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Monsoon moths (Lepidoptera: Heterocera) of Midnapore town, West Bengal, India: a preliminary checklist with a note on their diversity

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Abstract

An investigation on monsoon moth fauna of Midnapore town in West Bengal, India was carried out from June 1 to September 30, 2019. We documented 1084 individual moths representing 12 families, 29 subfamilies, 71 genera and 78 morphospecies during nocturnal surveys conducted over 36 survey nights. A preliminary illustrated checklist of all moths and their diversity status was created. Erebidae showed the maximum species richness followed by Crambidae, Geometridae and others, whereas highest proportion of moths were recorded from Crambidae (37.63%) followed by Erebidae (31.54%), Geometridae (15.40%), and others. August and September exhibited more species richness with an evenly distributed moth community as compared to the other two months. However, statistical analysis indicated no significant difference in moth abundance among the four monsoon months. The present work also recorded some of the very rare species like *Biston suppressaria, Dysgonia algira, Hypopyra vespertilio, Nannoarctia himalayana, Oruza divisa*, and others from this part of the state.

Key words: checklist, Midnapore town, monsoon moths, urbanization, West Bengal.
Abbreviations: C, common; R, rare; UN, uncommon.

Introduction

Moths belong to the insect order Lepidoptera (moths and butterflies) and constitute the vast majority of the order with approximately 160 000 described species and the total number of extant species is estimated to be around half a million (Kristensen et al. 2007). These are primarily nocturnal creatures that occupy a wide variety of habitats and constitute an important component of terrestrial ecosystems and serve as food resources for birds, small mammals as well as pollinators and nutrient recyclers (Lintott et al. 2014). Being sensitive to environmental pressures, moth assemblages of a region can act as indicators of environmental quality and help us in the detection of ecosystem level impacts (Kitching et al. 2000; Dennis et al. 2019). Investigation of local Lepidoptera diversity in different habitats under anthropogenic disturbances constitute an important aspect of global biodiversity monitoring and provides valuable information necessary for the conservation of invertebrate biodiversity in Southeast Asia, which is experiencing a massive habitat loss during the past few decades (Beck, Nässig 2008; Estoque et al. 2019).

India is one of the 17 megadiverse countries of the world and harbours a significant part of the Earth's species. It is a home for nearly 11 300 described species of Lepidoptera with more than 10 000 species of moths (Smetacek 2013). The pioneering work on moths of India was carried out by Hampson (1892; 1894; 1895; 1896) and Bell and Scott (1937). During the last few decades a large number of studies have reported the local moth diversity from different parts of India (Smetacek, Kitching 2012; Chandra, Sambath 2013; Sondhi, Sondhi 2016; Singh et al. 2017; Sivasankaran et al. 2017; Sondhi et al. 2018; Dar et al. 2020). The studies on moth fauna of West Bengal were initiated by Hampson (1892; 1894; 1895; 1896) followed by the contribution of Bell and Scott (1937). Further studies from several authors have contributed to the knowledge of moth diversity of the state (Bhattacharya l997a; Bhattacharya l997b; Ghosh, Chaudhury 1997a; Ghosh, Chaudhury 1997b; Gupta 1997; Mandal, Ghosh 1997; Mandal, Maulik 1997; Sanyal et al. 2012; Biswas et al. 2016; Biswas et al. 2017; Shah et al. 2018). Bhattacharya (l997a; 1997b) studied 35 species of Zygaenidae and 140 species of Pyralidae. Ghosh and Chaudhury (1997a) recorded 52 species, and Gupta (1997) described 20 species of moths from different districts of the state. Mandal and Ghosh (1997) studied 47 species of Geometridae, but Mandal and Maulik (1997) reported 182 species from West Bengal. Further studies (Sanyal et al. 2012; Biswas et al. 2017; Shah et al. 2018) described a large number of moth species from different parts of the state.

However, to date, there is no comprehensive study concerning the moth fauna of the West Midnapore district of West Bengal. The present study has prepared a preliminary checklist of moths found in the monsoon season (June to September) from Midnapore town of the district and focused on their diversity status. This study reports for the first time the diversity status of moth fauna in the monsoon months from West Bengal.

Materials and methods

Study area

The present study was conducted in different places of Midnapore town in the Midnapore Sadar community development block of West Midnapore District of West Bengal, India. The city consists of 24 wards with an area of 1855.19 ha and is located on bank of the Kangsabati River from 87°17218.573 to 87°20230.123 E and 22°23244.563 to 22°26034.913 N (Dinda et al. 2019). The study area was located 46 m above from sea level and belonged to a dry sub-tropical monsoon climate characterized by a very hot summer (45 to 47 °C), cold winter (7 to 8 °C) and an annual rainfall of 1550 mm (Dinda et al. 2019; Bhunia et al. 2020). The monsoon season (June to September) exhibits a relative humidity of nearly 80% and receives 75% of the total precipitation (Bhunia et al. 2020). A study by Guhathakurta et al. (2020) showed that over the past 30 years (1989 to 2018) the district has received the maximum (mean) rainfall (355.7 mm) in July followed by August (318.9 mm), June (283.9 mm) and September (262.5 mm) (Table 1). However, the monsoon of 2019 showed significant deviation from the above mentioned trend with the highest rainfall (397.9 mm) in the month of August followed by September (361.7 mm), July (216.9 mm) and June (128.0 mm) (Table 1). The urban green spaces in and around the the city exhibit a wide variety of vascular, medicinal and ornamental plant species. Some of the most common plants of the city are *Acacia auriculiformis, Azadiracta indica, Dalbergia sissoo, Delonix regia, Ficus benghalensis, Mangifera indica, Peltophorum pterocarpum, Terminalia arjuna, Tamarindus indica* etc. Vidyasagar University campus, one of the study sites, remains the most biodiversity rich region of the town with 117 species including herbs, shrubs, trees, climbers and branched thallus life forms (Saadi et al. 2017).

Moth surveys and identification

A total of 36 night surveys and a large number of opportunistic records were documented over a period of four months (June to September, 2019) in 10 locations of the town (Fig. 1). Moths were attracted and recorded by light trapping in three different locations of the town using a high power (23 W, 2300 lm and 30 W, 3000 lm, cool daylight 6500 to 7500 K, wavelength 380 to 780 nm) white LED (Light-Emitting Diode) lamp in front of a white cotton screen and house wall. A total of nine surveys were done in each month with three surveys in each site. Further, a large number of opportunistic records were collected from seven different sites of the town. The light trap was operated from 19:00 to 23:00 and moth counts were recorded and photographed using a Canon EOS 1200D DSLR Camera with a 55 to 250 mm lens and a smartphone camera (Nokia 3 Android, 8 MP, f/2.0) to support further identification. The moths were identified based on the digital photographs with the help of available literature (Hampson 1892; 1894; 1895; 1896; Bell, Scott 1937; Holloway 1987; 1999; 2005; Schintlmeister, Pinratana 2007; Kononenko, Pinratana 2013). Some of the web resources consulted for the purpose of identification were www.jpmoths.org; www.mothsofindia.org/ and https://www.flickr.com/groups/mothsofindia/. The higher-level classification of Order Lepidoptera by van Nieukerken et al. (2011) was followed for the present work. The study did not capture or kill any species during the entire period of the study.

Statistical data analysis

Statistical data analysis and graphical representations of data, except the sample-based rarefaction curve, were performed using Microsoft Office Excel, 2010. To assess any statistically significant differences between the means of month-wise group data, one-way analysis of variance (ANOVA) was conducted, setting alpha to 0.05. In order

Table 1. Mean rainfall (mm) and coefficient of variation of West Midnapore for the monsoon months during the past 30 years (1989 to 2018) and actual and normal rainfall (mm) statistics for the monsoon months of West Midnapore for 2019. CV, coeffcient of variation; PD, percentage difference from normal rainfall. Data are from Guhathakurta et al. (2020) and Annual Flood Report (2019) Government of West Bengal

Month	1989 – 2018		2019		
	Mean	CV	Actual	Normal	PD (%)
June	283.9	54.8	128.0	257.5	–50.3
July	355.7	33.0	216.9	329.3	–34.1
August	318.9	30.8	397.9	326.6	+21.8
September	262.5	37.2	361.7	271.1	+33.4
Monsoon	1220.9	24.3	–	–	–

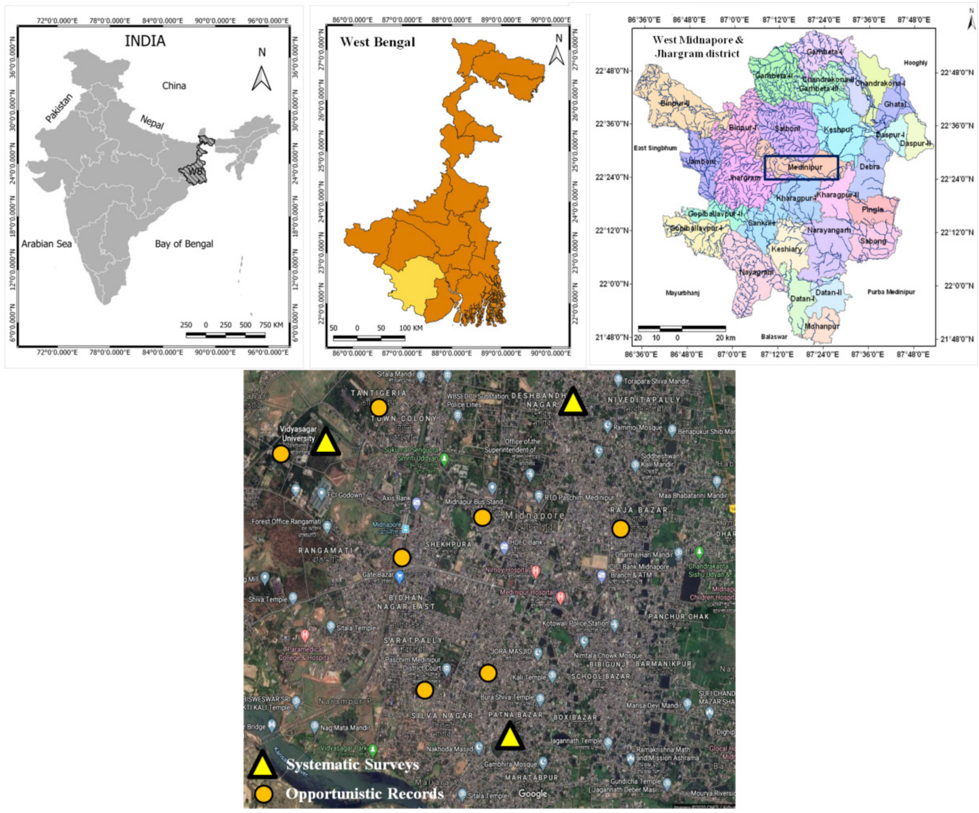

Fig. 1. Maps of the study area and survey locations: Map of India and West Bengal were generated using QGIS geographic information system application; map of West Midnapore and Jhargram district has been taken from Bhunia et al. 2012; Midnapore town map from @2020 Google Earth.

to assess the rarefied species richness of the pooled data a sample-based rarefaction curve was constructed using trap nights as sampling units for the whole study period with PAST version 4.03 software (Hammer et al. 2001). The software was also used for the calculation of month-wise diversity and evenness indices of moth population recorded during the study.

Results

The present study initially identified a total of 97 morphospecies of moths during the monsoon months from the study area. However, due to taxonomic ambiguities and uncertainties 19 morphospecies were subsequently excluded from the study of diversity. Finally the total moth catch (June to September, 2019) consisted of 1084 individual moths representing 12 families, 29 subfamilies, 71 genera and 78 morphospecies from different parts of the study area (Table 2, Figs. 2 to 5). A total of 61 morphospecies were identified to the species level and another 17 to genus level. Erebidae showed the maximum species richness (29 morphospecies) followed by Crambidae (22 morphospecies), Geometridae (12 morphospecies) and others (Table 2). However, the highest proportions of moths were recorded from Crambidae (37.63%) followed by Erebidae (31.54%), Geometridae (15.40%), and others. Based on their occurrence, the species were classified into three categories (Table 2) viz. common (C), uncommon (UN) and rare (R). The study documented 23 common, 36 uncommon and 19 rare species of moths in the monsoon season from the study area. The most frequent species encountered in the study was the rice yellow stem borer *Scirpophaga incertulas* followed by *Scopula* sp.1, *Hypsopygia mauritialis, Noorda blitealis, Endotricha* sp. and others. Some of the very less frequent or rare species recorded were *Biston suppressaria, Hypopyra vespertilio, Nannoarctia himalayana, Oruza divisa, Talanga sexpunctalis, Turnaca* sp. etc. Two species represented single captures: *Dysgonia algira* and *Risoba* sp.

In order to quantify the monthly moth diversity a number of diversity and evenness indices were calculated (Table 3). Species richness generally increased from June to September with a peak in August. Maximum diversity was recorded in August with a Simpson (1-D) value of 0.9808, Shannon_H 4.072, Brillouin 3.711, Menhinick 4.052, Margalef 11.99, Fisher_Alpha 28.64, and Chao 71.55 (Table 3). The highest value of Evenness (0.8507) and Equitability_J (0.9618) and lowest values of Dominance_D (0.01919) and Berger-Parker (0.03448) of August indicate that the moth community is not dominated by the most common species and is therefore more even in comparison to the other months (Table 3). Similar results were also obtained

Table 2. Preliminary checklist of moth fauna recorded during the monsoon season (June to September, 2019) in Midnapore town of West Bengal, India. Status: C, common (≥ 20 specimens recorded); U, uncommon (more than 5 but less than 20 specimens recorded); R, rare (≤ 5 specimens recorded)

No.	Family	Subfamily	Species	Author, year	Status
1	Limacodidae	Limacodinae	*Parasa lepida*	Cramer, 1799	R
2	Thyrididae	Striglinae	*Striglina scitaria*	Walker, 1862	R
3	Pyralidae	Pyralinae	*Endotricha* sp.		U
4	Pyralidae	Pyralinae	*Hypsopygia mauritialis*	Boisduval, 1833	C
5	Pyralidae	Pyralinae	*Tamraca torridalis*	Lederer, 1863	U
6	Crambidae	Acentropinae	*Parapoynx affinialis*	Guenée, 1854	U
7	Crambidae	Acentropinae	*Parapoynx diminutalis*	Snellen, 1880	U
8	Crambidae	Acentropinae	*Parapoynx fluctuosalis*	Zeller, 1852	U
9	Crambidae	Noordinae	*Noorda blitealis*	Walker, 1859	C
10	Crambidae	Pyraustinae	*Tatobotys biannulalis*	Walker, 1866	R
11	Crambidae	Schoenobiinae	*Scirpophaga incertulas*	Walker, 1863	C
12	Crambidae	Spilomelinae	*Aethaloessa calidalis*	Guenée, 1854	R
13	Crambidae	Spilomelinae	*Chabula acamasalis*	Walker, 1859	U
14	Crambidae	Spilomelinae	*Diaphania indica*	Saunders,1851	C
15	Crambidae	Spilomelinae	*Cnaphalocrocis medinalis*	Guenée, 1854	C
16	Crambidae	Spilomelinae	*Glyphodes bicolor*	Swainson, 1821	C
17	Crambidae	Spilomelinae	*Glyphodes caesalis*	Walker, 1859	U
18	Crambidae	Spilomelinae	*Haritalodes derogata*	Fabricius, 1775	C
19	Crambidae	Spilomelinae	*Herpetogramma* sp.		C
20	Crambidae	Spilomelinae	*Hymenia perspectalis*	Hübner, 1796	U
21	Crambidae	Spilomelinae	*Maruca vitrata*	Fabricius, 1787	U
22	Crambidae	Spilomelinae	*Nausinoe pueritia*	Cramer, 1780	R
23	Crambidae	Spilomelinae	*Parotis* cf. *marginata*	Hampson, 1893	C
24	Crambidae	Spilomelinae	*Pycnarmon cribrata*	Fabricius, 1794	U
25	Crambidae	Spilomelinae	*Sameodes cancellalis*	Zeller, 1852	C
26	Crambidae	Spilomelinae	*Spoladea recurvalis*	Fabricius,1775	U
27	Crambidae	Spilomelinae	*Talanga sexpunctalis*	Moore, 1887	R
28	Eupterotidae	Eupteroptinae	*Eupterote* sp.		U
29	Sphingidae	Macroglossinae	*Theretra* sp.		U
30	Uraniidae	Auzeinae	*Decetia subobscurata*	Walker, 1862	R
31	Uraniidae	Microniinae	*Micronia aculeata*	Guenée, 1857	U
32	Uraniidae	Microniinae	*Pseudomicronia advocataria*	Walker, 1861	R
33	Geometridae	Desmobathrinae	*Derambila* sp.		U
34	Geometridae	Ennominae	*Cleora* sp.		C
35	Geometridae	Ennominae	*Hyperythra lutea*	Stoll, 1781	C
36	Geometridae	Ennominae	*Hyposidra talaca*	Walker, 1860	U
37	Geometridae	Ennominae	*Biston suppressaria*	Guenée, 1858	R
38	Geometridae	Geometrinae	*Agathia laetata*	Fabricius, 1794	U
39	Geometridae	Geometrinae	*Comibaena fuscidorsata*	Prout,1912	U
40	Geometridae	Geometrinae	*Comostola pyrrhogona*	Walker, 1866	U
41	Geometridae	Geometrinae	*Hemithea* sp.		U
42	Geometridae	Sterrhinae	*Chrysocraspeda faganaria*	Guenée, 1858	U
43	Geometridae	Sterrhinae	*Scopula* sp.1		C
44	Geometridae	Sterrhinae	*Scopula* sp.2		C
45	Notodontidae	Biretinae	*Turnaca* sp.		R
46	Erebidae	Aganainae	*Asota caricae*	Fabricius, 1775	C
47	Erebidae	Arctiinae	*Amata passalis*	Fabricius, 1781	C
48	Erebidae	Arctiinae	*Creatonotos transiens*	Walker, 1855	U
49	Erebidae	Arctiinae	*Cyana puella*	Drury, 1773	R
50	Erebidae	Arctiinae	*Eressa confinis*	Walker, 1854	U

Table 2. *continued*

No.	Family	Subfamily	Species	Author, year	Status
51	Erebidae	Arctiinae	*Micraloa* sp.		U
52	Erebidae	Arctiinae	*Nannoarctia himalayana*	Dubatolov & Kishida, 2010	R
53	Erebidae	Arctiinae	*Pericallia ricini*	Fabricius, 1775	C
54	Erebidae	Arctiinae	*Syntomoides imaon*	Cramer, 1780	C
55	Erebidae	Boletobiinae	*Oruza divisa*	Walker, 1862	R
56	Erebidae	Calpinae	*Eudocima materna*	Linnaeus, 1767	U
57	Erebidae	Calpinae	*Rhesala moestalis*	Walker, 1865	U
58	Erebidae	Erebinae	*Achaea janata*	Linnaeus, 1758	U
59	Erebidae	Erebinae	*Artena dotata*	Fabricius, 1794	C
60	Erebidae	Erebinae	*Dysgonia algira*	Linnaeus, 1767	R
61	Erebidae	Erebinae	*Ercheia cyllaria*	Cramer, 1779	R
62	Erebidae	Erebinae	*Hypopyra vespertilio*	Fabricius, 1787	R
63	Erebidae	Erebinae	*Ophiusa tirhaca*	Cramer, 1773	U
64	Erebidae	Erebinae	*Pericyma cruegeri*	Butler, 1886	R
65	Erebidae	Erebinae	*Polydesma boarmoides*	Guenée, 1852	U
66	Erebidae	Erebinae	*Spirama* cf. *retorta*	Clerck, 1764	C
67	Erebidae	Erebinae	*Thyas coronata*	Fabricius, 1775	U
68	Erebidae	Herminiinae	*Simplicia* sp.		C
69	Erebidae	Lymantriinae	*Lymantria marginata*	Walker, 1855	U
70	Erebidae	Lymantriinae	*Lymantria semicincta*	Walker, 1855	U
71	Erebidae	Lymantriinae	*Lymantria* sp.1		R
72	Erebidae	Lymantriinae	*Lymantria* sp.2		U
73	Erebidae	Lymantriinae	*Olene mendosa*	Hübner, 1823	U
74	Erebidae	Pangraptinae	*Egnasia ephyrodalis*	Walker, 1858	U
75	Nolidae	Risobinae	*Risoba* sp.		R
76	Noctuidae	Condicinae	*Condica* sp.		U
77	Noctuidae	Heliothinae	*Helicoverpa armigera*	Hübner, 1808	C
78	Noctuidae	Noctuinae	*Leucania* sp.		U

in September, and minimum diversity and evenness were observed in June (Table 3).

The sample-based rarefaction curve (Fig. 6) for the whole monsoon season showed that species richness increased steadily with cummulative sampling effort. However, the non-asymptotic nature of the curve (Fig. 6) suggests that some additional species still remain undetected during the study period. This observation might be justified by the exclusion of a large number of species (19) due to their ambiguous identity. The average catch size per night in our study was nearly 30 using LED lamps (23 and 30 W) and this number could have been improved by the use of ultraviolet light trap or high power mercury vapour lamp (250 W). The rank abundance curve (Fig. 7) indicated an uneven community with few species representing most of the community abundance. Only 26 out of 78 morphospecies had more than 60% and another 27 morphospecies only 10% of the total abundance. Although the values of monthly moth abundance differed graphically (Fig. 8), these discrepancies remained statistically insignificant. The results of the ANOVA indicated no significant difference ($F = 0.9348$, $p < 0.05$) in moth abundance among the four months (results not shown).

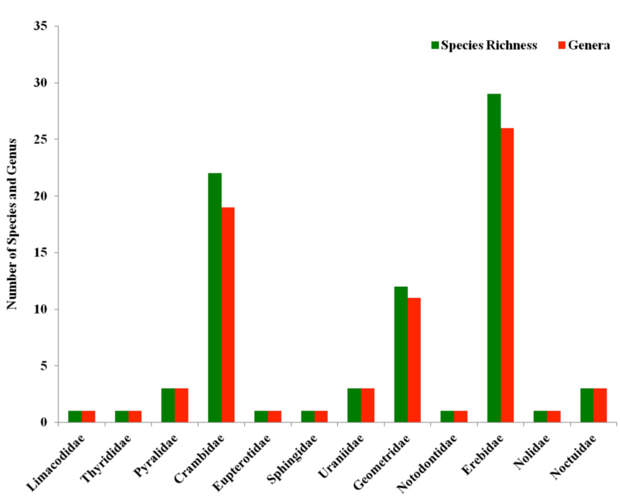

Fig. 2. Family wise moth species richness and number of genera recorded in the study area.

Discussion

Only a few species of moths have so far been described from the Midnapore district (presently three districts, East

Fig. 3. Different species of moths documented during the Monsoon season from Midnapore town, West Bengal, India. A, *Parasa lepida*; B, *Striglina scitaria*; C, *Endotricha* sp.; D, *Hypsopygia mauritialis*; E, *Tamraca torridalis*; F, *Parapoynx affinialis*; G, *Parapoynx diminutalis*; H, *Parapoynx fluctuosalis*; I, *Noorda blitealis*; J, *Tatobotys biannulalis*; K, *Scirpophaga incertulas*; L, *Aethaloessa calidalis*; M, *Chabula acamasalis*; N, *Diaphania indica*; O, *Cnaphalocrocis medinalis*; P, *Glyphodes bicolor*; Q, *Glyphodes caesalis*; R, *Haritalodes derogata*; S, *Herpetogramma* sp.; T, *Hymenia perspectalis*; U, *Maruca vitrata*; V, *Nausinoe pueritia*; W, *Parotis* cf. *marginata*; X, *Pycnarmon cribrata*; Y, *Sameodes cancellalis*; Z, *Spoladea recurvalis*; A1, *Talanga sexpunctalis*; B1, *Eupterote* sp.

Fig. 4. Different species of moths documented during the Monsoon season from Midnapore town, West Bengal, India. A, *Theretra* sp.; B, *Decetia subobscurata*; C, *Micronia aculeata*; D, *Pseudomicronia advocataria*; E, *Derambila* sp.; F, *Cleora* sp.; G, *Hyperythra lutea*; H, *Hyposidra talaca*; I, *Biston suppressaria*; J, *Agathia laetata*; K, *Comibaena fuscidorsata*; L, *Comostola pyrrhogona*; M, *Hemithea* sp.; N, *Chrysocraspeda faganaria*; O, *Scopula* sp.1; P, *Scopula* sp.2; Q, *Turnaca* sp.; R, *Asota caricae*; S, *Amata passalis*; T, *Creatonotos transiens*; U, *Cyana puella*; V, *Eressa confinis*; W, *Micraloa* sp.; X, *Nannoarctia himalayana*.

Fig. 5. Different species of moths documented during the Monsoon season from Midnapore town, West Bengal, India. A, *Pericallia ricini*; B, *Syntomoides imaon*; C, *Oruza divisa*; D, *Eudocima materna*; E, *Rhesala moestalis*; F, *Achaea janata*; G, *Artena dotata*; H, *Dysgonia algira*; I, *Ercheia cyllaria*; J, *Hypopyra vespertilio*; K, *Ophiusa tirhaca*; L, *Pericyma cruegeri*; M, *Polydesma boarmoides*; N, *Spirama* cf. *retorta*; O, *Thyas coronata*; P, *Simplicia* sp.; Q, *Lymantria marginata*; R, *Lymantria semicincta*; S, *Lymantria* sp.1; T, *Lymantria* sp.2; U, *Olene mendosa*; V, *Egnasia ephyrodalis*; W, *Risoba* sp.; X, *Condica* sp.; Y, *Helicoverpa armigera*; Z, *Leucania* sp.

Table 3. Monthly diversity and evenness indices of moth population recorded during the study

Indice	June	July	August	September
Taxa_S	50	63	69	67
Individuals	236	297	290	261
Dominance_D	0.03322	0.02543	0.01919	0.02077
Simpson_1-D	0.9668	0.9746	0.9808	0.9792
Shannon_H	3.617	3.869	4.072	4.016
Evenness_e^H/S	0.7445	0.7601	0.8507	0.8282
Brillouin	3.301	3.548	3.711	3.638
Menhinick	3.255	3.656	4.052	4.147
Margalef	8.968	10.89	11.99	11.86
Equitability_J	0.9246	0.9338	0.9618	0.9552
Fisher_alpha	19.4	24.46	28.64	29.16
Berger-Parker	0.07627	0.05387	0.03448	0.03831
Chao-1	61	74.14	71.55	70

Midnapore, West Midnapore and Jhargram) of West Bengal. These include *Agrius convolvuli* Linnaeus, 1758; *Antheraea paphia*, Linnaeus, 1758; *Bradina diagonalis* Guenée, 1854; *Scirpophaga incertulas* Walker, 1863; *Somena scintillans* Walker, 1856 and *Theretra clotho* Drury, 1773 (Bhattacharya l997a; Bhattacharya l997b; Gupta 1997; Mandal, Maulik 1997). The present work reports for the first time the presence of 78 species from this part of the state, including some very rare species like *Biston suppressaria, Dysgonia algira, Hypopyra vespertilio, Nannoarctia himalayana, Oruza divisa* and *Risoba* sp. Three families, Crambidae, Erebidae and Geometridae, represented more than 80% of all documented species. The dominance of these families in other parts of South Bengal has also been recorded (Nayak, unpublished data) previously.

The monsoon moth communities usually differ significantly from those in studies covering a year. Previous studies have shown that a number of weather factors, including humidity, moonlight, rainfall, temperature, and wind can influence the moth catch size (Yela, Holyoak 1997; Jonason et al. 2014). Further, artificial light sources and wavelengths have also been found to affect the nocturnal moth sampling (Jonason et al. 2014). Rainfall is a key factor that affect the catch size considerably by influencing moth behaviour and survival. Several studies have reported both positive and negative effects of heavy rainfall events on moth abundance in different parts of tropical and temperate environments (Kato et al. 1995; Intachat et al. 2001; Choi 2008; Sutrisno 2008; Uniyal et al. 2013). A study by Gadhikar et al. (2015) reported higher moth abundance in August (with highest average rainfall) in Amravati city of Maharashtra, India. A positive association between moth abundance and frequent rainfall during the summer months in England and Wales has been described Wilson et al. 2015). Studies have shown that high rainfall might play a positive role on moth abundance by encouraging leaf flushing in tropical forests, which will facilitate larval survivorship and therefore increase the number adult

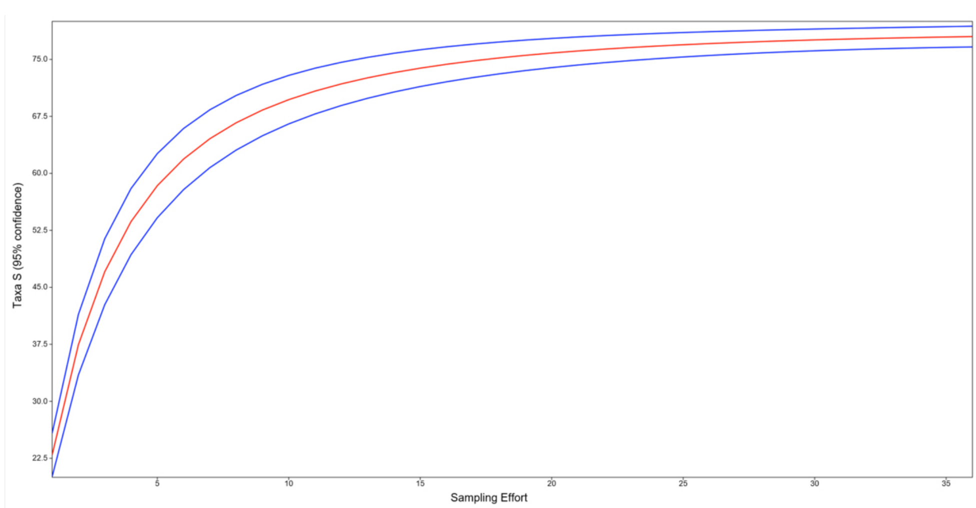

Fig. 6. Sample-based rarefaction curve for pooled samples (red line, mean; blue lines, 95% confidence interval) documented during the Monsoon season. Y axis, species richness; X axis, sampling efforts).

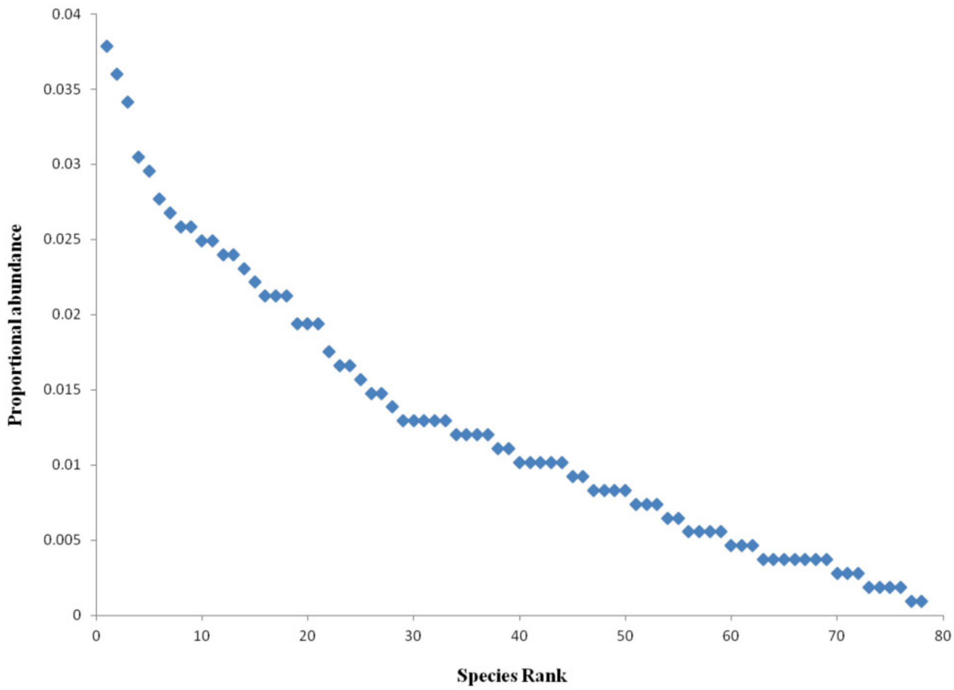

Fig. 7. Rank abundance curve (Whittaker plot) of moths recorded during the monsoon season (June to September, 2019) from Midnapore town, West Bengal, India.

moths in the following months (Intachat et al. 2001). However, high rainfall has been shown a negative effect on moth study by hindering adult moths from flying and also leading to higher mortality of larvae and pupae due to infection by microorganisms (Choi 2008). Higher diversity of geometrid moths at sites of lower rainfall in Gangotri landscape of Uttarakhand, India has been demonstrated (Uniyal et al. 2013). Although four monsoon months received different levels of precipitation in 2019 (Table 1) and species richness increased significantly in the months with higher rainfall (July to September), the current study could not find any significant effect of rainfall on moth abundance. These results are in accordance with a previous study demonstrating that species richness and abundance was not significantly influenced by rainfall near a village in the German federal state of Saxony (Jonason et al. 2014).

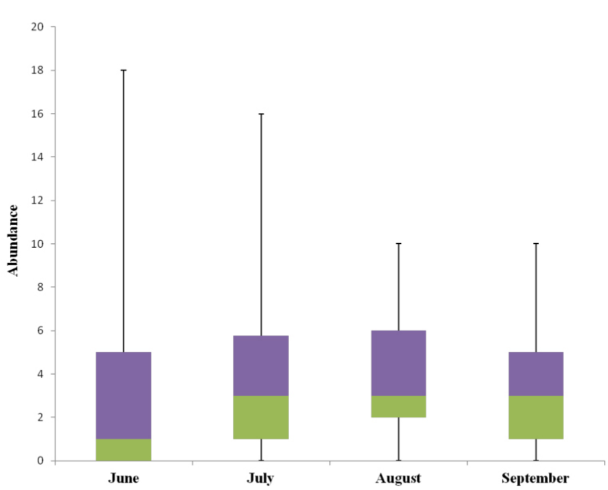

Fig. 8. Month-wise moth abundance (individuals) recorded during the present study in Midnapore town. Each box plot shows minimum, lower quartile, median, upper quartile and maximum values.

Urbanization exposes global biodiversity to anthropogenic disturbances through loss of natural and seminatural habitats that are critical for biodiversity conservation (Lintott et al. 2014). Midnapore municipality has experienced massive urbanization at an unprecedented rate during the last three decades. A study on 20 years of data revealed that dense and degraded vegetation of the municipality was reduced by 83.63 and 30.04%, respectively, with an improvement of the built-up area by 72.35% and a drastic decline of agricultural area (Dolui et al. 2014). More studies are needed to assess the negative effect of rapid urban sprawl on the Lepidoptera assemblage of the city.

Conclusions

The present work has created a preliminary checklist of moths in the monsoon season in Midnapore town of West Bengal. Further, a preliminary attempt was made to reveal the probable patterns of moth community assemblages of the area that has not been explored previously. The non-asymptotic nature of the sample-based rarefaction curve suggests that the species inventory was still incomplete. August and September exhibited more species richness with evenly distributed moth communities, as compared to the other two months. However, statistical analysis indicated no significant difference in moth abundance among the four monsoon months. The present study will provide baseline information to the study of moth diversity from the city and adjoining areas. Further studies with a long-term systematic approach are needed to ascertain the entire moth assemblages of the city.

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References

Beck J., Nässig W.A. 2008. Diversity and abundance patterns, and revised checklist, of saturniid moths from Borneo (Lepidoptera: Saturniidae). *Nachr. Entomol. Ver. Apollo* 28: 155–164.

Bell T.R.D., Scott F.B. 1937. *Fauna of British India, Including Ceyon and Burma*. Moths – Volume 5, Sphingidae. Taylor and Francis, London. 537p.

Bhattacharya D.P. 1997a. Insecta: Lepidoptera: Zygaenidae. In: Director, Zoological Survey of India (ed) *State Fauna Series 3: Fauna of West Bengal*. Part 7. Zoological Survey of India, Kolkata, pp. 225–246.

Bhattacharya D.P. 1997b. Insecta: Lepidoptera: Pyralidae. In: Director, Zoological Survey of India (ed) *State Fauna Series 3: Fauna of West Bengal.* Part 7. Zoological Survey of India, Kolkata, pp. 319–408.

Bhunia G.S., Samanta S., Pal D., Pal B. 2012. Assessment of groundwater potential zone in Paschim Medinipur District, West Bengal – a meso-scale study using GIS and remote sensing approach. *J. Environ. Earth Sci.* 5: 41–59.

Bhunia P., Das P., Maiti R. 2020. Meteorological drought study through SPI in three drought prone districts of West Bengal, India. *Earth Syst. Environ.* 4: 43–55.

Biswas O., Modak B.K., Mazumder A., Mitra, B. 2016. Moth (Lepidoptera: Heterocera) diversity of Sunderban Biosphere Reserve, India and their pest status to economically important plants. *J. Entomol. Zool. Stud.* 4: 13-19.

Biswas O., Shah S., Roy S., Modak B., Panja B., Chakraborti U., Mitra B. 2017. Additions to the Moth fauna of Sunderban biosphere Reserve, India. *Bionotes* 19: 58- 59.

Chandra K., Sambath S. 2013. Moth diversity of Tawang District, Arunachal Pradesh, India. *J. Threat. Taxa* 5: 3565–3570.

Choi S.W. 2008. Effects of weather factors on the abundance and diversity of moths in a temperate deciduous mixed forest of Korea. *Zoolog. Sci.* 25: 53-58.

Dar M.A., Akbar S.A., Wachkoo A.A., Ganai M.A. 2020. Moth (Lepidoptera) Fauna of Jammu and Kashmir State. In: Dar G., Khuroo A. (eds) *Biodiversity of the Himalaya: Jammu and Kashmir State*. Topics in Biodiversity and Conservation. Springer, Singapore, pp. 821–846.

Dennis E.B., Brereton T.M., Morgan B.J.T., Fox R., Shortall C.R., Prescott T., Foster S. 2019. Trends and indicators for quantifying moth abundance and occupancy in Scotland. *J. Insect Conserv.* 23: 369–380.

Dinda S., Das K., Chatterjee N.D., Ghosh S. 2019. Integration of GIS and statistical approach in mapping of urban sprawl and predicting future growth in Midnapore town, India. *Model. Earth Syst. Environ.* 5: 331–352.

Dolui G., Das S., Satpathy S. 2014. An application of remote sensing and GIS to analyze urban expansion and land use land cover change of Midnapore municipality, WB, India. *Int. Res. J. Earth Sci.* 2: 8–20.

Estoque R. C., Ooba M., Avitabile V., Hijioka Y., DasGupta R., Togawa T., Murayama Y. 2019. The future of Southeast Asia's forests. *Nat. Commun.* 10: 1829.

Gadhikar Y.A., Sambath S., Yattoo Y.I. 2015. A preliminary report on the moths (Insecta: Lepidoptera: Heterocera) fauna from Amravati, Maharashtra. *Int. J. Sci. Res.* 4: 883–887.

Ghosh S.K., Chaudhury M. 1997a. Insecta: Lepidoptera: Arctiidae. In: Director, Zoological Survey of India (ed) *State Fauna Series 3: Fauna of West Bengal*. Part 7. Zoological Survey of India, Kolkata, pp. 247–273.

Ghosh S.K., Chaudhury M. 1997b. Insecta: Lepidoptera: Ctexiuchidae and Hypsidae. In: Director, Zoological Survey of India (ed) *State Fauna Series 3: Fauna of West Bengal*. Part 7. Zoological Survey of India, Kolkata, pp. 689–704.

Government of West Bengal. 2019. *Annual Flood Report, 2019*. Kolkata: Irrigation and Waterways Department (IWD), Government of West Bengal.

Guhathakurta P., Khedikar S., Menon P., Prasad A.K., Sable S.T., Advani S.C. 2020. *Observed rainfall variability and changes over West Bengal state*. India Meteorological Department, Pune, Maharashtra, India. 27 p.

Gupta I.J. 1997. Insecta: Lepidoptera: Saturniidae. In: Director, Zoological Survey of India (ed) *State Fauna Series 3: Fauna of West Bengal.* Part 7. Zoological Survey of India, Kolkata, pp. 409–428.

Hammer Ø., Harper D.A.T., Ryan P.D. 2001. PAST: paleontological statistics software package for education and data analysis. *Palaentol. Electron.* 4: 1–9.

Hampson G.F. 1892. *The Fauna of British India, including Ceylon and Burma*. Moths – Vol. 1, Saturniidae to Hypsidae. Taylor and Francis, London, 527p.

Hampson G.F. 1894. *The Fauna of British India, including Ceylon and Burma*. Moths – Vol. 2, Arctiidae, Agrostidae, Noctuidae. Taylor and Francis, London, 609p.

Hampson G.F. 1895. *The Fauna of British India, including Ceylon and Burma*. Moths – Vol. 3, Noctuidae (cont.) to Geometridae. Taylor and Francis, London, 546p.

Hampson G.F. 1896. *The Fauna of British India, including Ceylon and Burma*. Moths – Vol. 4. Pyralidae. Taylor and Francis, London, 594p.

Holloway J.D. 1987. *The Moths of Borneo (Part 3): Lasiocampidae, Eupterotidae, Bombycidae, Brahmaeidae, Saturniidae, Sphingidae*. Southdene Sdn. Bhd., Kuala Lumpur, Malaysia. 199 p.

Holloway J.D. 1999. The Moths of Borneo (part 5): family Lymantriidae. *Malayan Nat. J.* 53: 1–188.

Holloway J.D. 2005. The Moths of Borneo: family Noctuidae, subfamily catocalinae. *Malayan Nat. J.* 58: 1–529.

Intachat J., Holloway J., Staines H. 2001. Effects of weather and phenology on the abundance and diversity of geometroid moths in a natural Malaysian tropical rain forest. *J. Trop. Ecol.* 17: 411–429.

Jonason D., Franzén M., Ranius T. 2014. Surveying moths using light traps: effects of weather and time of year. *PLOS One* 9: e92453.

Kato M., Inoue T., Hamid A.A., Nagamitsu T., Merdek M.B., Nona

A. R., Itino T., Yamane S., Yumoto T. 1995. Seasonality and vertical structure of light-attracted insect communities in a dipterocarp forest in Sarawak. *Res. Popul. Ecol.* 37: 59–79.

Kitching R.L., Orr A.G., Thalib L., Mitchell H., Hopkins M.S., Graham A.W. 2000. Moth assemblages as indicators of environmental quality in remnants of upland Australian rain forest. *J. Appl. Ecol.* 37: 284–297.

Kononenko V.S., Pinratana A. 2013. *Moth of Thailand.* Vol. 3, Part 2. Noctuoidea. An illustrated Catalogue of Erebidae, Nolidae, Euteliidae and Noctuidae (Insecta, Lepidoptera) in Thailand. Brothers of St Gabriel in Thailand, Bangkok. 625p.

Kristensen N.P., Scoble M.J., Karsholt O. 2007. Lepidoptera phylogeny and systematics: the state of inventorying moth and butterfly diversity. *Zootaxa* 1668: 699–747.

Lintott P.R., Bunnefeld N., Fuentes-Montemayor E., Minderman J., Blackmore L.M., Goulson D., Park K.J. 2014. Moth species richness, abundance and diversity in fragmented urban woodlands: implications for conservation and management strategies. *Biodiv. Conserv.* 23: 2875–2901.

Mandal D.K., Ghosh S.K. 1997. Insecta: Lepidoptera: Geometridae. In: Director, Zoological Survey of India (ed) *State Fauna Series 3: Fauna of West Bengal*. Part 7. Zoological Survey of India, Kolkata, pp. 491–532.

Mandal D.K., Maulik D.R. 1997. Insecta: Lepidoptera: Sphingidae, Lasiocampidae, Lymantriidae and Ratardidae. In: Director, Zoological Survey of India (ed) *State Fauna Series 3: Fauna of West Bengal.* Part 7. Zoological Survey of India, Kolkata, pp. 613–687.

Saadi S.M.A.I., Mondal I., Sarkar S., Mondal A.K., Bandyopadhyay J. 2017. Detecting medicinal plants species using GPS positioning in Vidyasagar University Campus, Midnapore, West Bengal, India. *Spat. Inf. Res.* 25: 49–56.

Sanyal A.K., Alfred J.R.B., Venkataraman K., Tiwari S.K., Mitra S 2012. *Status of Biodiversity of West Bengal*. Zoological Survey of India, Kolkata, 969p.

Schintlmeister A., Pinratana A. 2007. *Moths of Thailand*, Volume 5: Notodontidae. Brothers of St. Gabriel in Thailand, Bangkok. 322p.

Shah S., Das A., Dutta R., Mitra B. 2018. A Current List of the Moths (Lepidoptera) of West Bengal. *Bionotes* 20: 24-29.

Singh N., Ahmad J., Joshi R. 2017. Diversity of Moths (Lepidoptera) with New Faunistic Records from North East Jharkhand India. *Rec. Zool. Surv. India* 117: 326-340.

Sivasankaran K., Anand S., Mathew P., Ignacimuthu S. 2017. Checklist of the superfamily Noctuoidea (Insecta, Lepidoptera) from Tamil Nadu, Western Ghats, India. *Check List* 13: 1101–1120.

Smetacek P. 2013. Review of Indian Lepidoptera Collections and their significance in conservation. *ENVIS Bull*. 14: 135–139.

Smetacek P., Kitching I.J. 2012. The hawkmoths of Ladakh, Jammu & Kashmir, India (Lepidoptera: Sphingidae). *Nachr. Entomol. Ver. Apollo* 32: 113–115.

Sondhi Y., Sondhi S. 2016. A partial checklist of moths (Lepidoptera) of Dehradun, Mussoorie and Devalsari in Garhwal, Uttarakhand, India. *J. Threat. Taxa* 8: 8756–8776.

Sondhi Y., Sondhi S., Shashank P.R., Kunte K. 2018. Moth diversity (Lepidoptera: Heterocera) of Shendurney and Ponmudi in Agastyamalai Biosphere Reserve, Kerala, India, with notes on new records. *Trop. Lepid. Res.* 28: 66–89.

Sutrisno H. 2008. Moth diversity at Gunung Halimun-Salak National Park, West Java. *Hayati* 15: 111–117.

Uniyal V.P., Bhardwaj M., Sanyal A.K. 2013. *An Assessment of Entomofauna for Management and Conservation of Biodiversity in the Gangotri Landscape*. Annual Progress Report. Wildlife Institute of India, Dehradun. 237 p.

van Nieukerken E.J., Kaila L., Kitching I.J., Kristensen N.P., Lees D.C., Minet J., Mitter C., Mutanen M., Regier J.C., Simonsen T.J., Wahlberg N., Yen S.H., Zahiri R., Adamski D., Baixeras J., Bartsch D., Bengtsson B.A., Brown J.W., Bucheli S.R., Davis D.R., Prins J.D., Prins W.D., Epstein M.E., Gentili-Poole P., Gielis C., Hättenschwiler P., Hausmann A., Holloway J.D., Kallies A., Karsholt O., Kawahara A.Y., Koster S., Kozlov M.V., Lafontaine J.D, Lamas G., Landry J.F., Lee S., Nuss M., Park K.T., Penz C., Rota J., Schintlmeister A., Schmidt B.C., Sohn J.C., Solis M.A., Tarmann G.M., Warren A.D., Weller S., Yakovlev R.V., Zolotuhin V.V., Zwick A. 2011. Order Lepidoptera Linnaeus, 1758. In: Zhang Z.Q. (ed) *Animal Biodiversity: An Outline of Higher-Level Classification and Survey of Taxonomic Richness*. Zootaxa 3148: 212–221.

Wilson J.F., Baker D., Cook M., Davis G., Freestone R., Gardner D., Grundy D., Lowe N., Orridge S., Young H. 2015. Climate association with fluctuation in annual abundance of fifty widely distributed moths in England and Wales: a citizen-science study. *J. Insect Conserv. 1*9: 935–946.

Yela J.L., Holyoak M. 1997. Effects of moonlight and meteorological factors on light and bait trap catches of noctuid moths (Lepidoptera: Noctuidae). *Popul. Ecol.* 26: 1283–1290.

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