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Biodiversity of Moths (Lepidoptera: Heterocera) in Three Areas of Rajmahal Hills, Jharkhand, India

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ABSTRACT

Moth species were collected from three different locations of Rajmahal hills in Jharkhand State, India from March 2011 to May 2013. Month-wise collection of moths was done using light trap and sweeping net. Totally 222 species of moths belonging to 18 different families were recorded. Family Erebidae contained higher number of subfamilies (11), genera (37) and species (74) and was the dominant family in the study area. Noctuidae, was the second largest family represented by 44 species. Moth population was very high during monsoon season. The diversity analysis clearly indicated that species evenness was closer to the maximum level during monsoon and winter periods. The present study clearly shows that Rajmahal hills are a suitable ecosystem for moth fauna in all seasons.

Introduction

Moths are economically important insects to mankind. On the one hand they are good pollinators and some of them give useful products like silk, but on the other hand many moth species destroy crops and stored products. Besides their economic importance they play important role in different types of ecosystems. Many parasitoids, predatory insects and predatory vertebrates survive on the life stages of moths. Moreover moths are remarkable indicators of environmental health (Holloway *et al*. 1992).

Surveillance and diversity analysis of moths are important requisites in pest monitoring and ecosystem analysis programmes. Global warming and climate change, deforestation and man-made activities affect the moth diversity. Biodiversity studies of moths in natural ecosystems in different seasons, different years and different decades will give a clear idea about the impact of climate on invertebrates like moths.

Rajmahal Hills are located in the state of Jharkhand in India. They formed from rocks dating from the Jurassic period and are named after the town of Rajmahal. Rajmahal hills are one of the most stable and sensitive ecosystems of the tropic. The hills are approximately located within 24°19’ 460” N to 25° .04’.949” N and 87° 12’ 821” E to 87°.39’.181”E. The hills are oriented in a north-south axis and extend to nearly 200 kilometers covering the districts of Dumka, Pakur and Sahibganj. The average elevation of the region is around 350 m to 600 meters above sea level. Rajmahal hills are home to many precious fauna and flora. But there are no studies on moth diversity in this region. So the present study was conducted in chosen places of Rajmahal hills to record the moth fauna and to assess the biodiversity of moths.

Materials and methods

Study Area

The state of Jharkhand is divided into Chotanagpur plateau and Santhal Parganas. Chotanagpur plateau is a densely forested area having great biodiversity that is yet to be explored. Santhal Parganas is a division of the state of Jharkhand, which is a highly forested area of India (29.56% forest cover), with six districts. Geographically, Santhal Parganas comes within 24°N and 26°N and 87°E. Maharo and Dumka are at 24° 19’ 450” to 460” N and 87° 12’ 820-821”E, Satia is at 24° 44’ 786”N and 87° 34’ 625”E and Bathbanga is at 25° 04’ 949”N and 87° 39’ 181”E. Maharo is around 454 meters above sea level, Satia is around 534.5 meters above sea level and Bathabanga is around 428 meters above sea level. The highest hills of the area will be around 1000 meters above sea level. Rajmahal hills run along a South-North axis in Dumka, Pakur and Sahibganj districts of Santhal Parganas. Hence these three districts were chosen for the present study. From these three districts, three villages namely Maharo, Satia and Bathbanga were chosen for field study (Fig. 1). These three villages were chosen because of the abundance of forest cover here and all the three places are situated around 350 – 460 meters above the sea level. Bathbanga is in Sahibganj district and is surrounded by thick forested hills. It is geographically situated at 25° 04’ 949” N and 87° 39’ 181” E. The elevation of the place is around 328 meters above sea level. Maharo is located in Dumka district. It is geographically situated at 24° 19’ 460” N and 87° 12’ 821” E. The elevation of the land is around 454 meters above sea level. Satia is in Pakur district and is about 100 kilometers from Dumka. This is a thickly forested area having high hills covered with trees. It is geographically situated at 24° 44’ 786” N and 87° 34’ 625” E. The elevation of the place is around 534.5 meters above sea level.

The normal temperatures during non-winter months are between 20°C to 37°C. In summer the temperature may go up to 47°C and in winter months the normal temperature ranges between 10°C to 23°C but can come down to 5°C. The area gets South-western monsoon in the months of June, July, August and September; the heaviest rains are in the months of July and August. The average annual rainfall of the area is around 135 cm but may vary from 100 to 150 cm.

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Flora of the region include trees like Sisso (*Dalbergia sisso*), Gamhar (*Gonleina arborea*), Seemal (*Bombax ceiba*), Jackfruit (*Artocorpus integrefolia*), sapodilla (*manilkara zapota*), mango (*Mangifera indica*), Mahogani (*Swictenia mahogani*), Neem (*Azadirachta indica*), Arjun (*Terminalia arjun*), teak (*Tectona grandis*), litchi (*Litchi chinensis*), Bel (*Aegle marmelos*), bamboo (*Bembosa arindinoceae*), Palas (*Butea monosperma*), Karanj (*Pongamia pinnata*), Sal (*Shorea robusta*), Asna (*Streblus asper*), Kendu (*Diospyros strenoxylon*), Gulmohar (*Delonix regia*) and many other varieties of shrubs and herbs (Fig. 1.3 to 1.5). Hembrom in his book "Adivasiaushadh" (Vol.7) has mentioned that 480 medicinal plants were available in Rajmahal hills (Hembrom 1994).

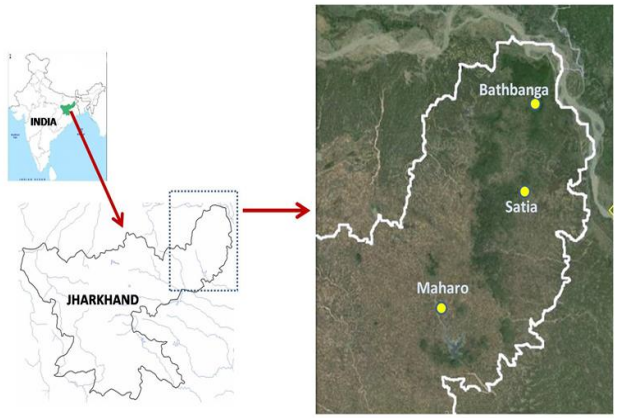

Figure 1. Location map of moth collection sites in Rajmahal hills, Jharkhand in India

Collection of moths

A calendar year was divided into four different seasons namely, summer (March-May), monsoon (June–August), postmonsoon (September–November) and winter (December–February). Moth collection began in the month of March 2011 and continued up to the month of May 2013 on a regular basis, i.e. two days in the beginning, one day in the middle and another two days in the end of every month. Sweeping net and battery-operated light traps were used to collect specimens. A white cloth of about three meters long was tied to two poles and allowed to hang vertically near the light trap. All the moths sitting in and around the cloth were collected.

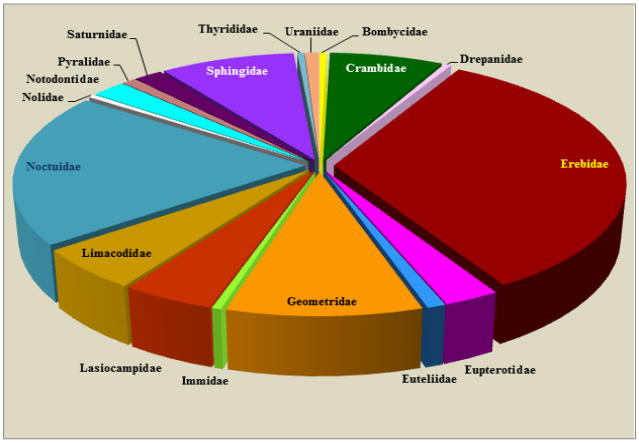

Figure 2. Percentage of species collected under different families of moths

Identification of moths

The collected specimens were killed by ethyl acetate vapour and pinned to a board in insect boxes. The collected specimens were first grouped into families based on the morphological family characters. Then all the species in each family were identified up to species level by studying their morphological characters following the identification keys provided by "Hampson (1892, 1895, 1896)", "Bell and Scot (1937)" and many other known materials available in the websites in the internet; for example, Moths of Borneo. 'A catalogue of Moths of India' by Cotes and Swinhoe (1887-89) in six volumes was also referred for the identification of the moths. After identification of the moths the species names were confirmed by experts. Noctuid moths were identified and confirmed by Dr. K. Sivasankaran, Entomology Research Institute, Loyola College in Chennai. Voucher specimens of all the collected moths were deposited at ERI insect museum (Voucher numbers ERI-RM-M001 to ERI-RM-M220)

Meteorological data

Data on maximum mean temperature, minimum mean temperature and average rainfall in the study areas were collected from the Meteorological Department, Dumka.

Diversity indices calculation

Evenness, dominance, Shannon-Weiner index and Simpson's index were calculated using the software, PAST (version 3.04; November 2014). Jaccard similarity index between any two places of collection and Jackknife pseudo-values for 95% confidence interval were derived using an online tool (www.comparingpartitions.info).

Results

Meteorological data

The temperature (maximum and minimum) and rainfall data for three districts namely Bathbanga, Maharo and Satia are presented in Table 1. In the year 2011, the atmospheric temperature ranged between 4^{o}C (minimum) and 38.7^{o}C (maximum) in Maharo; between 9.4^{o}C and 43.5^{o}C in Satia and between 5.6^{o}C and 44.4^{o}C in Bathbanga. In 2011 the highest temperatures in Maharo (38.7^{o}C), Satia (43.5^{o}C) and Bathbanga (44.4^{o}C) were recorded in May, June and May, respectively. In 2012 the atmospheric temperature was very high compared to the year 2011. The highest temperatures in the summer season in 2012 were recorded in May and June months. Maximum rainfall was recorded in June, July and August in all the three places. In Maharo, the highest rainfall (357mm) was reported in July 2011. In Bathbanga and Satia the highest rainfall data were obtained in July 2012 (413mm) and June 2011 (719mm), respectively. In general, high rainfall occurred up to September in both years.

Taxonomic composition

Totally 18 families consisted of 52 subfamilies and 148 genera of moths were collected. Altogether around 222 morpho-species of moths were collected during this study (Table 2). The collected families were: Bombycidae, Crambidae, Drepanidae, Erebidae, Eupterotidae, Euteliidae, Geometridae, Immidae, Lasiocampidae, Limacodidae, Noctuidae, Nolidae, Notodontidae, Pyralidae, Saturnidae, Sphingidae, Thyrididae and Uraniidae. Family Erebidae contained the highest number of species (74). Erebidae had 11 subfamilies and 37genera. The next large family was Noctuidae in terms of number of species, which was represented by 44 species, 13 subfamilies and 36 genera. Aventiinae, Hypeninae, Hypocalinae and Boletobiinae were the smallest subfamilies with only one representative species in the study areas. Aganainae, pangraptinae and Calpinae were also small subfamilies each with two representative species. The percentage of species in Erebidae was 33.33% in the study areas. Noctudia contributed 19.82% species (Fig. 2).

Species population in three study areas

The total number of individuals collected under each species is given in table 2. In Bathbanga, the highest number of

individuals, i.e., 13,470 individuals of moths were collected during the entire study period. In Satia and Maharo, 11,965 and 11,400 individuals were collected respectively. *Eupterote undata* (Eupterotidae) and *Eudocima phalonica* (Erebidae) were found to be the most dominant species in all the three study areas.

Moth diversity in summer

The diversity of moths was fluctuating due to the variations in environmental temperature and rainfall. High temperatures in summer did not support the moth diversity. In Satia the Shannon-Wiener index (4.985) and Evenness (0.7857) were very low in summer season in 2011. Menhinick, Margalef and Fishers alpha indices were high during summer and winter, whereas Shannon-Wiener index, Simpson's index of diversity and Evenness were low during summer. The same trend was found in other two study areas namely Bathbanga and Maharo in both years (Table 3).

Moth diversity in monsoon

Monsoon was found to be slightly favourable to the moths. The Shannon-Wiener index, evenness, Menhinick index, Margalef index, Fishers alpha and Berger-Parker index of moths for monsoon in 2011 were 5.28, 0.8928, 5.613, 29.85, 70.32 and 0.02083 in Bathbanga, respectively; they were 5.208, 0.9045, 5.469, 27.85, 65.53 and 0.01466 in Satia, respectively; they were 5.184, 0.9106, 5.496, 27.28, 64.74 and 0.01179 in Maharo, respectively (Table 4). During the monsoon season in 2012, the Shannon-Wiener index, Evenness, Menhinick index, Margalef index, Fishers alpha and Berger-Parker index of moths were calculated as 5.278, 0.8907, 5.581, 29.8, 69.96 and 0.01416, respectively in Bathbanga; 5.239, 0.9193, 5.699, 28.47, 68.58 and 0.01082 respectively in Maharo and 5.235, 0.8856, 5.618, 29.06, 68.94 and 0.01334 respectively in Satia.

Moth diversity in post monsoon

Post-monsoon seasons in 2011 and 2012 were highly favourable to the moths. Some moth species were collected in the post-monsoon season only. Due to the occurrence of new species and high population in post-monsoon period, the diversity and distribution of moths was very high in this season. Even though the Simposon's index of diversity and Shannon-Wiener index were high in this season the Evenness was slightly lower during post-monsoon season. But this decrease was statistically not significant. This slight decrease in Evenness was due to the dominance of few moth species, which were reported emerging during post-rainy seasons only.

During the post-monsoon season in 2011, the Shannon-Wiener index, Evenness, Menhinick index, Margalef index, Fishers alpha and Berger-Parker index of moths were calculated as 5.31, 0.9155, 4.006, 27.43, 54.76 and 0.01544 in Bathbanga respectively, 5.245, 0.9163, 4.025, 26.14, 52.56 and 0.01323 in Maharo respectively and 5.254, 0.8982, 4.113, 26.85, 54.35and 0.0138 in Satia, respectively (Table 5).

In 2012, the Shannon-Wiener index, Evenness, Menhinick index, Margalef index, Fishers alpha and Berger-Parker index of moths were calculated as 5.293, 0.9003, 4.134, 27.65, 55.9 and 0.01575 in Bathbanga respectively, 5.233, 0.9048, 4.221, 26.46, 54.28 and 0.0158 in Maharo respectively and 5.235, 0.8813, 4.23, 27.05, 55.39 and 0.01538 in Satia, respectively.

Moth diversity in winter

In winter moth population slightly decreased compared to post-monsoon seasons. During the winter season in 2011, the Shannon-Wiener index, Evenness, Menhinick index, Margalef index, Fishers alpha and Berger-Parker index of moths were calculated as 5.247, 0.8635, 5.478, 29.65, 68.84 and 0.01116 in Bathbanga respectively, 5.174, 0.8659, 5.484, 28.07, 66.04 and 0.01156 in Maharo respectively and 5.187, 0.8523, 5.532, 28.74, 67.64 and 0.0118 in Satia, respectively (Table 6).

In 2012, the Shannon-Wiener index, Evenness, Menhinick index, Margalef index, Fishers alpha and Berger-Parker index of moths were calculated as 5.217, 0.8618, 6.355, 30.28, 78.01 and 0.0194 in Bathbanga respectively, 5.148, 0.8397, 6.755, 29.89, 81.79 and 0.02172 in Maharo respectively and 5.168, 0.8438, 6.529, 29.9, 79.22 and 0.0197 in Satia, respectively.

Jaccard index of similarity between places

Table 7 shows the similarity index for moth diversity between any two places of collection. Higher similarities were noticed between the places during summer 2012 and winter 2011-12. Monsoon and post-monsoon seasons recorded lower similarity indices between the places.

Discussion

Insects in the order Lepidoptera, particularly the moths (heterocera), occupy an important position in the food chain in agricultural, horticultural and forest ecosystems. They are also ecological indicators and hence they are the most preferable organisms for the study of environmental quality. Many scientists across the world have studied the biological diversity of moths in response to climatic factors, natural disasters or human interference. Studies on moth diversity in hilly regions are scanty in India. Mathew and Menon (1984), Mathew (1990) and Chandra and Sambath (2013) have recorded moth fauna from natural ecosystems in India. There is no report on the moth fauna and diversity in Rajmahal hills in Jhakhand state. Hence the present study was undertaken.

In this study 222 macro moth species were recorded from three different study areas in the Rajmahal hills. Sweeping net was mainly used for the collection and all the three sites were equally sampled. The total area of Rajmahal hills is very large and hence there is a possibility of finding many more moth species if the sampling sites will be more. Totally 18 different families of moths were recorded in the study areas. Among the different families, Erebidae was the largest family. Erebidae dominated in the collection with 74 species. Erebidae is a family of moths, most of which were formerly classified in the family Noctuidae. All of the former members of the families Arctiidae and Lymantriidae are also now classified under Erebidae (Lafontaine and Fibiger, 2006). However this re-classification has not yet met with general consensus. Many investigators still follow the older classification scheme.

Next to Erebidae, family Noctuidae was found to be the second largest in the study areas. Noctuidae was represented by 44 species. In the earlier classification, most of the moths of Erebidae were included in this family. Erebidae and Noctuidae were the dominant families in all three places showing the dominance of these two groups in Rajmahal hills. Geometridae comes third with 21 species. Sphingidae with 19 species comes fourth. Though the number of species and specimens vary in places, their dominance cannot be doubted.

Since we could collect 18 families of moths from this region, moth population and diversity can be assumed as very good. According to the studies conducted by several authors like Young (1997), McGeachie (1989), Hardwick (1972), Holyoak *et al.* (1997), Raimondo *et al.* (2004), Williams (1961), Fry and Waring (2001), night temperature and catch size are positively correlated and temperature has significant effect on moth trapping. According to Young (1997), Williams (1961), McGeachie (1989) and Nemec (1971), most of the moth trappings take place on a new moon night and traps are least effective on a full moon night.

Table 1. Mean monthly rainfall and mean atmospheric temperature (mean maximum and mean minimum) recorded in three Districts in Jharkhand state from March 2011 to February 2013

Month and year	Dumka			Pakur			Sahibganj		
	Mean Temperature (^{o}C)		Rainfall	Mean Temperature (^{o}C)		Rainfall	Mean Temperature ((^{o}C)		Rainfall
	Maximum	Minimum	(mm)	Maximum	Minimum	(mm)	Maximum	Minimum	(mm)
March 2011	38.5	10.0	9.0	39.7	12.3	6.6	41.4	16.4	12.0
April 2011	38.5	17.5	24.5	38.9	16.4	11.6	43.2	17.5	50.6
May 2011	38.7	20.0	69.8	41.0	22.6	91.6	44.4	23.7	128.3
June 2011	37.5	18.8	357.1	43.5	22.0	303.0	36.4	20.2	719.3
July 2011	36.0	22.8	147.9	40.1	24.8	199.6	35.9	21.2	333.1
Aug. 2011	35.2	22.8	322.8	40.2	24.6	404.0	38.5	22.1	290.5
Sept. 2011	35.2	23.5	198.5	36.0	23.6	197.0	36.9	22.4	148.6
Oct. 2011	35.0	15.2	14.8	36.3	19.4	0	34.7	17.9	48.7
Nov. 2011	31.3	11.0	0	36.1	14.2	0	30.5	13.6	0
Dec. 2011	29.5	4.0	0	31.2	9.4	0	30.1	5.6	0
Jan. 2012	20.0	4.5	0	26.2	7.1	3.4	20.6	6.6	4.2
Feb. 2012	34.2	5.7	0	29.8	7.5	0	26.4	6.9	0.8
March 2012	38.8	8.8	0	34.7	9.7	0	35.6	15.5	0.6
April 2012	42.0	18.0	2.5	41.9	19.3	23.4	41.2	22.1	52.0
May 2012	45.0	20.0	9.46	45.3	21.2	2.0	43.3	23.1	13.1
June 2012	45.0	23.0	96.28	45.3	22.8	67.0	44.9	23.5	123.4
July 2012	36.0	23.0	298.8	37.4	24.0	413.7	37.3	23.5	588.1
Aug. 2012	34.5	23.0	156.8	35.9	24.4	106.9	35.4	24.6	194.0
Sept. 2012	34.2	19.0	299.8	36.2	21.6	289.0	35.9	24.6	317.0
Oct. 2012	34.5	11.5	60.76	34.8	18.9	72.1	33.3	19.8	114.5
Nov. 2012	31.0	7.5	54.92	30.9	12.6	4.2	32.0	17.4	91.1
Dec. 2012	29.0	6.0	0	31.3	6.2	0	28.3	5.3	0
Jan. 2013	27.5	4.0	0	26.3	5.2	0	24.6	5.2	0
Feb. 2013	32.0	7.0	15.3	27.7	6.8	0	26.9	8.4	0

Table 2. Taxonomic composition and total number of individuals of heterocera from three different regions of Rajmahal hills, Jharkhand

Sl. No.	Species Name	Sub-family	Number of moths collected in		
			Maharo	Satia	Bathbanga
Family: BOMBYCIDAE					
1	*Trilocha varians* F. Walker	Bombycinae	43	31	57
Family: CRAMBIDAE					
2	*Botyodes* sp.	Spilomelinae	52	44	38
3	*Calamotropha* sp.	Crambinae	0	0	48
4	*Chilo* sp.	Crambinae	0	43	26
5	*Cirrhochrista brizoalis* Walker	Spilomelinae	80	75	88
6	*Cydalima laticostalis*	Spilomelinae	0	49	36
7	*Omphisa anastomosalis*	Spilomelinae	36	24	61
8	*Paligama choeralis* Walker	Pyraustinae	37	32	60
9	*Palpita quadristigmalis* Guenee	Spilomelinae	70	85	84
10	*Palpita vitrealis*	Spilomelinae	62	70	41
11	*Parapoynx stagnalis* Zeller	Acentropinae	57	61	71
12	*Parotis marginata* Hampson	Spilomelinae	42	63	75
13	*Parotis suralis* Lederer	Spilomelinae	54	48	42
14	*Ramila angustifimbrialis* Warren-Swinhoe	Schoenobiinae	66	69	65
15	*Sameodes cancellalis* Zeller	Spilomelinae	48	39	53
16	*Scirpophaga incertulas* Walker	Schoenobiinae	62	60	74
17	*Tyspanodes linealis* Moore	Spilomelinae	35	93	63
Family: DREPANIDAE					
18	*Cyclidia substigmaria*	Cyclidiinae	74	76	72
Family: EREBIDAE					
19	*Achaea janata* Linn.	Erebinae	85	103	96
20	*Achaea serva* Fab.	Erebinae	52	80	67
21	*Acyphas semiochrea* HerrichSchaffer	Lymantriinae	50	58	51
22	*Aloa lactinea* Cramer	Arctiinae	86	89	87
23	*Amata passalis* Fab.	Arctiinae	40	46	47
24	*Amerila astrea* Drury	Arctiinae	98	81	83
25	*Anomis flava* Fab.	Scoliopteryginae	61	31	46
26	*Anomis fulvida* Guenee	Scoliopteryginae	54	22	43
27	*Anomis involuta* Walker	Scoliopteryginae	53	73	65
28	*Anomis mesogona* Walker	Scoliopteryginae	63	74	69
29	*Anomis privata* Walker	Scoliopteryginae	77	56	65
30	*Anomis scitipennis* Walker	Scoliopteryginae	38	56	44
31	*Arctia villica* Linn.	Arctiinae	51	45	99
32	*Artaxa nubilosa* VanEcke	Lymantriinae	47	0	59
33	*Asota caricae* Fab.	Aganainae	119	113	148
34	*Asota producta*	Aganainae	58	59	84
35	*Asota ficus* Fab.	Aganainae	40	61	53
36	*Ataboruza divisa* Walker	Aventiinae	74	39	24
37	*Bastilla amygdalis*	Erebinae	10	16	18
38	*Bastilla crameri* Moore	Erebinae	37	45	41
39	*Bastilla joviana* Stoll.	Erebinae	31	38	42
40	*Bastilla maturata* Walker	Erebinae	78	109	99
41	*Bastilla simellima* Guenee	Erebinae	50	50	51
42	*Bastilla stuposa* Fab.	Erebinae	85	128	110
43	*Bastilla* sp.	Erebinae	23	38	43
44	*Creatonotos gangis* Linn.	Arctiinae	71	67	77
45	*Creatonotos* sp.	Arctiinae	15	21	30
46	*Creatonotos transiens* Walker	Arctiinae	77	94	97
47	*Cyana puella* (Drury)	Arctiinae	43	86	85
48	*Eilema lutarella* Linn.	Arctiinae	80	82	85
49	*Eilema nigripes* Hampson	Arctiinae	0	54	25
50	*Episparis exprimens* Guenee	Pangraptinae	59	23	44
51	*Episparis liturata*	Pangraptinae	0	0	10
52	*Eudocima phalonia* Clerk	Calpinae	122	155	143
53	*Eudocima materna* Linn.	Calpinae	161	175	164
54	*Erebus ephesperis* Hubner	Erebinae	34	51	53
55	*Erebus hieroglyphica* Drury	Erebinae	123	109	106
56	*Erebus macrops* Linn.	Erebinae	108	134	134
57	*Euproctis magna* Swinhoe	Lymantriinae	37	48	47
58	*Euproctis marginata* Moore	Lymantriinae	33	40	41

59	*Grammodes geometrica* Fab.	Erebinae	62	70	66
60	*Hypena subvittalis* Walker	Hypeninae	37	17	38
61	*Hypocala rostrata* Fab.	Hypocalinae	30	45	53
62	*Lemyra stigmata* (Moore)	Arctiinae	85	82	90
63	*Lymantria beatrix* Stoll.	Lymantriinae	43	50	47
64	*Lymantria concolor* Walker	Lymantriinae	41	45	45
65	*Lymantria semicincta* Walker	Lymantriinae	0	32	51
66	*Nygmia atrisignata* Swinhoe	Lymantriinae	55	55	61
67	*Nygmia icilia* Stoll.	Lymantriinae	43	35	41
68	*Mocis frugalis* Fab.	Erebinae	99	114	105
69	*Mocis trifasciata* Stephens	Erebinae	0	8	8
70	*Mocis undata* Fab.	Erebinae	99	121	119
71	*Olepa ricini* Fab.	Arctiinae	56	61	64
72	*Olepa schleini*	Arctiinae	42	36	79
73	*Olepa ocellifera* Walker	Arctiinae	59	62	67
74	*Ophiusa olista* Swinhoe	Erebinae	83	95	88
75	*Ophiusa tirhaca* Cramer	Erebinae	40	40	43
76	*Ophiusa trapezium* Guenee	Erebinae	69	37	59
77	*Orvasca subnotata* Walker	Lymantriinae	43	53	52
78	*Pericyma* sp.	Erebinae	60	24	39
79	*Polydesma lindsayi* Hampson	Erebinae	44	29	35
80	*Rajendra perrottetii* (Guérin-Méneville)	Arctiinae	66	75	81
81	*Saroba antecedens* Walker	Boletobiinae	55	17	35
82	*Spilarctia obliqua*	Arctiinae	10	17	23
83	*Spilarctia postrubida*	Arctiinae	80	83	94
84	*Spilosoma melanthus*	Arctiinae	32	76	32
85	*Spilosoma multiguttata* Walker	Arctiinae	76	74	76
86	*Spilosoma* sp.	Arctiinae	52	74	54
87	*Spilosoma thomasi* Holloway	Arctiinae	51	59	59
88	*Syntomoides imaon*	Arctiinae	42	54	53
89	*Spirama helicina* Hubner	Erebinae	121	136	136
90	*Spirama retorta* Clerk	Erebinae	38	53	48
91	*Trigonodes disjuncta* Moore	Erebinae	78	65	63
92	*Trigonodes hyppasia*	Erebinae	53	59	58
Family: EUPTEROTIDAE					
93	*Eupterote lineosa* Walker	Eupterotinae	56	47	65
94	*Eupterote multiarcuata* Holloway	Eupterotinae	46	64	86
95	*Eupterote naessigi* Holloway	Eupterotinae	62	56	73
96	*Eupterote undata* Blanchard	Eupterotinae	132	89	220
97	*Ganisa similis* Moore	(Subfamily unknown)	25	24	52
98	*Sangatissa subcurvifera* Walker	Subfamily unassigned	33	64	60
Family: EUTELIIDAE					
99	*Lophoptera* sp.	Stictopterinae	0	0	43
100	*Odontodes seranensis* Prout	Stictopterinae	60	73	60
Family: GEOMETRIDAE					
101	*Agathia laetata* (Fab.)	Geometrinae	98	109	108
102	*Aporandria specularia* Guenee	Geometrinae	52	55	61
103	*Aspitates* sp.	Ennominae	27	35	40
104	*Chiasmia eleonora* (Cramer)	Ennominae	49	36	52
105	*Chiasmia emersaria* (Walker)	Ennominae	56	29	61
106	*Chiasmia hebesata* (Walker)	Ennominae	78	74	83
107	*Chiasmia perfusaria* (Walker)	Ennominae	60	34	71
108	*Chrysocraspeda* sp.	Sterrhinae	53	27	64
109	*Cleora determinata* Walker	Ennominae	68	42	52
110	*Dindica alaopis* Prout	Geometrinae	60	52	67
111	*Eumelea rosalia* (Stoll.)	Desmobathrinae	52	51	53
112	*Eumelea* sp.	Desmobathrinae	53	50	49
113	*Heterostegane tritocampsis* Prout	Ennominae	36	49	54
114	*Hyperythra lutea* Stoll	Ennominae	30	54	58
115	*Hypochrosis albodecorata* (Swinhoe)	Ennominae	42	57	60
116	*Hyposidra talaca* Walker	Ennominae	29	44	55
117	*Leucula festiva* Cramer	Ennominae	27	25	64
118	*Maxates* sp.	Geometrinae	41	45	64
119	*Ornithospila cincta* Walker	Geometrinae	56	53	55
120	*Pelagodes* sp.	Geometrinae	58	59	46
121	*Scopula* sp.	Sterrhinae	35	42	48

Family: IMMIDAE					
122	*Imma acosma* Turner		0	0	27
Family: LASIOCAMPIDAE					
123	*Euthrix laeta* Walker	Lasiocampinae	45	50	42
124	*Gastropacha leopoldi* Linn.	Pinarinae	38	33	44
125	*Gastropacha pardale* Formosa	Pinarinae	55	52	48
126	*Gastropacha* sp.1	Pinarinae	42	59	53
127	*Gastropacha* sp.2	Pinarinae	0	33	44
128	*Lebeda nobilis*	Pinarinae	17	31	44
129	*Malacosoma disstria*	Malacosomatinae	15	17	17
130	*Metanastria hyrtaca* Cramer	Pinarinae	22	31	50
131	*Trabala* sp.	Lasiocampinae	50	48	00
132	*Trabala vishnou* Lefebvre	Lasiocampinae	49	35	43
Family: LIMACODIDAE					
133	*Belippa ochreata*	Limacodinae	26	44	70
134	*Birthamoides junctura* Walker	Limacodinae	45	44	74
135	*Cotonis* sp.	Limacodinae	52	0	57
136	*Miresa albipuncta* Herrich-Schäffer	Limacodinae	30	0	41
137	*Miresa bracteata* Walker	Limacodinae	35	42	50
138	*Miresa* sp.	Limacodinae	46	32	41
139	*Parasa chloris* (Herrich-Schäffer)	Limacodinae	47	46	51
140	*Parasa lepida* Cramer	Limacodinae	40	33	36
141	*Parasa pastoralis* Butler	Limacodinae	52	49	48
142	*Phocoderma velutina* Kollar	Limacodinae	53	52	52
143	*Scopelodes albipalpalis* Herring	Limacodinae	47	46	34
144	*Thosea biguttata* Walker	Limacodinae	50	35	48
Family: NOCTUIDAE					
145	*Acronicta pruinosa*	Acronictinae	39	31	68
146	*Aedia acronyctiodes* Guenee	Aediinae	54	47	38
147	*Aegocera* sp.		44	33	65
148	*Agrotis ipsilon* Hufnagel	Noctuinae	46	20	41
149	*Amyna octo* (Guenée)	Bagisarinae	33	39	31
150	*Artena dotata* Fab.	Catocalinae	75	60	74
151	*Athetis* sp.	Noctuinae	45	28	43
152	*Callopistria repleta* Walker	Eriopinae	39	26	41
153	*Chalciope mygdon* Cramer	Catocalinae	71	73	68
154	*Chasmina candida* Walker	Amphipyrinae	79	58	64
155	*Chrysopera combinans* Walker	Catocalinae	40	48	55
156	*Condica dolorosa*	Condicinae	31	30	44
157	*Dasypodia cymatodes* Guenee	Catocalinae	51	60	54
158	*Diarsia canescens*	Noctuinae	0	0	27
159	*Entomogramma fautrix* Guenee	Catocalinae	49	55	53
160	*Ercheia cyllaria* Guenee	Catocalinae	54	50	48
161	*Ercheia inangulata* Guenee	Catocalinae	69	93	85
162	*Fodina contigua* Strand	Amphipyrinae	36	28	109
163	*Helicoverpa armigera* Hubner	Heliothinae	72	66	70
164	*Homoptera glausinans*		40	46	62
165	*Hulodes caranea* Cramer	Catocalinae	88	136	123
166	*Hulodes drylla* Guenee	Catocalinae	41	23	37
167	*Hypopyra pudens* Walker	Catocalinae	46	58	37
168	*Hypopyra vespertilio* Fab.	Catocalinae	62	76	56
169	*Ischyja manlia* Cramer	Catocalinae	63	75	68
170	*Lyncestis amphix* Cramer	Catocalinae	0	49	58
171	*Mecodina praecipua* Walker	Catocalinae	49	60	49
172	*Mixomelia* sp		0	0	62
173	*Mythimna l-album* Linn.	Noctuinae	37	53	51
174	*Mythimna pallens* Linn.	Noctuinae	58	35	50
175	*Mythimna unipuncta* Hawarth	Noctuinae	70	59	63
176	*Oraesia emarginata* Fab.	Catocalinae	53	45	41
177	*Pindara illibata* Fab.	Catocalinae	74	61	50
178	*Polytela gloriosae* Fab.	Glottulinae	30	10	37
179	*Sarbanissa* sp.	Agaristinae	56	34	72
180	*Spodoptera exigua* Hubner	Noctuinae	57	50	61
181	*Spodoptera litura* Fab.	Noctuinae	77	53	59
182	*Spodoptera mauritia* Boisduval	Noctuinae	74	60	69
183	*Tamaraca torridalis*		28	42	53
184	*Thyas coronata* Fab.	Catocalinae	99	119	120

185	*Tiracola plagiata*	Hadeninae	0	33	43
186	*Tycracona obliqua*	Amphipyrinae	37	39	60
187	*Xanthodes* sp.		0	28	63
188	*Xanthodes transversa* Guenee	Bagisarinae	63	25	27
Family: NOLIDAE					
189	*Risoba* sp.	Risobinae	74	75	62
Family: NOTODONTIDAE					
190	*Antheua exanthemata* Moore	Phalerinae	43	74	80
191	*Antheua* sp.	Phalerinae	6	9	11
192	*Phalera grotei* Moore	Phalerinae	37	67	53
193	*Phalera procera* Felder	Phalerinae	64	53	74
194	*Phalera styx* Holloway	Phalerinae	62	75	94
Family: PYRALIDAE					
195	*Etiella zinckenella* Treitschke	Phycitinae	56	82	68
196	*Phycitini* sp.	Phycitinae	33	64	50
Family: SATURNIDAE					
197	*Actias selene* Hubner	Saturniinae	24	31	37
198	*Anisota senatoria* JE Smith	Ceratocampinae	40	42	52
199	*Antheraea frithi* Moore	Saturniinae	41	88	51
200	*Antheraea mylitta* Drury	Saturniinae	59	50	61
Family: SPHINGIDAE					
201	*Acherontia atropos* Linn.	Sphinginae	38	49	53
202	*Acherontia lachesis* Fab.	Sphinginae	77	59	68
203	*Acherontia styx* Westwood	Sphinginae	88	71	75
204	*Agrius convolvuli* Linn.	Sphinginae	52	48	57
205	*Clanis hyperion* Cadiou & Kitching	Smerinthinae	54	51	51
206	*Cypoides parachinensis* Brechlin	Smerinthinae	43	52	56
207	*Daphnis nerii* Linn.	Macroglossinae	51	69	62
208	*Hippotion boerhaviae* Fab.	Macroglossinae	43	52	56
209	*Hippotion celerio* Linn.	Macroglossinae	61	56	57
210	*Hippotion rosetta* Swinhoe	Macroglossinae	64	69	69
211	*Nephele hespera* Fab.	Macroglossinae	38	64	59
212	*Pergesa acteus* Cramer	Macroglossinae	56	62	55
213	*Psilogramma increta* Walker	Sphinginae	54	53	61
214	*Theretra alecto* Linn.	Macroglossinae	84	59	78
215	*Theretra clotho* Drury	Macroglossinae	76	57	69
216	*Theretra gnoma* Fab.	Macroglossinae	68	62	76
217	*Theretra latreillii* Macleay	Macroglossinae	64	70	70
218	*Theretra nessus* Drury	Macroglossinae	78	66	63
219	*Xylophanes kiefferi* Cadiou	Macroglossinae	66	62	66
Family: THYRIDIDAE					
220	*Rhodoneura* sp.	Siculodinae	42	39	33
Family: URANIIDAE					
221	*Acropteris* sp.	Microniinae	50	70	87
222	*Micronia aculeata* Guenee	Microniinae	70	86	78
Total			11,400	11,965	13,470

Table 3. Diversity indices of moth fauna in summer seasons (2011 and 2012) in three different places in Rajmahal hills

Diversity indices	Summer 2011			Summer 2012		
	Bathbanga	Maharo	Satia	Bathbanga	Maharo	Satia
Taxa (S)	209	182	186	214	202	205
Individuals	850	679	694	881	800	809
Dominance (D)	0.006779	0.008214	0.008093	0.005601	0.005925	0.005957
Simpson's index of Diversity (1-D)	0.9932	0.9918	0.9919	0.9944	0.9941	0.994
Shannon (H)	5.143	4.959	4.985	5.277	5.218	5.216
Evenness (e^H/S)	0.8192	0.7825	0.7857	0.9145	0.9135	0.8986
Brillouin	4.769	4.57	4.594	4.892	4.823	4.823
Menhinick	7.169	6.985	7.06	7.21	7.142	7.207
Margalef	30.84	27.76	28.28	31.41	30.07	30.47
Equitability (J)	0.9627	0.9529	0.9538	0.9833	0.983	0.9799
Fisher_alpha	88.52	81.49	83.27	89.95	86.99	88.49
Berger-Parker	0.02118	0.0162	0.01729	0.01816	0.015	0.0136
Chao-1	220	217.4	207.5	215.8	203.2	216.3

Table 4. Diversity indices of moth fauna in monsoon seasons (2011 and 2012) in three different places in Rajmahal hills

Diversity indices	monsoon 2011			monsoon 2012		
	Bathbanga	Maharo	Satia	Bathbanga	Maharo	Satia
Taxa (S)	220	196	202	220	205	212
Individuals	1536	1272	1364	1554	1294	1424
Dominance (D)	0.005719	0.006012	0.005938	0.005652	0.005746	0.005911
Simpson's index of Diversity (1-D)	0.9943	0.994	0.9941	0.9943	0.9943	0.9941
Shannon (H)	5.28	5.184	5.208	5.278	5.239	5.235
Evenness (e^H/S)	0.8928	0.9106	0.9045	0.8907	0.9193	0.8856
Brillouin	5.019	4.908	4.94	5.019	4.955	4.967
Menhinick	5.613	5.496	5.469	5.581	5.699	5.618
Margalef	29.85	27.28	27.85	29.8	28.47	29.06
Equitability (J)	0.979	0.9823	0.9811	0.9785	0.9842	0.9773
Fisher_alpha	70.32	64.74	65.53	69.96	68.58	68.94
Berger-Parker	0.02083	0.01179	0.01466	0.01416	0.01082	0.01334
Chao-1	223.5	196.6	202.8	220.9	206	217.3

Table 5. Diversity indices of moth fauna in post-monsoon seasons (2011 and 2012) in three different places in Rajmahal hills

Diversity indices	Post-monsoon 2011			Post-monsoon 2012		
	Bathbanga	Maharo	Satia	Bathbanga	Maharo	Satia
Taxa (S)	221	207	213	221	207	213
Individuals	3044	2645	2682	2858	2405	2536
Dominance (D)	0.005376	0.005688	0.005743	0.005619	0.005889	0.006044
Simpson's index of Diversity (1-D)	0.9946	0.9943	0.9943	0.9944	0.9941	0.994
Shannon (H)	5.31	5.245	5.254	5.293	5.233	5.235
Evenness (e^H/S)	0.9155	0.9163	0.8982	0.9003	0.9048	0.8813
Brillouin	5.152	5.079	5.086	5.128	5.054	5.06
Menhinick	4.006	4.025	4.113	4.134	4.221	4.23
Margalef	27.43	26.14	26.85	27.65	26.46	27.05
Equitability (J)	0.9837	0.9836	0.98	0.9805	0.9812	0.9764
Fisher_alpha	54.76	52.56	54.35	55.9	54.28	55.39
Berger-Parker	0.01544	0.01323	0.0138	0.01575	0.0158	0.01538
Chao-1	221	207	213	221	207	213

Table 6. Diversity indices of moth fauna in winter seasons (2011-12 and 2012-13) in three different places in Rajmahal hills

Diversity indices	Winter 2011-12			Winter 2012-13		
	Bathbanga	Maharo	Satia	Bathbanga	Maharo	Satia
Taxa (S)	220	204	210	214	205	208
Individuals	1613	1384	1441	1134	921	1015
Dominance (D)	0.005981	0.006491	0.006475	0.006129	0.006723	0.006615
Simpson's index of Diversity (1-D)	0.994	0.9935	0.9935	0.9939	0.9933	0.9934
Shannon (H)	5.247	5.174	5.187	5.217	5.148	5.168
Evenness (e^H/S)	0.8635	0.8659	0.8523	0.8618	0.8397	0.8438
Brillouin	4.997	4.909	4.925	4.902	4.796	4.835
Menhinick	5.478	5.484	5.532	6.355	6.755	6.529
Margalef	29.65	28.07	28.74	30.28	29.89	29.9
Equitability (J)	0.9728	0.9729	0.9701	0.9723	0.9672	0.9682
Fisher_alpha	68.84	66.04	67.64	78.01	81.79	79.22
Berger-Parker	0.01116	0.01156	0.0118	0.0194	0.02172	0.0197
Chao-1	220.5	204.5	211	215.9	206.1	208.9

Table 7. Jaccard Index and Jackknife pseudo-values 95% CI

Seasons	Similarity index between places		
	Bathbanga (vs.) Maharo	Bathbanga (vs.) Satia	Maharo (vs.) Satia
Summer 2011	0.093(0.077-0.109)	0.089(0.073-0.105)	0.094(0.078-0.111)
Summer 2012	0.146(0.121-0.173)	0.135(0.113-0.159)	0.134(0.112-0.157)
Monsoon 2011	0.066(0.055-0.078)	0.082(0.068-0.096)	0.071(0.058-0.085)
Monsoon 2012	0.085(0.068-0.103)	0.078(0.060-0.096)	0.087(0.070-0.105)
Post-monsoon 2011	0.047(0.036-0.058)	0.057(0.045-0.069)	0.051(0.039-0.065)
Post-monsoon 2012	0.057(0.042-0.072)	0.049(0.039-0.059)	0.060(0.043-0.076)
Winter 2011-12	0.111(0.088-0.135)	0.105(0.087-0.123)	0.109(0.088-0.129)
Winter 2012-13	0.074(0.061-0.087)	0.074(0.060-0.089)	0.095(0.070-0.121)

(Values in parantheses are lower and upper confidence intervels)

It is also suggested that some of the moths fly late at night and so unless the trap works for the whole night, you may not be able to trap all moths.

Many of the moth species reported in the present study are pests of forest plants and some are fruit borers. *Eudocima* spp. are fruit borers and are already reported from India. *Eudocima fullonia* (Clerck), *Eudocima materna* (Linnaeus), *Eudocima homaena* Hübner and *Eudocima cajeta* (Cramer) and others are known to occur in India (Susainathan, 1924a, 1924b; Ayyar, 1944). Larvae of *E. fullonia* were reported to feed on leaves of *Tinospora cordifolia* and *Cocculus hirsutus* Diels (Rakshpal, 1945; Nair, 1975; Ayyar, 1944; Susainathan 1924a; Bajpai, 1955). *Helicoverpa armigera*, *Spodoptera litura* and *S. mauritia* are agricultural pests.

Among the three places of collection, Bathbanga recorded the highest number of genera and species while Satia came next to it. Some of the families like Immidae are altogether absent in Maharo and Satia. *Calamotropha* sp. of Crambidae, *Lophoptera* sp of Eutellidae and *Imma acosma* of Immidae were absent in both Maharo and Satia while *Artaxa nubilosa* of Erebidae, *Cotonis* sp. and *Miresa albipuncta* of Limacodidae were absent in Maharo, *Chilo* sp. of Crambidae, *Eilema nigripes* of Erebidae, *Limantria semicincta* of Notodontidae, *Gastropacha* sp. of Lasiocampidae and *Lincastis amphix* of Noctuidae were absent in Satia. It was also noted that all these species of moths were found in the collections sites in Bathbanga. This might be due to the virgin forest cover of Bathbanga area though Satia is also under such forest cover.

The climatic factors play important role in insects' diversity and population of species. In the present study rainfall and atmospheric temperature were recorded during the study. Summer and winter were the worst seasons for moths as their number was very low during these seasons. The temperature in winter season came down to 4°C to 15°C that was not suitable for moths to survive. Winter season was also marked by very low humidity and less sunshine. Another factor may be the presence of fog in winter. In summer the host plants were not available for many moth species. This led to low species richness during the study period.

According to Varley *et al.* (1973) weather and climate affect the physiology and behavior of insects. Jaroensutasinee *et al.* (2011) found that weather was a limiting factor for the macro moth diversity at Khao Nan National Park in Thailand. According to them, moth population was very high in October and December which had a positive correlation with mean/max/Min temperatures and negative correlation with relative humidity. Ferro and Romanowski (2012) studied the diversity and composition of tiger moths in Atlantic forest in southern Brazil. They found that tiger moth assemblages were related to environment, habitat type, altitude, temperature, relative humidity and the location of the site. Day length and temperature have important effects on the insect endocrine system, leading to various types of activities. This also can be seen in this case as the day time is the shortest during winter; normally 7 A.M. to 4.30 P.M. and fog covering sometimes half the day. Temperature becomes very low and cold wind makes life almost unbearable for smaller animals like insects. The sharp drop in number can be attributed to such weather conditions. This was very clear in the month of January.

Abundance and rarity of moths are highly variable; some species were very common while others were rare (Bell and Scott, 1937). In our study the highest peaks in collection are found during post monsoon seasons of 2011 and 2012 in all three places. This was due to the rainfall, humidity and optimum temperature during this season. During September, October and November there was intermittent rain, humidity was high and temperature ranged from 20°C to 35° C that was very suitable for any form of life. This season was also marked by high floristic diversity as the rainy season started in the middle of June, plenty of plants were found for the larvae to feed. Day light was longer; normally from 5 A.M. to 6 P.M, and sunshine was longer, 6A.M. to 5.30 P.M. So all the climatic conditions favoured multiplication and growth of moths and so the peak was the highest during this season.

The next season of abundance of moth was monsoon period of July, August and September in both the years of collection. This was also due to the favourable climatic conditions. Temperature during this time was very optimal for living organisms though sometimes it went very high. Humidity was also high and rainfall was very high. Green leaves were plenty as plants grew very fast during this season. So, all the conditions were favourable except for the very heavy rain that may destroy the eggs, larvae and pupae of moths. Due to the heavy rain, moths might not be able to come out freely and may be killed.

Temperature is a key factor affecting most Lepidoptera because it has direct effects on larval behavior and performance, flight activity and associated behaviours such as foraging and territoriality (Broersma *et al*., 1976; Scriber and Slansky, 1981; Hrdy *et al*., 1996; Shirai *et al*., 1998; Kuhrt *et al*., 2005; Nabeta *et al.*, 2005; Merckx *et al.*, 2006;). Temperature is also seen to affect the seasonal distribiution of some species (Turner *et al*., 1987) and the abundance and diversity patterns of moths (Brehm *et al*., 2007; Choi, 2008). When we calculated the diversity index in Shannon-Weiner scale, the lowest diversity was in summer and winter and the highest diversity was in post-monsoon. In most of the biological communities the Shannon-Weiner index does not go beyond 5.0 (Washington, 1984). But sometimes the value exceeds 5.0 when there is more number of taxa. In the present study the H' value for monsoon, post-monsoon and winter in both study years exceeded 5.0. Similar results were obtained by Hayat *et al.* (2010). They obtained Shannon-Weiner index (H') value of 5.61 for plant species diversity at Pasir Tengkorak forest reserve, Langkawi Island, Malaysia. Simpson's index of diversity was almost equal in all seasons.

Conclusion

In Rajmahal hills, the moth diversity was the highest either in monsoon or post-monsoon periods, because in those seasons all species were almost evenly distributed and species richness was very high. Erebidae and Noctuidae were the dominated families in the moth assemblage having almost 118 species of them among the 222 species identified. Among the places chosen for collection of moths, Bathbanga towards the south most end of the Rajmahal hills had the highest species richness and abundance while Maharo had the lowest species richness and diversity. Weather and climatic conditions have a telling effect on moth diversity in Rajmahal hills. Moths were more abundant when there was good sunshine, moderate temperature and intermittent raining. Post-monsoon supported the moths in many ways and so their diversity was rich in that season. Different diversity indices helped to understand the impact of temperature and rainfall on moth species richness, evenness and dominance. The study will help to predict the moth assemblages at different climatic conditions.

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