climate change hastens population extinctions. Proceedings of the National Academy of Sciences of the United States of America, 99(9): 6070-6074

Memmott J, Craze PG, Waser NM, Price MV. 2007. Global warming and the disruption of plant-pollinator interactions. Ecological Letters, 10(8): 710-717

Menendez R, Gonzalez-Megias A, Collingham Y, Fox R, Roy DB, Ohlemuller R, Thomas CD. 2007. Direct and indirect effects of climate and habitat factors on diversity. Ecology, 88(3): 605-611

Mevi-Schutz J, Erhardt A. 2003. Larval nutrition affects female nectar amino acid preference in the map butterfly (*Araschnia levana*). Ecology, 84(10): 2788-2794

Mielke OHH, Casagrande MM. 1997. Papilionoidea and Hesperioidea (Lepidoptera) of the Parque Estadual do Morro do Diabo, Teodoro Sampaio, São Paulo, Brazil.Revista Brasileira de Zoologia, 14(4): 967-1001

Molleman F, Grunsven RHA, Liefting M, Zwaan BJ, Brakefield PM. 2005. Is male puddling behaviour of tropical butterflies targeted at sodium for nuptial gifts or activity? Biological Journal of the Linnean Society, 86(3): 345-361

Molleman F, Midgley J. 2009. $\delta^{15}N$ analyses of butterfly wings and bodies suggest minimal nitrogen absorption in carrion and dung puddling butterflies (Lepidoptera: Nymphalidae). The Journal of Research on the Lepidoptera, 41: 14-16

Moss D, Pollard E. 1993. Calculation of collated indices of abundance of butterflies based on monitored sites. Ecological Entomology, 18(1): 77-83

Mukul SA, Uddin BM, Tito RM. 2007. Medicinal plant diversity and local healthcare among the people living in and around a conservation area of northern Bangladesh. International Journal of Forest Usufructs Management, 8(2): 50-63

Nimbalkar RK, Chandekar SK, Khunte SP. 2011. Butterfly diversity in relation to nectar food plants from Bhor Tahsil, Pune District, Maharashtra, India. Journal of Threatened Taxa, 3(3):1601-1609

Norris MJ. 1936. The feeding habit of the adult Lepidoptera Heteroneura. Trans. R. Entomological Society of London, 85(2): 61-90

Nylin S. 1989. Effects of changing photoperiods in the life cycle regulation of the comma butterfly, *Polygonia c-album* (Nymphalidae). Ecological Entomology, 14(2): 209-18

Öckinger E, Eriksson AK, Smith HG. 2006. Effects of grassland abandonment, restoration and management on butterflies and vascular plants. Biological Conservation, 133(3):291 300

Ojianwuna CC. 2015. Climatic variables as factors affecting diversity and abundance of butterflies in Okomu National Park, Edo State, Nigeria. Journal of Natural Science Research, 5(2): 70-76

Pasha KM, Uddin SB. 2013. Dictionary of plant names of Bangladesh (vascular plants). 1-434, Janokalyan Prokashani, Chittagong, Bangladesh

Perveen F, Ahmad A. 2012a. Checklist of butterfly fauna of Kohat, Khyber Pakhtunkhwa, Pakistan. Arthropods, 1(3): 112-117

Perveen F, Ahmad A. 2012b. Exploring butterfly fauna of Kohat, Khyber Pakhtunkhwa, Pakistan. SOAJ of Entomological Studies, 1(2): 94-107

Perveen F, Fazal F. 2013. Checklist of butterfly fauna from Hazara University, garden campus, Mansehra, Pakistan. SOAJ of Entomological Studies, 2: 26-33

Pielou EC. 1969. An Introduction to Mathematical Ecology. 1-294, John Wiley, New York, USA

Pivnick KA, McNeil JN. 1987. Puddling in butterflies: sodium affects reproductive success in *Thymelicus lineola*. Physiological Entomology, 12(4): 461-472

Pollard E. 1977. A method for assessing changes in the abundance of butterflies. Biological Conservation, 12(2): 115-134

Pollard E, Yates V. 1993. Monitoring Butterflies for Ecology and Conservation. 1-292, Chapman and Hall, London, UK

Pollard E, Van Swaay CAM, Yates TJ. 1993. Changes in butterfly numbers in Britain and the Netherlands 1990-91. Ecological Entomology, 18(1): 93-94

Pollard E, Moss D, Yates TJ. 1995. Population trends of common British butterflies at monitored sites. Journal of Applied Ecology, 32(1): 9-16

Porter K, Steel C, Thomas JA. 1992. Butterflies and Communities: The ecology of Butterfly in Britain. 1-335, Oxford University Press, New York, USA

Poulin B, Wright SJ, Lefebvre G, Calderon O. 1999. Interspecific synchrony and asynchrony in the fruiting phenologies of congeneric bird dispersed plants in Panama. Journal of Tropical Ecology, 15(2): 213-227

Roy DB, Sparks TH. 2000. Phenology of British butterflies and climate change. Global Change Biology, 6(4): 407–416

Roy D, Rothery P, Moss D, Pollard E, Thomas J. 2001. Butterfly numbers and weather: predicting historical trends in abundance and the future effects of climate change. Journal of Animal Ecology, 70(2): 201-207

Sawchik J, Dufrene M, Lebrun P. 2005. Distribution patterns and indicator species of butterfly assemblages of wet meadows in southern Belgium. Belgian Journal of Zoology, 135(1): 43-52

Shannon CE, Weiner W. 1948. A mathematical theory of communication. 379-423, University of Illinois Press, Urbana, USA

Shanthi R, Hussain KJ, Sanjayan KP. 2009. Influence of weather on the incidence of sucking pest complex on summer-irrigated cotton crops of Tamil Nadu. Hexapoda, 16(1): 89-92

Sharma R. 2006. Management Plan for Satchari National Park. 1-75, Nishorgo Support Project, Forest Department, Government of the People's Republic of Bangladesh, Bangladesh

Shihan TR, Prodhan MAH. 2014. Butterflies of Rema-Kalenga Wildlife Sanctuary, Habiganj, Bangladesh. International Journal of Fauna and Biological Studies, 1(6): 96-100

Shihan TR, Kabir N. 2015. Butterfly diversity in relation to *Chromolaena odorata* (L.) King and H.E. Robins as a nectar plant from two selected regions of Bangladesh. Journal of Entomology and Zoological Studies, 3(3): 258-264

Simpson EH. 1949. Measurement of diversity. Nature, 163: 688

Sparrow H, Sisk T, Ehrlich P, Murphy D. 1994. Techniques and guidelines for monitoring Neotropical butterflies. Conservation Biology, 8(3): 800-809

Sultana R. 2007. Linking fuelwood collection and community livelihoods in Satchari National Park. In: Making Conservation Work: linking rural livelihoods and protected area management in Bangladesh (Fox J, Bushley BR, Dutta S, Quazi SA, eds). 110-130, East-West Center, Honolulu; Nishorgo Program of the Bangladesh Forest Department, Dhaka

Tiple AD, Khurad AM, Dennis RLH. 2007. Butterfly diversity in relation to a human impact gradient on an

Indian university campus. Nota lepidopterologica, 30(1): 179-188

Uddin MB, Steinbauer MJ, Jentsch A, Mukul SA. 2013. Do environmental attributes, disturbances and protection regimes determine the distribution of exotic plant species in Bangladesh forest ecosystem? Forest Ecology and Management, 303: 72-80

Van Strien AJ, Van De Pavert R, Moss D, Yates TJ, Van Swaay CAM, Vos P. 1997. The statistical power of two butterfly monitoring schemes to detect trends.Journal ofApplied Ecology, 34(3): 817-828

Ward NL, Masters JM. 2007. Linking climate change and species invasion: an illustration using insect herbivores. Global Change Biology, 13(8): 1605-1615

Wright DH, Currie DJ, Maurer BA. 1993. Energy supply and patterns of species richness on local and regional scales. In:Species diversity in ecological communities: historical and geographical perspectives (Ricklefs RE, Schluter D). 66-74, University of Chicago Press, Chicago, Illinois, USA

Wynter-Blyth MA. 1957. Butterflies of Indian region. 1-523, Bombay Natural History Society, Bombay, India

Young AM. 1982. Population Biology of Tropical Insects. 1-524, Plenum Press, London, UK

Zhang WJ. 2018. Fundamentals of Network Biology. World Scientific Europe, London, UK

Zhang WJ, Chen B. 2011. Environment patterns and influential factors of biological invasions: a worldwide survey. Proceedings of the International Academy of Ecology and Environmental Sciences, 1(1): 1-14

Zhang WJ, Li X. 2015. Linear correlation analysis in finding interactions: Half of predicted interactions are undeterministic and one-third of candidate direct interactions are missed. Selforganizology, 2(3): 39-45