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A study on the butterfly diversity of Haldia industrial belt and adjacent rural area in Purba Medinipur district, West Bengal, India

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ABSTRACT

67 species of butterflies under 5 families and 51 genera were recorded from Haldia industrial belt and adjacent rural area. Industrial zone had fewer species low diversity and evenness indices and high dominance index. Nymphalidae outnumbered all other families in the industrial zone with 48% of the total species of that area. Such preponderance of any single family was not evident in the rural area, likewise industrial belt had 3 dominant species but no dominant species could be seen in the rural zone. Results suggest that industrialization could alter the butterfly diversity but it was not enough to make the two sites dissimilar as revealed by the index of similarity (0.52).

Keywords: Butterfly diversity, effect of industrialization, evenness, dominance and similarity indices, ecological indicator

1. INTRODUCTION

India has a rich diversity of butterflies with 1318 species (Varshney and Smetacek, 2015). These are important components of terrestrial community structure and their loss makes

adverse effects on ecosystem functioning (Altermatt and Pearse, 2011). Butterfly diversity is positively related with plant diversity (Leps and Spitzer 1990) and (Padhye et al., 2006). Butterflies are very sensitive to change in microclimate (Fordyce, 2003). Any change in vegetation structure may cause a change in butterfly diversity (Koh, 2007). As such these act as rapid indicator of the habitat quality (Ramana, 2010) and these are one of the most suitable tools for biodiversity studies (Hortal et al., 2015).

Anthropogenic interferences like urbanization and industrialization cause migration or local extinction of butterflies (Mennechez et al., 2003). In recent years butterflies of India have been investigated by several author like Ramesh et al., 2010; Thakur and Mattu, 2010; Majumder et al., 2013; Tiple and Khured, 2009; Sengupta et al., 2014 and Priya et al., 2017. In West Bengal, diversity of butterfly have been studied by Ghosh and Siddique, 2005; Chowdhury and Chowdhury, 2006; Chowdhury and Soren, 2011; Roy et al., 2012; Sanyal et al., 2012; Chowdhury, 2014; Raychaudhuri and Saha, 2014; Mukherjee et al., 2015; Ghosh and Mukherjee, 2016; Ghosh and Saha, 2016; Mandal, 2016; Samanta et al., 2017 and Dey et al., 2017.

The main objective of the present study is to investigate the butterfly fauna of Haldia industrial belt, in West Bengal and to find out if industrialization and urbanization have any adverse impact on the density and diversity of butterflies.

2. MATERIALS AND METHODS

2. 1. Study sites

Present study was conducted in Haldia industrial region and adjacent rural area (Figure 1). Haldia (22.080767 N, 88.142876 E) is one of the most rapidly growing industrial township in West Bengal situated on the deltaic tidal zone of the Ganga basin, at the confluence of river, Hoogly and Haldi. Average elevation of is 6 meters MSL. Haldia is predominantly a petrochemical industrial belt. The major industries which are Indian Oil Corporation Haldia Refinery, Haldia Petrochemicals Ltd., Haldia Met Coke and Power Ltd., Exide Industries Ltd., TATA Chemicals, Shaw Wallace & Co Ltd., Mitsubishi PTA (I) Ltd., Petro Carbon & Chemical Ltd., Shree Renuka Sugars Ltd., Dhunseri Petrochem & Tea Ltd., CESC Haldia Thermal Power Plant and Electro Steel Castings Ltd. Every day considerable quantities of pollutants are released in air and water. Average temperature of summer (March - June) is 24 °C to 38 °C and average winter (October - February) temperature is 12 °C to 20 °C. Haldia gets 1451 mm of rain mostly between June and September.

The study was conducted in an area spreading over 185 sq. km was divided into two zones viz. Haldia industrial zone (22° 4' 4.1628" N, 88° 7' 35.3568" E) having an area of 89 sq. km. and the adjacent rural region (22° 6' 30.7548" N & 88° 5' 54.006" E) having an area of 96 sq. km. 5 sampling sites were selected from each zone (Figure 1). Selected sampling sites in industrial zone were 1) CESC Haldia power plant area, 2) Shaw Wallace patikhali river side, 3) Durgachak town railway station area, 4) Chiranjibpur area, 5) Haldia Township children park and that in adjacent rural area were 1) Chitanyapur-Kukrahati road, 2) Begunberia, 3) Sutahata, 4) Barabari, 5) Balughata sunset point. The average aerial distance between two sampling zones was about 7 km. The industrial zone and adjacent rural area were also distinguished by their floral composition.

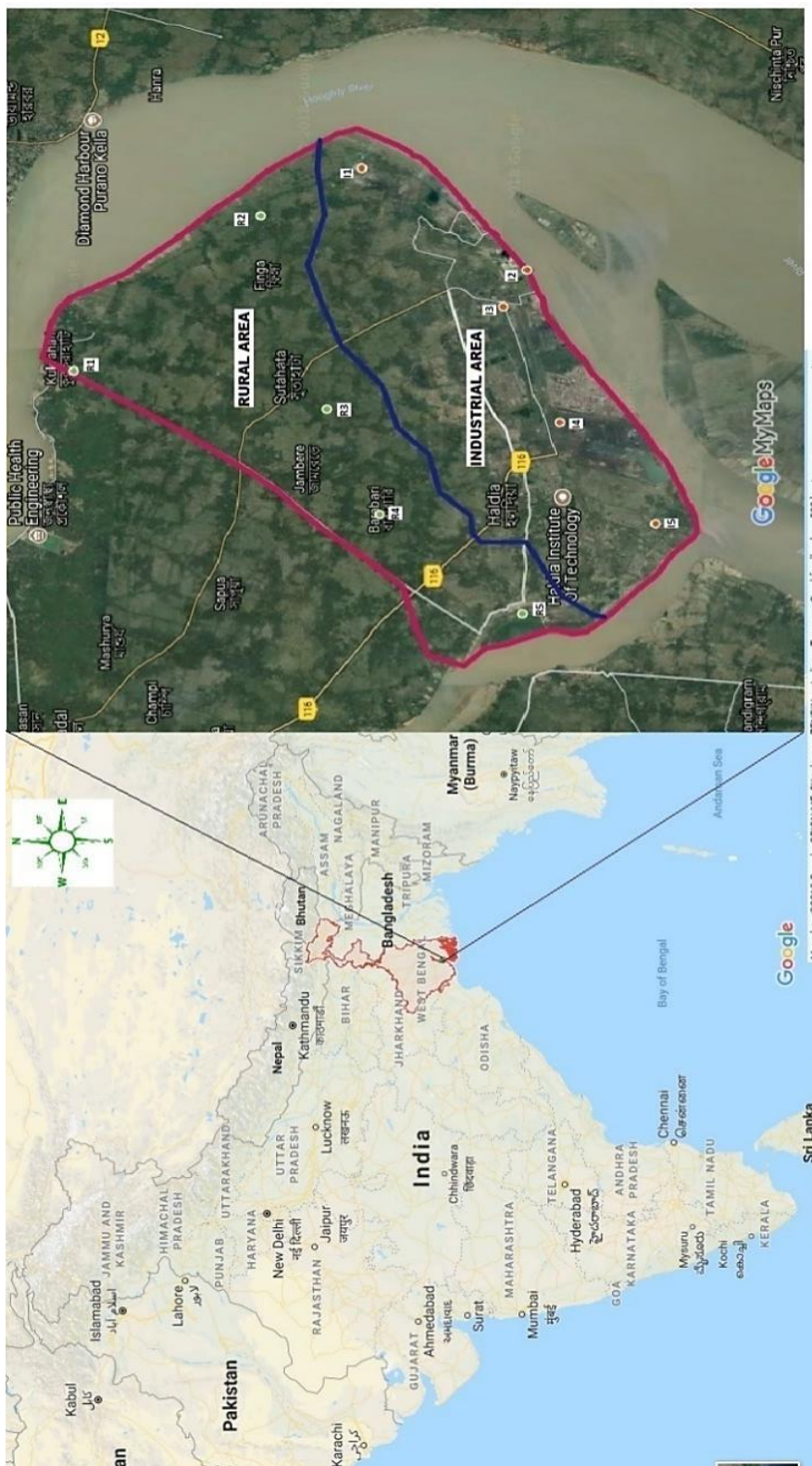


Figure 1. Map of Haldia Municipality & adjoining rural area, West Bengal, Highlighting the Industrial sampling site with red point & rural area with green point.

Rural area harbors 33 plant species under 18 families where as industrial zone has only 19 species under 13 families. 11 plant species were common to both the study sites. *Rhizophora mangle* (Rhizophoraceae), *Dioscorea sp* (Dioscoreaceae) were found in rural area, on the other hand *Ixora sp*, *Mussaenda laxa* under the family Rubiaceae and *Terminalia sp* (Combretaceae) were mainly present in industrial area.

2. 2. Sampling techniques

The study was conducted from October 2016 to September 2017. Each site was visited twice in a month between 8 AM to 3 PM, during normal climatic condition with no strong wind and heavy rains. In each site, two transect 1000 meter long paths of 3 meter width were taken with a gap of 200 meter in between. Thus a total of 4 km (1000 m × 4) transect path was followed during each sampling occasion. Butterflies were counted on either side of this transects. Same transect path was followed during each sampling occasion to reduce the number of variables as suggested by (Pyle, 1992). The number of individuals under each species of butterflies were counted along transects following Pollard walk method (Pollard, 1977; Pollard and Yates, 1993). Average air quality index was measured by taking the air quality data on each survey time following Central Pollution Control Board (National Air Quality Index, 2016-2017).

2. 3. Taxonomic procedure and documentation

Butterflies were photographed by a digital Nikon D3200 camera. Some specimen were captured using butterfly hand net and after identification those were released in the same habitat with least damage to scales on the wings. All the data were recorded with date, place and associated plants. Species level identification was done with the help of standard field guides and taxonomic literature of Kehimkar, 2016; Wynter Blyth, 2009; Varshney & Smetacek, 2015 and Smetacek, 2017.

2. 4. Community Analysis

Butterfly community structure was analyzed with reference to abundance, relative abundance, species Shannon diversity index, Simpson's dominance index, Pielou's evenness index using the PAST software. Dominance status of each species was ascertained on the basis of relative abundance following Engelmann's scale (Engelmann, 1978). Similarity or otherwise of the butterfly species composition was determined follow Sørensen's Index of similarity (Sørensen, 1948).

3. RESULT AND DISCUSSION

67 species of butterflies under 5 families and 51 genera were recorded from Haldia industrial region and the adjacent rural area (Table 1). Of these 37 species belongs to 28 genera were collected from the industrial zone and were 54 species under 44 genera were recorded in the rural zone (Table 1). There were 24 species common to both the zones and index of similarity was found to be 0.52 suggesting that both the study areas were slightly similar in respect to the butterfly species composition (Table 1).

Table 1. Checklist of butterflies in Haldia industrial area and adjacent rural area

SL. NO.	COMMON NAME	SCIENTIFIC NAME	RURAL AREA	INDUSTRIAL AREA
Family: Pieridae				
Subfamily: Coliadinae				
1.	Common Emigrant	<i>Catopsilia pomona</i> (Fabricius, 1775)	+	-
2.	Mottled Emigrant	<i>Catopsilia pyranthe</i> (Linnaeus, 1758)	+	+
3.	Common Grass Yellow	<i>Eurema hecabe hecabe</i> (Linnaeus, 1758)	+	-
4.	One Spot Grass Yellow	<i>Eurema andersoni jordani</i> (Corbet & Pendlebury, 1932)	+	+
Subfamily: Pierinae				
5.	Common Gull	<i>Cepora nerissa evagete</i> (Cramer, 1779)	+	+
6.	Yellow Orange Tip	<i>Ixias pyrene sesia</i> (Fabricius, 1777)	+	-
7.	Striped Albatross	<i>Appias libythea olferna</i> (Swinhoe, 1890)	+	-
8.	Indian Cabbage White	<i>Pieris canidia</i> (Linnaeus, 1768)	+	-
9.	Common Jezebel	<i>Delias eucharis</i> (Drury, 1773)	+	-
10.	Psyche	<i>Leptosia nina nina</i> (Fabricius, 1793)	+	+
11.	Common Wanderer	<i>Pareronia valeria hippia</i> (Fabricius, 1787)	+	+
12.	Small Salmon Arab	<i>Colotis amata modestus</i> (Butler, 1876)	+	-
Family: Papilionidae				
Subfamily: Papilioninae				
13.	Common Jay	<i>Graphium doson eleius</i> (Fruhstorfer, 1907)	-	+
14.	Tailed Jay	<i>Graphium agamemnon menides</i> (Fruhstorfer, 1904)	+	+
15.	Common Rose	<i>Pachliopta aristolochiae aristolochiae</i> (Fabricius, 1775)	+	+
16.	Common Mime	<i>Papilio clytia clytia</i> (Linnaeus, 1758)	+	-
17.	Common Mormon	<i>Papilio polytes romulus</i> (Cramer, 1775)	+	+
18.	Lime Butterfly	<i>Papilio demoleus demoleus</i> (Linnaeus, 1758)	+	+
Family: Lycaenidae				
Subfamily: Curetinae				
19.	Indian Sunbean	<i>Curetis thetis thetis</i> (Drury, 1773)	-	+
Subfamily: Miletinae				
20.	Apefly	<i>Spalgis epius epius</i> (Westwood, 1852)	+	-

Subfamily: Aphnaeinae				
21.	Common Silverline	<i>Spindasis vulcanus vulcanus</i> (Fabricius, 1775)	+	+
22.	Slate Flash	<i>Rapala manea schistacea</i> (Moore, 1879)	+	-
23.	Monkey Puzzle	<i>Rathinda amor</i> (Fabricius, 1775)	+	-
Subfamily: Polyommatae				
24.	Ciliate Blue	<i>Anthene emolus emolus</i> (Godart, 1824)	+	-
25.	Pointed Ciliate Blue	<i>Anthene lycaenina lycaenina</i> (Felder, 1868)	+	-
26.	Dark Grass Blue	<i>Zizeeria karsandra</i> (Moore, 1865)	+	+
27.	Plains Cupid	<i>Luthrodes pandava</i> (Horsfield, 1829)	+	-
28.	Tiny Grass Blue	<i>Zizina hylax</i> (Fabricius, 1775)	+	+
29.	Gram Blue	<i>Euchrysops cnejus</i> (Fabricius, 1798)	+	-
30.	Small Cupid	<i>Chilades parrhasius</i> (Fabricius, 1793)	-	+
31.	Lime Blue	<i>Chilades lajus lajus</i> (Stoll, 1780)	+	-
32.	Pale Grass Blue	<i>Pseudozizeeria maha</i> (Kollar, 1844)	+	+
33.	Forget-Me-Not	<i>Catochrysops strabo strabo</i> (Fabricius, 1793)	+	-
34.	Quaker	<i>Neopithecops zalmora zalmora</i> (Butler, 1870)	+	-
Subfamily: Theclinae				
35.	Falcate Oakblue	<i>Mahathala ameria</i> (Hewiton, 1862)	+	-
Family: Nymphalidae				
Subfamily: Danaeinae				
36.	Blue Tiger	<i>Tirumala limniace exoticus</i> (Gmelin, 1790)	+	+
37.	Common Tiger	<i>Danaus genutia genutia</i> (Cramer, 1779)	+	+
38.	Plain Tiger	<i>Danaus chrysippus chrysippus</i> (Linnaeus, 1758)	+	+
39.	White Tiger	<i>Danaus melanippus indicus</i> (Fruhstorfer, 1899)	-	+
40.	Common Crow	<i>Euploeini core core</i> (Cramer, 1780)	+	+
41.	Double Branded crow	<i>Euploea sylvester</i> (Fabricius, 1793)	+	-
42.	King Crow	<i>Euploea klugii kollari</i> (C. & R. Felder, 1865)	-	+
Subfamily: Satyrinae				
43.	Common Evening Brown	<i>Melanitis leda leda</i> (Linnaeus, 1758)	-	+
44.	Dark Evening Brown	<i>Melanitis phedima bela</i> (Moore, 1857)	-	+
45.	Common Palmfly	<i>Elymnias hypermnestra undularis</i> (Drury, 1773)	+	-

46.	Common Bush Brown	<i>Mycalesis perseus</i> (Fabricius, 1775)	+	-
Subfamily: Acraeinae				
47.	Tawny Coster	<i>Acraea violae</i> (Fabricius, 1793)	+	+
Subfamily: Heliconiinae				
48.	Common Leopard	<i>Phalanta phalantha phalantha</i> (Drury, 1773)	+	+
Subfamily: Limenitidinae				
49.	Chestnut-streaked Sailer	<i>Neptis jumbah jumbah</i> (Moore, 1858)	-	+
50.	Common Baron	<i>Euthaliaacontheaanagama</i> (Fruhstorfer, 1913)	+	-
Subfamily: Biblidinae				
51.	Angled Castor	<i>Ariadne ariadne indica</i> (Moore, 1884)	+	+
52.	Common Castor	<i>Ariadne merione tapestrina</i> (Moore, 1884)	-	+
Subfamily: Nymphalinae				
53.	Peacock Pansy	<i>Junonia almanac almana</i> (Linnaeus, 1758)	+	+
54.	Grey Pansy	<i>Junonia atlites atlites</i> (Linnaeus, 1763)	+	+
55.	Lemon Pansy	<i>Junonia lemonias lemonias</i> (Linnaeus, 1758)	-	+
56.	Blue Pansy	<i>Junonia orithya swinhoei</i> (Butler, 1885)	+	-
57.	Great Eggfly	<i>Hypolimnas bolina jacintha</i> (Drury, 1758)	-	+
Family: Hesperiiidae				
Subfamily: Coeliadinae				
58.	Brown Awl	<i>Badamia exclamationis</i> (Fabricius, 1775)	-	+
59.	Common Banded Awl	<i>Hasora chromus chromus</i> (Cramer, 1780)	-	+
Subfamily: Hesperinae				
60.	Dark Palm Dart	<i>Telicota bambusae</i> (Moore, 1878)	+	-
61.	Common Redeye	<i>Matapa aria</i> (Moore, 1866)	+	-
62.	Bush Hopper	<i>Ampittia dioscorides dioscorides</i> (Fabricius, 1793)	+	+
63.	Grass Demon	<i>Udaspes folus</i> (Cramer, 1775)	+	-
64.	Rice Swift	<i>Borbo cinnara</i> (Wallace, 1866)	+	-
65.	Small branded Swift	<i>Pelopidas thrax</i> (Huebner, 1821)	+	+
66.	Banana Skipper	<i>Erionota torus</i> (Evaus, 1941)	+	-
Subfamily: Pyrginae				
67.	Bengal Spotted Flat	<i>Celaenorrhinus putra</i> (Moore, 1866)	+	-

No. of Species	54	37
Sørensen's Index of Similarity	0.52	

Table 2a. Dominance status of species recorded from industrial area.

Sl. No.	Common Name	Scientific Name	Abundance	Relative Abundance (%)	Dominance Status*
Family: Pieridae					
Subfamily: Coliadinae					
1.	Mottled Emigrant	<i>Catopsilia pyranthe</i> (Linnaeus, 1758)	181	2.146	R
2.	One Spot Grass Yellow	<i>Eurema andersoni jordani</i> (Corbet & Pendlebury, 1932)	91	1.078	SR
Subfamily: Pierinae					
3.	Common Gull	<i>Cepora nerissa evagete</i> (Cramer, 1779)	39	0.462	SR
4.	Psyche	<i>Leptosia nina nina</i> (Fabricius, 1793)	113	1.339	R
5.	Common Wanderer	<i>Pareronia valeria hippia</i> (Fabricius, 1787)	56	0.663	SR
Family: Papilionidae					
Subfamily: Papilioninae					
6.	Common Jay	<i>Graphium doson eleius</i> (Fruhstorfer, 1907)	816	9.675	SD
7.	Tailed Jay	<i>Graphium agamemnon menides</i> (Fruhstorfer, 1904)	81	0.960	SR
8.	Common Rose	<i>Pachliopta aristolochiae aristolochiae</i> (Fabricius, 1775)	358	4.244	SD
9.	Common Mormon	<i>Papilio polytes romulus</i> (Cramer, 1775)	107	1.268	R
10.	Lime Butterfly	<i>Papilio demoleus demoleus</i> (Linnaeus, 1758)	641	7.600	SD
Family: Lycaenidae					
Subfamily: Curetinae					
11.	Indian Sunbean	<i>Curetis thetis thetis</i> (Drury, 1773)	979	11.607	D
Subfamily: Aphnaeinae					
12.	Common Silverline	<i>Spindasis vulcanus vulcanus</i> (Fabricius, 1775)	97	1.150	R
Subfamily: Polyommatainae					
13.	Dark Grass Blue	<i>Zizeeria karsandra</i> (Moore, 1865)	11	0.130	SR
14.	Tiny Grass Blue	<i>Zizina hylax</i> (Fabricius, 1775)	17	0.201	SR

15.	Small Cupid	<i>Chilades parrhasius</i> (Fabricius, 1793)	24	0.284	SR
16.	Pale Grass Blue	<i>Pseudozizeeria maha</i> (Kollar, 1844)	9	0.106	SR
Family: Nymphalidae					
Subfamily: Danainae					
17.	Blue Tiger	<i>Tirumala limniace exoticus</i> (Gmelin, 1790)	793	9.402	SD
18.	Common Tiger	<i>Danaus genutia genutia</i> (Cramer, 1779)	53	0.628	SR
19.	Plain Tiger	<i>Danaus chrysippus chrysippus</i> (Linnaeus, 1758)	85	1.007	SR
20.	King Crow	<i>Euploea klugii kollari</i> (C. & R. Felder, 1865)	287	3.402	SD
21.	Common Crow	<i>Euploeini core core</i> (Cramer, 1780)	41	0.486	SR
22.	White Tiger	<i>Danaus melanippus indicus</i> (Fruhstorfer, 1899)	867	10.279	D
Subfamily: Satyrinae					
23.	Common Evening Brown	<i>Melanitis leda leda</i> (Linnaeus, 1758)	89	1.055	SR
24.	Dark Evening Brown	<i>Melanitis phedima bela</i> (Moore, 1857)	101	1.197	R
Subfamily: Acraeinae					
25.	Tawny Coster	<i>Acraea violae</i> (Fabricius, 1793)	92	1.090	SR
Subfamily: Heliconiinae					
26.	Common Leopard	<i>Phalanta phalantha phalantha</i> (Drury, 1773)	126	1.493	R
Subfamily: Limenitidinae					
27.	Chestnut-streaked Sailer	<i>Neptis jumbah jumbah</i> (Moore, 1858)	941	11.157	D
Subfamily: Biblidinae					
28.	Angled Castor	<i>Ariadne ariadne indica</i> (Moore, 1884)	51	0.604	SR
29.	Common Castor	<i>Ariadne merione tapestrina</i> (Moore, 1884)	158	1.873	R
Subfamily: Nymphalinae					
30.	Peacock Pansy	<i>Junonia almana almana</i> (Linnaeus, 1758)	64	0.758	SR
31.	Grey Pansy	<i>Junonia atlites atlites</i> (Linnaeus, 1763)	54	0.640	SR
32.	Lemon Pansy	<i>Junonia lemonias lemonias</i> (Linnaeus, 1758)	102	1.209	R
33.	Great Eggfly	<i>Hypolimnas bolina jacintha</i> (Drury, 1758)	159	1.885	R
Family: Hesperiiidae					
Subfamily: Coeliadinae					
34.	Brown Awl	<i>Badamia exclamationis</i> (Fabricius, 1775)	613	7.268	SD

35.	Common Banded Awl	<i>Hasora chromus chromus</i> (Cramer, 1780)	47	0.557	SR
Subfamily: Hesperinae					
36.	Bush Hopper	<i>Ampittia dioscorides dioscorides</i> (Fabricius, 1793)	57	0.675	SR
37.	Small branded Swift	<i>Pelopidas thrax</i> (Huebner, 1821)	34	0.403	SR

* RA<1 = SUBRECEDENT (SR); 1.1-3.1 = RECEDENT (R); 3.2-10 = SUBDOMINANT (SD); >10.1 31.6 = DOMINANT (D)

Table 2b. Dominance status of species recorded from rural area.

Sl. No.	Common Name	Scientific Name	Abundance	Relative Abundance (%)	Dominance Status *
Family: Pieridae					
Subfamily: Coliadinae					
1.	Common Emigrant	<i>Catopsilia pomona</i> (Fabricius, 1775)	147	1.406	R
2.	Mottled Emigrant	<i>Catopsilia pyranthe</i> (Linnaeus, 1758)	201	1.923	R
3.	Common Grass Yellow	<i>Eurema hecabe hecabe</i> (Linnaeus, 1758)	193	1.846	R
4.	One Spot Grass Yellow	<i>Eurema andersoni jordani</i> (Corbet & Pendlebury, 1932)	679	6.496	SD
Subfamily: Pierinae					
5.	Common Gull	<i>Cepora nerissa evagete</i> (Cramer, 1779)	170	1.626	R
6.	Yellow Orange Tip	<i>Ixias pyrene sesia</i> (Fabricius, 1777)	144	1.377	R
7.	Striped Albatross	<i>Appias libythea olferna</i> (Swinhoe, 1890)	165	1.578	R
8.	Indian Cabbage White	<i>Pieris canidia</i> (Linnaeus, 1768)	91	0.870	SR
9.	Common Jezebel	<i>Delias eucharis</i> (Drury, 1773)	38	0.363	SR
10.	Psyche	<i>Leptosia nina nina</i> (Fabricius, 1793)	191	1.827	R
11.	Common Wanderer	<i>Pareronia valeria hippia</i> (Fabricius, 1787)	217	2.076	R
12.	Small Salmon Arab	<i>Colotis amata modestus</i> (Butler, 1876)	33	0.315	SR
Family: Papilionidae					
Subfamily: Papilioninae					
13.	Tailed Jay	<i>Graphium Agamemnon menides</i> (Fruhstorfer, 1904)	254	2.430	R
14.	Common Rose	<i>Pachliopta aristolochiae aristolochiae</i> (Fabricius, 1775)	156	1.492	R

15.	Common Mime	<i>Papilio clytia clytia</i> (Linnaeus, 1758)	313	2.994	R
16.	Common Mormon	<i>Papilio polytes romulus</i> (Cramer, 1775)	391	3.741	SD
17.	Lime Butterfly	<i>Papilio demoleus demoleus</i> (Linnaeus, 1758)	512	4.899	SD
Family: Lycaenidae					
Subfamily: Miletinae					
18.	Apefly	<i>Spalgis epius epius</i> (Westwood, 1852)	121	1.157	R
Subfamily: Aphnaeinae					
19.	Common Silverline	<i>Spindasis vulcanus vulcanus</i> (Fabricius, 1775)	421	4.028	SD
20.	Slate Flash	<i>Rapala manea schistacea</i> (Moore, 1879)	128	1.224	R
21.	Monkey Puzzle	<i>Rathinda amor</i> (Fabricius, 1775)	357	3.415	SD
Subfamily: Polyommatae					
22.	Ciliate Blue	<i>Anthene emolus emolus</i> (Godart, 1824)	108	1.033	SR
23.	Dark Grass Blue	<i>Zizeeria karsandra</i> (Moore, 1865)	129	1.234	R
24.	Plains Cupid	<i>Luthrodes pandava</i> (Horsfield, 1829)	134	1.282	R
25.	Tiny Grass Blue	<i>Zizina hylax</i> (Fabricius, 1775)	257	2.459	R
26.	Gram Blue	<i>Euchrysops cnejus</i> (Fabricius, 1798)	21	0.200	SR
27.	Pale Grass Blue	<i>Pseudozizeeria maha</i> (Kollar, 1844)	124	1.186	R
28.	Forget-Me-Not	<i>Catochrysops strabo strabo</i> (Fabricius, 1793)	132	1.263	R
29.	Quaker	<i>Neopithecops zalmora zalmora</i> (Butler, 1870)	301	2.880	R
30.	Pointed Ciliate Blue	<i>Anthene lycaenina lycaenina</i> (Felder, 1868)	151	1.444	R
31.	Lime Blue	<i>Chilades lajus lajus</i> (Stoll, 1780)	158	1.511	R
Subfamily: Theclinae					
32.	Falcate Oakblue	<i>Mahathala ameria</i> (Hewiton, 1862)	73	0.698	SR
Family: Nymphalidae					
Subfamily: Danainae					
33.	Blue Tiger	<i>Tirumala limniace exoticus</i> (Gmelin, 1790)	243	2.325	R
34.	Common Tiger	<i>Danaus genutia genutia</i> (Cramer, 1779)	123	1.176	R
35.	Plain Tiger	<i>Danaus chrysippus chrysippus</i> (Linnaeus, 1758)	231	2.210	R
36.	Common Crow	<i>Euploeini core core</i> (Cramer, 1780)	211	2.018	R
37.	Double Branded crow	<i>Euploea sylvester</i> (Fabricius, 1793)	47	0.449	SR

Subfamily: Satyrinae					
38.	Common Palmfly	<i>Elymnias hypermnestra undularis</i> (Drury, 1773)	118	1.129	R
39.	Common Bush Brown	<i>Mycalesis perseus</i> (Fabricius, 1775)	41	0.392	SR
Subfamily: Acraeinae					
40.	Tawny Coster	<i>Acraea violae</i> (Fabricius, 1793)	449	4.296	SD
Subfamily: Heliconiinae					
41.	Common Leopard	<i>Phalanta phalantha phalantha</i> (Drury, 1773)	184	1.760	R
Subfamily: Limenitidinae					
42.	Common Baron	<i>Euthalia aconthea anagama</i> (Fruhstorfer, 1913)	61	0.583	SR
Subfamily: Biblidinae					
43.	Angled Castor	<i>Ariadne ariadne indica</i> (Moore, 1884)	113	1.081	SR
Subfamily: Nymphalinae					
44.	Peacock Pansy	<i>Junonia almanac almana</i> (Linnaeus, 1758)	281	2.688	R
45.	Grey Pansy	<i>Junonia atlites atlites</i> (Linnaeus, 1763)	109	1.042	SR
46.	Blue Pansy	<i>Junonia orithya swinhoi</i> (Butler, 1885)	29	0.277	SR
Family: Hesperidae					
Subfamily: Hesperinae					
47.	Dark Palm Dart	<i>Telicota bambusae</i> (Moore, 1878)	56	0.535	SR
48.	Common Redeye	<i>Matapa aria</i> (Moore, 1866)	35	0.334	SR
49.	Bush Hopper	<i>Ampittia dioscorides dioscorides</i> (Fabricius, 1793)	373	3.569	SD
50.	Grass Demon	<i>Udaspes folus</i> (Cramer, 1775)	271	2.593	R
51.	Rice Swift	<i>Borbo cinnara</i> (Wallace, 1866)	581	5.559	SD
52.	Small branded Swift	<i>Pelopidas thrax</i> (Huebner, 1821)	341	3.262	SD
53.	Banana Skipper	<i>Erionota torus</i> (Evaus, 1941)	13	0.124	SR
Subfamily: Pyrginae					
54.	Bengal Spotted Flat	<i>Celaenorrhinus putra</i> (Moore, 1866)	31	0.296	SR

* RA<1 = SUBRECEDENT (SR); 1.1-3.1 = RECEDENT (R); 3.2-10 = SUBDOMINANT (SD); >10.1-31.6 = DOMINANT (D)

Lower number of lepidopteran species in Haldia industrial zone as compared to the non-industrial rural area as in the present study was also previously reported by Jana et al., 2006 who ascribed this to the effect of industrialization. Jana et al., 2013 recorded 27 species of

butterflies from Digha coastal area and Hajra et al., 2015 reported 46 species of butterflies from Contai in Purba Medinipur district. Thus the present study has added to the butterfly fauna of Purba Medinipur district. Lower number of species in Haldia industrial belt might be due to sensitivity of some species to pollutants. Kunte, 2000; Thomas, 2005; Bonebrake et al., 2010 have also suggested that butterfly diversity can be affected by human disturbances like habitat loss and pollution. 13 species which were exclusively present in the industrial zone may be considered as more tolerant to pollutants and 30 species which were confined to the rural area may be considered as more sensitive to pollutants. Having complex resource utilization pattern, butterflies are more sensitive towards decline ecosystem health (Thomas et al., 2004 and Thomas, 2005). Any change in native vegetation composition, through anthropogenic interactions, might also be detected by the alteration in species composition of butterflies. Even minor change in habitat may lead to migration or local extinction of native butterflies populations (Blair, 1999; Mennechez et al., 2003). Change in land pattern leading to changes in landscape profile may also lead to change in their diversity (Ghosh and Saha, 2016). In terms of the number of species Nymphalidae was the most common family in Haldia industrial zone with 17 species. This was followed by Lycaenidae (6 species), Pieridae, Papilionidae (5 species each) and Hesperidae (4 species) respectively (Figure 2a). Preponderance of Nymphalidae was also reported by Tiple and Khurad, 2009 in Nagpur, Majumder et al., 2013 in Tripura, Nair et al., 2014 in Kolkata, Harsh, 2014 in Bhopal, Mondal, 2016 in Chinsurah and Samanta et al., 2017 at Bugmundi hill, Purulia, West Bengal, Khyade and Jagtap, 2017 at Pune and Priya et al., 2017 in a village of Kerala. Nymphalidae is polyphagous in nature, can live in variety of habitats and the species under this family are active fliers (Majumder et al., 2013). Nymphalidae, therefore is best adapted butterfly family and it dominates in different environmental conditions throughout the country. Pieridae and Hesperidae were less frequent due to their low ecological tolerance and for their preference for relatively less disturbed habitats (Majumder et al., 2013).

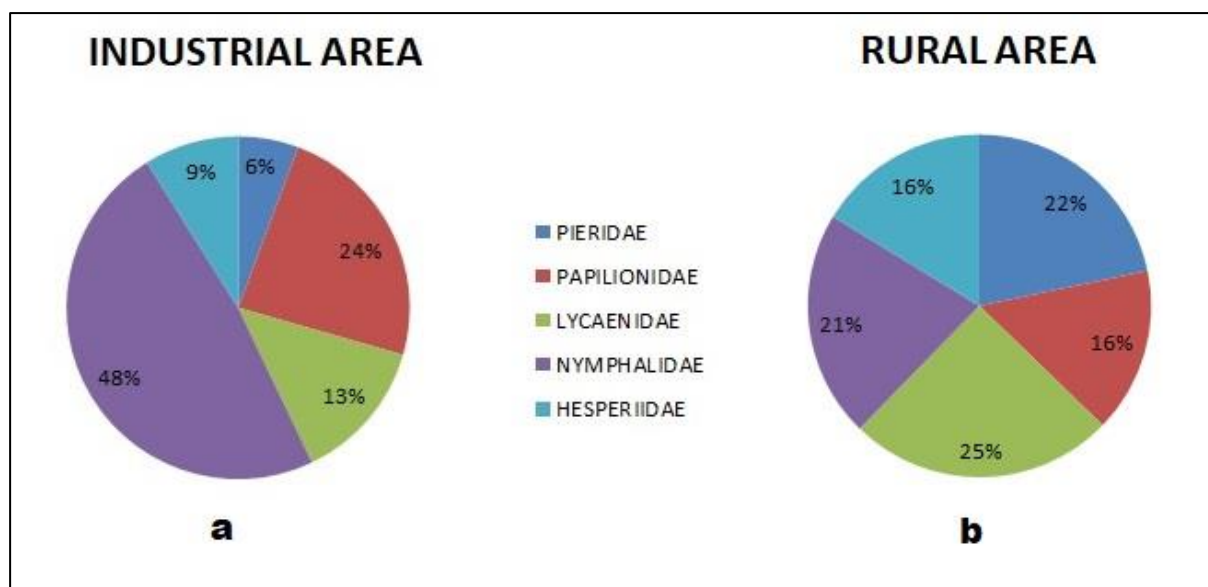


Figure 2a-2b. Family wise percentage of individuals in two sites.

In Rural area, on the contrary, species wise the most dominating family was Lycaenidae with 15 species. It was followed by Nymphalidae (14 species), Pieridae (12 species) and Hesperidae (8 species) respectively. Papilionidae (16%) in that order preponderance of Lycaenidae and Nymphalidae (Figure 2b) was also reported by Mukherjee et al., 2015 in Kolkata.

It appears Lycaenidae, Pieridae, Hesperidae prefer relatively undisturbed and less stressed environment as in rural areas. Patil et al., 2014 reported Lycaenidae as second most abundant family. Prabakaran et al., 2014 observed that Hesperidae had maximum number of species in Tamil Nadu.

An analysis of relative abundance revealed that in the industrial area 3 species viz., *Curetis thetis thetis*, *Neptis jumbah jumbah* and *Danaus melanippus indicus* were dominant and 6 species were subdominant in nature (Table 2a). In rural area there was no dominant species but 9 species were subdominant (Table 2b). The dominance index (C) was found to be notably lower in the rural zone (0.028) as compared to the industrial zone (0.071) (Table 3). This clearly suggests that industrial zone represents harsher environmental condition as compared to the nearby rural zone.

Table 3. Comparison of different indices of the study sites.

Study area	Shanon diversity index (\bar{H})	Pielou evenness index (e)	Simpson dominance index (C)
Industrial zone	2.96	0.814	0.071
Rural zone	3.72	0.979	0.028

There was little difference in diversity (\bar{H}) and evenness (e) indices which were relatively higher in the non-industrial rural area ($\bar{H} = 3.72, e = 0.979$) than industrial zone ($\bar{H} = 2.96, e = 0.814$) (Table 3). The diversity indices in industrial zone indicates moderate pollution level which also be supported by the average air quality index (112) by Central Pollution Control Board (National Air Quality index, 2016-2017). Higher diversity in rural belt was also reported by Kitahara and Sei, 2001 in Japan and this was due to agricultural landscape with rural areas which provides habitat heterogeneity and available host plant species (Kuussaari et al., 2007).

In the study area 9 species were found which are listed in the Indian Wildlife (Protection) Act schedule I, II & IV. Only two species viz., *Neptis jumbah jumbah* of the industrial zone and *Papilio clytia clytia* of the rural zone are listed under Schedule - I.

4. CONCLUSIONS

Present study revealed that, Haldia industrial zone has less number of butterflies species, lower diversity and evenness indices and higher dominance index as compared to the adjacent rural belt. Findings suggest that industrialized area offered a relatively harsh environment to butterflies which responded adversely to that predominance of Nymphalidae

has also been seen in the industrial zone. In spite of these the two zones under consideration were slightly similar in butterfly faunal composition as revealed by the index of similarity. This was due to close proximity of the two zones. However, the study suggests that butterflies have the potentiality to be used as good ecological indicator.

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