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Diversity and distribution of moths (Lepidoptera: Heterocera), Department of Life Sciences, M K Bhavanagar University, Bhavanagar, Gujarat, India

Sudhir Vaghela[1], Khushee Shah[2], Dr. Bharatsinh Gohil[2]
[1] Department of Life Sciences, Maharaja Krishna Kumar Sinhji Bhavnagar University, Bhavnagar, Gujarat, India
[2] Assistant Professor, Head of Department of Life Sciences, Maharaja Krishna Kumar Sinhji Bhavnagar University, Bhavnagar, Gujarat, India

Abstract
The present study was conducted at the campus of Department of Life Sciences, M.K. Bhavanagar University, Bhavanagar, Gujarat. Study compiled as baseline contribution to diversity and distribution of moths in the campus, Population status of moth, a species richness, abundance, evenness, diversity indices. Selected site was surveyed from July 2022 - December 2022.130 species of Moths were yield as a result of present study. Noctuoidea was found to be the most species rich super-family with 59 species and 2 super-families represent least diversity with single species illustrative. A pellucid change was seen in a number of species during peak of monsoon, September. Maximum species were recorded in the month of September (88) whereas least number of species were recorded in the month of December (11), which marks the beginning of winter. The survey enhanced understanding of the bio-diversity of Moths in Gujarat region and will be helpful in conducting further research and conservation operations. The diversity indices for moth fauna of this area have been calculated for the first time from the department of life sciences. Across the survey, Simpson's Diversity Index (D), Shannon Diversity Index (H), Pielou's evenness index (J) were respectively as 0.28,1.54 and 0.67.

Keywords: ecological status, moths' diversity, diversity indices, richness

Introduction
Order Lepidoptera is majorly stand for moths with 1,65,000 worldwide reported species or more [1]. and likely similar number of unreported species [2]. Among which 12,000 species of moths have been represented by India [3]. In Gujarat solitary recent study visible in Bhavnagar. [11]
Moths are environmental indicators as they are well dispersing in different habitat, closely interact with the diverse vegetation [4] and are responsive to environmental changes [5]. Most of the vegetation are rely on many different moths' species for pollination. Reduction of the moth population and their diversity might lead adverse effect on the vegetation's they pollinate.[6] In order to develop a conservation strategy, a checklist of biodiversity is of primary significance as part of biodiversity conservation for viable development [7]. They are also considered crucial for ecosystem services because they paly numerous roles such as agricultural pests [8]. Moths and their larvae are required as food for many other species, such as amphibians, bats, small mammals, and also bird species [9] and indicators of ecological fitness.[10] A recent study in Bhavnagar listed 232 species of moths in which family Erebidae with 62 species, Crambidae with 44 species and other different 11 Families showed least diversity [11]. The present study was contribute to understand distribution and diversity of moths in this region.

Material and method
1. Study area
The campus of Department of Life Sciences, M.K. Bhavnagar University; lies between 21.756002N & 72.129193E (Goggle map). The Campus landscape overspread with diverse vegetation. Remaining part is open land with rocky topography. The campus also possesses a seasonal lake that remains filled for around 6 months during and after monsoon.

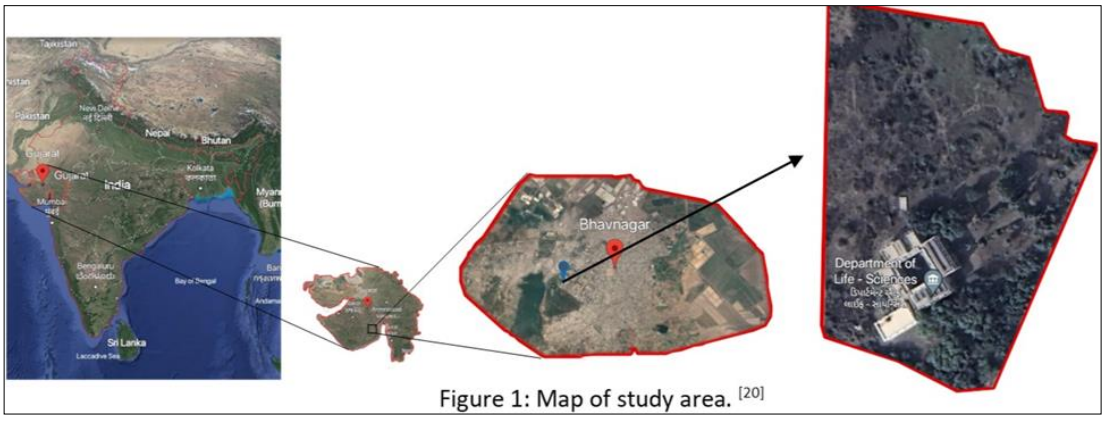

Figure 1: Map of study area. [20]

Fig 1

As we mentioned earlier campus of Department of Life Sciences is rich in their vegetation. we observed many host plants of moths which provide them wide food riched habitat specially for their larval stages. The host plant we found in campus are as following table 1.

Table 1: Host plants

Sr No.	Host plant	Sr No.	Host plant	Sr No.	Host plant
1.	*Abelmoschus esculentus*	14.	*Euphorbia hirta*	27.	*Melia azedarach*
2.	*Ailanthus triphysa*	15.	*Ficus racemosa*	28.	*Nerium oleander*
3.	*Annona squamosa*	16.	*Ficus religiosa*	29.	*Pithecellobium dulce*
4.	*Argemone Mexicana*	17.	*Ficus religiosa*	30.	*Pongamia pinnata*
5.	*Azadirachta indica*	18.	*Hibiscus rosa-sinensis*	31.	*Sida cordifolia*
6.	*Boerhavia diffusa*	19.	*Hibiscus sp.*	32.	*Terminalia catappa*
7.	*Butea monosperma*	20.	*Ipomoea sp.*	33.	*Tinospora sinensis*
8.	*Cassia fistula*	21.	*Jasminum arborescens*	34.	*Vitex negundo*
9.	*Combretum indicum*	22.	*Jasminum auriculatum,*	35.	*Vitex negundo*
10.	*Corchorus capsularis*	23.	*Jasminum samba*	36.	*Ziziphus jujuba*
11.	*Cordia dichotoma*	24.	*Lantana camara*	37.	*Ziziphus oenopolia*
12.	*Crotolaria juncea*	25.	*Madhuca longifolia*	38.	*Ziziphus sp.*
13.	*Delonix sp.*	26.	*Mangifera indica*		

2. Survey

Surveys were conducted from July 2022 to December 2022 at selected site, the campus of Department of Life Sciences, MKBU Bhavanagar, Gujarat, India, to study the diversity of moths. Moths were attracted to light sources already available in the department. We also done night field once during moth week 2022, in which we used normal 60watt filament electric bulb with white cotton piece. We also done day field within campus. We clicked photographs with a Smartphone camera.

3. Identification

We compared photographed moths with available scientific publication [Bharatsinh G, Karan T. & Gaurang G., 2022] [11], [Chembakassery JA., Koladyparambil CS.& Thavalathadathil VS.] [12], [Rohith S, Vikas MN., 2021] [13],[Vikas MN, Rohith S & Mahathi N,2021] [14],[Sachin AG & Santosh M, 2013] [15], Nivedita P, Aryjit S, Devi P,*2021*] [16], [Nayak A and Ghosh S, 2020] [17] for identification and other citizen science platform well known iNaturalist (https://www.inaturalist.org) [21] and Moths of India(http://www.mothsofindia.org) [19] were used as reference for identification. Moths of India (http://www.mothsofindia.org) [18] was also used for compiling list of host plant.

Table 2: Checklist of Moths

No.	SUPER FAMILY	Family	Species
1	BOMBYCOIDEA	Sphingidae	*Acherontia lachesis (Fabricius,1798)*
2	BOMBYCOIDEA	Sphingidae	*Hippotion rosetta (Swinhoe,1892)*
3	BOMBYCOIDEA	Sphingidae	*Polyptychus dentatus (Crame, 1777)*
4	BOMBYCOIDEA	Sphingidae	*Hippotion Celerio (linnaeus,1758)*
5	BOMBYCOIDEA	Sphingidae	*Nephele hespera (Fabricius,1775)*
6	BOMBYCOIDEA	Sphingidae	*Theretra nessus(Drury,1773)*
7	BOMBYCOIDEA	Bombycidae	*Ocinara albicollis (Walker, 1862)*
8	BOMBYCOIDEA	Bombycidae	*Trilocha varians (Walker,1855)*
9	GELECHIIOIDEA	Stathmopodidae	*Stathmopoda auriferella (Walker, 1864)*
10	GELECHIOIDEA	Stathmopodidae	*Stathmopoda sp.*
11	GELECHIOIDEA	Gelechiidae	*Metzneria lappella (Linnaeus,1758)*
12	GEOMETROIDEA	Geometridae	*Pelagodes sp.*
13	GEOMETROIDEA	Geometridae	*Chiasmia emersaria (francis walker,1861)*
14	GEOMETROIDEA	Geometridae	*Pingasa chlora(casparstoll,1782)*
15	GEOMETROIDEA	Geometridae	*Hypomecis infixari (Walker,1860)*
16	GEOMETROIDEA	Geometridae	*Petelia medardaria (Herrich-Schäffer 1856)*
17	GEOMETROIDEA	Geometridae	*Iridopsis sp.*
18	GEOMETROIDEA	Geometridae	*Scopula addictaria (Walker, 1861)*
19	GEOMETROIDEA	Geometridae	*Hypomecis sp.*
20	GEOMETROIDEA	Geometridae	*Pelagodes sp.*
21	GEOMETROIDEA	Geometridae	*Traminda mundissima (Walker,1861)*
22	GEOMETROIDEA	Geometridae	*Scopula emissaria (Walker,1861)*
23	GEOMETROIDEA	Geometridae	*Scopula ochraceata (Staudinger,1901)*
24	GEOMETROIDEA	Geometridae	*Hyposidra talaca (Walker,1860)*
25	GEOMETROIDEA	Geometridae	*Idaea macroscipla (Prout, 1926)*
26	GEOMETROIDEA	Geometridae	*Hypomecis sp.*
27	GEOMETROIDEA	Gametroidae	*Chrysocraspeda faganaria (Guenee,1858)*
28	GEOMETROIDEA	Geometridae	*Scopula pulchellata (Fabricius,1794)*
29	GEOMETROIDEA	Geometridae	*Nemoria lixaria (Guenee,1858)*

30	GEOMETROIDEA	Geometridae	*Isturgia disputaria (Guenee,1858)*
31	GEOMETROIDEA	Geometridae	*Chiasmia fidoniata (Guenee,1858)*
32	GEOMETROIDEA	Geometridae	*Hyperythra lutea (Stoll,1781)*
33	GEOMETROIDEA	Uraniidae	*Micronia aculeata (Guenee, 1857*
34	GEOMETROIDEA	Uraniidae	*Phazaca theclata (Guenee,1858*
35	NOCTUOIDEA	Erebidae	*Sphingomorpha chlorea (Cramer,1777)*
36	NOCTUOIDEA	Erebidae	*Olepa ricini (Fabricious,1775)*
37	NOCTUOIDEA	Erebidae	*Achaea serva (Fabricius,1775)*
38	NOCTUOIDEA	Erebidae	*Mocis undata (Fabricius,1775)*
39	NOCTUOIDEA	Erebidae	*Mocis frugalis (Fabricius,1775)*
40	NOCTUOIDEA	Erebidae	*Eublemma anachoresis (Wallengren,1863)*
41	NOCTUOIDEA	Erebidae	*Episparis liturata (hampson,1893)*
42	NOCTUOIDEA	Erebidae	*Ataboruza divisa (walker,1862)*
43	NOCTUOIDEA	Erebidae	*Cecharismena sp.*
44	NOCTUOIDEA	Erebidae	*Pericyma umbrina (Guenée,1852)*
45	NOCTUOIDEA	Erebidae	*Olene mendosa (Hubner,1823)*
46	NOCTUOIDEA	Erebidae	*Creatonotos gangis (Linnaeus,1763)*
47	NOCTUOIDEA	Erebidae	*Amerila astreus (Drury,1773)*
48	NOCTUOIDEA	Erebidae	*Achaea janata (Linnaeus,1758)*
49	NOCTUOIDEA	Erebidae	*Eudocima materna (Linnaeus,1767)*
50	NOCTUOIDEA	Erebidae	*Dysgonia algira (Linnaeus,1767)*
51	NOCTUOIDEA	Erebidae	*Trigonodes hyppasia (Cramer,1779)*
52	NOCTUOIDEA	Erebidae	*Eublemma baccalix (Swinhoe,1886)*
53	NOCTUOIDEA	Erebidae	*Utethesia pulchelloides (Hampson,1907)*
54	NOCTUOIDEA	Erebidae	*Orvasca subnotata (Walker,1865)*
55	NOCTUOIDEA	Erebidae	*Thyas coronata (Fabricius,1775)*
56	NOCTUOIDEA	Erebidae	*Aloa lactinea (Cramer,1777)*
57	NOCTUOIDEA	Erebidae	*Euproctis lutea (Fabricius,1775)*
58	NOCTUOIDEA	Erebidae	*Katha sp.*
59	NOCTUOIDEA	Erebidae	*Amata passalis (Fabricuius,1781)*
60	NOCTUOIDEA	Erebidae	*Spirama helicina (Hubner,1824)*
61	NOCTUOIDEA	Erebidae	*Pericyma glaicinans (Guenée,1852).*
62	NOCTUOIDEA	Erebidae	*Hypena laceratalis (Walker,1859)*
63	NOCTUOIDEA	Erebidae	*Eublemma amabilis (Saalmuller,1891)*
64	NOCTUOIDEA	Erebidae	*pericyma sp.*
65	NOCTUOIDEA	Erebidae	*Syntomoides imaon (Cramer,1780)*
66	NOCTUOIDEA	Erebidae	*Polydesma boarmoides(Guenee,1852)*
67	NOCTUOIDEA	Erebidae	*Bamra mundata (Walker,1858)*
68	NOCTUOIDEA	Erebidae	*Grammodes geometrica (Fabricius,1775)*
69	NOCTUOIDEA	Erebidae	*Argina astrea (Drury,1773)*
70	NOCTUOIDEA	Erebidae	*Eublemma accedens (Wallengren,1863)*
71	NOCTUOIDEA	Erebidae	*Olene sp.*
72	NOCTUOIDEA	Nolidae	*Earias vittella (Fabricius, 1794)*
73	NOCTUOIDEA	Nolidae	*Selepa celtis(Moore,1858)*
74	NOCTUOIDEA	Nolidae	*Xanthodes albago (Fabricius,1794).*
75	NOCTUOIDEA	Nolidae	*Nola triquetrana(Fitch,1856)*
76	NOCTUOIDEA	Nolidae	*Earias cupreoviridis (Walker,1862)*
77	NOCTUOIDEA	Nolidae	*Xanthodes transversa (Guenée,1852)*
78	NOCTUOIDEA	Nolidae	*Eligma sp.*
79	NOCTUOIDEA	Noctuidae	*Acondia crocata (Guenee,1852)*
80	NOCTUOIDEA	Noctuidae	*Leucania sp.*
81	NOCTUOIDEA	Noctuidae	*Ozarba sp.*
82	NOCTUOIDEA	Noctuidae	*Spodoptera cilium (Guenee,1852)*
83	NOCTUOIDEA	Noctuidae	*Aegocera venulia (cramer,1777)*
84	NOCTUOIDEA	Noctuidae	*Ozarba sp.*
85	NOCTUOIDEA	Noctuidae	*Spodoptera litura (Fabricius,1775)*
86	NOCTUOIDEA	Noctuidae	*Helicoverpa armigera (Hubner,1808)*
87	NOCTUOIDEA	Noctuidae	*Acontia marmoralis (Fabricius,1794)*
88	NOCTUOIDEA	Noctuidae	*Maliattha quadripartite (Walker,1865)*
89	NOCTUOIDEA	Noctuidae	*Adisura marginalis (Walker,1858)*
90	NOCTUOIDEA	Noctuidae	*Crithote sp.*
91	NOCTUOIDEA	Noctuidae	*Agrotis spinifera (Hubner,1808)*
92	NOCTUOIDEA	Noctuidae	*Ozarba sp.*
93	NOCTUOIDEA	Noctuidae	*Mythimna unipuncta (Haworth,1809)*
94	NOCTUOIDEA	Noctuidae	*Autographa precationis (Guenee,1852)*
95	PYRALOIDEA	Pyralidae	*Endotricha sp.*
96	PYRALOIDEA	Crambidae	*Cirrhochrista brizoalis (Walker,1859)*
97	PYRALOIDEA	Crambidae	*Spoladea recurvalis Ffabricious,1775)*

98	PYRALOIDEA	Crambidae	*Eurrhyparodes bracteolalis (zeller,1852)*
99	PYRALOIDEA	Crambidae	*Chabula acamasalis (Walker,1859)*
100	PYRALOIDEA	Crambidae	*Notarcha qunternalis(Zeller,1852)*
101	PYRALOIDEA	Crambidae	*Diaphania indica (Saunders,1851)*
102	PYRALOIDEA	Crambidae	*Hodebertia testalis (Fabricius,1794)*
103	PYRALOIDEA	Crambidae	*Synclera traducalis (Zeller,1852)*
104	PYRALOIDEA	Crambidae	*Parapoynx diminutalis (Zeller,1852)*
105	PYRALOIDEA	Cambidae	*Haritalodes derogate (Fabricius,1775)*
106	PYRALOIDEA	Crambidae	*Cnaphalocrocis medinalis (Guenée,1854)*
107	PYRALOIDEA	Crambidae	*Pyrausta panopealis (Walker,1859)*
108	PYRALOIDEA	Crambidae	*Pyrausta sp.*
109	PYRALOIDEA	Crambidae	*Maruca vitrata (Fabricius,1787)*
110	PYRALOIDEA	Crambidae	*Conogethes semifascialis (Walker,1856)*
111	PYRALOIDEA	Crambidae	*Eoophyla sejunctalis (Snellen,1876)*
112	PYRALOIDEA	Crambidae	*Antigastra catalaunalis (Duponchel,1833)*
113	PYRALOIDEA	Crambidae	*Pachynoa sabelialis (Guenee,1854)*
114	PYRALOIDEA	Crambidae	*Palpita vitrealis (Rossi, 1794)*
115	PYRALOIDEA	Crambidae	*Calamotropha sp.*
116	PYRALOIDEA	Crambidae	*Nausinoe geometralis (Guenee,1854)*
117	PYRALOIDEA	Crambidae	*Isocentris filalis (Guenée,1854)*
118	PYRALOIDEA	Crambidae	*Autocharis sp.*
119	PYRALOIDEA	Crambidae	*Cnaphalocrocis billinealis (Hompson,1891)*
120	PYRALOIDEA	Crambidae	*Paliga ochrealis (Moore,1886)*
121	PYRALOIDEA	Crambidae	*Marasmia traoezalis (Guenee,1854)*
122	THYRIDOIDEA	Thyrididae	*Banisia sp.*
123	THYRIDOIDEA	Thyrididae	*Banisia sp.*
124	THYRIDOIDEA	Thyrididae	*Banisia myrsusalis (Walker,1859)*
125	TORTRICOIDEA	Tortricidae	*Loboschiza koenigiana (Fabricius,1775)*
126	YPONOMUTOIDEA	Attevidae	*Atteva fabriciella (Swederus,1787)*
127	ZYGAENOIDEA	Limacodidae	*Altha subnotata (Walker,1865)*
128	ZYGAENOIDEA	Limacodidae	*Aphendala tripartite (Moore,1884)*
129	ZYGAENOIDEA	Limacodidae	*Parasa lepida (Cramer,1799)*
130	-	Psychodidae	*Clogmia albipunctata (Willistiom,1893)*

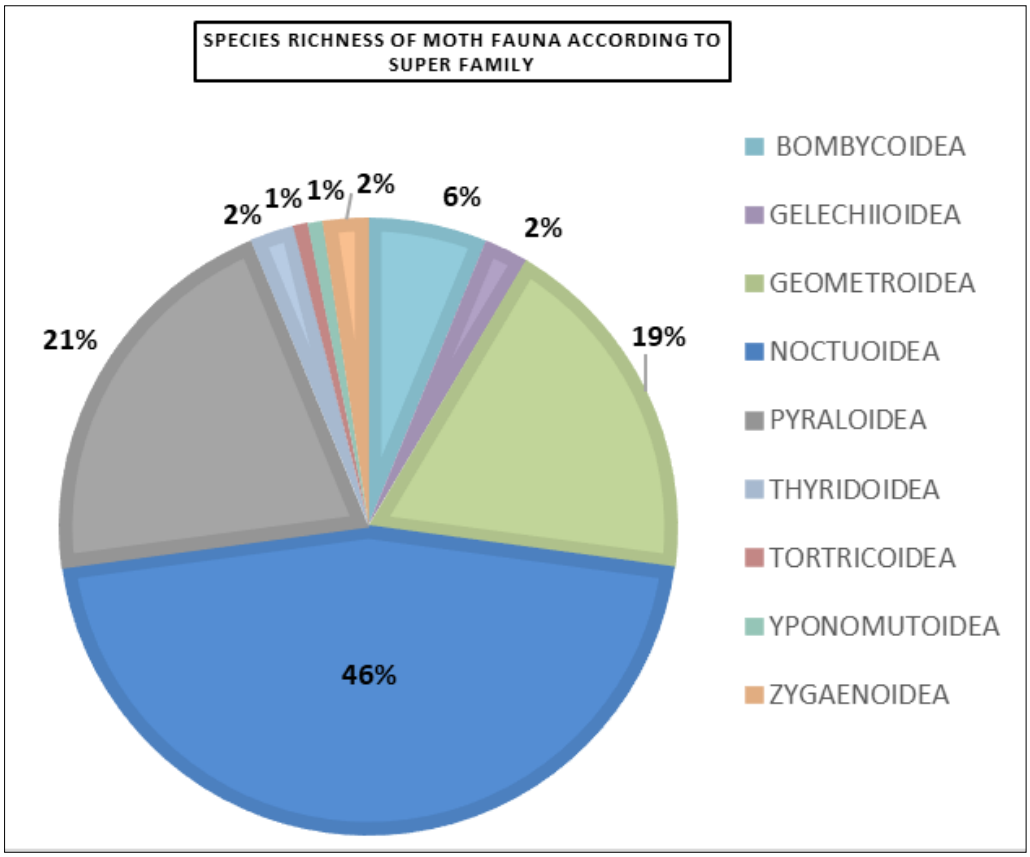

Fig 2: Species richness of moth fauna according to super family.

Fig 3

1- Spirama helicina,2- Dysgonia algira (Linnaeus,1767),3- Trigonodes hyppasia (Cramer,1779),4- Grammodes geometrica (Fabricius,1775),5- Notarcha qunternalis (zeller,1852),6- Eublemma accedens (Wallengren, 1863),7- Argina astrea (Drury,1773),8- Euproctis lutea (Fabricius,1775),9- Micronia aculeata (Guenee, 1857),10- Altha subnotata (Walker, 1865),11- Cirrhochrista brizoalis (walker,1859),12- Palpita vitrealis,13- Eurrhyparodes bracteolalis,14- Parasa lepida (Cramer,1799),15- Chrysocraspeda faganaria (Guenee,1858),16- Pyrausta sp.,17- Phazaca theclata (Guenee,1858),18- Marasmia traoezalis (Guenee,1854),19- Cnaphalocrocis billinealis (Hompson,1891),20- Haritalodes derogate (fabricius,1777),21-. Utethesia pulchelloides (Hampson,1907), 22-. Orvasca subnotata (Walker, 1865),23- Spoladea recurvalis (fabricious,1775),24- Parapoynx diminutalis (zeller,1852)

Fig 4

25-Nausinoe geometralis (Guenee 1854),26- Autocharis sp.,27- Antigastra catalaunalis (Duponchel,1833),28-Sphingomorpha chlorea (Cramer,1777),29- Conogethes semifascialis (walker,1856) 30- Cnaphalocrocis medinalis (Guenée,1854),,31- Chabula acamasalis (Walker,1859),32-Creatonotos gangis (Linnaeus,1763),33-91-Banisia sp.,34-Isocentris filalis (Guenée,1854),35-. Thyas coronata (Fabricius,1775),36- Hippotion rosetta (Swinhoe,1892),37-. Xanthodes transversa (Guenée,1852),38- Atteva fabriciella (Swederus, 1787),39- Maliattha quadripartite (walker,1865),40- Idaea macroscipla (Prout, 1926),41-Earias cupreoviridis (Walker, 1862),42- Banisia sp.,43-Aegocera venulia (cramer,1777),44- Amata passalis (Fabricuius, 1781),45- Mocis undata (Fabricius, 1775),46-Ataboruza divisa(walker,1862),47- Cecharismena (Möschler,1890),48- Nemoria lixaria (Guenee, 1858).

4. Diversity indices

4.1 Shannon Wiener diversity index

To calculate the diversity of moth fauna we use Shannon index (H) as a measure of species richness. Shannon index is derived using the following equation:

$$H = \sum_{i=1}^{s} p_i * lnp_i$$

Where:
H = Shannon Wiener index for species diversity
S = Number of species
P_i = Proportion of total sample belonging to the i^{th} species, and
ln = Natural log

4.2. Simpson's index

$$D = p_i * p_i$$

Where:
D = Simpson's Index of species diversity
S = No. of species, and
P_i = proportion of total sample belonging to i^{th} species

4.3 Pielou's evenness index

$$J = \frac{H}{H_{max}}$$

J: Pielou's evenness index
H: The observed value of Shannon-Wiener index
Hmax: ln S (S: Total number of species, ln: The natural logarithm)

5. Measurement of diversity

For evaluation of diversity it is necessary to calculate index. With the help of diversity indices, we measure Species Richness (the total number of species), Abundance (total number of individuals) and Evenness were calculated for site. The statistical analysis was done by Shannon Weiner index (H), this index was generally use to analyze the diversity, Simpson's diversity index(D) which is generally used to measure diversity and abundance (here, total number of individual species according to their family) and we also measure Pielou's Evenness index (J) which evaluate about evenness. (Here, evenness is calculated according to families). They are as following:

Table 3: Species diversity, Richness, Evenness and Abundance of families recorded for Moth fauna of the selected sites in campus of Department of Life Sciences.

Site	No. of Species	No. of Families	Simpson's diversity index (D)	Shannon Weiner diversity index (H)	Pielou's Evenness index (J)
Department of Life Sciences, M.K. Bhavanagar University, Bhavnagar, Gujarat, India.	130	16	0.28	1.54	0.67

Result

A total number of 130 species of moths (Table-2) from 16 different Families in 9 Super-families (Figure-3) were recorded in present study. Where, 108 moths were identified up to species level, 22 were identified up to genus level and 24 species remained unidentified. Most number of species (36) found in this study belongs to the family Erebidiae followed by Crambidae with 26 species followed by Geometridae with 22 species continue with Noctuidae having 16 species, Nolidae with 7 species, sphingidae with 6 species, Thyrididae and Limacodidae with 3 species, Bombycidae, Stathmopodadie and Uraniidae with 2 species and 5 Families represent least diversity with single species illustrative. We found Noctuoidea as dominant super family with 46% followed by Pyraloidea with 21% followed by Geometroidea with 19 % followed by Bombycoidea with 6% remaining 3 super families representing 2% and only 2 super families representing 1% (Figure-2).

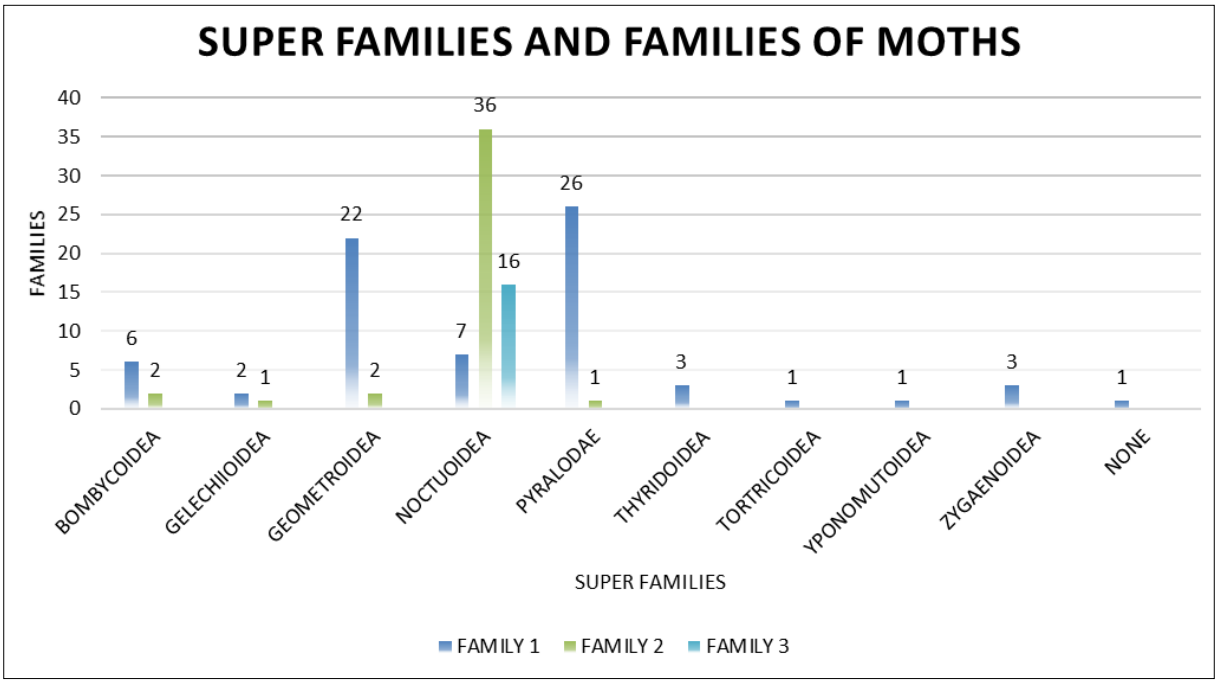

Fig 5: Super families and families of moths

Table 4

		SUPER FAMILY									
		Bombycoidea	Gelechiioidea	Geometroidea	Noctuoidea	Pyraloidea	Thyridoidea	Tortricoidea	Yponomutoidea	Zygaenoidea	None
FAMILY	Sphingidae	6									
	Bombycidae	2									
	Stathmopodadie		2								
	Gelechiidae		1								
	Geometridae			22							
	Uraniidae			2							
	Erebidiae				36						
	Noctuidae				16						
	Nolidae				7						
	Crambidae					26					
	Pyralidae					1					
	Thyrididae						3				
	Tortricidae							1			
	Attevidae								1		
	Limacodidae									3	
	Psychodidae										1

Discussion

Department Of Life Sciences is eco-diverse habitat with dispersed diverse vegetation and rocky topography. Which contain convenient soil for diverse vegetation. We consider different abiotic parameters for soil which are: Temperature, pH, soil moisture, reductivity of soil etc. Temperature varies between 30℃ to 45℃, pH of soil varies 7 to 8.8, soil reductivity is low and soil moisture is 100% so from these parameters we can conclude that soil influence
the growth of various host plants. Environmental factors make the habitat favorable for survival and reproduction of moths. Host plants provide enough food source for moth's larvae. After the survey we measure diversity indices where Simpson's Diversity Index (D) is 0.28. Shannon Diversity Index (H) is 1.54 and Pielou's evenness index(J) was 0.67 from which we can conclude that moth fauna is diverse in this area. A recent study in Bhavnagar listed 232 species of Moths in which family Erebidae with 62 species, crambidae with 44 species and other different 11 Families showed least diversity] [11]. The aim of present study was to understand distribution and diversity of moths in this region.

Conclusion

The biodiversity of moth fauna in Department of Life Sciences is mostly because of rich vegetation in this area. Vegetation plays a significant role that provides the main food source to insect fauna and abiotic factors plays important role in habitat structure. Further future study will help to understand widespread species diversity seasonal variations of moths and also ecological status of moths in this region.

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