Entomology

Studies on the species richness, evenness and diversity of moth fauna of Jaipur, Rajasthan

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Abstract

Jaipur, the capital city of state of Rajasthan was surveyed for Moth fauna during 2019–2020. Observations were made at four locations and collection was done mainly in Pre-monsoon, Monsoon and Post-monsoon seasons. A checklist was prepared that enlisted 65 species belonging to 13 families, grouped into 31 genera under 9 super families. Five families viz. Erebidae, Geometridae, Sphingidae, Noctuidae and Crambidae were the most commonly occurred and rest of eight families were the least. A total of 1337 specimens were collected. Species Richness (J) calculated was 1.667, Evenness 0.719, Shannon Index (H) 1.844.

Keywords: moth, lepidoptera, margalef's index, shannon's index, pielou's index, species richness, evenness, diversity

Introduction

Diversity refers dissimilar life forms that exist in different ecosystems. Biologically, it measures variety of organisms in a particular ecosystem. It includes genetic diversity, ecosystem diversity, species diversity and phylogenetic diversity. Genetic diversity refers to different species as well as the diversity within a particular species. Ecosystem diversity is the diversity of an area at an ecosystem level. Species diversity is an effective number of species represented in a data set. Phylogenetic diversity deals with the diversity that incorporates phylogenetic variations between various species (Myers *et al*., 2000) [18].

Insects comprise more than half of the world's known animal species (Wilson, 1992) [26] of which the second major and more diverse order is Lepidoptera of the class Insecta (Benton, 1995) [3]. Lepidoptera is the most enormous order which mainly comprises butterflies, moths, and skippers. Lepidoptera is divided into 89 families and sub-families (Hampson, 1918) [14]. Hamlyn (1969) [15] reported over 1,40,000 species of moths worldwide, including 13,000 butterflies whereas Alfred *et al.*, (1998) [1] estimated 1,27,000 species of moths around the globe, of which over 12,000 species are recorded from India (Chandra and Nema, 2007) [4]. Lepidopteran species currently number over 1,74,250 and are classified into 126 families and 46 super families (Dhaliwal *et al*., 2015) [7]. Recent estimates of diversity within Lepidoptera from the Indian sub-region reveal that the group comprises over 15,000 species and many more sub-species distributed over 84 families and 18 super families. Earlier reports on moth fauna of Rajasthan are however, available. 36 species of Lepidoptera collected from different regions of Rajasthan out which 9 species of moths were reported (Gupta and Thakur, 1986) [8]; 30 species from Ranthambhore National Park (Chandra *et al*., 2010) [5]; 19 species from Jhunjhunu (Sima and Srivastava, 2014) [22]; 56 species from Ajmer (Sharma, 2016) [23]; 51 species from Keoladeo National Park (Trigunayat and Trigunayat, 2021) [25]; 34 species from Aravalli Hill area (Dar *et al*., 2021) [6]; 154 species from Southern Rajasthan (Koli and Prajapati, 2021) [16] and 19 species from Jodhpur (Gehlot *et al*., 2021) [9]. The diversity of moth fauna of Jaipur is poorly studied. Information on these cryptic creatures are therefore, very scanty. A checklist of 28 species was prepared earlier by the authors (Ramu and Trigunayat, 2021) [25]. Present work on moth diversity, evenness, and species richness is extension of the earlier work.

Jaipur lies between 26°32' and 27°51' N latitudes and 74°55' and 76°50' E longitudes. It has a geographical area of 14068 Km^2, which is 3.23% of the total area of the state. It is designated as "World Heritage Sites" by UNESCO in July 2019. The main objective of this communication is to update the species list and calculate the diversity, species richness and evenness of the moth fauna of Jaipur.

Material and Methods

The study was conducted from 2019 to 2020. Moths were collected seasonally (Pre-monsoon, Monsoon, and Post-monsoon). Collections were made following standard methods viz. Net sweeping, Light trap and Hand-picking. Sampling was carried out twice within a week. Opportunistic observations for all the potential microhabitats, i.e. leaves, tree bark, bushes, shrubs, herbs, ceiling/wall and under street light posts were taken at evening hours (7:30-11:30 pm).

For light trap, a 260W mercury vapour bulb over a $3x3m^2$ white cloth sheet was used during the same period of time. The cloth sheet was hung between two trees. The light was focused towards the white cloth sheet, so that the maximum moths could be attracted to it. The moths sitting on the white cloth were photographed by CANON 700D DSLR camera with different lenses [lens 18-250mm most commonly used] and spot unidentified moths were then captured and observed under stereo microscope (Olympus SZX-10 and SZX-16 models) in laboratory next day, later transferred into the killing bottles saturated with ethyl acetate and stretched properly, dried and pinned in wooden box using entomological pins of different

size. Moths were then stored carefully for further study and species identification. Wing size measurements were done in millimeters by measuring the length of the distance between the two forewing tips. Identification was done with the help of authentic keys (Hampson, 1892, 1894, 1895, 1896) [10-13]; (Bell & Scott, 1937) [2]; (Shubhalaxmi, 2018) [24]; various web resources; pictorial source and other literature were also consulted.

Survey and sampling sites

Surveys were conducted weekly and fortnightly at the following sites seasonally whose GPS locations are given (Table 2). Sites were chosen on the basis of size, longitude, vegetation etc. A stratified random sampling method was used in random order in the field during survey to avoid any pre-decided conclusion. Mainly four sites given below (Table 1) were regularly sampled and others were visited opportunistically.

a) Amer Fort Area (AFA)
b) Jamwa Ramgarh (JR)
c) Nahargarh Fort Area (NFA)
d) University of Rajasthan Campus (UoR Campus)

Table 1: Number of trap nights and specimens collected are given

	Location	Vegetation	No of trap night	Specimen collected
Site I	AFA	Hilly/ Wetland	10	295
Site II	JR	Grassland/Hilly	14	141
Site III	NFA	Hilly Area	11	382
Site IV	UoR CAMPUS	Urban Area	33	519
Total			68	1337

Table 2: Study sites with their GPS location

Sites	Latitude	Longitude	Elevation (m)
Site I (AFA)	26º59'11'' N	75º51'11'' E	424
Site II (JR)	27º02'54'' N	76º03'20'' E	373
Site III (NFA)	26º 56'32'' N	75º49'04'' E	589
Site IV (UoR)	26º53'23'' N	75º48'56'' E	441

Fig 1: Locations of the study area with reference to India and Rajasthan; (Pic source: google)

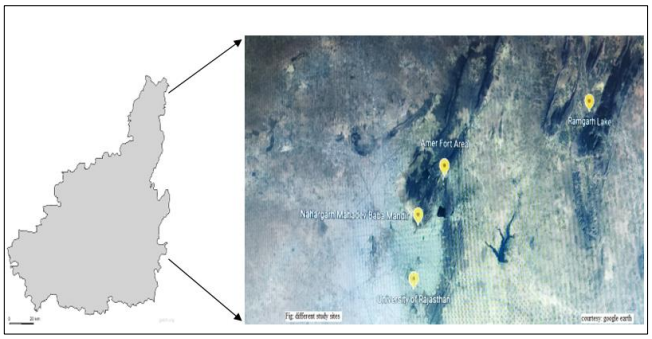

Fig 2: Map showing study locations

Data analysis

Biodiversity indices were used for the calculation of species diversity, richness and evenness determination at different localities.

Measurement of diversity

To calculate the diversity, Shannon – Wiener diversity index (H') (1948) was used here, and the alpha diversity were calculated, it denotes diversity of species contained by a community or habitat. The Shannon – Wiener diversity index was designed by using the following equation:

$$(H') = -\sum_{i=1}^{s} Pi * (lnPi)$$

Where,
H = Shannon-Wiener diversity index
Pi = total sample proportion belong to i^{th} species
S = total individuals count of a species
ln = Natural log
If the value of Shannon's Index is less than 1.5 = low diversity; if value is greater than 1.5 but less than 2.5 means medium diversity, and if the value is higher than 2.5, indicates the high diversity.

Measurement of species richness

Species richness is the entire number of the species within a community. For calculating species richness, Margalef's index (D) was used (Margalef, 1958):

$$D = \frac{S-1}{ln\, N}$$

S = total number of species
N = total individuals' number in the sample
ln = Natural logarithm

Measurement of evenness

Evenness expresses how uniformly the individuals in a group of population are dispersed among the different species. For calculating the evenness of species, the Pielou's Evenness Index (J) was used (Pielou, 1966) [19].

$J = H' / ln\ S$

H = Shannon – Wiener diversity index
S = total species number in the sample
ln = Natural logarithm
If the Evenness value is closer to 1 = more Evenness is found
If the value is closer to 0 = less Evenness is present

Results and Discussion

A total 65 species of 31 genera and 13 families grouped into 9 super families are being reported. A total of 1337 specimens were collected during the study from different locations, viz. JR, NFA, AFA, and UoR Campus. The checklist of moth is presented (Table 4). Out of 1337 specimens, 614 were collected in 2019 and 723 in 2020. The species wise break up of moth numbers is 382 in Crambiade, 275 in Erebidae, 213 specimens in Noctuidae, 189 in Geometridae, 131 in Sphingidae, 72 in Pyralidae, 60 in Pterophoridae, 5 in Uraniidae & Bombycidae each, 2 in Thyrididae, and 1 in Limacodidae, Acrolophidae and Tortricidae each (Fig. 4 & 6). Based on numbers the most abundant family was Erebidae which has 22 species, followed by Geometridae with 12 species, Noctuidae and Sphingidae each have 9 species; Crambidae with 5 species; Pyralidae, Thyrididae, Pterophoridae, Uraniidae, Bombycidae, Limacodidae, Acrolophidae and Tortricidae has 1 species each (Fig. 3).

Subfamily Erebinae was the most abundant followed by Ennominae, Macroglossiinae, Lymantriinae and Spilomelinae respectively. *Spoladea* (=*Hymenia*) *recurvalis* was the most dominant species at each site. Larva feeds on spinach, maize, Amaranthus and kharif weeds in the area. The adult is capable of long-distance flights. Which help to survive in different habitats, and the least dominant species was *Parasa cloris* which was seldomly observed. Most of the species were observed in the Monsoon season followed by Post-monsoon and Pre-monsoon (Fig. 5). During the survey, the overall diversity of all study sites was calculated separately and collectively (Table 3). The diversity indices Shannon's index (H'), Pielou Evenness index (J') and Margalef's Species richness index (D) calculated were 1.844, 1.667, and 0.719 respectively. These value shows that the overall moth fauna of Jaipur is very diverse with high evenness and richness (Table 3). Amongst the UoR site has the highest diversity value which indicate abundance of various species. How many different types of taxa are present in a community is species diversity, and richness is number of various species found in an area. Evenness of species is, how homogeneously the species distributed (Table 3). As Evenness and Richness increase, the Diversity is also increased. None of the species recorded here, comes under Wild Life Protection Act, 1972.

Jaipur has a hot semi-arid climate under the Koppen climate classification, receiving over 650 millimetres of rainfall annually. Temperature remains relatively high during summer months of April to early July. The winter months November to February are serene and pleasant. Aravalli hills passes around the city, this causes variations in the velocity of wind, altitudes, slope etc. that affect the vegetation grown in this area. It has mixed xerophytic and sparse vegetation having climatic fluctuations for existence, development, and growth. Climatic factors directly affect the moth occurrence and abundance. High rainfall coupled with hot and humid climate favours occurrence of moths in this area. The UoR Campus is receives more rainfall and therefore, comparatively rich in vegetation density followed by NFA and AFA. In addition, UoR Campus is rich in many types of medicinal, flowering and wild plants that served rich source of food for moths as compared to other sites who have tropical deciduous dry forests and disperse vegetation. Nursery in the campus has many flowering and ornamental plants that serve a food source of nectar and plenty space to hide. This might probably be the reason of high species richness and diversity. The present work therefore on moths is inevitable to fill the gap in the fauna and food chains.

Table 3: Species Evenness, Richness and Diversity of moths

All locations	Evenness (J')	Species Richness (D)	Shannon Index (H')
	0.719	1.667	1.844
AFA	0.946	2.17	1.69
JR	0.959	1.67	1.33
NFA	0.845	1.74	1.36
UoR	0.792	2.73	1.90

Table 4: Moth fauna recorded from the different study sites of Jaipur, Rajasthan

Sr. No.	Scientific Name	Abundance	Locality	Subfamily	Family
Superfamily - Noctuoidea					
1	*Achaea janata* Hubner, 1823	Monsoon	UoR	Erebinae	Erebidae
2	*Amata cyssea*, Stoll, 1782	Pre-monsoon	NFA	Arctiinae	Erebidae
3	*Anomis flava*, Fabricius, 1775	Monsoon	JR	Scoliopteryginae	Erebidae
4	*Anticarsia irrorata*, Fabricius, 1781	Post monsoon	UoR	Calpinae	Erebidae
5	*Asota ficus*, Fabricius, 1775	Monsoon	NFA	Aganainae	Erebidae
6	*Bastilla joviana*, Stoll, 1782	Pre and Post monsoon	UoR	Erebinae	Erebidae
7	*Cerynea trogobasis*, Hampson, 1910	Monsoon	UoR	Boletobiinae	Erebidae
8	*Coscinia sp.*	Post monsoon	UoR	Arctiinae	Erebidae
9	*Erabus macrops* Linneaus, 1770	Monsoon	NFA	Erebinae	Erebidae
10	*Eudocima maternal* Linnaeus, 1767	Monsoon	UoR	Calpinae	Erebidae
11	*Euproctis chrysorrhoea*, Linnaeus, 1758	Monsoon	UoR	Lymantriinae	Erebidae
12	*Euproctis fraterna*, Moore, 1883	Monsoon	AFA	Lymantriinae	Erebidae
13	*Euproctis lutea*, Fabricius, 1775	Monsoon	AFA	Lymantriinae	Erebidae
14	*Grammodes stolida* Fabricius, 1775	Monsoon	NFA	Erebinae	Erebidae
15	*Hypena proboscidalis*, Schrank, 1802	Post monsoon	UoR	Hypeninae	Erebidae
16	*Melipotis* sp. Hubner, 1818	Post monsoon	AFA	Erebinae	Erebidae

17	*Mocis frugalis*, Fabricius, 1775	Monsoon and post monsoon	UoR	Erebinae	Erebidae
18	*Mocis undata*, Fabricius, 1775	Monsoon and post monsoon	UoR	Erebinae	Erebidae
19	*Nygmia plana*, Walker, 1856	Pre and post monsoon	NFA	Lymantriinae	Erebidae
20	*Ophiusa tirhaca* Cramer, 1780	Monsoon	UoR	Erebinae	Erebidae
21	*Orgyia postica*, Walker, 1855	Monsoon	UoR	Lymantriinae	Erebidae
22	*Eilema griseola*, Hubner, 1803	Post monsoon	UoR	Arctiinae	Erebidae
23	*Acontia lucida*, Hufnagel, 1766	Monsoon	NFA	Acontiinae	Noctuidae
24	*Aegocera venulia*, Cramer, 1777	Monsoon	JR	Agaristinae	Noctuidae
25	*Amyna stricta*, Walker, 1858	Monsoon	UoR	Bagisarinae	Noctuidae
26	*Apamea remissa*, Hubner, 1809	Monsoon	UoR	Xyleninae	Noctuidae
27	*Chasmina candida*, Walker, 1865	Monsoon	UoR	Bagisarinae	Noctuidae
28	*Chrysodeixis acuta*, Walker, 1858	Monsoon	UoR	Plusiinae	Noctuidae
29	*Chrysodeixis chalcites*, Esper, 1789	Pre monsoon and monsoon	UoR	Plusiinae	Noctuidae
30	*Imosca megastigmata*, Hampson, 1894	Post monsoon	AFA	Noctuinae	Noctuidae
31	*Galgula partita*, Guenee, 1852	Monsoon	JR	Noctuinae	Noctuidae
Superfamily - Geometroidea					
32	*Aethalura intertexta* Walker, 1860	Monsoon	UoR	Ennominae	Geometridae
33	*Chiasmia eleonora* Cramer, 1780	Pre monsoon and monsoon	UoR	Ennominae	Geometridae
34	*Cleora injectaria*, Walker, 1860	Monsoon	NFA	Ennominae	Geometridae
35	*Dichromodes longidens* Prout, 1910	Monsoon and post monsoon	JR	Oenochrominae	Geometridae
36	*Horisme sp.* Hubner, 1825	Monsoon	UoR	Larentiinae	Geometridae
37	*Hyperythra lutea*, Stoll, 1781	Monsoon and post monsoon	UoR	Ennominae	Geometridae
38	*Hypomecis costaria*, Guenee, 1857	Monsoon	UoR	Ennominae	Geometridae
39	*Hypomecis transcissa*, Walker, 1860	Monsoon	UoR	Ennominae	Geometridae
40	*Idaea subsericeata*, Haworth, 1809	Pre monsoon	AFA	Sterrhinae	Geometridae
41	*Macaria abydata*, Guenée, 1857	Monsoon	UoR	Ennominae	Geometridae
42	*Orthonama obstipata*, Fabricius, 1794	Monsoon	UoR	Larentiinae	Geometridae
43	*Rhodometra sacraria*, Linnaeus, 1767	Monsoon	NFA	Sterrhinae	Geometridae
44	*Phazaca theclata*, Guenee, 1858	Monsoon and post monsoon	UoR	Epipleminae	Uraniidae
Superfamily - Bombycoidea					
45	*Acherontia styx*, Westwood, 1848	Monsoon	AFA	Sphinginae	Sphingidae
46	*Agrius convolvuli*, Linnaeus, 1758	Monsoon	UoR	Sphinginae	Sphingidae
47	*Daphnis nerii*, Linnaeus, 1758	Monsoon	UoR	Smerinthinae	Sphingidae
48	*Hippotion celerio*, Linnaeus, 1758	Monsoon	UoR	Macroglossinae	Sphingidae
49	*Hippotion rosetta*, Swinhoe, 1892	Pre monsoon and Post monsoon	NFA	Macroglossinae	Sphingidae
50	*Macroglossum stellatarum*, Linnaeus, 1758	Monsoon	UoR	Macroglossine	Sphingidae
51	*Nephele hespera*, Fabricius, 1775	Monsoon and post monsoon	AFA	Macroglossinae	Sphingidae
52	*Theretra alecto*, Linnaeus, 1758	Monsoon	UoR	Macroglossinae	Sphingidae
53	*Xylophanes tersa*, Linnaeus, 1771	Monsoon and post monsoon	UoR	Macroglossinae	Sphingidae
54	*Ocinara bifurcula*, Dierl, 1978	Post monsoon	UoR	Bombycinae	Bombycidae
Superfamily - Pyraloidea					
55	*Spoladea recurvalis*, Fabricius, 1775	Pre and Post monsoon	JR	Pyraustinae	Crambidae
56	*Cnaphalocrocis mendinalis*, Guenee, 1854	Monsoon	NFA	Spilomelinae	Crambidae
57	*Diaphania hyalinata*, Linnaeus, 1767	Monsoon	AFA	Spilomelinae	Crambidae
58	*Gplyphodes* sp.	Post monsoon	AFA	Spilomelinae	Crambidae
59	*Diaphania indica* Saunders, 1851	Monsoon and post monsoon	JR	Spilomelinae	Crambidae
60	*Hypsopygia olinalis*, Guenee, 1854	Monsoon and post monsoon	UoR	Pyralinae	Pyralidae
Superfamily - Pterophoroidea					
61	*Sphenarches anisodactylus*, Walker, 1864	Post monsoon	UoR	Pterophorinae	Pterophoridae
Superfamily - Zygaenoidea					
62	*Parasa cloris*, Herrich-Schäffer, 1854	Monsoon and post monsoon	AFA	Limacodinae	Limacodidae
Superfamily - Tineoidea					
63	*Acrolophus heppneri*, Davis, 1990	Monsoon	UoR	Acrolophinae	Acrolophidae
Superfamily - Tortricoidea					
64	*Cydia pomonella*, Linnaeus, 1758	Post monsoon	UoR	Olithreutinae	Tortricidae
Superfamily - Thyridoidea					
65	*Banisia myrsusalis*, Walker, 1859	Monsoon	UoR	Strigliniinae	Thyrididae

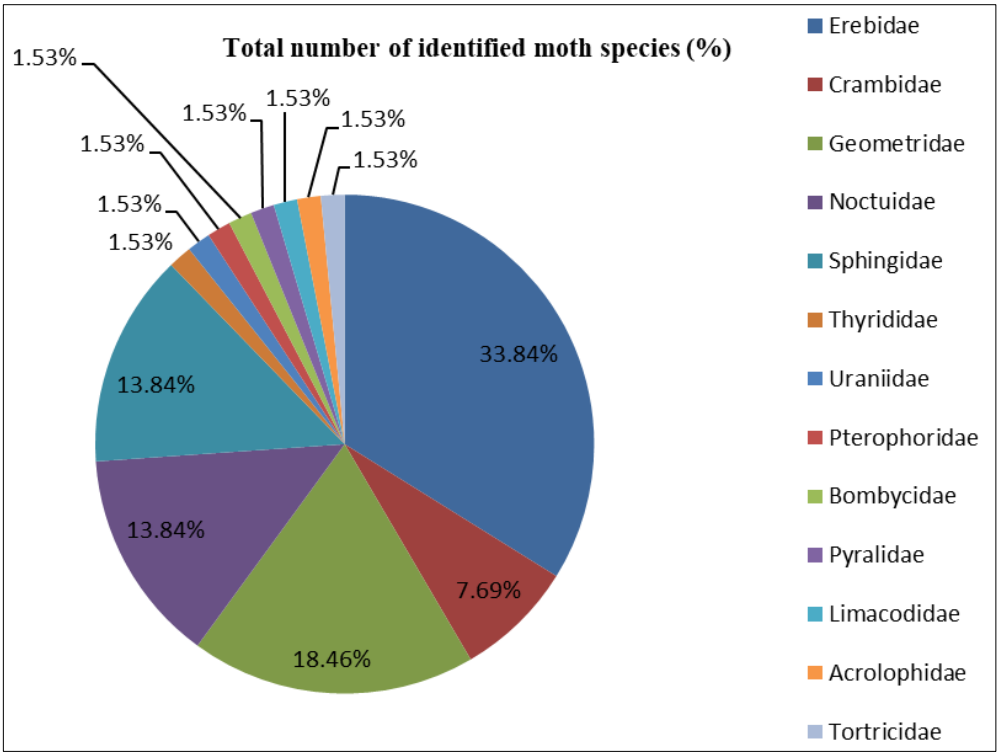

Fig 3: Species richness of moths with reference to families

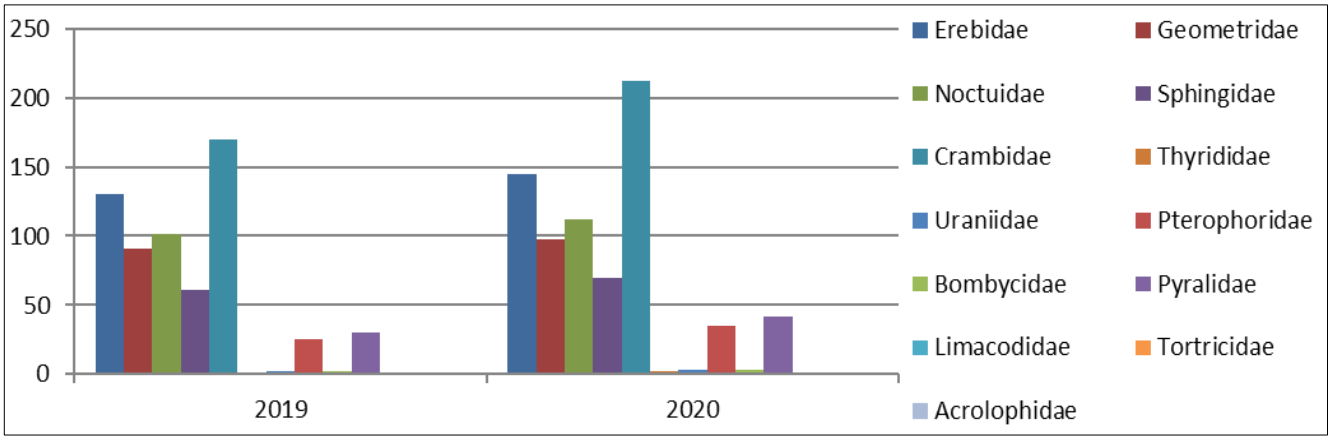

Fig 4: Number of moths specimens collected in different years

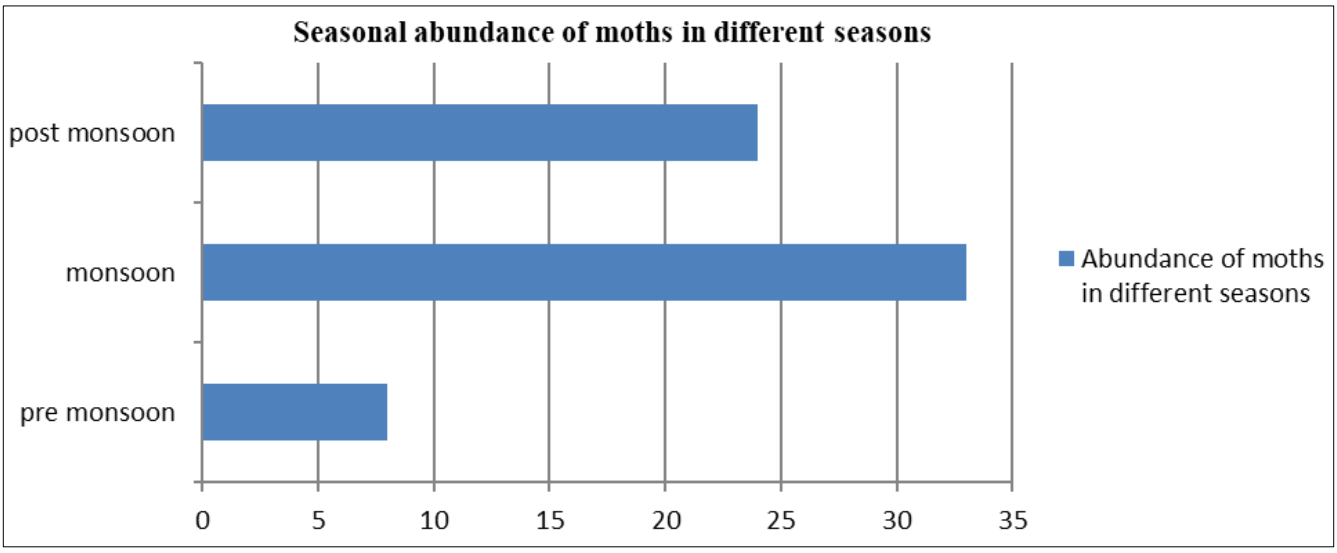

Fig 5: Seasonal abundance of moths

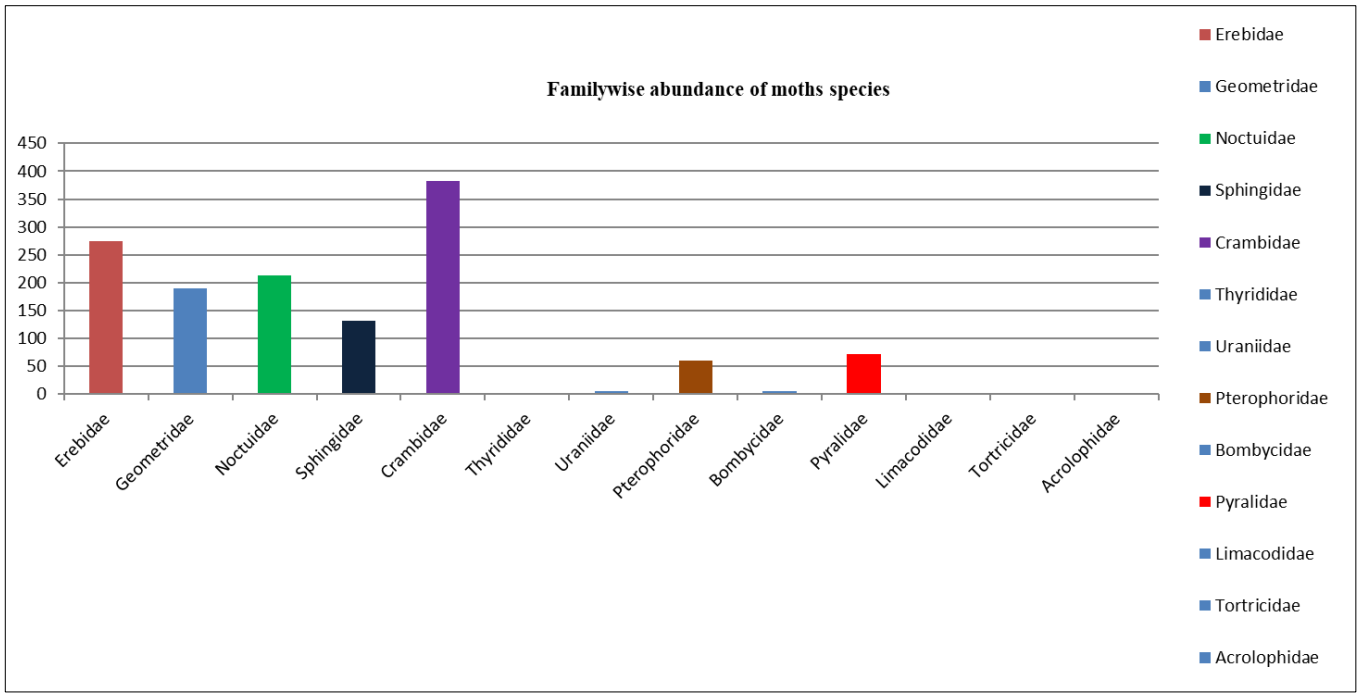

Fig 6: Species abundance family wise

Conclusion

Jaipur is a fast-growing city which has to strike a balance between natural biodiversity and upcoming infrastructures that is a challenge for present entomologists. This paper is first report on moth diversity along with different land use pattern and seasonality of their occurrence which further encourages taking up the challenge of finding out the fine association with moth pollinators and their native host plants in the city. UoR Campus is comparatively less disturbed and pollution free as compared to AFA that is supporting heavy traffic. The moths are sensitive creatures and likely to be affected by pollution and population pressures. JR is populated and agriculture area where several crops are grown. Various pesticides are frequently applied to agriculture crops in the said area that can leave a negative effect on the occurrence of moths.

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