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Observations of Papilionoidea (Lepidoptera) fauna from heterogeneous patches of Jhargram district with new distribution reports from West Bengal, India

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Abstract

Diversity and abundance of butterfly (Papilionoidea) species were studied intensively between January 2017 and December 2021 from six heterogeneous sites of the newly created Jhargram district in West Bengal state, India. A total of 142 species from all six butterfly families were recorded from the study sites, of which 45 belong to the family Lycaenidae, 42 to Nymphalidae, 29 to Hesperiidae, 14 from Pieridae, 11 from Papilionidae and 1 from Riodinidae. Thirteen of the species observed are new reports from the district. New distributional records of *Deudorix epijarbas* (Moore), *Notocrypta curvifascia* (C. Felder and R. Felder) from the southern part of West Bengal are reported. *Rachana jalindra* (Horsfield) is rediscovered from the southern part of West Bengal after a long period. *Gangara thyrsis* (Fabricius) is reported from this part of the state for only the second time. Additionally, *Cupitha purreea* (Moore), *Gerosis bhagava* (Moore), *Sarangesa dasahara* Moore, *Celaenorrhinus leucocera* (Kollar), *Rapala pheretima* (Hewitson), *Athyma inara* Westwood, *Athyma selenophora* (Kollar) and *Tanaecia lepidea* (Butler) are among the other notable species which are reported for the first time from Jhargram district. The statistical analysis of the diversity and abundance of the study sites and the analysis of variance and rarefaction have been performed to study the β-diversity and compare the abundance of the sites in order to understand the heterogeneity of butterfly observations. The distribution by site of the species has also been studied.

Key words: Butterfly, Chhotanagpur, *Euripus*, new record, *Notocrypta*, Peninsular India, *Rachana*

Introduction

Butterflies constitute some of the most beautiful insects (Martin, 1958). As larvae, they are mostly herbivorous insects and are known to have co-evolved with plants (Ehrlic and Raven, 1964). As adults, they feed on nectar as a source of sugar and amino acids (Inouye and Ogilvie, 2017). As adults, members of the order Lepidoptera, comprising the moths and butterflies, are one of the most important pollinators (Berenbaum, 2007). The adult butterflies, particularly the nymphalids, lycaenids and hesperiids are known to mud-puddle in search of proteins, while the papilionids and pierids do more in search of sodium (Beck et al., 1999). A significant majority of the larvae of lycaenid butterflies are known for strong mymecophilic associations (Pierce et al., 2002). Due to their sensitivity to ecological parameters, butterflies are also considered to be one of the most important indicator species (Kremen, 1992; Launer and Murphy, 1994).

Jhargram district of West Bengal is a part of the Chhotanagpur Plateau and thus represents an undulating landscape along with some eroded plains in the river valleys. While the butterfly fauna of Gangetic West Bengal has been extensively studied, the butterfly diversity in this western part of West Bengal which is significantly different, is very much understudied. Very few studies (Crawford, 1921) have been conducted in the plateau region of West Bengal before the independence of India. Of late, some studies have however been initiated (Samanta et al., 2017; Biswas et al., 2019; Chowdhury and Chowdhury, 2020; Dwari and Mondal, 2020; Mukherjee and Mondal, 2020; Nayak, 2020; Roy et al., 2021), which were far from exhaustive.

Material and Methods

Study sites

Jhargram district is located in the western fringe of southern West Bengal (Fig. 1). It constitutes the south-eastern slope of undulating Chhotanagpur Plateau (Rodgers et al., 2000), the northernmost extension of the Deccan Plateau. The district, formed only in 2017, is bordered by the Paschim Medinipur district in the east, Bankura and Purulia districts in the north, Purbi Singhbhum district of Jharkhand state in the west and Mayurbhanj district of Odisha state in the south. It is located from 21°51'30" N to 22°48'49" N latitudes and 86°33'50" E to 87°15'31" E longitudes. The study area consists of eight blocks, namely Binpur–I, Binpur–II, Jamboni, Jhargram, Gopiballavpur–I, Gopiballavpur–II, Sankrail and Nayagram. Out of a total area of 3037 sq. km, 595 sq. km is under forest cover and 2682 sq. km covers agricultural fields. The forest dominated by *Shorea robusta* is dry deciduous in nature (Champion and Seth, 1968).

Kankrajhore and Belpahari regions in Binpur–I block (north-western part of the district) have the highest altitude in the district, nearly 300 meters and is very densely forested, with quite a few seasonal hilly streams. This region is a part of residual Chhotanagpur Plateau and can be divided into three parts, viz., Chhotanagpur flanks with hills in the north-west, rolling lands in the western part, Rahr plain with lateritic uplands in the middle part (Gayen et al., 2013; Shit et al., 2015). The six study sites (numbered from S1 to S6 in the Table 1) are chosen such that they cover the diversity of the landscapes present in the study area (Jhargram district). S1 and S2, Amlasol and Dhangikusum respectively, represent the dense primary forests on rolling hilly remnants of the residual Chhotanagpur Plateau. Chilkigarh (S3) in Jamboni block represents a sacred riverside grove, which is a mixture of secondary forests, medicinal and fruiting plants and ornamental garden plants. Banstola (S4) is a roadside grassland and wasteland near the railway tracks, infested with a number of invasive weeds. S5 is an urban backyard of the residence of the first author BM. Gopiballavpur (S6) is a riverside grassland bordering the sandy riverbed.

Köppen-Geiger classified this region to have Tropical Dry Savannah climate (Beck et al., 2018), characterised by dry winters. The annual mean maximum and minimum temperatures are 31.9 °C and 21.5 °C respectively, with temperatures known to soar up to 47 °C in May and plummet to 5 °C in January. The average annual rainfall is 121 cm. More than 75% of the precipitation occurs during June to September (Anonymous, 2008). The ombrothermic diagram showing the wet and xeric periods is provided (Fig. 2).

Data collection

In order to attempt a thorough investigation of the butterfly diversity of Jhargram district, six heterogeneous study sites (Fig. 3) from different landscapes and varying degrees of human intervention were chosen for regular surveys.

The six selected sites were surveyed between January 2017 to December 2021 to assess the diversity of butterflies. The Wider Countryside Butterfly Survey (Brereton et al., 2011) method was applied to record diversity and abundance of the lepidopterans. Each study site has been surveyed at least twice every month during this study period of five years in order to understand the seasonal variation of occurrence and abundance of the butterflies.

The butterflies have been photographed using Nikon Coolpix P600 point and shoot camera, and Canon EOS 7D Mark II DSLR camera along with a Canon EF 100–400 mm f/4.5–5.6L IS II USM lens. The individuals have been photographed and generally identified in situ. The photographed individuals, in special cases, have been identified using standard field guides (Evans, 1932; Wynter-Blyth, 1957; Kehimkar, 2016; Bhakare and Ogale, 2018; Ramachandran and Raju, 2020). The identifications of *Tarucus* spp., which was avoided in Dwari and Mondal (2020) have been done and included in the checklist in accordance with Basu et al. (2019).

Data interpretation

Single-factor ANOVA was calculated among the six study sites to find out the variance among them. The Dominance_D index (Simpson, 1949), Simpson's 1-D (Hurlbert, 1971), Shannon's 1-D index (Shannon, 1948), Evenness index (Pielou, 1966) were calculated. Individual rarefaction analysis (Sanders, 1968; Hurlbert, 1971; Heck et al., 1975) of the butterfly individuals was done among the study sites. Hierarchical clustering was done using a single linkage algorithm using the Bray-Curtis similarity index (Bray and Curtis, 1957) and 10000 bootstraps across the study sites. The α-diversity (Whittaker, 1960) of the study sites is calculated to analyse the comparative diversity of the study sites. The global β-diversity of the entire study area has been calculated using Whittaker's index (Whittaker, 1960). UPGMA Dendrogram (Sokal and Michener, 1958) provides us with the ecological proximity relationship of the study sites. The entire analysis has been done using the PAST software (Version 4.08), developed by Øyvind Hammer at Natural History Museum, University of Oslo (Anonymous, 2021).

Results

The prolonged study resulted in finding 142 species of butterflies from Jhargram district. While 14 of the species reported previously from the district (Dwari and Mondal, 2020) have not been observed in this study, 13 species of butterflies previously not reported from the district have been observed across the four study sites in varying degrees of commonality. Some of them, though not reported from the adjoining districts in West Bengal, however, are reported from the neighboring and nearby districts in the states of Jharkhand (Morrison-Godfrey, 1948; Sambath, 2014; Dey et al., 2020) and Odisha (Payra et al., 2016; Boruah et al., 2018).

The site-wise findings and their relative abundances have been provided in Table 2. Of the 142 species of butterflies recorded during the study, 45 belong to the family Lycaenidae, 42 belong to Nymphalidae, 29 belong to Hesperiidae with only 14 from Pieridae, 11 from Papilionidae and 1 from Riodinidae (Fig. 4).

Table 1: Brief description of the selected study sites including altitude, geo-coordinates (Using Google Earth Version 9.135.0.3) and habitat types.

Site No.	Location	Altitude (elevation from the sea level in meters); Coordinates (latitude and longitude)	Habitat type	Vegetation type
S1	Amlasol	225 m; 22°42’14” N, 86°35’58” E	Forested hills with a seasonal stream	Dry deciduous forest
S2	Dhangikusum	215 m; 22°37’25” N, 86°38’28” E	Forested hills with a perennial stream and a waterfall in its course	Dry deciduous forest with a grassland at its basin
S3	Chilkigarh Kanak Aranya	75 m; 22°27’06” N, 86°52’48” E	Scared grove on the bank of Dulung River	Dry deciduous forest with dense undergrowth. A small garden of ornamental and exotic plants
S4	Banstola	85 m; 22°25’23” N, 87°03’56” E	Grassland and field near railway station	Grassland
S5	Jhargram (Residence of BM)	95 m; 22°26’11” N, 86°59’42” E	Backyard of an urban residence	Mixed vegetation of fruiting trees and garden plants
S6	Gopiballavpur	50 m; 22°13’03” N, 86°53’57” E	Subarnarekha riverbank	Riverside grassland and riverine freshwater-associated flora

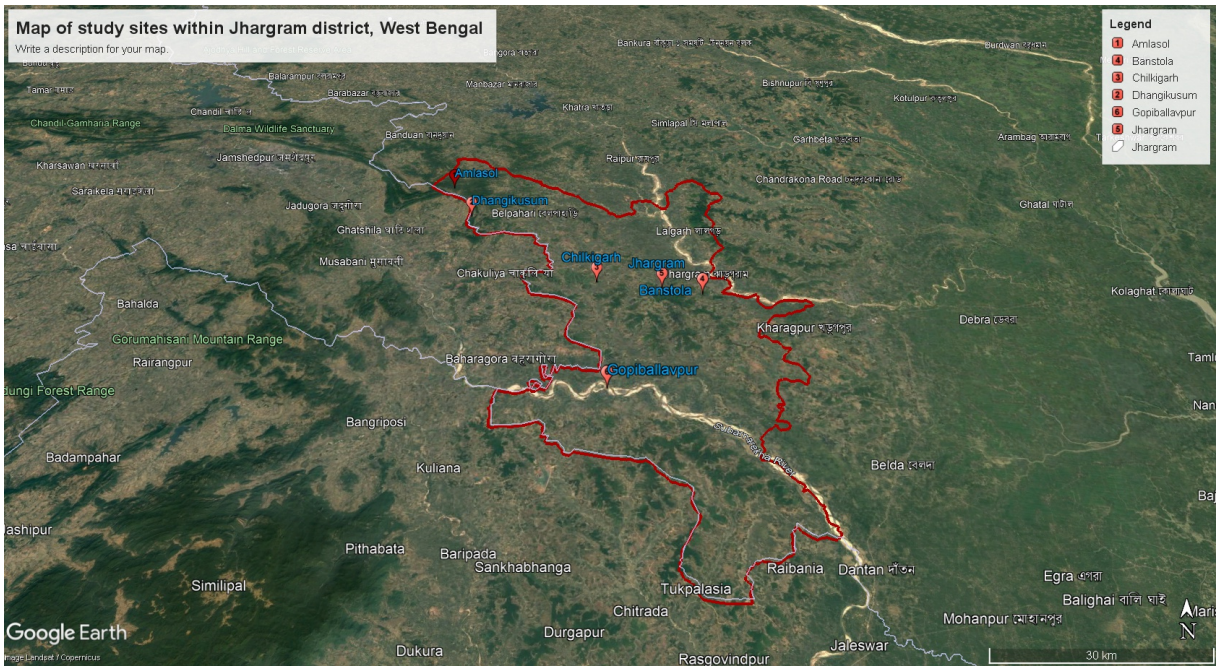

Figure 1: Study sites (S1–S6) under present investigation from Jhargram district in West Bengal, India (Prepared using Google Earth Pro 7.3.6.9285)

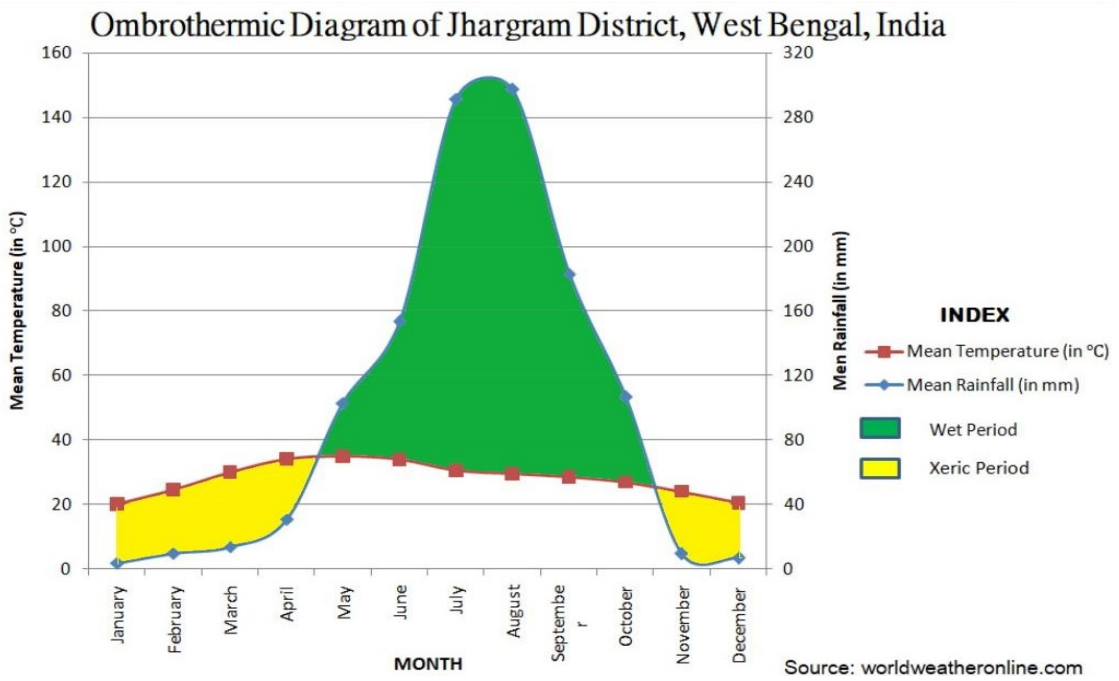

Figure 2: Ombrothermic diagram of the study area in Jhargram district, West Bengal showing wet and xeric periods.

Table 2: Updated checklist of Butterflies from Jhargram district, West Bengal, India along with their abundance (species marked with an asterisk (*) are new records for the district). Abbreviations used: A – Abundant, C – Common, UC – Uncommon, R – Rare, VR – Very Rare, LC – Locally Common, LA – Locally Abundant.

Sl. No.	Butterfly species	S1	S2	S3	S4	S5	S6	Abundance in study site
Family Hesperiidae								
Subfamily Coeliadinae								
1	*Badamia exclamationis* (Fabricius, 1775)	+	+	+		+		UC
2	*Hasora chromus* (Cramer, [1780])	+	+	+	+	+	+	UC
Subfamily Hesperiinae								
3	*Ampittia dioscorides* (Fabricius, 1793)	+		+	+		+	C
4	*Baoris farri* (Moore, 1878)			+				UC
5	*Borbo cinnara* (Wallace, 1866)				+	+	+	LA
6	*Cupitha purreea* (Moore, 1877)*	+	+	+				LC
7	*Gangara thyrsis* (Fabricius, 1775)*			+				VR
8	*Halpe porus* (Mabille, [1877])			+		+		R
9	*Hyarotis adrastus* (Stoll, [1780])	+	+	+	+	+	+	C
10	*Iambrix salsala* (Moore, [1866])	+	+	+	+	+	+	A
11	*Matapa aria* (Moore, [1866])	+		+		+		C
12	*Notocrypta curvifascia* (C. Felder and R. Felder, 1862)*			+				LC
13	*Oriens goloides* (Moore, [1881])			+		+		LC
14	*Parnara bada* (Moore, 1878)	+	+	+	+	+	+	A
15	*Parnara ganga* Evans, 1937			+		+		R
16	*Pelopidas agna* (Moore, [1866])	+	+	+		+	+	C
17	*Pelopidas mathias* (Fabricius, 1775)			+		+		UC
18	*Suastus gremius* (Fabricius, 1798)	+	+	+	+	+	+	A
19	*Telicota bambusae* (Moore, 1878)	+	+	+	+	+	+	A
20	*Telicota colon* (Fabricius, 1775)	+	+	+	+	+	+	A
21	*Udaspes folus* (Cramer, [1775])	+	+	+	+	+	+	C
Subfamily Pyrginae								
22	*Caprona ransonnetii* (R. Felder, 1868)		+					R
23	*Celaenorrhinus leucocera* (Kollar, [1844])*	+		+				LC
24	*Coladenia indrani* (Moore, [1866])	+	+	+				UC
25	*Gerosis bhagava* (Moore, [1866])*			+				R
26	*Sarangesa dasahara* (Moore, [1866])*			+		+		LC
27	*Spialia galba* (Fabricius, 1793)	+	+	+	+	+	+	A
28	*Tagiades japetus* (Stoll, [1781])	+	+	+	+	+	+	C
29	*Tagiades litigosa* Moeschler, 1878	+	+	+		+		LC

Table 2: (Continued).

Sl. No.	Butterfly species	S1	S2	S3	S4	S5	S6	Abundance in study site
Family Lycaenidae								
Subfamily Aphnaeinae								
30	*Spindasis ictis* (Hewitson, 1865)	+	+			+		LA
31	*Spindasis lohita* (Horsfield, [1829])					+		R
32	*Spindasis vulcanus* (Fabricius, 1775)	+	+	+	+	+	+	A
Subfamily Curetinae								
33	*Curetis thetis* (Drury, [1773])	+	+	+			+	C
Subfamily Miletinae								
34	*Spalgis epius* (Westwood, 1852)	+		+		+	+	C
Subfamily Polyommatinae								
35	*Actyolepis puspa* (Horsfield, [1828])	+	+			+	+	LA
36	*Anthene emolus* (Godart, 1824)	+	+	+	+	+	+	A
37	*Anthene lycaenina* (C. Felder, 1868)	+		+				UC
38	*Caleta decidia* (Hewitson, 1876)			+				UC
39	*Castalius rosimon* (Fabricius, 1775)	+	+	+	+	+	+	A
40	*Catochrysops strabo* (Fabricius, 1775)	+	+	+	+	+	+	A
41	*Chilades lajus* (Stoll, [1780])	+	+	+	+	+	+	A
42	*Euchrysops cnejus* (Fabricius, 1798)	+	+	+	+	+	+	A
43	*Everes lacturnus* (Godart, [1824])		+	+				LC
44	*Freyeria putli* (Kollar, [1844])				+		+	LA
45	*Jamides bochus* (Stoll, [1782])			+		+		UC
46	*Jamides celeno* (Cramer, [1775])	+	+	+	+	+	+	A
47	*Lampides boeticus* (Linnaeus, 1767)	+	+	+	+	+	+	A
48	*Leptotes plinius* (Fabricius, 1793)		+	+	+	+	+	A
49	*Luthrodes pandava* (Horsfield, [1829])	+	+	+	+	+	+	A
50	*Megisba malaya* (Horsfield, [1829])					+		R
51	*Neopithecops zalmora* (Butler, [1870])	+		+	+	+	+	A
52	*Prosotas dubiosa* (Semper, [1879])	+	+	+		+		C
53	*Prosotas nora* (C. Felder, 1860)		+	+		+	+	C
54	*Pseudozizeeria maha* (Kollar, [1844])	+	+	+	+	+	+	A
55	*Tarucus balkanicus* (Freyer, 1844)*	+	+	+	+	+	+	A
56	*Tarucus nara* (Kollar, 1848)	+	+	+	+	+	+	A
57	*Zizeeria karsandra* (Moore, 1865)			+	+	+	+	C
58	*Zizina otis* (Fabricius, 1787)			+		+	+	LA
59	*Zizula hylax* (Fabricius, 1775)			+	+	+	+	LA
Subfamily Theclinae								
60	*Amblypodia anita* Hewitson, 1862	+	+	+	+	+	+	A
61	*Arhopala amantes* (Hewitson, 1862)	+	+	+	+	+	+	A
62	*Arhopala atrax* (Hewitson, 1862)	+	+	+	+	+	+	C
63	*Deudorix epijarbas* (Moore, 1857)*					+		VR
64	*Iraota timoleon* (Stoll, [1790])			+				UC
65	*Loxura atymnus* (Stoll, 1780)	+	+	+		+		C
66	*Rachana jalindra* (Horsfield, 1829)*					+		VR
67	*Rapala iarbus* (Fabricius, 1787)	+		+		+	+	C
68	*Rapala manea* (Hewitson, 1863)	+	+	+		+	+	A
69	*Rapala pheretima* (Hewitson, 1863)*	+		+		+		UC
70	*Rapala varuna* (Horsfield, [1829])	+	+	+		+	+	UC
71	*Rathinda amor* (Fabricius, 1775)	+	+	+	+	+	+	C
72	*Tajuria cippus* (Fabricius, 1798)	+	+			+		C
73	*Virachola isocrates* (Fabricius, 1793)	+				+		UC
74	*Zeltus amasa* (Hewitson, 1865)	+						R
Family Nymphalidae								
Subfamily Acraeinae								
75	*Acraea terpsicore* (Linnaeus, 1758)	+	+	+	+	+	+	A
Subfamily Apaturinae								
76	*Euripus consimilis* (Westwood, 1850)					+		VR
Subfamily Biblidinae								
77	*Ariadne ariadne* (Linnaeus, 1763)	+	+	+	+	+	+	A
78	*Ariadne merione* (Cramer, [1777])	+	+	+	+	+	+	A
Subfamily Charaxinae								
79	*Charaxes psaphon* Westwood, 1847	+	+	+		+		LC
80	*Charaxes solon* (Fabricius, 1793)	+				+		UC
81	*Polyura bharata* (C. Felder and R. Felder, [1867])	+		+				LC

Table 2: (Continued).

Sl. No.	Butterfly species	S1	S2	S3	S4	S5	S6	Abundance in study site
Subfamily Danainae								
82	*Danaus chrysippus* (Linnaeus, 1758)	+	+	+	+	+	+	A
83	*Danaus genutia* (Cramer, [1779])	+	+	+	+	+	+	C
84	*Euploea core* (Cramer, [1780])	+	+	+	+	+	+	A
85	*Euploea klugii* Moore, [1858]			+				UC
86	*Euploea sylvester* (Fabricius, 1793)	+	+	+		+		UC (Seasonal)
87	*Tirumala limniace* (Cramer, [1775])	+	+	+		+		C
Subfamily Heliconiinae								
88	*Phalanta phalantha* (Drury, [1773])	+	+	+	+	+	+	A
Subfamily Limenitidinae								
89	*Athyma inara* Westwood, 1850*	+		+				LC
90	*Athyma perius* (Linnaeus, 1758)	+	+	+	+	+	+	C
91	*Athyma selenophora* (Kollar, [1844])*			+				R
92	*Euthalia aconthea* (Cramer, [1777])	+	+	+	+	+	+	A
93	*Euthalia lubentina* (Cramer, [1777])	+	+			+		C
94	*Euthalia nais* (Forster, 1771)	+	+	+	+	+	+	A
95	*Moduza procris* (Cramer, [1777])	+	+	+		+		C
96	*Neptis hylas* (Linnaeus, 1758)	+	+	+	+	+	+	A
97	*Neptis jumbah* Moore, [1858]	+	+	+	+	+	+	C
98	*Pantoporia hordonia* (Stoll, [1790])	+	+					LC
99	*Tanaecia lepidea* (Butler, 1868)*	+	+	+		+		LA
Subfamily Nymphalinae								
100	*Hypolimnas bolina* (Linnaeus, 1758)	+	+	+	+	+	+	C
101	*Hypolimnas misippus* (Linnaeus, 1758)	+	+	+	+	+	+	A
102	*Junonia almana* (Linnaeus, 1758)	+	+	+	+	+	+	A
103	*Junonia atlites* (Linnaeus, 1763)	+	+	+	+	+	+	A
104	*Junonia hierta* (Fabricius, 1798)	+	+	+	+	+	+	A
105	*Junonia iphita* (Cramer, [1779])	+	+	+	+	+	+	C
106	*Junonia lemonias* (Linnaeus, 1758)	+	+	+	+	+	+	A
107	*Junonia orithya* (Linnaeus, 1758)	+	+	+	+	+	+	A
108	*Vanessa cardui* (Linnaeus, 1758)			+		+		R
Subfamily Satyrinae								
109	*Discophora sondaica* Boisduval, 1836	+		+		+		UC
110	*Elymnias hypermnestra* (Linnaeus, 1763)	+	+	+	+	+	+	A
111	*Lethe europa* (Fabricius, 1775)			+		+		LC
112	*Melanitis leda* (Linnaeus, 1758)	+	+	+	+	+	+	A
113	*Mycalesis mineus* (Linnaeus, 1758)	+	+	+	+	+	+	C
114	*Mycalesis perseus* (Fabricius, 1775)	+	+	+	+	+	+	A
115	*Ypthima baldus* (Fabricius, 1775)					+		R
116	*Ypthima huebneri* Kirby, 1871	+	+	+	+	+	+	A
Family Papilionidae								
Subfamily Papilioninae								
117	*Graphium agamemnon* (Linnaeus, 1758)	+	+	+	+	+	+	C
118	*Graphium antiphates* (Cramer, [1775])	+		+		+		UC
119	*Graphium doson* (C. Felder and R. Felder, 1864)	+	+	+	+	+	+	C
120	*Graphium nomius* (Esper, 1799)	+	+	+	+	+	+	UC
121	*Pachliopta aristolochiae* (Fabricius, 1775)	+	+	+	+	+	+	A
122	*Pachliopta hector* (Linnaeus, 1758)			+		+		R
123	*Papilio clytia* Linnaeus, 1758	+	+	+	+	+	+	C
124	*Papilio crino* Fabricius, 1793	+	+	+		+	+	C
125	*Papilio demoleus* Linnaeus, 1758	+	+	+	+	+	+	A
126	*Papilio polymnestor* Cramer, [1775]	+	+	+	+	+	+	C
127	*Papilio polytes* Linnaeus, 1758	+	+	+	+	+	+	A
Family Pieridae								
Subfamily Coliadinae								
128	*Catopsilia pomona* (Fabricius, 1775)	+	+	+	+	+	+	A
129	*Catopsilia pyranthe* (Linnaeus, 1758)	+	+	+	+	+	+	A
130	*Gandaca harina* (Horsfield, [1829])			+				R
131	*Eurema andersoni* Moore, 1886	+		+		+	+	UC
132	*Eurema blanda* (Boisduval, 1836)	+	+	+	+	+	+	C
133	*Eurema brigitta* (Stoll, [1780])	+	+	+				LA
134	*Eurema hecabe* (Linnaeus, 1758)			+	+	+	+	A
Subfamily Pierinae								
135	*Appias albina* (Boisduval, 1836)			+				VR
136	*Appias libythea* (Fabricius, 1775)	+	+	+	+	+	+	A
137	*Cepora nerissa* (Fabricius, 1775)	+	+	+	+	+	+	A
138	*Delias eucharis* (Drury, 1773)	+	+	+	+	+	+	A
139	*Delias hyparete* (Linnaeus, 1758)	+	+			+		UC
140	*Leptosia nina* (Fabricius, 1793)	+	+	+	+	+	+	A
141	*Pareronia hippia* (Fabricius, 1787)	+	+	+	+	+	+	C
Family Riodinidae								
142	*Abisara bifasciata* Moore, 1877	+	+	+		+		LA

Figure 3: Photographs of the study sites in Jhargram district, West Bengal, India: S1. Amlasole, S2. Dhangikusum, S3. Chilkigarh, S4. Banstola, S5. Jhargram town (Residence of BM), and S6. Gopiballavpur.

Discussion

Insect diversity is known to be highest in habitats with the most plant diversity and is lowest in shrub, grassland and open fields (Davies, 1988). However, butterfly diversity is known to be higher in disturbed forests and highest in moderately disturbed forests (Blair and Launer, 1997; Schulze et al., 2004; Bobo et al., 2006) or forests edges (Vu, 2008), and comparatively lower in natural forests (Spitzer et al., 1993; Van Lien and Yuan, 2003).

Butterfly species diversity is generally found to be low in habitat with thick forest canopy (Warren, 1985). Diversity of butterflies increases with increasing habitat scale and vegetation structure complexity (Price, 1997).

The highest number of butterfly species was recorded from S3 (124), followed by S5 (118), S1 (107), S2 (95). S4 and S6 yielded the least numbers of species counting 76 and 85 respectively (Table 2). The sequence of the sites according to the number of individual butterflies is also similar (Table 3). The Dominance index of all six study sites lies between 0.01244 (S3) and 0.01895 (S6). The Simpson's 1D index of all sites is more than 0.98, indicating very high diversity of butterflies in the study area. The Shannon's index also shows a similar trend. The Evenness index shows S4 to be the most even (0.7919) and S1 to be the least even (0.7516). α-diversity indices of the study sites are shown in Table 3. The comparative count of the specimens observed

is illustrated through the individual-based rarefaction curves (95% confidence interval) (Fig. 5).

The α-diversity profile (Fig. 6) shows S3 and S5 to be the most diverse sites. The global β-diversity of the entire study area across the study sites has been found to be 0.408 according to Whittaker's index. The UPGMA dendrogram (Fig. 7) demonstrates that the hilly forests of S1 and S2 are intimately related, while the plain grasslands, wastelands and agricultural lands of S4 and S6 are also very similar. The highest diversity of butterflies observed in S3 and S5, which can be attributed to the mixed vegetation in the sacred grove and backyard of BM, respectively. On the parameter of species diversity, the above mentioned two sites are followed by S1 and S2, which are pristine primary forests, dry deciduous, characteristic of the Chhotanagpur Plateau. This finding is concurrent with the previous studies mentioned above.

The higher degree of human interference and lack of forest cover caused lower species diversity and abundance in S4 and S6. However, the common species, known to have wider geographical ranges and reported to have a polyphagous diet, have been found to be more abundant in these regions. The greater range of larval host plants, fewer invertebrate predators and more access to sunlight account for their greater abundance.

Most of the uncommon and rare species of butterflies have been observed after the start of the monsoon rain, during the period between late June and early November, peaking in September, which conform with the comprehensive study in the surrounding region of south Bihar (Morrison-Godfrey, 1948). A significant exception of rare species not occurring in the said period and rather being sighted in the spring season (March and early April) is found with lycaenids, such as *Deudorix epijarbas* (Moore, [1858]), *Rachana jalindra* (Horsfield, [1829]) and a nymphalid species, *Euripus consimilis* (Westwood, [1851]), which coincides with the flowering period of *Syzgium cumini* (L.) Skeels. (de Sousa Sabino et al., 2018), a tree native to the Indian subcontinent, known to bear purple drupaceous fruits consumed commonly by humans. The butterflies of these species were found to be nectaring on the flowers of the tree. Regular, but infrequent, sightings of *Coladenia indrani* (Moore, 1865) can be attributed to the presence of its newly known host plant *Schleichera oleosa* (Lour.) Oken (Banerjee et al. 2023), which is common in the dry deciduous forests of the study area.

A brief account of some notable species sightings is discussed below.

Cupitha purreea (Moore, 1877) – After the report of Morrison-Godfrey (1948), Dey et al. (2020) rediscovered the presence of this skipper (Fig. 8.1) from adjacent Purbi Singhbhum district (in Jharkhand) (only 45 km Aerial Distance (AD)). The repeated sightings of this distinctive skipper from S3 by the first and second authors affirm their sizable population in this region.

Gangara thyrsis (Fabricius, 1775) – A single individual (Fig. 8.2) was sighted on 15 October 20 at S3. Very rarely observed in the surrounding region, the only report from the nearby districts in the state was from Shankarpur coast (115 km AD) in Purba Medinipur district (Payra et al., 2017).

Halpe porus (Mabille, [1877]) – Though rare, this widely distributed distinctive species (Fig. 8.3) of an otherwise cryptic genus has been reported from the region and surroundings (Payra et al., 2017, Dwari et al., 2020). The first author observed individuals of this species multiple times from S3.

Notocrypta curvifascia (C. Felder and R. Felder, 1862) – New report from district (and south Bengal). Nearest report in the state is from Raimatang in Alipurduar district (545 km AD). This species (Fig. 8.4) has been sighted repeatedly during the post-monsoon rain period between July and October at S3.

Oriens goloides (Moore, [1881]) – It (Fig. 8.5) is locally common in the region. It was claimed to be reported several times from Kolkata and surroundings (Mukherjee et al., 2015; Bhowal et al., 2020) in the Gangetic delta. However, presence of double cell spots and the band being continuous through spaces 4 and 5 confirm both of the photographed individuals published in the said papers to be *Oriens gola* (Moore, 1877) (Seitz, 1927; Evans, 1949).

Parnara ganga Evans, 1937 – This species has often been confused with the much more common and abundant (in India) *Parnara bada* (Moore, 1878). The regular, larger central spots in UNH (under hindwing) points to this individual (Fig. 8.6) to be *Parnara ganga* instead of *P. bada* (Chiba and Eliot, 1991; Kimura et al., 2009).

Gerosis bhagava (Moore, [1866]) – An individual (Fig. 8.9) was observed to puddle on a wet laterite walking trail at S3 on 17 November 2020. Though only a single individual has been observed during the study, the species is occasionally sighted from surrounding districts, mostly in the same season (Roy et al., 2021).

Tarucus balkanica (Freyer, 1844) – The male individuals of the species can be distinguished from the very similar *Tarucus nara* (Kollar, 1848) (Fig. 8.13) by the presence of more than one discal black spot in UP (upperwing) of the forewing (Evans, 1932; 1955; Cantlie, 1962) instead of one, and the presence of a narrow black border (Evans, 1932) instead of a conspicuous black bar at cell-end (Basu et al., 2019). Both species are locally abundant, particularly in open fields and grasslands.

Table 3: Diversity indices of the study sites in Jhargram district, West Bengal, India.

Diversity indices	Amlasole	Dhangikusum	Chilkigarh	Banstola	Jhargram Town	Gopiballavpur
Taxa_S	107	95	124	76	118	85
Individual	762	749	1241	573	993	618
Dominance_D	0.01604	0.01726	0.01244	0.02012	0.01405	0.01895
Simpson_1D	0.984	0.9827	0.9876	0.9799	0.9860	0.9810
Shannon_H	4.387	4.297	4.577	4.097	4.491	4.1680
Evenness Index	0.7516	0.7738	0.7840	0.7919	0.7559	0.7598

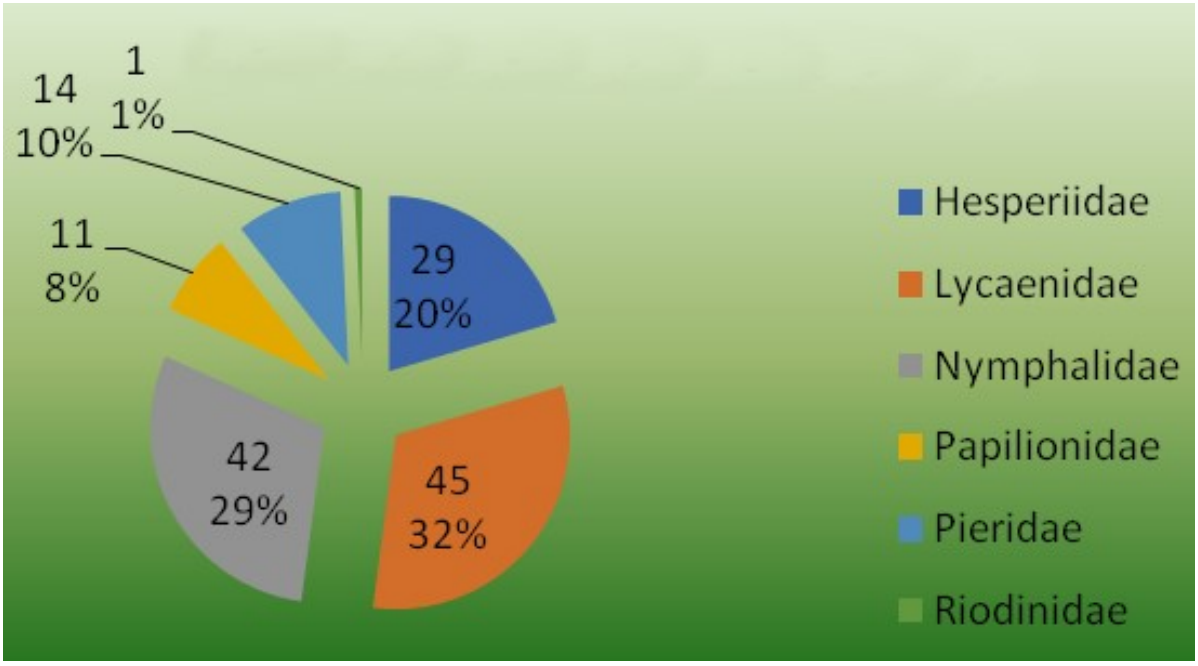

Figure 4: Pie chart of representation of butterfly species by family observed during the study in Jhargram district, West Bengal, India.

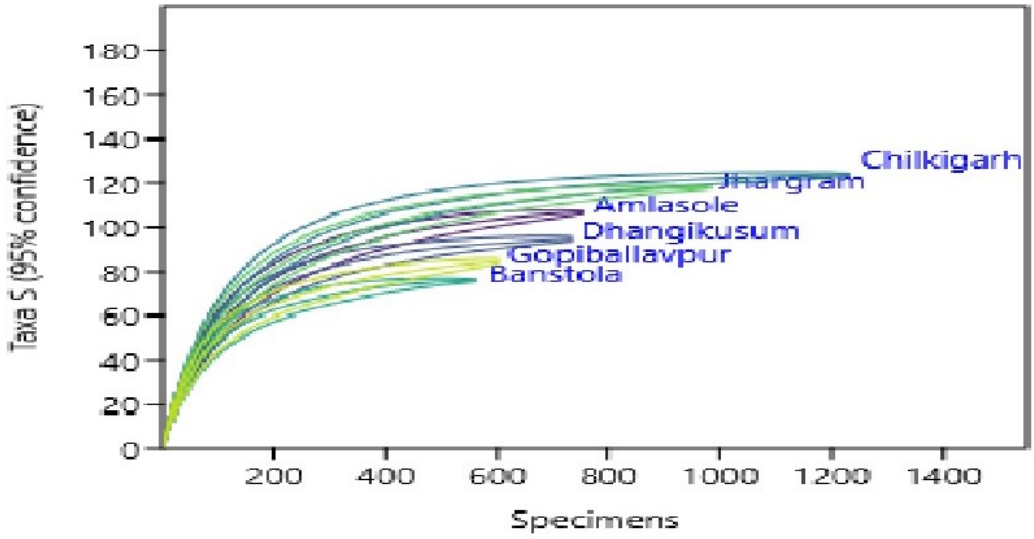

Figure 5: Individual-based rarefaction curves of the study sites in Jhargram district, West Bengal, India.

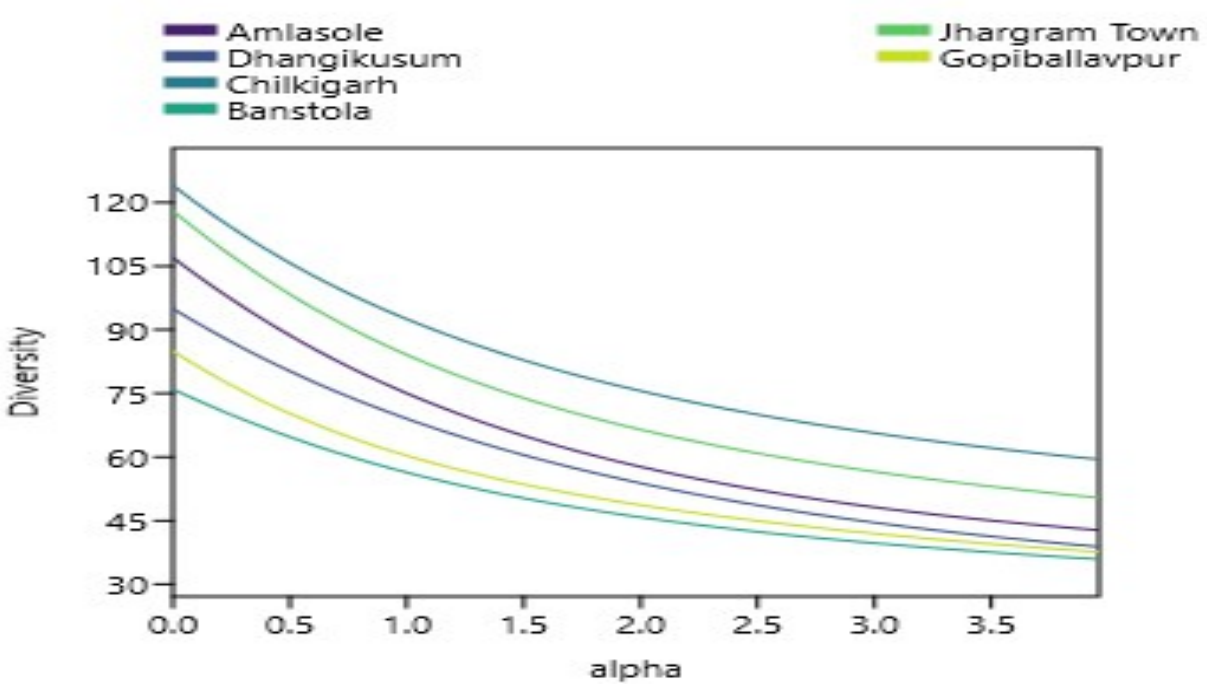

Figure 6: α-diversity profile of the study sites in Jhargram district, West Bengal, India.

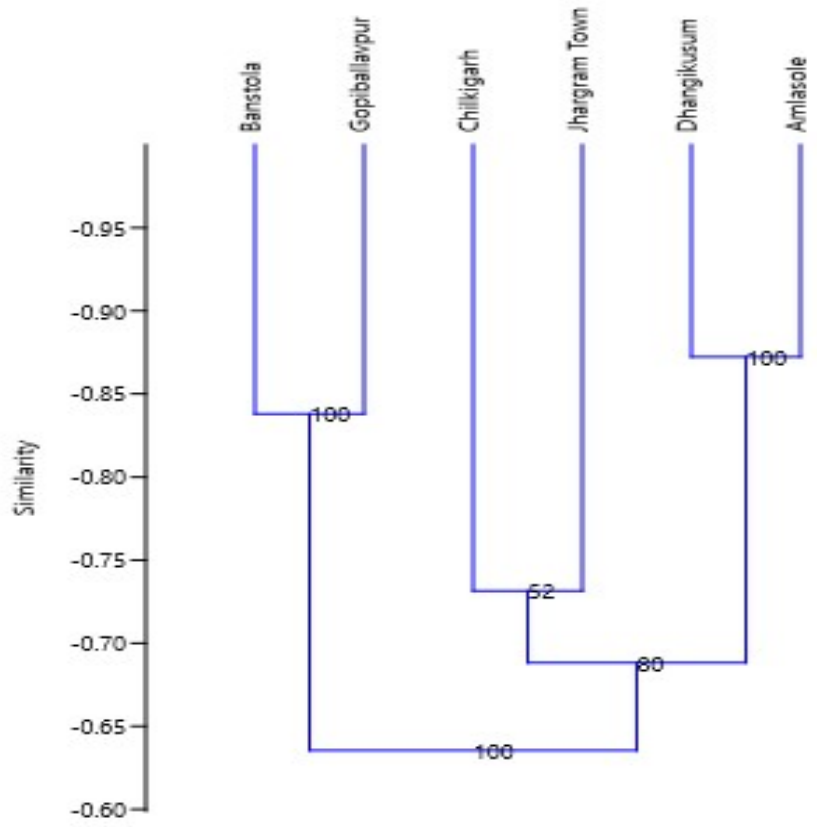

Figure 7: Hierarchical clustering of the study sites in Jhargram district, West Bengal, using UPGMA dendrogram with 10000 Bootstraps applied through Bray-Curtis similarity indices.

Figure 8: Photos of some selected butterfly species encountered during the survey in Jhargram district, West Bengal, India. 1. *Cupitha purreea*, 2. *Gangara thyrsis*, 3. *Halpe porus*, 4. *Notocrypta curvifascia*, 5. *Oriens goloides*, 6. *Parnara ganga*, 7. *Celaenorrhinus leucoceera*, 8. *Coladenia indrani*, 9. *Gerosis bhagava*, 10. *Sarangesa dasahara*, 11. *Caleta decidia*, 12. *Megisba malaya*, 13. *Tarucus nara*, 14. *Deudorix epijarbas*, 15. *Rachana jalindra*, 16. *Rapala pheretima*, 17. *Zeltus amasa*, 18. *Euripus consimilis*, 19. *Athyma inara*, 20. *Athyma selenophora*, 21. *Pantoporia hordonia*, 22. *Tanaecia lepidea*, 23. *Vanessa cardui*, 24. *Gandaca harina*, 25. *Eurema andersonii*, 26. *Eurema brigitta*, 27. *Appias albina*, 28. *Delias hyparete*.

Deudorix epijarbus – A worn out individual (Fig. 8.14) was sighted and photographed on 29 March 2020 at S5. The species has again been observed from the same location on 21 March 2021. Like *Rachana jalindra*, the sightings of this species in the spring season concurs with the flowering period of *Syzgium cumini*, on whose nectar it has been observed to drink on both occasions.

Rachana jalindra (Horsfield, [1829]) – An individual (Fig. 8.15) was observed by the first author at S5 at the backyard of his residence on 05 April 2020. It is distinguished from similar looking *Charana mandarinus* (Hewitson, [1863]) by distinctly smaller tails near the second black spot near the tornal area, and an orange border instead of brown around the other black spot in the submarginal area closer to the apex (Evans, 1932). Very rarely found in southern West Bengal, it was reported to be very rarely found in "Calcutta" (Sanders, 1955).

Zeltus amasa (Hewitson, 1865) – A not-uncommon species in certain waterfalls and stream sides (rarer in other habitats) in surrounding regions of Odisha and Jharkhand, it is quite rare in this study area. Only one individual (Fig. 8.17) was sighted in the hill forests of S1 on 23 November 2020.

Euripus consimilis – This species (Fig. 8.18) is very rarely observed in the southern part of West Bengal. However, Biswarup Mandal has repeatedly observed a few individuals from both genders of the species nectaring on flowers of *Syzgium cumini* tree in the backyard of his residence (S5).

Athyma inara Westwood, 1850 – Individuals of this species (Fig. 8.19) have been repeatedly observed at S3 particularly during the rainy season and after the rains between July and early November. The species is also regularly observed from surrounding districts in West Bengal, Jharkhand and Odisha.

Athyma selenophora (Kollar, [1844]) – An individual (Fig. 8.20) was observed from S3 on 07 November 2020. An individual has again been observed further during the same season near S3 in 2021 too by Biswarup Mandal. It was observed in the month of October from surrounding Jharkhand (south Bihar) (Morrison-Godfrey, 1948), which more or less coincides with the season of sightings in this study.

Vanessa cardui (Linnaeus, 1758) – The most widespread butterfly species in the world, *Vanessa cardui* is known to migrate across continents (Pollard et al., 1998; Stefanescu et al., 2007; Talavera and Vila, 2017; Dobrosonov, 2019) is rarely encountered in this study area and surrounding region (Morrison-Godfrey, 1948). An individual (Fig. 8.23) was sighted at S3 on 08 December 2019.

Gandaca harina (Horsfield, [1829]) – This species (Fig. 8.24) has been observed mud-puddling on muddy trails at S3 after monsoon rains between the months of July and September.

Eurema brigitta (Stoll, [1780]) – It (Fig. 8.26) is locally abundant, particularly in the primary deciduous forests in hilly regions of the plateau. In certain occasions, such as in S1 and S2, authors have observed hundreds of individuals without finding a single individual of the more common and abundant *Eurema hecabe* (Linnaeus, 1758). However, in the plains with the increase of disturbance and human intervention, *Eurema hecabe* starts dominating the niche and *E. brigitta* becomes rarer, occurring mostly in mixed forest patches (S3, S5), but in significantly lesser abundance compared to the primary hill forests (S1, S2).

Appias albina (Boisduval, 1836) – A single individual (Fig. 8.27) in semiflava form, characterized by pale ochre forewing apex and entire hindwings (Seitz, 1927), at S3 on 23 August 2021. The species happens to be very rare in the region, and though it is distributed in the Chhotanagpur Plateau in neighboring Jharkhand (Morrison-Godfrey, 1948) and Odisha (Varshney and Smetacek, 2015), the authors have found it to be rare in the study area with very few reports on social media sites and citizen science platforms. This particular form in itself is also rare

Simlipal hills, located in the adjoining Mayurbhanj district of Odisha is known to have both Himalayan and southern Indian floral elements (Saxena and Brahmam, 1989). The similarities of the floral diversity (Sen and Bhakat, 2021) and the continuity of the forest corridor with Simlipal and Singhbhum allow the diversity of butterfly fauna in Jhargram district, to include elements of both the Himalayan foothills and the Peninsular India butterfly fauna. Sustained, in-depth, and thorough investigation of the butterflies, and Lepidoptera fauna in general, in this region, will provide better information about distributions of species in West Bengal state, India.

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Conflict of interest

The authors declare that there are no conflicting issues related to this research article.

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