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Research Article

Moth (Lepidoptera: Heterocera) diversity of Bhubaneswar, Odisha, India: a preliminary study

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Abstract

A preliminary checklist has been compiled to study the moth diversity of Bhubaneswar, Odisha, an eastern state of India. The present study has recorded a total of 154 species belonging to 129 genera and 19 families. The highest diversity of moths was recorded in the family Crambidae (48 species, 38 genera), followed by the families Erebidae (42 species, 37 genera), Geometridae (15 species, 12 genera), Noctuidae (13 species, 11 genera) and others. The study was conducted over a period of 18 months from May 2019 to October 2020. Here we present an illustrated checklist of 154 moth species from Bhubaneswar which improves our insight into the lesser-known lepidopterans from the state of Odisha. This shall further help us strengthen our knowledge about the importance of moths in our environment and contribute towards its conservation at large.

Keywords: checklist; conservation; documentation; Khordha; moth species; urban habitat

Introduction

Moths are biologically, economically (Sharma and Bisen, 2013) and aesthetically a very important group of insects (Devoto *et al.*, 2011; Le Croy *et al.*, 2013; Dey *et al.*, 2015). They are one of the most heterogeneous groups of insects (Soggard, 2009) consisting of around 1,27,000 species identified around the world as estimated by Hamlyn in 1969 (Alfred *et al.*, 1998) and around 12,000 species reported from India alone (Chandra and Nema, 2007).

India lies in the Indo-Malayan biogeographic realm of the world and is listed amongst the 17 mega biodiverse countries. It consists of four biodiversity hotspots which indicates the uniqueness of its flora and fauna. It shelters around 6.5% of the species known across the globe on 2.4% of the world's total area (Faunal Diversity of India, 2020; *http://www.zsienvis.nic.in/*).

Odisha is unique in its geographic location with major part of the state falling in the Deccan Peninsula including Chhota Nagpur Province and Eastern Highlands while it is guarded by a 480 kms long coastline on its east. Since a considerable part of the Eastern Ghats falls within the territory of Odisha, it is speculated that the diversity of moths will be unique and interesting to investigate. In Odisha, the earliest works on moths have

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been contributed by Hampson (1892, 1894, 1895, 1896) in the Fauna of British India. The State Fauna of Odisha (Part-III) by ZSI (Mandal and Maulik, 1991) reported 87 species under 3 families. There have been several records of moths as pest insects from various studies done in the crop fields. Of these some prominent works are those of paddy (Arora, 2000; Rath *et al.*, 2020), brinjal (Kar *et al.*, 2020), tomato (Sridhar and Srinivas, 2019) and teak (Tripathy *et al.*, 2018); but no compiled work on the diversity of moths has yet been done in the present study area from the capital city of Odisha. However, in a recent work, Jena *et al.* (2018) reported 30 species from Gupteswar of Koraput district. In the present study, we have investigated the moth diversity primarily of Bhubaneswar city and adjoining urban areas under Khordha district, Odisha, India. A preliminary checklist containing 154 species under 19 families is presented here from the survey of ten study sites over a period of 18 months from May 2019 to October 2020.

Materials and Methods

The biodiversity documentation of moths has been primarily done in the urban areas of Bhubaneswar (20.2961^{0}N, 85.8245^{0}E), and its outskirts from May 2019 to October 2020 (Figure 1). The state lies in the tropical region and experiences a tropical savanna climate. It witnesses an average annual rainfall of about 1451.2mm (Envis Centre of Odisha, 2020; *http://www.orienvis.nic.in/*). The district of Khordha has mostly open forests with some moderately dense forests and scrub vegetation. Bhubaneswar is enveloped on one side by Chandaka with semi-evergreen forests and surrounded mostly by dry deciduous forests on its other boundaries. The selected sites for the study were namely, Acharya Vihar (S1), Jaydev Vihar (S2), BJB Nagar (S3), Saheed Nagar (S4), Khandagiri (S5), Pokhariput (S6), Ghangapatna (S7), Dhauli (S8), Dalua (S9) and Raghunathpur (S10) as detailed with GPS locations in Table 1, Figure 2. The regions prominently have urban habitat with fragmented vegetation. Khordha district has a geographical area of 2813 sq. km. of which 456 sq. km. has forest cover (Envis Centre of Odisha, 2020; *http://www.orienvis.nic.in/*).

Table 1. Coordinates of study sites in Bhubaneswar

Study site	Name of the study site	Coordinates
S1	Acharya Vihar	20.2994°N, 85.8319°E
S2	Jaydev Vihar	20.2997°N, 85.8173°E
S3	BJB Nagar	20.2506°N, 85.8448°E
S4	Saheed Nagar	20.2910°N, 85.8456°E
S5	Khandagiri	20.2569°N, 85.7792°E
S6	Pokhariput	20.2408°N, 85.8064°E
S7	Ghangapatna	20.3088°N, 85.7308°E
S8	Dhauli	20.1882°N, 85.8448°E
S9	Dalua	20.3634°N, 85.7176°E
S10	Raghunathpur	20.3782°N, 85.8278°E

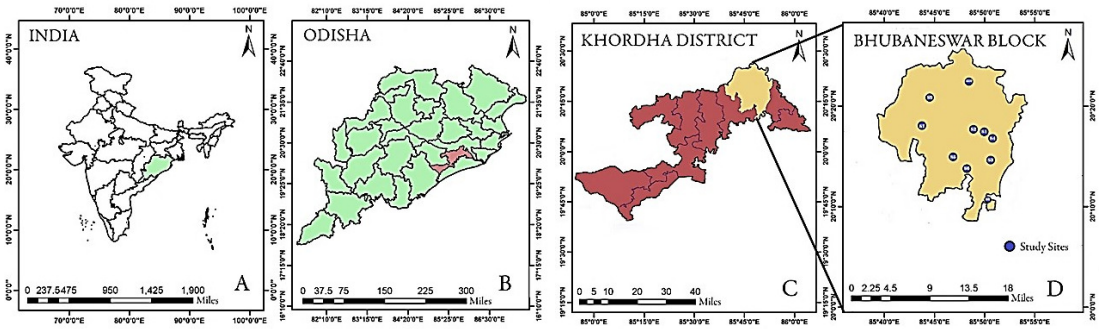

Figure 1. Map of Study Area: A. India, B. Odisha State, C. Khordha District, D. Bhubaneswar Block with site locations

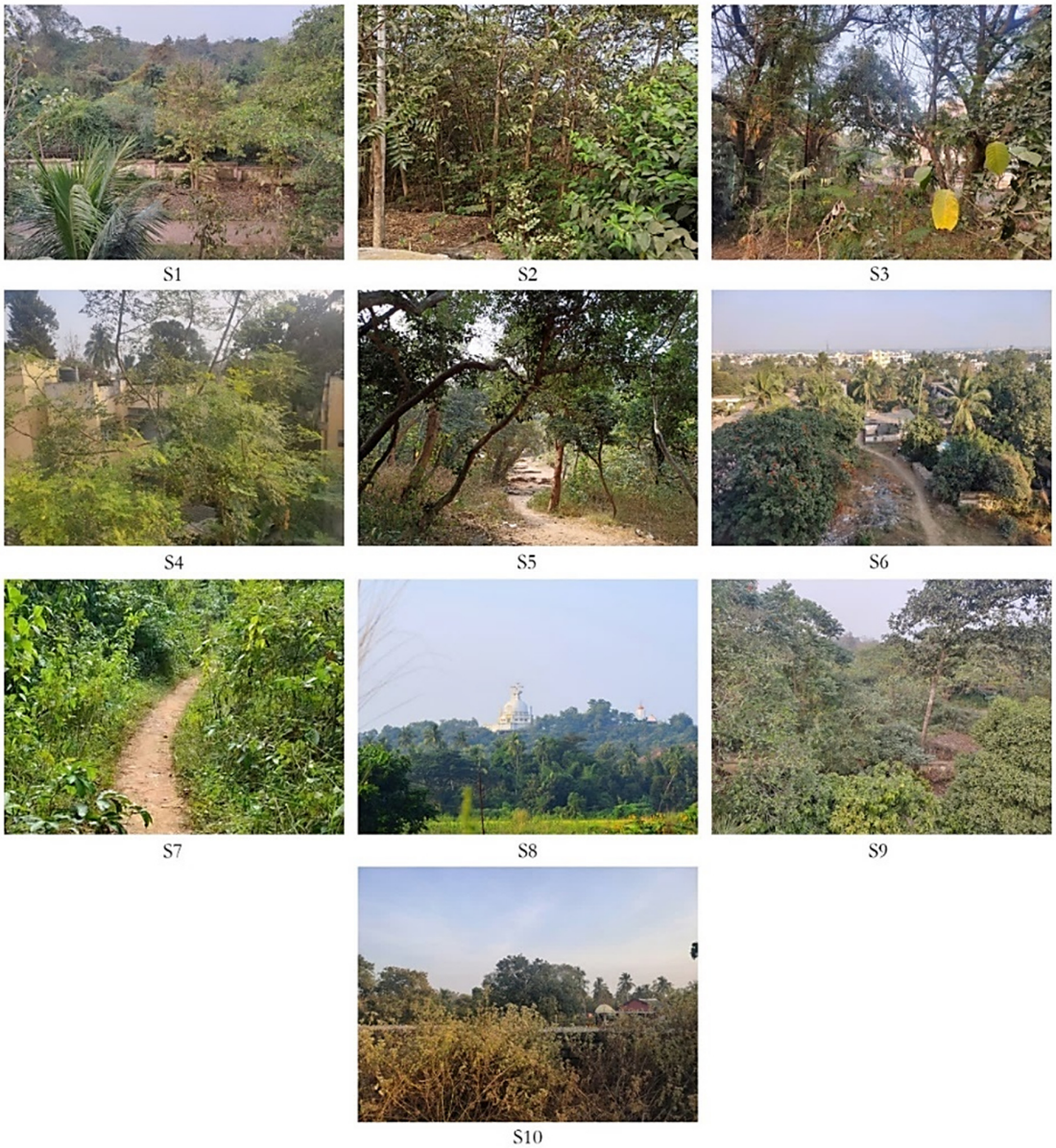

Figure 2. Study sites photographs (S1-S10)

The moths have been found by random sampling, opportunistic sightings and by setting up of light traps in some of the mentioned locations. The study areas have been searched extensively in the morning (6:00 hrs-8:00hrs) and evening (16:00hrs-19:00 hrs). Net sweeping was done with a standard-sized butterfly net for the day-flying moths and during the evenings for suitable photography from closer angles. Each study site was visited for around 20 days in every season. The light traps had been set in selective study sites using 100-Watt bulbs, which were placed in front of a 15ft × 5ft white cloth supported by the wall, for about 15 nights in every season (Figure 3). Standard tungsten bulbs were used for moth trapping. Efforts were made to create the least disturbance for the creatures in their natural environment while resting, feeding etc. except for instances when it was required to be caught for photography.

A B

Figure 3. Moth light trap: A. During evening; B. During night

Moths were photographed using DSLR cameras (Nikon D5300, 18-55mm and 70-300mm lens; and Canon EOS 80D, Tamron 90mm lens) and smartphone cameras. Identification was done by referring to the available literature (Hampson, 1892-1896; Bell and Scott, 1937; Holloway, 1985-2011; Shubhalaxmi *et al.*, 2011; Kononenko and Pinratana, 2013; Dey *et al.*, 2018). Some online sources like Moths of India database (Sondhi *et al.* 2021; *http://www.mothsofindia.org/*); India Biodiversity Portal database (Vattakaven *et al.*, 2016; *https://indiabiodiversity.org/*), Natural History Museum database (HOSTS, 2020; *https://www.nhm.ac.uk/*), National Bureau of Agricultural Insect Resources database (Insect Pests, 2020; *https://databases.nbair.res.in/*) and iNaturalist database (iNaturalist, 2020; *https://www.inaturalist.org/*), were quite helpful in the process of identification apart from the published references. Museum collections in Lepidoptera section from Regional Museum of Natural History, Bhubaneswar were also referred for identification of some of the macrolepidoptera moths. For the present study, none of the moths was collected or killed and therefore live photography of the moths was done as presented in the image plates. Due to several constraints, the identification was primarily done based on external morphological characters and no sophisticated methods such as genitalia dissection, DNA barcoding etc. were used to identify the moth species.

The system of classification detailed by Van Nieukerken *et al.* (2011) has been followed for identifying moths to the families. This method mostly follows the classification by Kristensen (1999), Kristensen *et al.* (2007) as well as the recent developments by Zahiri *et al.* (2010, 2011). A few of the moths have been assigned only to the genus as the morphological identification was not enough for many individuals to designate them to species level. There have been repetitive observations of the same moth species in different survey sites. In such cases, only one observation has been taken into consideration. The map has been created in ArcGIS, using reference from NIC (Khordha Web Portal, 2021; *https://khordha.nic.in/*).

Results and Discussion

We examined major studies on moths from the eastern region of India in the post-Victorian era. Saha and Raychaudhuri (1998) reported about 31 moths from West Bengal while Gurule and Nikam (2013) reported that Ghosh in 2003 documented 260 moths only in the family Geometridae from the same state. Further, Sanyal *et al.* (2012) also compiled 707 moths from West Bengal. Chandra and Nema (2007) reported 142 moths from Madhya Pradesh and Chhattisgarh, Singh and Ranjan (2016) added 23 new species from the superfamily Noctuoidea to the list of 138 moths from Dalma wildlife sanctuary. Singh *et al.* (2018) have reported 140 species of moths from Koderma, Jharkhand. From the information available about the moth fauna of Odisha state, it is understood that scanty studies have been done and few species reported till date about non-pest moths from the state. Studies done by (Mandal and Maulik, 1991) reports 87 species of moths in the Fauna of Orissa (Part-III) by ZSI out of which only six moth species were found in the present study. Seven moths found in this study were also reported by Jena *et al.* (2018). Although the moth *Glyphodes bicolor* has been reported by Jena *et al.* (2018), it appears to be a case of misidentification, which as per the pictures provided in the paper, suggest the same to be *Glyphodes bivitralis* Guenée, 1854. This was identified from various online resources like Moths of India database (Sondhi *et al.*, 2021; *http://www.mothsofindia.org/*), iNaturalist database (iNaturalist, 2020; *https://www.inaturalist.org/*) and confirmed from other available literature.

Although there have been some scattered works on the pest moths of various crops from the state, the present study is an attempt to come up with a compiled checklist to enlist the diversity of moth fauna from Bhubaneswar. In the present study, a total of 154 moths have been identified out of the several individuals recorded, belonging to 19 families and 12 superfamilies from surveys in ten different study sites across Bhubaneswar city and its outskirts as presented in Table 2, Plates 1- 5. All the photographs have been contributed by the authors unless credited otherwise.

Table 2. Preliminary checklist of moths recorded during the study at various study sites

Sl. No.	Subfamily	Scientific name	Common name	Author and year of description	Survey site
Superfamily Tineoidea					
Family Tineidae					
1	Acrolophinae	*Acrolophus sp.*			S1
Superfamily Yponomeutoidea					
Family Attevidae					
2	Attevinae	*Atteva sp.*			S3
Superfamily Gelechioidea					
Family Lecithoceridae					
3	Lecithocerinae	*Lecithocera sp.*			S2
Family Scythrididae					
4	Scythridinae	*Eretmocera impactella*		(Walker, 1864)	S1
Superfamily Tortricoidea					
Family Tortricidae					
5	Tortricinae	*Adoxophyes fasciculana*		(Walker, 1866)	S4
6	Tortricinae	*Archips micaceana*		(Walker, 1863)	S4
Superfamily Zygaenoidea					
Family Limacodidae					
7	Limacodinae	*Aphendala tripartita*		Moore, 1884	S3
8	Limacodinae	*Parasa sp.*			S2
Superfamily Thyridoidea					

Family Thyrididae					
9	Strigliniae	*Banisia sp.*			S3
Superfamily Hyblaeoidea					
Famliy Hyblaeidae					
10		*Hyblaea sp.*			S3
Superfamily Pyraloidea					
Family Pyralidae					
11	Pyralinae	*Endotricha mesenterialis*		(Walker, 1859)	S3
12	Pyralinae	*Endotricha repandalis*		Fabricius, 1794	S4
13	Pyralinae	*Hypsopygia sp.*			S3
14	Pyralinae	*Pyralis manihotalis*	Tropical Meal Moth	Guenée, 1854	S3
15	Pyralinae	*Pyralis pictalis*	Painted Meal Moth	(Curtis, 1834)	S3
16	Pyralinae	*Sacada sp.*			S2
17	Pyralinae	*Zitha torridalis*		(Lederer, 1863)	S8
Family Crambidae					
18	Acentropinae	*Parapoynx fluctuosalis*		(Meyrick, 1899)	S6
19	Acentropinae	*Parapoynx stagnalis*		(Zeller, 1852)	S3
20	Crambinae	*Ancylolomia sp.*			S3
21	Glaphyriinae	*Noorda blitealis*		Walker, 1859	S3
22	Pyraustinae	*Isocentris filalis*		(Guenée, 1854)	S1
23	Pyraustinae	*Pagyda salvalis*		Walker, 1859	S3
24	Pyraustinae	*Paliga sp.*			S1
25	Schoebiinae	*Scirpophaga incertulas*	Yellow Stem Borer Moth	(Walker, 1863)	S3
26	Schoebiinae	*Scirpophaga nivella*		(Fabricius, 1794)	S3
27	Spilomelinae	*Arthroschista hilaralis*		(Walker, 1859)	S3
28	Spilomelinae	*Bradina admixtalis*		(Walker, 1859)	S4
29	Spilomelinae	*Chalcidoptera appensalis*		Snellen, [1884]	S3
30	Spilomelinae	*Cnaphalocrocis medinalis*		(Guenée, 1854)	S3
31	Spilomelinae	*Cnaphalocrocis ruralis*		(Walker, 1859)	S3
32	Spilomelinae	*Conogethes sp.*			S1
33	Spilomelinae	*Cydalima laticostalis*		(Guenée, 1854)	S10
34	Spilomelinae	*Diaphania indica*	Cucumber Moth	(Saunders, 1851)	S1
35	Spilomelinae	*Dysallacta negatalis*	Karanj Leaf Borer Moth	(Walker, 1859)	S1
36	Spilomelinae	*Elophila difflualis*		(Snellen, 1880)	S3
37	Spilomelinae	*Endocrossis flavibasalis*		(Moore, 1867)	S8
38	Spilomelinae	*Eurrhyparodes tricoloralis*		(Zeller, 1852)	S1
39	Spilomelinae	*Glyphodes actorionalis*		Walker, 1859	S1
40	Spilomelinae	*Glyphodes bicolor*		(Swainson, 1821)	S3

41	Spilomelinae	*Glyphodes caesalis*	Jack Fruit Borer Moth	(Walker, 1859)	S3
42	Spilomelinae	*Glyphodes canthusalis*		Walker, 1859	S2
43	Spilomelinae	*Haritalodes derogata*		(Fabricius, 1775)	S2
44	Spilomelinae	*Herpetogramma basalis*		(Walker, 1866)	S3
45	Spilomelinae	*Herpetogramma phaeopteralis*	Tropical Sod Webworm Moth	(Guenée, 1854)	S7
46	Spilomelinae	*Herpetogramma rudis*		(Warren, 1892)	S3
47	Spilomelinae	*Hydriris ornatalis*	Ornate Hydriris Moth	(Duponchel, 1832)	S3
48	Spilomelinae	*Leucinodes orbonalis*	Eggplant Fruit and Shoot Borer Moth	Guenée, 1854	S3
49	Spilomelinae	*Mabra eryxalis*		(Walker, 1859)	S2
50	Spilomelinae	*Maruca vitrata*	Maruca Pod Borer Moth	(Fabricius, 1787)	S6
51	Spilomelinae	*Metoeca foedalis*		(Guenée, 1854)	S1
52	Spilomelinae	*Nausinoe geometralis*		(Guenée, 1854)	S8
53	Spilomelinae	*Nausinoe perspectata*		(Fabricius, 1775)	S8
54	Spilomelinae	*Nosophora sp.*			S2
55	Spilomelinae	*Omiodes indicata*		(Fabricius, 1775)	S5
56	Spilomelinae	*Pachynoa sp.*			S8
57	Spilomelinae	*Parotis sp.*			S3
58	Spilomelinae	*Pycnarmon cribrata*	Leaf Folder Moth	(Fabricius, 1794)	S1
59	Spilomelinae	*Pycnarmon virgatalis*		Moore, 1867	S2
60	Spilomelinae	*Pygospila tyres*	Spotted Grass Moth	(Cramer, [1780])	S3
61	Spilomelinae	*Sameodes cancellalis*		(Zeller, 1852)	S1
62	Spilomelinae	*Spoladea recurvalis*	Beet Webworm Moth	(Fabricius, 1775)	S3
63	Spilomelinae	*Synclera traducalis*		(Zeller, 1852)	S1
64	Spilomelinae	*Syngamia latimarginalis*		(Walker, 1859)	S1
65	Spilomelinae	*Tatobotys biannulalis*		(Walker, 1866)	S3
Superfamily Lasiocampoidea					
Family Lasiocampidae					
66	Lasiocampinae	*Trabala vishnou*	Rose Myrtle Lappet Moth	(Lefèbvre, 1827)	S1
Superfamily Bombycoidea					
Family Eupterotidae					
67	Eupterotinae	*Eupterote bifasciata*		Kishida, 1994	S3
68	Eupterotinae	*Eupterote undata*		Blanchard, [1844]	S3
Family Bombycidae					
69	Bombycinae	*Trilocha varians*		(Walker, 1855)	S3

Family Sphingidae					
70	Macroglossinae	*Daphnis nerii*	Oleander Hawkmoth	(Linnaeus, 1758)	S3
71	Macroglossinae	*Hippotion celerio*	Silver-Striped Hawkmoth	(Linnaeus, 1758)	S3
72	Macroglossinae	*Macroglossum sp.*			S1
73	Macroglossinae	*Theretra lucasii*	Lucas's Hawkmoth	(Walker, 1856)	S1
74	Macroglossinae	*Theretra oldenlandiae*	White-Banded Hunter Hawkmoth	(Fabricius, 1775)	S1
75	Sphinginae	*Acherontia styx*	Lesser Death's Head Hawkmoth	(Westwood, 1847)	S4
76	Sphinginae	*Psilogramma sp.*			S1
Superfamily Geometroidea					
Family Uraniidae					
77	Epipleminae	*Phazaca theclata*	Cotton Leaf Roller Moth	(Guenée, 1857)	S3
78	Microniinae	*Micronia aculeata*		Guenée, 1857	S7
Family Geometridae					
79	Desmobathrinae	*Eumelea ludovicata*		Guenée, [1858]	S4
80	Ennominae	*Chiasmia emersaria*		(Walker, 1861)	S8
81	Ennominae	*Chiasmia sp.*			S3
82	Ennominae	*Hyperythra lutea*		(Stoll, [1781])	S3
83	Ennominae	*Cleora alienaria*		(Walker, 1860)	S3
84	Geometrinae	*Agathia laetata*		(Fabricius, 1794)	S1
85	Geometrinae	*Agathia lycaenaria*		(Kollar, 1848)	S1
86	Geometrinae	*Comibaena sp.*			S3
87	Geometrinae	*Dysphania militaris*		(Linnaeus, 1758)	S1
88	Geometrinae	*Pingasa sp.*			S7
89	Geometrinae	*Thalassodes sp.*			S3
90	Sterrhinae	*Chrysocraspeda faganaria*		Guenée, [1858]	S3
91	Sterrhinae	*Scopula emissaria*		(Walker, 1861)	S3
92	Sterrhinae	*Scopula sp.*			S1
93	Sterrhinae	*Traminda aventiaria*	Cross-Line Wave Moth	(Guenée, [1858])	S2
Superfamily Noctuoidea					
Family Erebidae					
94	Aganainae	*Asota caricae*		(Fabricius, 1775)	S3
95	Arctiinae	*Aloa lactinea*	Red Costate Tiger Moth	(Cramer, [1777])	S5
96	Arctiinae	*Amata passalis*		(Fabricius, 1781)	S3
97	Arctiinae	*Amerila astreus*		(Drury, 1773)	S3

98	Arctiinae	*Creatonotos gangis-interrupta complex*			S8
99	Arctiinae	*Creatonotos transiens*		(Walker, 1855)	S3
100	Arctiinae	*Katha sp.*			S4
101	Arctiinae	*Micraloa lineola*		(Fabricius, 1793)	S3
102	Arctiinae	*Miltochrista sp.*			S1
103	Arctiinae	*Olepa ricini*		Fabricius, 1775	S1
104	Arctiinae	*Utetheisa sp.*			S3
105	Boletobiinae	*Eublemma accedens*		(Felder & Rogenhofer, 1874)	S3
106	Boletobiinae	*Zurobata vacillans*		(Walker, 1864)	S2
107	Calpinae	*Calyptra sp.*			S2
108	Calpinae	*Eudocima hypermnestra*		(Cramer, 1780)	S2
109	Calpinae	*Eudocima materna*	Dot Underwing Moth	(Linnaeus, 1767)	S3
110	Eulepidotinae	*Anticarsia irrorata*		(Fabricius, 1781)	S3
111	Erebinae	*Achaea janata*		(Linnaeus, 1758)	S3
112	Erebinae	*Bastilla simillima*		(Guenée, 1852)	S3
113	Erebinae	*Chalciope mygdon*		(Cramer, [1777])	S6
114	Erebinae	*Dysgonia angularis*		(Boisduval, 1833)	S2
115	Erebinae	*Dysgonia torrida*	Jigsaw Moth	(Guenée, 1852)	S1
116	Erebinae	*Ercheia sp.*			S3
117	Erebinae	*Erebus hieroglyphica*		(Drury, 1773)	S1
118	Erebinae	*Grammodes geometrica*		(Fabricius, 1775)	S6
119	Erebinae	*Hulodes sp.*			S3
120	Erebinae	*Mocis frugalis*	Sugarcane Looper Moth	(Fabricius, 1775)	S3
121	Erebinae	*Mocis undata*	Brown-Striped Semi-Looper	(Fabricius, 1775)	S3
122	Erebinae	*Pericyma cruegeri*	Poinciana Looper Moth	(Butler, 1886)	S3
123	Erebinae	*Serrodes partita*	Catapult Moth	(Fabricius, 1775)	S3
124	Erebinae	*Spirama sp.*			S1
125	Erebinae	*Thyas coronata*	Yellow Underwing Moth	(Fabricius, 1775)	S5
126	Lymantriinae	*Arctornis cygna*		(Moore, 1879)	S3
127	Lymantriinae	*Arctornis sp.*			S8
128	Lymantriinae	*Artaxa digramma*		(Boisduval, 1844)	S2
129	Lymantriinae	*Euproctis sp.*			S3

130	Lymantriinae	*Lymantria ampla*		Walker, 1855	S1
131	Lymantriinae	*Olene mendosa*	Brown Tussock Moth	Hübner, 1823	S3
132	Lymantriinae	*Orvasca subnotata*		Walker, 1865	S3
133	Lymantriinae	*Perina nuda*	Banyan Tussock Moth	(Fabricius, 1787)	S3
134	Pangraptinae	*Egnasia ephyrodalis*		Walker, 1858	S2
135	Scoliopteryginae	*Anomis flava*	Cotton Looper Moth	(Fabricius, 1775)	S1
Family Nolidae					
136	Chloephorinae	*Carea angulata*		(Fabricius, 1793)	S1
137	Eariadinae	*Earias luteolaria*		Hampson, 1891	S8
138	Eariadinae	*Earias vittella*	Spotted Bollworm Moth	Fabricius, 1794	S3
139	Eligminae	*Selepa celtis*		Moore, [1858]	S2
140	Nolinae	*Nola sp.*			S3
141	Risobinae	*Risoba repugnans*		(Walker, 1865)	S8
Family Noctuidae					
142	Acontiinae	*Acontia lucida*	Pale Shoulder Moth	(Hufnagel, 1766)	S1
143	Acontiinae	*Acontia marmoralis*		(Fabricius, 1794)	S1
144	Acontiinae	*Naranga aenescens*		Moore, 1881	S3
145	Agaristinae	*Episteme sp.*			S1
146	Catocalinae	*Gesonia obeditalis*		Walker, [1859]	S6
147	Condicinae	*Condica illecta*		(Walker, 1865)	S3
148	Eriopinae	*Callopistria sp.*			S3
149	Hadeninae	*Mythimna separata*		(Walker, 1865)	S1
150	Hadeninae	*Mythimna sp.*			S2
151	Heliothinae	*Helicoverpa armigera*		(Hübner, [1808])	S3
152	Noctuinae	*Polytela gloriosae*	Lily Moth	(Fabricius, 1781)	S9
153	Noctuinae	*Spodoptera litura*	Tobacco Cutworm Moth	(Fabricius, 1775)	S10
154	Plusiinae	*Chrysodeixis eriosoma*		(Doubleday, 1843)	S3
S1 to S10 Study Sites: [S1- Acharya Vihar, S2- Jaydev Vihar, S3- BJB Nagar, S4- Saheed Nagar, S5- Khandagiri, S6- Pokhariput, S7- Ghangapatna, S8- Dhauli, S9- Dalua, S10- Raghunathpur]					

Plate 1. 1- *Acrolophus sp.;* 2- *Atteva sp.;* 3- *Lecithocera sp.*; 4- *Eretmocera impactella*; 5- *Adoxophyes fasciculana*; 6- *Archips micaceana*; 7- *Aphendala tripartita*; 8- *Parasa sp.*; 9- *Banisia sp.*; 10- *Hyblaea sp.;* 11- *Endotricha mesenterialis*; 12- *Endotricha repandalis*; 13- *Hypsopygia sp.*; 14- *Pyralis manihotalis*; 15- *Pyralis pictalis*; 16- *Sacada sp.*; 17- *Zitha torridalis*; 18- *Parapoynx fluctuosalis*; 19- *Parapoynx stagnalis*; 20- *Ancylolomia sp.*; 21- *Noorda blitealis*; 22- *Isocentris filalis*; 23- *Pagyda salvalis*; 24- *Paliga* sp.; 25- *Scirpophaga incertulas*; 26- *Scirpophaga nivella*; 27- *Arthroschista hilaralis*; 28- *Bradina admixtalis*; 29- *Chalcidoptera appensalis*; 30- *Cnaphalocrocis medinalis*; 31- *Cnaphalocrocis ruralis*; 32- *Conogethes sp.*; 33- *Cydalima laticostalis*; 34- *Diaphania indica*; 35- *Dysallacta negatalis*

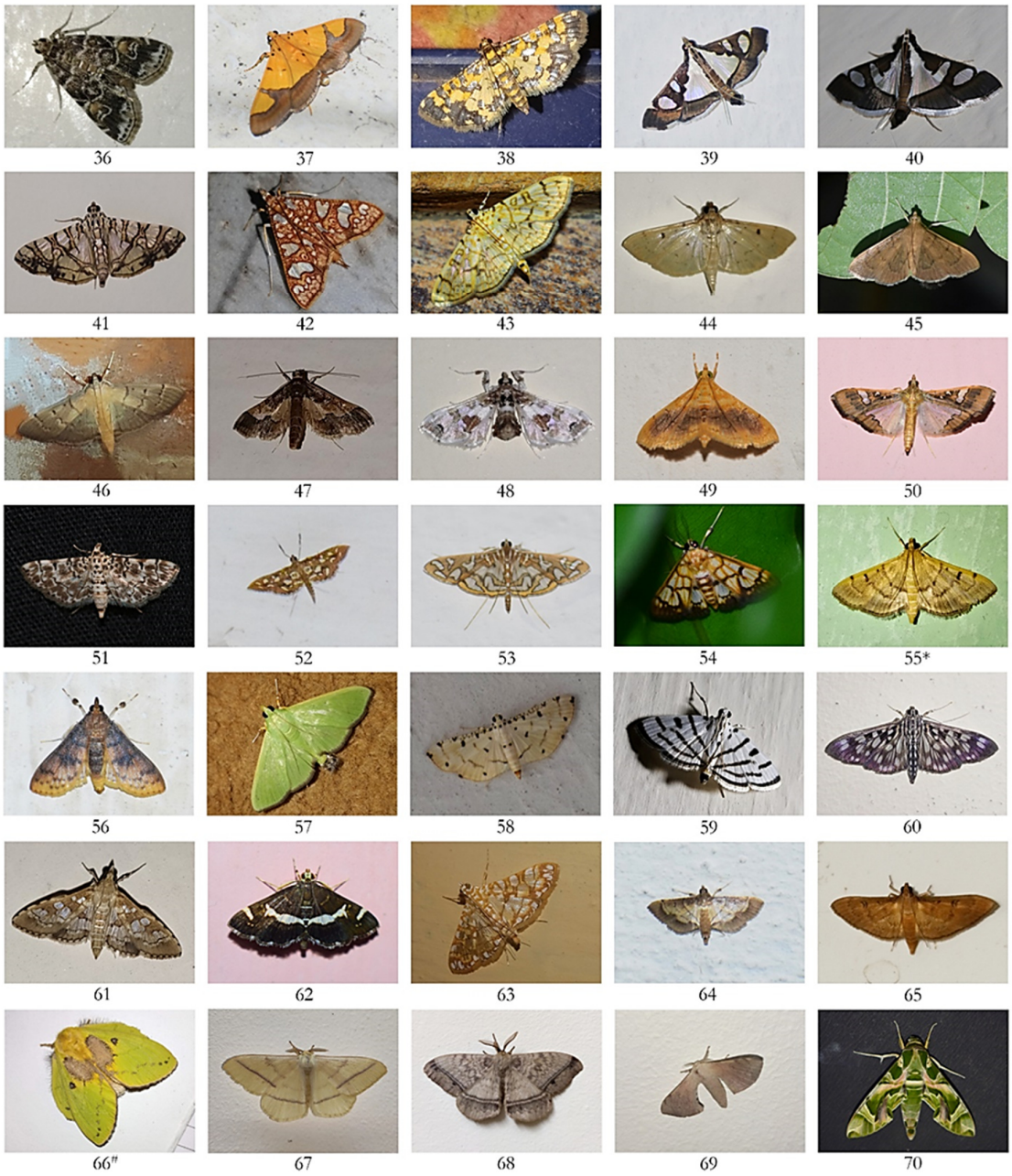

Plate 2. 36- *Elophila difflualis;* 37- *Endocrossis flavibasalis;* 38- *Eurrhyparodes tricoloralis;* 39- *Glyphodes actorionalis;* 40- *Glyphodes bicolor;* 41- *Glyphodes caesalis;* 42- *Glyphodes canthusalis;* 43- *Haritalodes derogata;* 44- *Herpetogramma basalis;* 45- *Herpetogramma phaeopteralis;* 46- *Herpetogramma rudis;* 47- *Hydriris ornatalis;* 48- *Leucinodes orbonalis;* 49- *Mabra eryxalis;* 50- *Maruca vitrata;* 51- *Metoeca foedalis;* 52- *Nausinoe geometralis; 53- Nausinoe perspectata;* 54- *Nosophora sp.;* 55- *Omiodes indicata;* 56- *Pachynoa sp.*; 57- *Parotis sp.;* 58- *Pycnarmon cribrata;* 59- *Pycnarmon virgatalis;* 60- *Pygospila tyres;* 61- *Sameodes cancellalis;* 62- *Spoladea recurvalis;* 63- *Synclera traducalis;* 64- *Syngamia latimarginalis;* 65- *Tatobotys biannulalis;* 66- *Trabala vishnou;* 67- *Eupterote bifasciata;* 68- *Eupterote undata;* 69- *Trilocha varians;* 70- *Daphnis nerii*

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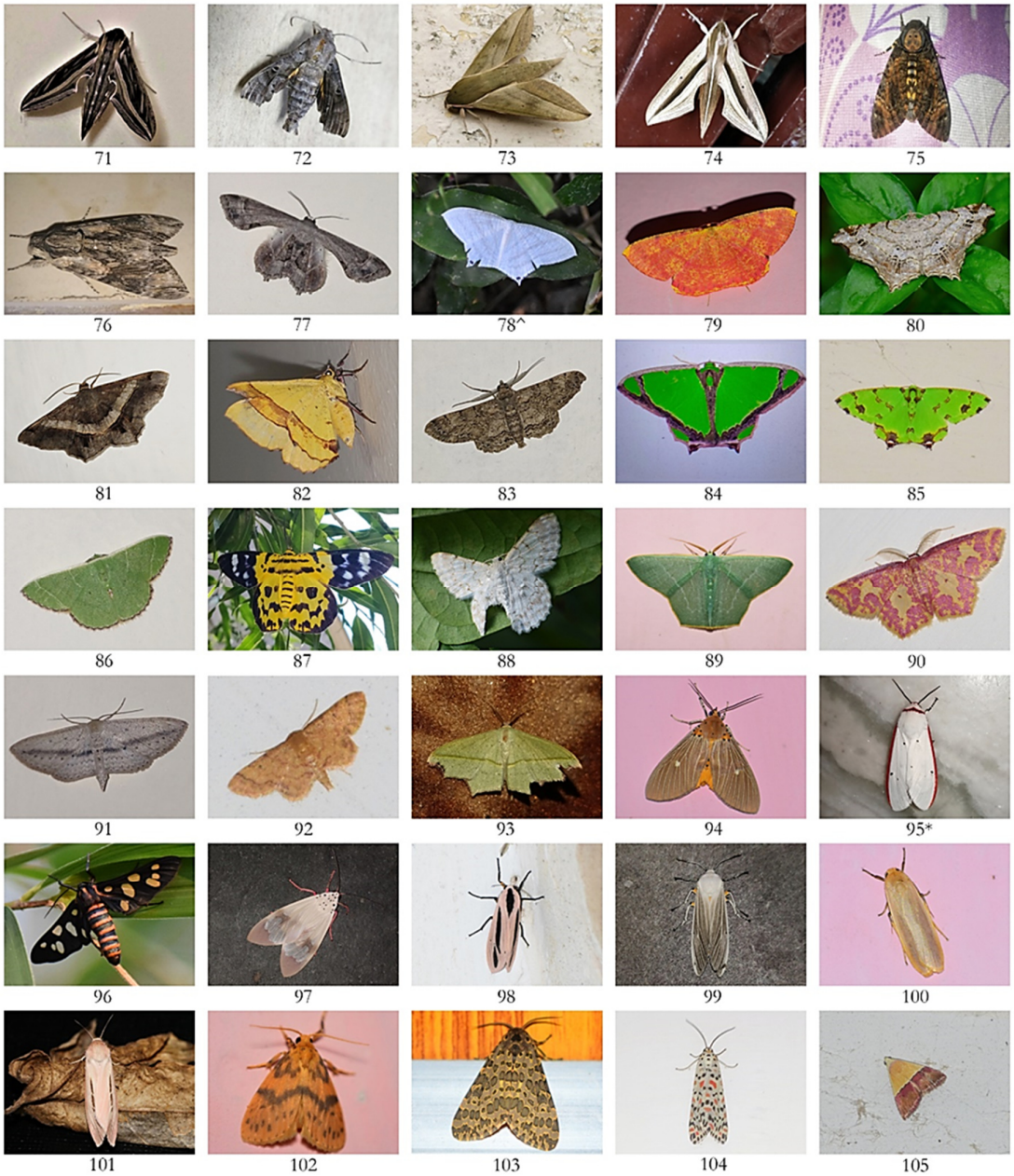

Plate 3. 71- *Hippotion celerio;* 72- *Macroglossum sp.;* 73- *Theretra lucasii;* 74- *Theretra oldenlandiae;* 75- *Acherontia styx;* 76- *Psilogramma sp.;* 77- *Phazaca theclata;* 78- *Micronia aculeata;* 79- *Eumelea ludovicata;* 80- *Chiasmia emersaria;* 81- *Chiasmia sp.;* 82- *Hyperythra lutea;* 83- *Cleora alienaria;* 84- *Agathia laetata;* 85- *Agathia lycaenaria;* 86- *Comibaena sp.;* 87- *Dysphania militaris;* 88- *Pingasa sp.;* 89- *Thalassodes sp.;* 90- *Chrysocraspeda faganaria;* 91- *Scopula emissaria;* 92- *Scopula sp.;* 93- *Traminda aventiaria;* 94- *Asota caricae;* 95- *Aloa lactinea;* 96- *Amata passalis;* 97- *Amerila astreus;* 98- *Creatonotos gangis-interrupta complex;* 99- *Creatonotos transiens;* 100- *Katha sp.;* 101- *Micraloa lineola;* 102- *Miltochrista sp.;* 103- *Olepa ricini;* 104- *Utetheisa sp.;* 105- *Eublemma accedens*

^Picture Credits: Sabindra Kumar Samal; *Picture Credits: B. Swarup Kumar Subudhi

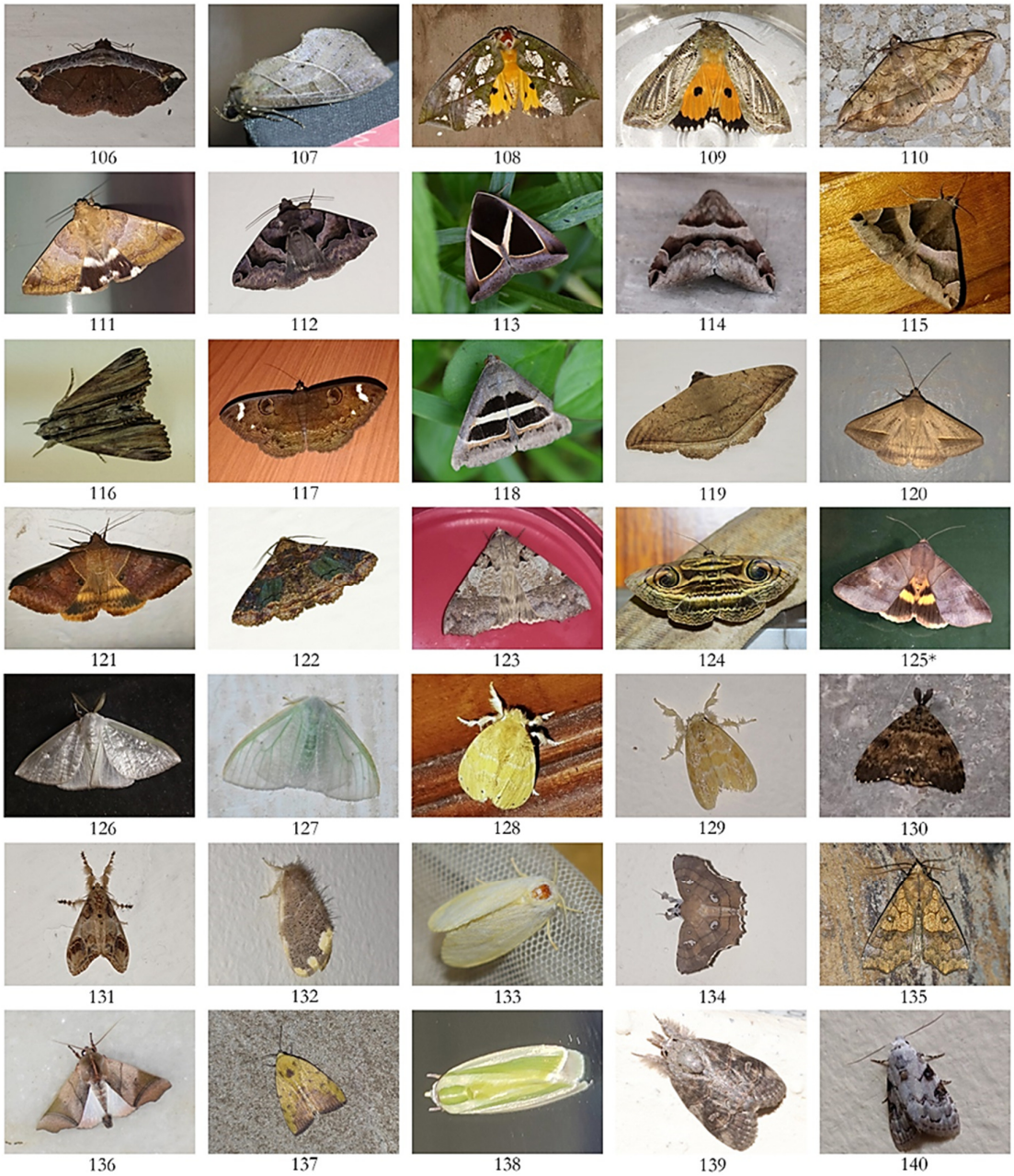

Plate 4. 106- *Zurobata vacillans;* 107- *Calyptra sp.;* 108- *Eudocima hypermnestra;* 109- *Eudocima materna*; 110- *Anticarsia irrorata;* 111- *Achaea janata;* 112- *Bastilla simillima;* 113- *Chalciope mygdon;* 114- *Dysgonia angularis;* 115- *Dysgonia torrida;* 116- *Ercheia sp.;* 117- *Erebus hieroglyphica;* 118- *Grammodes geometrica;* 119- *Hulodes sp.;* 120- *Mocis frugalis;* 121- *Mocis undata;* 122- *Pericyma cruegeri;* 123- *Serrodes partita;* 124- *Spirama sp.;* 125- *Thyas coronata;* 126- *Arctornis cygna;* 127- *Arctornis sp.;* 128- *Artaxa digramma;* 129- *Euproctis sp.;* 130- *Lymantria ampla;* 131- *Olene mendosa;* 132- *Orvasca subnotata;* 133- *Perina nuda;* 134- *Egnasia ephyrodalis;* 135- *Anomis flava;* 136- *Carea angulata;* 137- *Earias luteolaria;* 138- *Earias vittella;* 139- *Selepa celtis;* 140- *Nola sp.*
*Picture Credits: B. Swarup Kumar Subudhi

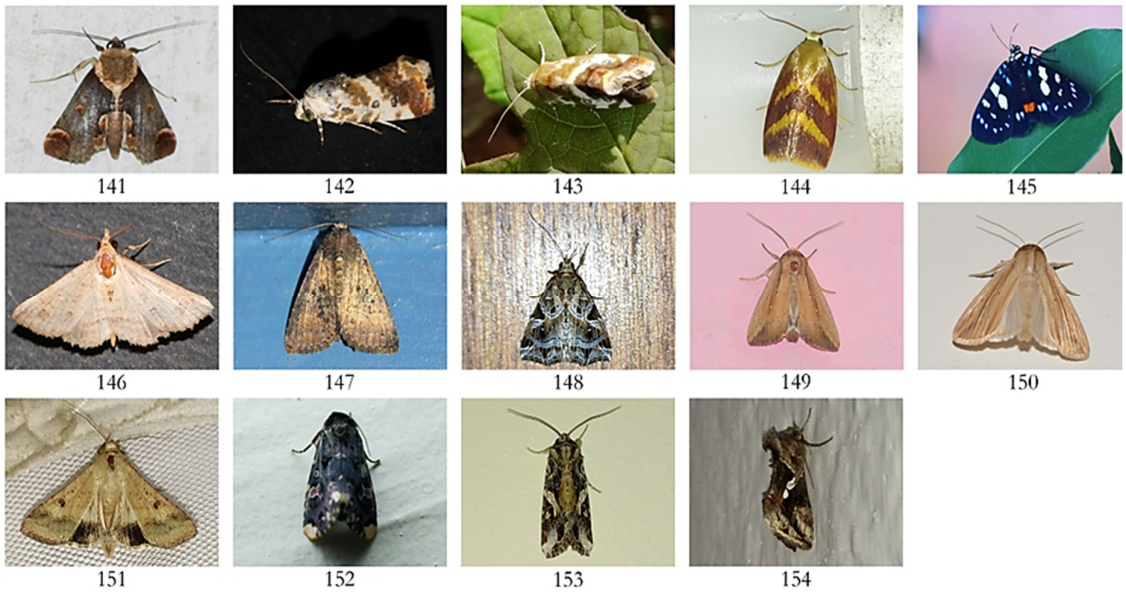

Plate 5. 141- *Risoba repugnans;* 142- *Acontia lucida;* 143- *Acontia marmoralis;* 144- *Naranga aenescens;* 145- *Episteme sp.;* 146- *Gesonia obeditalis;* 147- *Condica illecta;* 148- *Callopistria sp.;* 149- *Mythimna separata;* 150- *Mythimna sp.;* 151- *Helicoverpa armigera;* 152- *Polytela gloriosae;* 153- *Spodoptera litura;* 154- *Chrysodeixis eriosoma*

Here in this study, we have recorded 19 moth families being reported from the state of Odisha which includes 154 species under 129 genera. Out of these, 34 moths have been identified only up to the genus level, while the rest have been identified up to species level as indicated in Table 2. In the study, family Crambidae dominated in species diversity, composing 31.2% of the total species (48 species, 38 genera), followed by Erebidae composing 27.3% (42 species, 37 genera), Geometridae making up for 9.7% (15 species, 12 genera) and Noctuidae at 8.4% (13 species, 11 genera). The other families found in less numbers were in the following order of species diversity namely, Sphingidae with seven species in six genera (4.5%), Pyralidae with seven species in five genera (4.5%) and Nolidae with six species in five genera (3.9%). Further, the families Limacodidae, Tortricidae and Uraniidae were represented by two species in two genera each while, Eupterotidae had one genus with two species and the rest eight families (Tineidae, Scythrididae Lasiocampidae, Attevidae, Thyrididae, Bombycidae, Hyblaeidae and Lecithoceridae) were found with a single species in each (Figure 4).

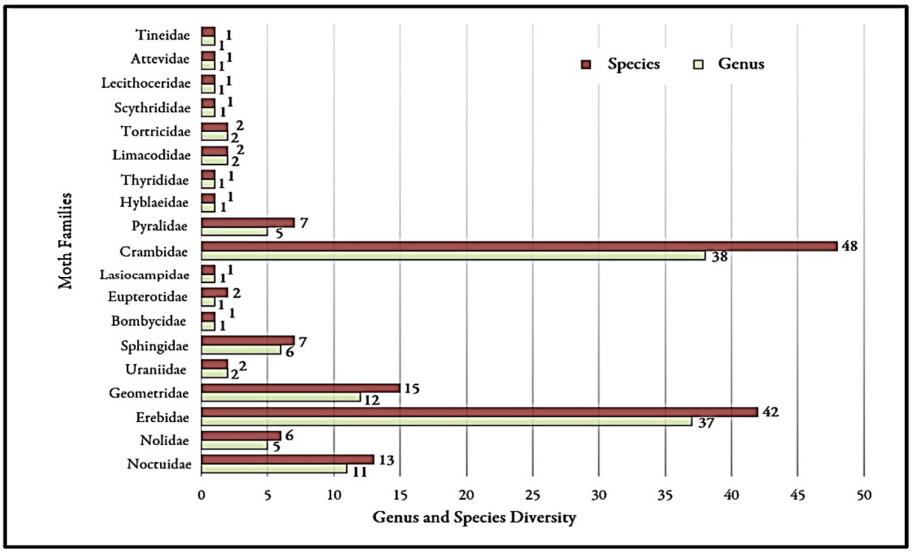

Figure 4. Graph denoting genus and species diversity in observed moth families

The study reveals a specific pattern of presence of moth families across various months in a year. Moths from the family Crambidae were found all throughout the year, followed by Erebidae and Geometridae which were recorded in around ten months across the year. Noctuidae, Pyralidae and Sphingidae were observed in seven different months of the year. Nolidae and Bombycidae moths were seen in around four to six months in different seasons. The families of moths which were less found were reported in one or two months in the whole year. These were Uraniidae, Eupterotidae, Lasiocampidae, Scythrididae, Lecithoceridae, Thyrididae, Tineidae, Hyblaeidae, Attevidae, Limacodidae and Tortricidae (Table 3). While most moths that have been found were crepuscular in their time of activity and presence, day-flying moths like *Episteme sp.* and *Dysphania militaris* were also recorded amongst macrolepidoptera.

Table 3. Presence of different moth families across different months

Superfamily	Family	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tineoidea	Tineidae					+							
Yponomeutoidea	Attevidae							+					
Gelechioidea	Lecithoceridae										+		
	Scythrididae						+	+					
Tortricoidea	Tortricidae			+					+	+			
Zygaenoidea	Limacodidae								+		+	+	
Thyridoidea	Thyrididae										+	+	
Hyblaeoidea	Hyblaeidae								+				
Pyraloidea	Pyralidae	+		+			+	+	+	+	+		
	Crambidae	+	+	+	+	+	+	+	+	+	+	+	+
Lasiocampoidea	Lasiocampidae					+						+	
Bombycoidea	Eupterotidae					+		+			+		
	Bombycidae	+					+	+	+				
	Sphingidae	+				+	+	+	+	+		+	
Geometroidea	Uraniidae								+			+	
	Geometridae	+	+	+	+	+	+		+	+	+	+	
Noctuoidea	Erebidae	+	+			+	+	+	+	+	+	+	+
	Nolidae	+					+	+	+		+	+	
	Noctuidae	+	+		+		+	+		+	+		

The month of August recorded the highest diversity of moths from 11 different families out of all 19 families reported in the study. July and October recorded a considerably higher number of moths with ten families reported in each month. Moths from families Crambidae, Geometridae and Erebidae were found across most seasons while others like Limacodidae, Thyrididae and Lecithoceridae were only seen during autumn and winters. The families represented by a greater number of moth species were mostly found around monsoon (Figure 5). Hence from the study, it can be said that the diversity of moths is quite rich in Odisha. Since the present inventory relied mostly on opportunistic findings and seasonal surveys of 18 months yet reports a diversity of 19 families with 154 species from a single district of Khordha, it is contemplated that further studies in detail with intensive light trapping sessions can reveal the actual diversity of the eastern state of Odisha.

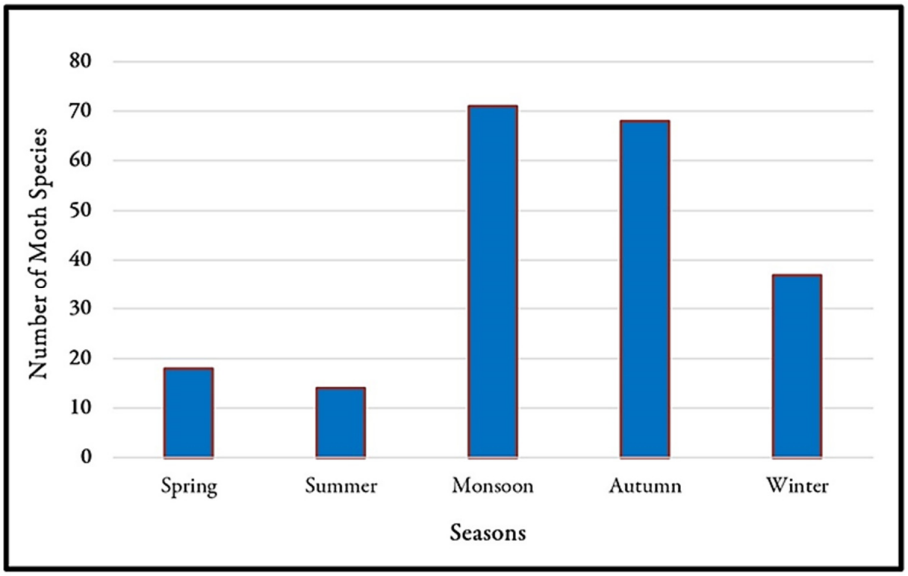

Figure 5. Seasonal distribution of recorded moth species

Conclusions

The study compiles a preliminary moth diversity of the city of Bhubaneswar and adjoining outskirts, recording a total of 154 moths in 19 families. It can be said that the presence of various moth species in any particular landscape is related to the different types of vegetation of a region, cropping seasons, the flowering of plants and various other factors controlling their diversity and abundance. Hence, this suggests that the moth diversity of the state is quite rich as evident from a preliminary survey in a single district and needs to be extensively studied, to gather more information about their present status for further conservation. Many species found in the study could be keyed only till the genus level while many other unidentified moths await proper taxonomic studies and documentation. As the state of Odisha is rich in forest cover and has diverse biogeographic zones from the East Coast to Deccan Peninsula including tropical dry deciduous and semi-evergreen forest types, therefore it can be easily speculated that the moth fauna of the state is unique and rich as found from the present sample study of one district.

It is evident that with further intensive studies in the other parts of the state, the moth diversity can be explored in greater detail in relation to the biogeographic regions and vegetation types across the state. The results of the present survey indicate a diverse population of moths present in the landscape of Odisha with 19 families reported, characterized majorly by Crambidae, Erebidae, Geometridae and Noctuidae. The presence

of families less encountered like, Tineidae, Attevidae, Lecithoceridae and Hyblaeidae also indicate that moths can be easily considered as bioindicators for particular regions when correlated to their presence in particular forest types or habitat. We also suggest that since inventorying is necessary for conservation of a taxon, more biodiversity assessments need to be done on these largely nocturnal lepidopterans. Along with natural history documentation, scientific records of the same can also reveal more information about interactions with plants and their vital role which they play in the ecosystem as indicators, pollinators and pests, other than the usual importance given to few silk moths for economic benefits. It would be further interesting to compare the diversity from urban areas like the present study locations with forested areas which stand unaffected by the city light pollution, which affects moths and their natural navigation in a huge way.

Authors' Contributions

The study was supervised by DP. AS has majorly contributed towards photography of the moths while NP identified the species and drew maps and figures. AS and NP put together the data into tables and charts. All authors contributed together for fieldwork and preparation of the manuscript, while review and editing were done by DP.

All authors read and approved the final manuscript.

Ethical approval (for researches involving animals or humans)

For the present study, none of the moths were collected or killed and therefore live photography of the moths was done as presented in the image plates.

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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