Entomology

A preliminary study of moth species of verna

Dafilgo Fernandes[1, 2*]

[1] Verna Biodiversity Management Committee (VBMC), Goa State Biodiversity Board (GSBB), Saligao, Goa, India

[2] School of Earth, Ocean and Atmospheric Sciences, Goa University, Taleigao Plateau, Goa, India

Correspondence Author: Dafilgo Fernandes

Received 9 Dec 2023; Accepted 20 Jan 2024; Published 29 Jan 2024

Abstract

Insect studies based on their diversity and ecological distribution in Goa are rare and can help us understand the differences in biodiversity within the region. Goa is a tropical region that is part of the Western Ghats hotspot, but there is paucity of literature on insects especially moth species, in this region. A moth survey was conducted during the monsoon season to observe moth species over a period of several months in Verna village in the southern part of Goa. The current exploration is the first report of moth observations on the Sal River in the Verna residential area. A total of 193 moth species were identified. Based on the number of species, the family Erebidae was the most dominant with 61 species, followed by Crambidae with 42 species, Noctuidae with 26 species, Geometridae with 19 species and Sphingidae with 5 species. The least dominant were Nolidae, Zygaenidae and Pterophoridae with 4 species each. Moth diversity and abundance in Verna is highest during the monsoon and is directly dependent on rainfall, probably because it stimulates the growth of various plant species on which moth larvae feed. This moth species in this discovery contributes significantly to the moth ecology in Verna, expanding the list of known moth species and furthering our understanding of their ecological role in the ecosystems of Goa.

Keywords: environment, biodiversity, insects, butterfly, moths

1. Introduction

Moths are flying insects of the order Lepidoptera, which are nocturnal relatives of butterflies and represent a diverse and ecologically important group of insects. Moths have evolved physiological adaptations that show complex wing patterns and sensory organs that allow them to thrive in diverse habitats and migrate over long distances (Eisner, 1964; Kennedy and Marsh 1974; Kingsolver, 1983; Kent et al. 1986; Fullard, 1998; Yack and Fullard, 2000; Brakefield and Liebert, 2000; Zeng et al 2011; Neil et al., 2020;) [4, 11, 13, 12, 6, 29, 1, 30, 15]. These insects play important roles in ecosystems as nocturnal pollinators, decomposers and prey for various predators such as mammals and birds, but are also critically important as indicators of environmental health (Pierce, 1995; Vaughan, 1997; Wilson et al., 1999; Thomas, 2005; Warren and Bourn 2011; Macgregor et al., 2015; Goto et al., 2021) [17, 23, 26, 22, 24, 14, 7]. Despite their ecological importance, moths face various threats, including habitat loss, climate change and pesticide use. Studying the ecological distribution of moths is important for understanding the broader dynamics of ecosystems. While moths are integral components of terrestrial ecosystems, many of them cause crop damage as pests in agro-ecosystems, particularly the noctuid moths, which cause significant crop damage in the adult stage (Fitt, 1989; Cho et al., 2008; Sinu et al., 2013) [5, 3, 20].

Moth research has received considerable attention in recent years, due to increasing recognition of their ecological importance and the availability of advanced research tools. The aim of this manuscript is to provide a comprehensive overview of the current knowledge about moths and to summarize information from taxonomy and ecology. The focus is to emphasize their contribution to the functioning of ecosystems and the challenges they face in a constantly changing environment.

The Western Ghats hotspot is known to be home to about 6000 species of insects (George and Binoy, 2009). National estimates suggest that there are approximately ~12000 species of moths in India (Chandra and Nema, 2007) [2]. Goa is a small state in the Konkan region and is located in this hotspot of the Western Ghats. Documentation of moth species in Goa is particularly limited. The recent moth diversity study conducted at the University of Goa documented around 200 species of moths (Gurule and Brookes, 2021). The present investigation aims to contribute to the understanding of moth diversity in Goa by specifically documenting the species in Verna village and providing valuable insights into the overall moth diversity of the region.

2. Study area

The climate of Goa follows southwest monsoon, which is influenced by tropical weather and where the climate remains humid throughout the year. The physiography of Goa shows a varied terrain ranging from the hilly Western Ghats in the east to middle extensive plateaus with low-lying gullies, and flat coastal plains in the west (Widdowson, 2009) [25]. Extensive laterization, is a result of the tropical moist climate with strong seasonal changes, and plays an important role in rock weathering, that contributes to the formation of lateritic soils and influences regional vegetation. Many of the estuaries along the coast have large sandy river plains, known locally as khazans, which are used for rice cultivation and coconut plantations. Goa has diverse ecosystems including tropical evergreen dry forests, scrub forests, grasslands, riverine plains, mangroves and sand dune habitats. These different topographical conditions create a range of habitats that support a rich diversity of flora and fauna. With an average temperature of about 27.4 °C and an annual mean rainfall of 292.6 cm, Goa

offers rich biodiversity and is home to 1512 plant species, 275 genera of birds, 48 genera of animals, and 60 genera of reptiles (Sonak, 2013) [21]. Despite sustained efforts by the authors on insect diversity in Goa, comprehensive studies in this area remain limited.

The location of the study area for this moth observation is a small village of Verna in Salcete taluka of Goa (Fig. 1.). The sampling site is located just a few meters from the source of the Sal River, on the sandy plain in close proximity to the paddy cultivation and within the residential area of Matol, which has a dense coconut plantation. Verna has a unique topography with a higher plateau in the east and a lower flat riverine plain in the west. The plateaus in higher regions form large open areas covered with tranquil mountain grass during monsoons, providing a perfect habitat for various wildlife including black-naped hares, wild fowl, peacocks, porcupines, wild dogs, and wild boars. The hilly plateau slopes are dense tropical deciduous forests, while the lower flat sandy deposits of riverine plains are cultivated areas. Coconut plantations, interspersed with dense tribal settlements, line the roots of these plateau hills. Verna is the birthplace of the Sal River, which flows south on the southeastern border of Verna. Ambulor Lake is a small man-made reservoir for irrigation, in the center of Verna. Lake Ambulor is known for attracting migratory birds for nesting and breeding, even from the north of the Russian steppes. The Sal River is important source of irrigation for crops and has a unique ecosystem for wildlife. Verna, with its abundance of natural resources, remains poorly documented. The plateau slopes of Verna represent an untapped biodiversity hotspot and are home to numerous plant and animal species that are yet to be discovered.

3. Methods

Moths were randomly photographed in the field at several locations indicated in Fig. 1. From the beginning of May 2023, regular and periodic moth observations were carried out by surveying house walls in the area. Moths visiting tube lights on accessible walls were also recorded. In addition, field surveys were conducted in daylight, which included bushes and grasslands. These surveys were conducted twice weekly to generate comprehensive data to assess species seasonality and moth abundance throughout the year. In keeping with ethical principles, no live moth specimens were collected in this survey. The moths were documented through visual observation and photography, using a Redmi 9 camera. The identification of moth species was achieved by comparing the external morphology of observed moths with descriptions by Hampson (1892). Indiabiodiversity.org and websites like www.mothsofindia.org and www.inaturalist.org were used to identify moths.

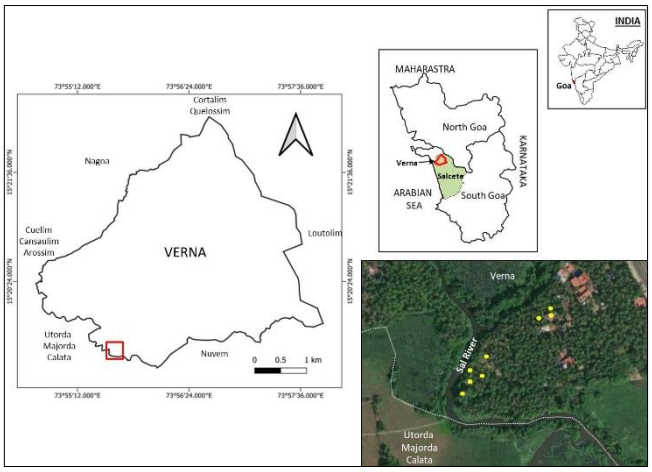

Fig 1: Map of the sampling area showing the location of Verna village in Goa and in Google Earth showing the sampling locations (yellow dots).

4. Results

The observation provided photos of a total of 193 moth species recorded at these locations. The taxonomic grouping of these moth photos mainly includes families, 61 species of Erebidae, 42 species of Crambidae, 26 species of Noctuidae, 19 species of Geometridae, 5 species of Sphingidae, and 4 species of Nolidae, Zygaenidae, Pyralidae and Pterophoridae. Other families that contribute to overall moth diversity are represented in much smaller numbers. The detailed list of individual moth species recorded during the study is listed in Table 1 and represents the local moth population of the region. Particularly, 183 of the listed species including six moth larvae were captured through photography and their images are presented in plates 1-11. In addition, the temporal distribution of moths is shown in Fig. 2. Moth diversity across families and their numbers are shown in Fig. 3.

Table 1: List of moth species recorded during monsoon in Verna, District South Goa

Specie Name	Family
Agathia laetata (Fabricius, 1794)	Geometridae
Biston strigaria (Moore, 1879)	
Cepphis advenaria (Hubner, 1790)	
Chiasmia nora (Walker, 1861)	
Digrammia ocellinata (Walker, 1857)	
Dysphania percota (Swinhoe, 1891)	
Eupithecia vulgata (Haworth, 1809)	
Hemithea tritonaria (Walker, 1863)	
Hyperythra lutea (Stoll, 1781)	
Idaea gemmaria (Hampson, 1896)	
Idaea rusticata (Denis & Schiffermuller, 1775)	
Oenospila flavifusata (Walker, 1861)	
Perixera absconditaria (Walker, 1862)	
Pleuroprucha insulsaria (Guenée, 1857)	
Scopula emissaria (Walker, 1861)	

Scopula pulchellata (Fabricius, 1794)	
Scopula umbilicata (Fabricius, 1794)	
Thalassodes quadraria (Guenee, 1857)	
Traminda mundissima (Walker, 1861)	
Achaea janata (Linnaeus, 1758)	Erebidae
Aemene taprobanis (Walker, 1854)	
Aroa spp. (Walker, 1855)	
Anomis flava (Fabricius, 1775)	
Anomis involute (Walker, 1858)	
Arctornis submarginata (Walker, 1855)	
Argina astrea (Drury, 1773)	
Artena dotata (Fabricius, 1794)	
Artena submira (Walker, 1858)	
Asota caricae (Fabricius, 1775)	
Bastilla simillima (Guenee, 1852)	
Bocula diffisa (Swinhoe, 1890)	
Bocula xanthostola (Hampson, 1926)	
Creatonotos gangis (Linnaeus, 1763)	
Creatonotos transiens (Walker, 1855)	
Cyana peregrine (Walker, 1854)	
Dichromia sagitta (Fabricius, 1775)	
Eilema caniola (Hubner, 1808)	
Ercheia cyllaria (Cramer, 1779)	
Ericeia inangulata (Guenee, 1852)	
Eublemma anachoresis (Wallengren, 1863)	
Eublemma baccalix (C. Swinhoe, 1886)	
Eublemma cochylioides (Guenee, 1852)	
Eudocima hypermnestra (Cramer, 1780)	
Eudocima materna (Linnaeus, 1767)	
Eudocima phalonia (Linnaeus, 1763)	
Euproctis chrysorrhoea (Linnaeus, 1758)	
Euproctis similis (Fussli, 1775)	
Grammodes geometrica (Fabricius, 1775)	
Hulodes caranea (Cramer, 1780)	
Hypena eductalis (Walker, 1859)	
Hypena laceratalis (Walker, 1859)	
Hypena mandatalis (Walker, 1859)	
Hypena obacerralis (Walker, 1859)	
Hypena rostralis (Linnaeus, 1758)	
Lithosiini-genera spp. (Billberg, 1820)	
Lymantria dispar (Linnaeus, 1758)	
Lymantria fuliginosa (Moore, 1883)	
Lymantria marginata (Walker, 1855)	
Mecodina agrestis (Swinhoe, 1890)	
Miltochrista semifascia (Walker, 1854)	
Mocis frugalis (Fabricius, 1775)	
Mocis undata (Fabricius, 1775)	
Nyctemera lacticinia (Grote, 1873)	
Nygmia icilia (Stoll, 1790)	
Nygmia plana (Walker, 1856)	
Olepa clavatus (Swinhoe, 1885)	
Orgyia leucostigma (J. E. Smith, 1797)	
Parallelia stuposa (Fabricius, 1794)	
Perina nuda (Fabricius, 1787)	
Polydesma boarmoides (Guenee, 1852)	
Polydesma umbricola (Boisduval, 1833)	
Rivula bioculalis (Moore, 1877)	
Rivula sericealis (Scopoli, 1763)	
Rusicada combinans (Walker, 1858)	
Sigela lynx (Troubridge, 2020)	
Spirama retorta (Clerck, 1764)	
Syntomoides imaon (Cramer, 1779)	
Tamba occidinawa (Holloway, 2005)	
Thumatha fuscescens (Walker, 1866)	
Trigonodes hyppasia (Cramer, 1779)	

Aethaloessa calidalis (Guenee, 1854)	Crambidae
Antigastra catalaunalis (Duponchel, 1833)	
Bocchoris inspersalis (Zeller, 1852)	
Bradina admixtalis (Walker, 1859)	
Bradina atopalis (Walker, 1858)	
Chabulina onychinalis (Guenee, 1854)	
Cnaphalocrocis medinalis (Guenee, 1854)	
Conogethes punctiferalis (Guenée, 1854)	
Crambinae-genera spp.	
Diaphania indica (Saunders, 1851)	
Eurrhyparodes bracteolalis (Zeller, 1852)	
Eurrhyparodes tricoloralis (Zeller, 1852)	
Glyphodes bicolor (Swainson, 1821)	
Hahncappsia pergilvalis (Hulst, 1886)	
Herpetogramma basalis (Walker, 1866)	
Herpetogramma licarsisalis (Walker, 1859)	
Herpetogramma phaeopteralis (Guenee, 1854)	
Herpetogramma rudis (Warren, 1892)	
Herpetogramma spp. (Lederer, 1863)	
Marasmia poeyalis (Boisduval, 1833)	
Maruca vitrata (Fabricius, 1787)	
Metoeca foedalis (Guenee, 1854)	
Musotima suffusalis (Hampson, 1893)	
Nacoleia satsumalis (South in Leech & South, 1901)	
Nausinoe perspectata (Fabricius, 1775)	
Omiodes diemenalis (Guenee, 1854)	
Orthospila tigrina (Moore, 1886)	
Palpita vitrealis (Rossi, 1794)	
Parapoynx fluctuosalis (Zeller, 1852)	
Parotis marginata (Hampson, 1893)	
Patania iopasalis (Walker, 1859)	
Pycnarmon cribrata (Fabricius, 1794)	
Pyrausta phoenicealis (Hubner, 1818)	
Sameodes cancellalis (Zeller, 1852)	
Scirpophaga innotata (Walker, 1863)	
Spoladea recurvalis (Fabricius, 1775)	
Sufetula diminutalis (Walker, 1866)	
Sufetula hemiophthalma (Meyrick, 1884)	
Sufetula sunidesalis (Walker, 1859)	
Sylepta derogate (Fabricius, 1775)	
Symmoracma minoralis (Snellen, 1880)	
Tatobotys biannulalis (Walker, 1866)	
Acontia crocata (Guenee, 1852)	Noctuidae
Agrotis ipsilon (Hufnagel, 1766)	
Amphipyra tragopoginis (Clerck, 1759)	
Amyna axis (Guenee, 1852)	
Anadevidia peponis (Fabricius, 1775)	
Calesia haemorrhoa (Guenee, 1852)	
Callopistria exotica (Guenee, 1852)	
Chrysodeixis acuta (Walker, 1857)	
Condica illecta (Walker, 1865)	
Dierna patibulum (Fabricius, 1794)	
Egnasia ephyrodalis (Walker, 1858)	
Gesonia obeditalis (Walker, 1859)	
Gesonia sp. (Walker, 1859)	
Gesonia stictigramma (Hampson, 1926)	
Helicoverpa armigera (Hubner, 1808)	
Ischyja manlia (Cramer, 1776)	
Leucania loreyi (Duponchel, 1827)	
Leucania obsolete (Hubner, 1803)	
Leucania yu (Guenee, 1852)	
Panilla dispila (Walker, 1865)	
Polytela gloriosae (Fabricius, 1781)	
Progonia kurosawai (Owada, 1987)	
Spodoptera frugiperda (J. E. Smith, 1797)	

Spodoptera litura (Fabricius, 1775)	
Spodoptera mauritia (Boisduval, 1833)	
Thyas honesta (Hubner, 1824)	
Eupterote mollifera (Walker, 1865)	Eupterotidae
Eupterote gardneri (Bryk, 1950)	
Tetragonus catamitus (Geyer, 1832)	Callidulidae
Antheraea mylitta (Drury, 1773)	Saturniidae
Acherontia lachesis (Fabricius, 1798)	Sphingidae
Daphnis nerii (Linnaeus, 1758)	
Hippotion rosetta (Swinhoe, 1892)	
Theretra lucasii (Walker, 1856)	
Theretra silhetensis (Walker, 1856)	
Cyclosia latipennis (Hampson, 1891)	Zygaenidae
Eterusia aedea (Linnaeus, 1763)	
Procridinae-genera spp. (Boisduval, 1829)	
Thyrassia penangae (Moore, 1859)	
Azygophleps scalaris (Fabricius, 1775)	Cossidae
Adoxophyes privatana (Walker, 1863)	Tortricidae
Archips spp.(Hubner, 1822)	
Cadra cautella (Walker, 1863)	Pyralidae
Corcyra cephalonica (Stainton, 1866)	
Orthaga exvinacea (Hampson, 1891)	
Pyralis manihotalis (Guenee, 1854)	
Europlema desistaria (Walker, 1861)	Uraniidae
Micronia aculeate (Guenee, 1857)	
Birthamoides juncture (Walker, 1865)	Limacodidae
Thosea sinensis (Walker 1855)	
Targalla delatrix (Guenee, 1852)	Euteliidae
Phereoeca allutella (Rebel, 1892)	Tineidae
Tineola bisselliella (Hummel, 1823)	
Eumeta variegate (Snellen, 1879)	Psychidae
Earias cupreoviridis (Walker, 1862)	Nolidae
Nola analis (Wileman & West, 1928)	
Selepa celtis (Moore, 1858)	
Xanthodes transversa (Guenee, 1852)	
Phalacra vidhisara (Walker, 1860)	Drepanidae
Archigargetta viridigrisea (Hampson, 1898)	Notodontidae
Eretmocera impactella (Walker, 1864)	Scythrididae
Lecithocera concinna (Turner, 1919)	Lecithoceridae
Lecithocera tenella (Turner, 1919)	
Ressia quercidentella (Sinev, 1988)	Cosmopterigidae
Deuterocopus planeta (Meyrick, 1908)	Pterophoridae
Emmelina monodactyla (Linnaeus, 1758)	
Exelastis pumilio (Zeller, 1873)	
Lantanophaga pusillidactylus (Walker, 1864)	
Trabala vishnou (Lefebvre, 1827)	Lasiocampidae
Odites ricinella (Stainton, 1859)	Depressariidae
Helcystogramma hystricella (Braun, 1921)	Gelechiidae

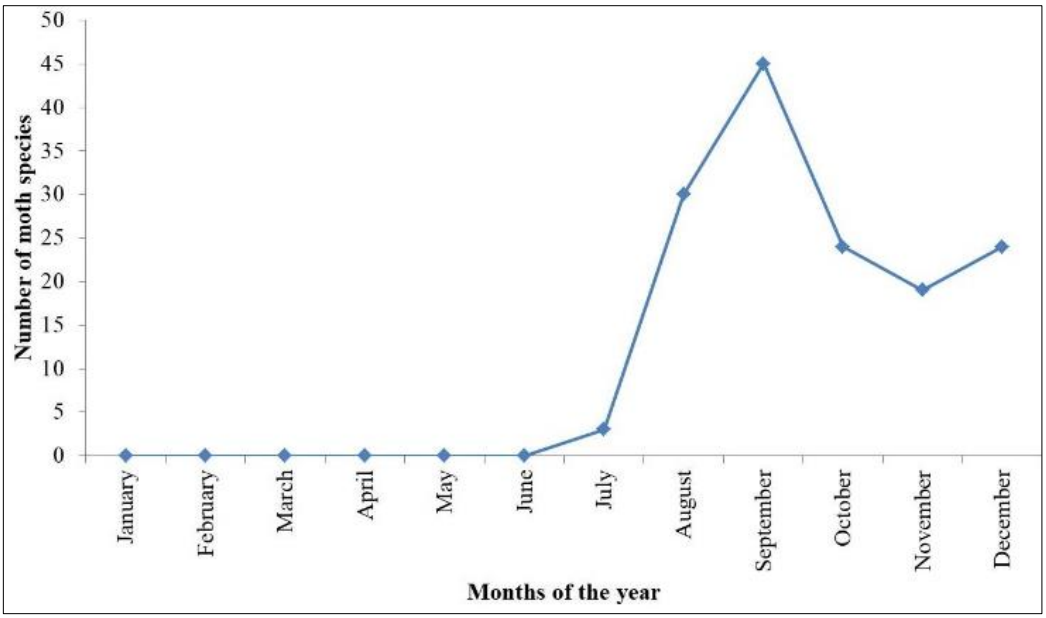

Fig 2: Monthly variation of moth population of Verna

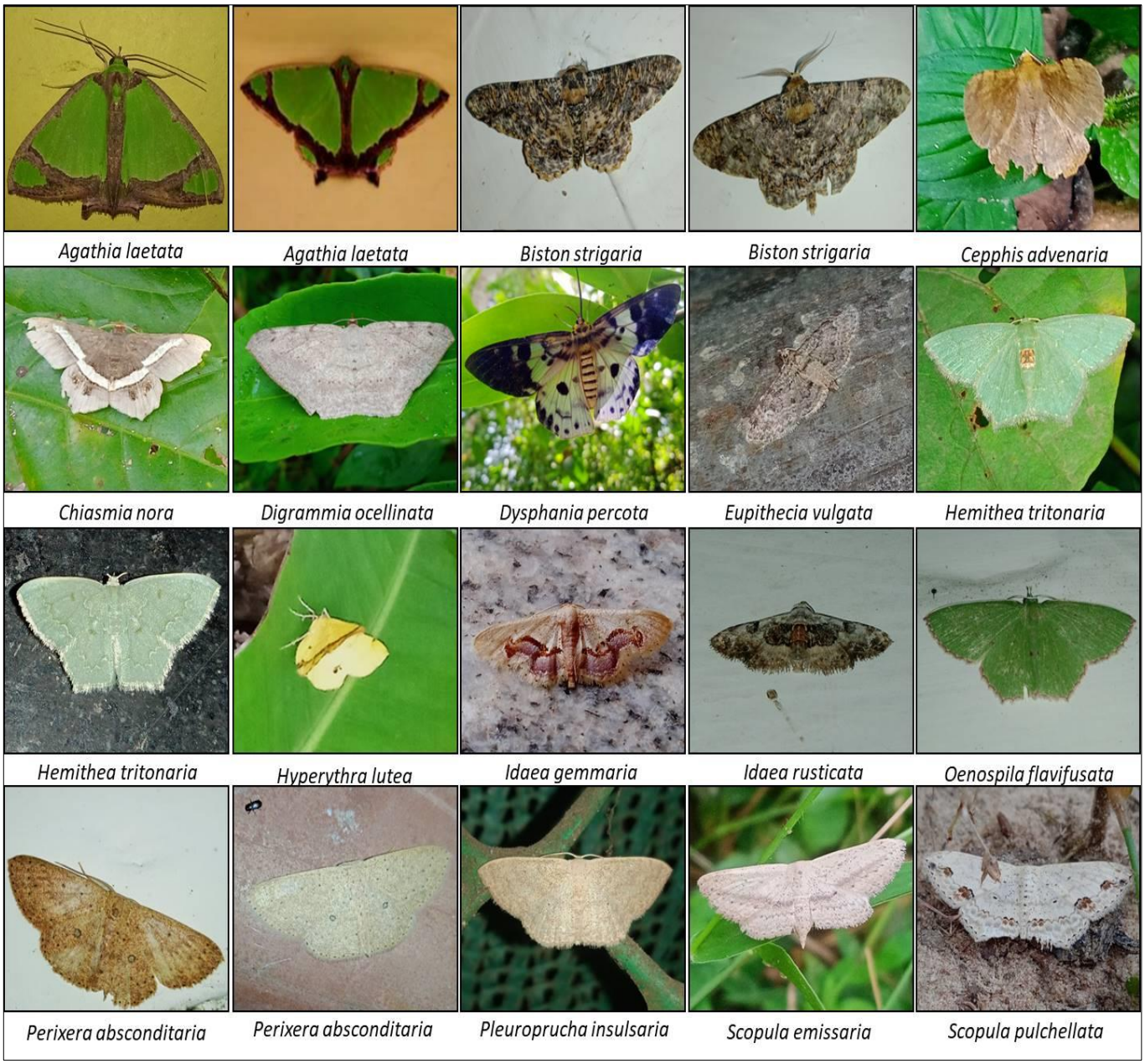

Plate 1

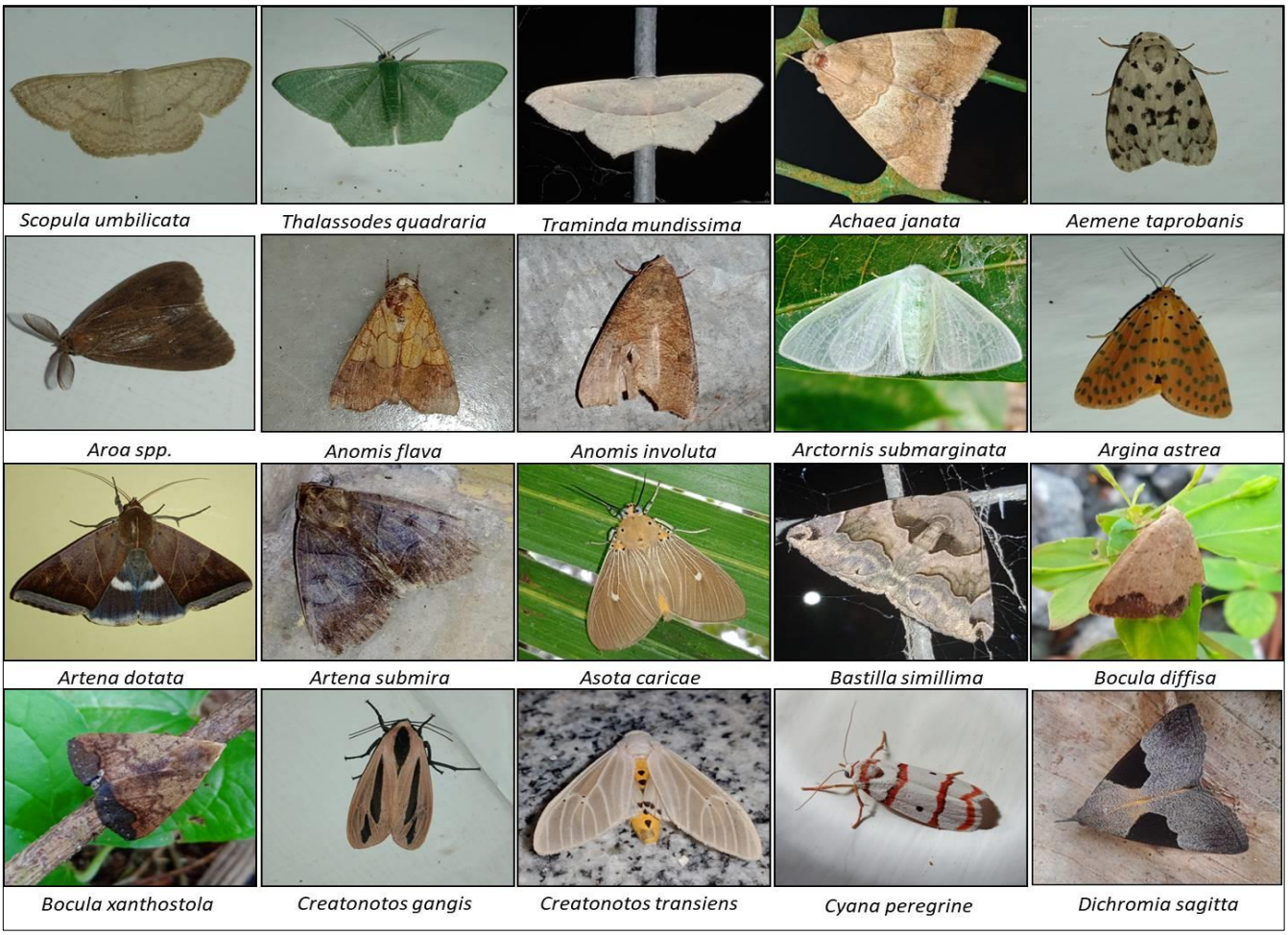

Plate 2

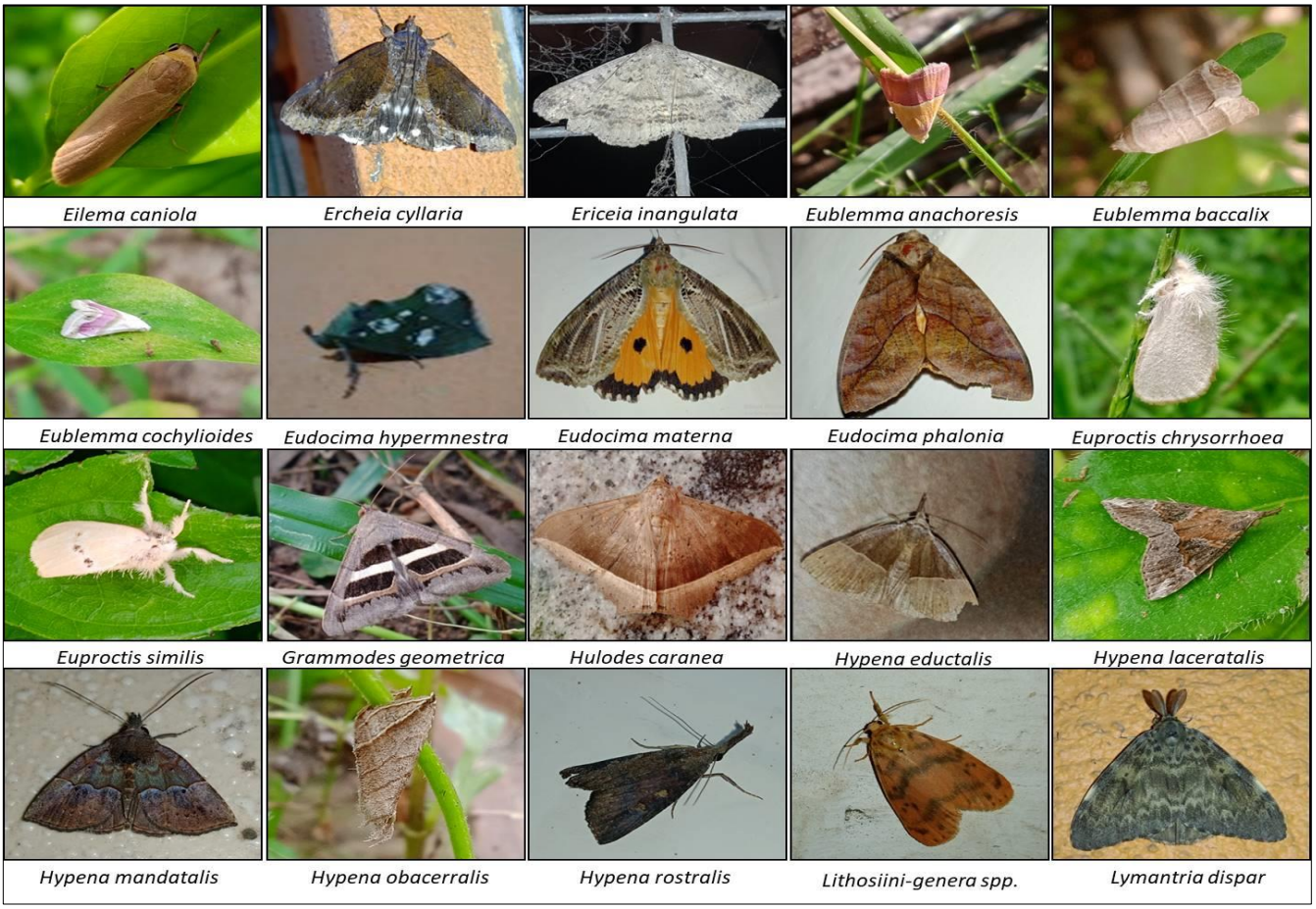

Plate 3

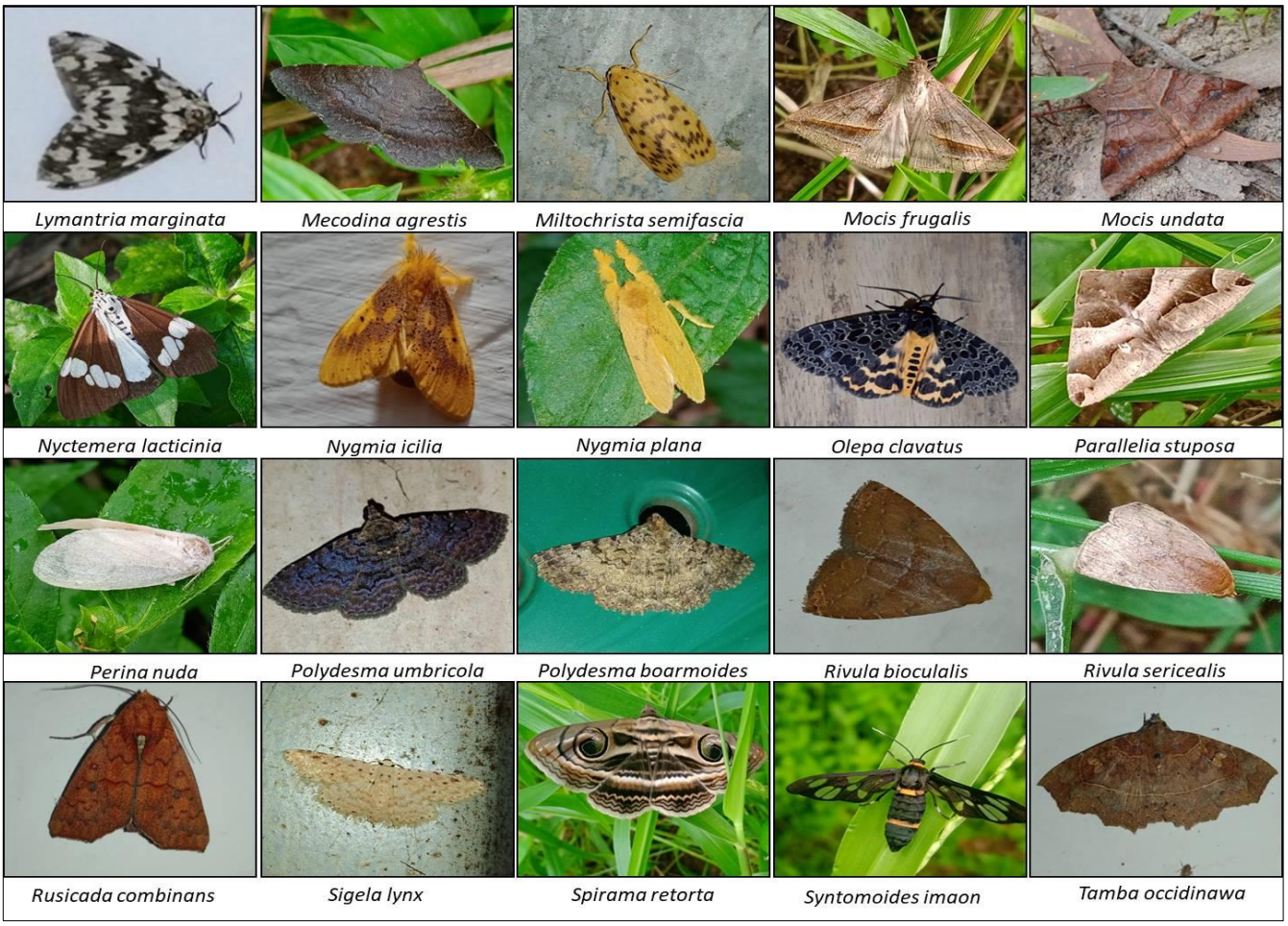

Plate 4

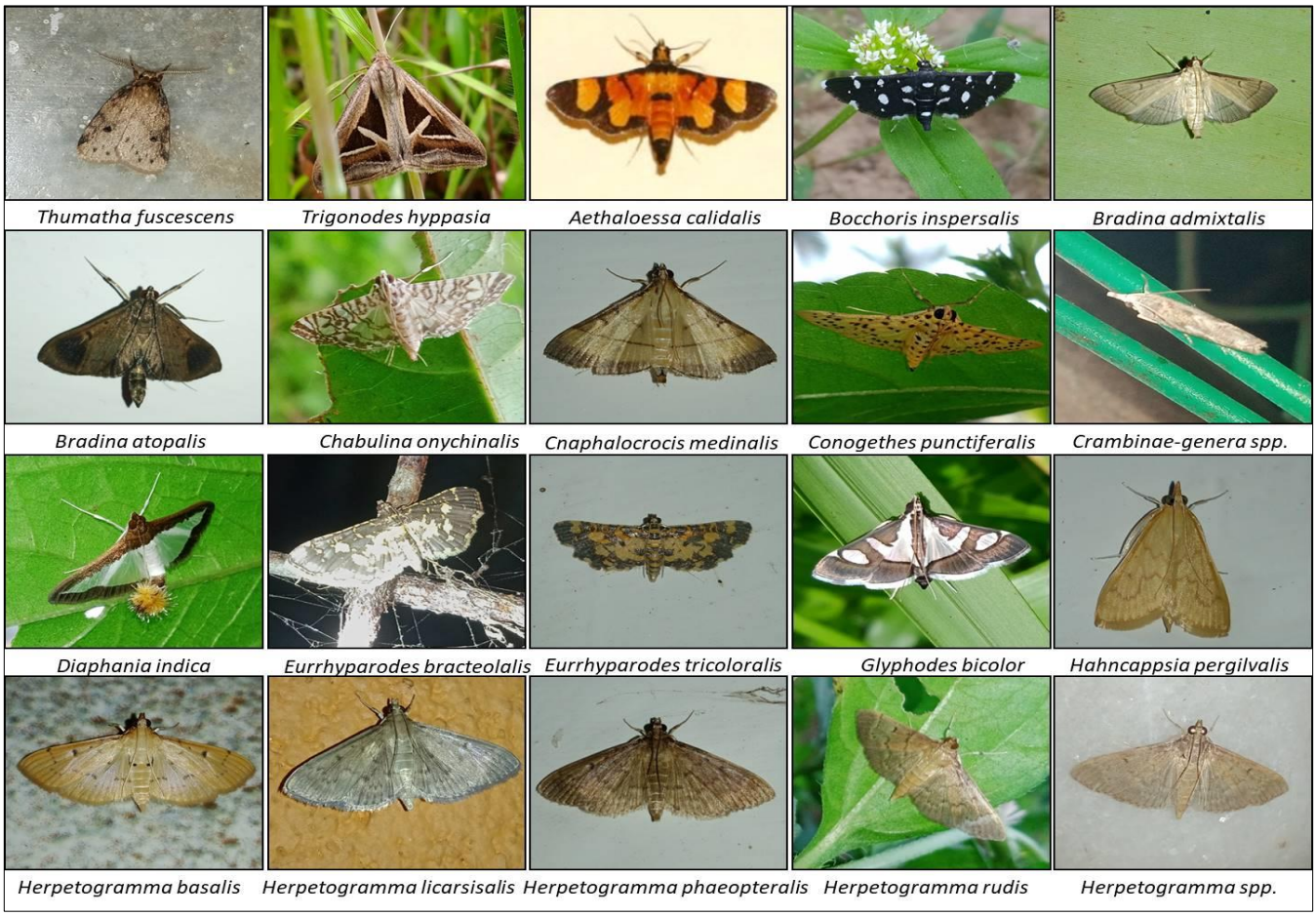

Plate 5

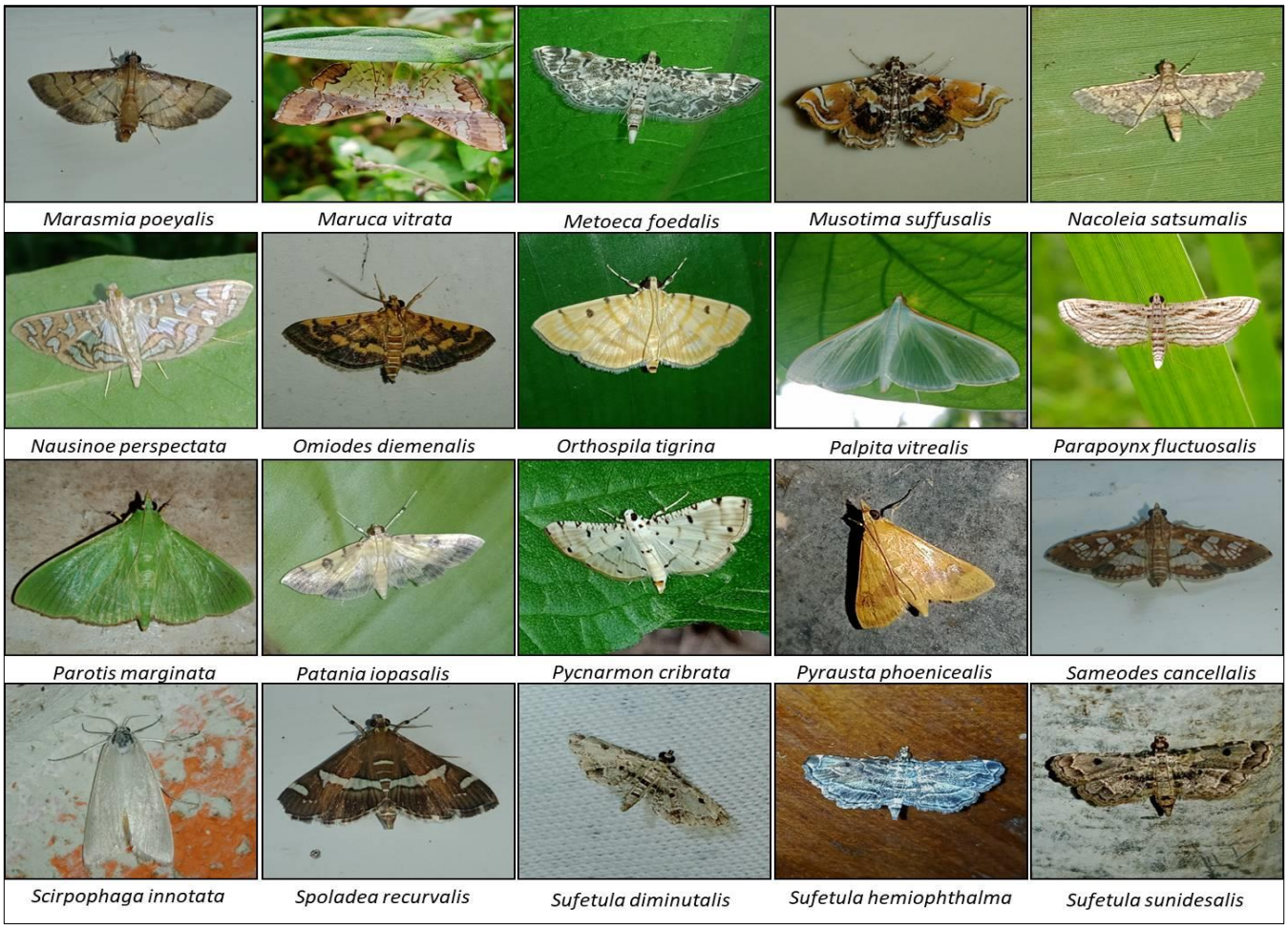

Plate 6

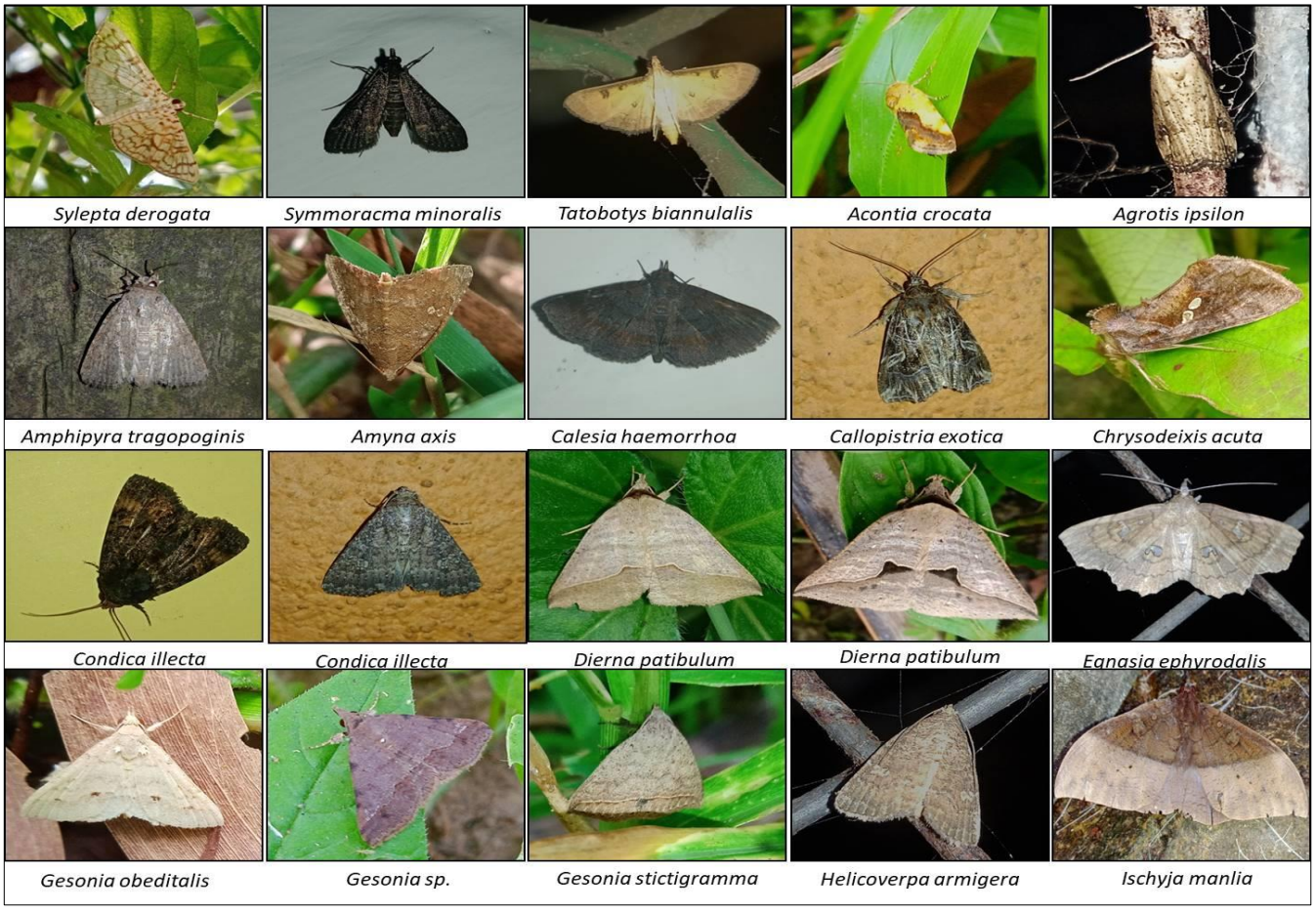

Plate 7

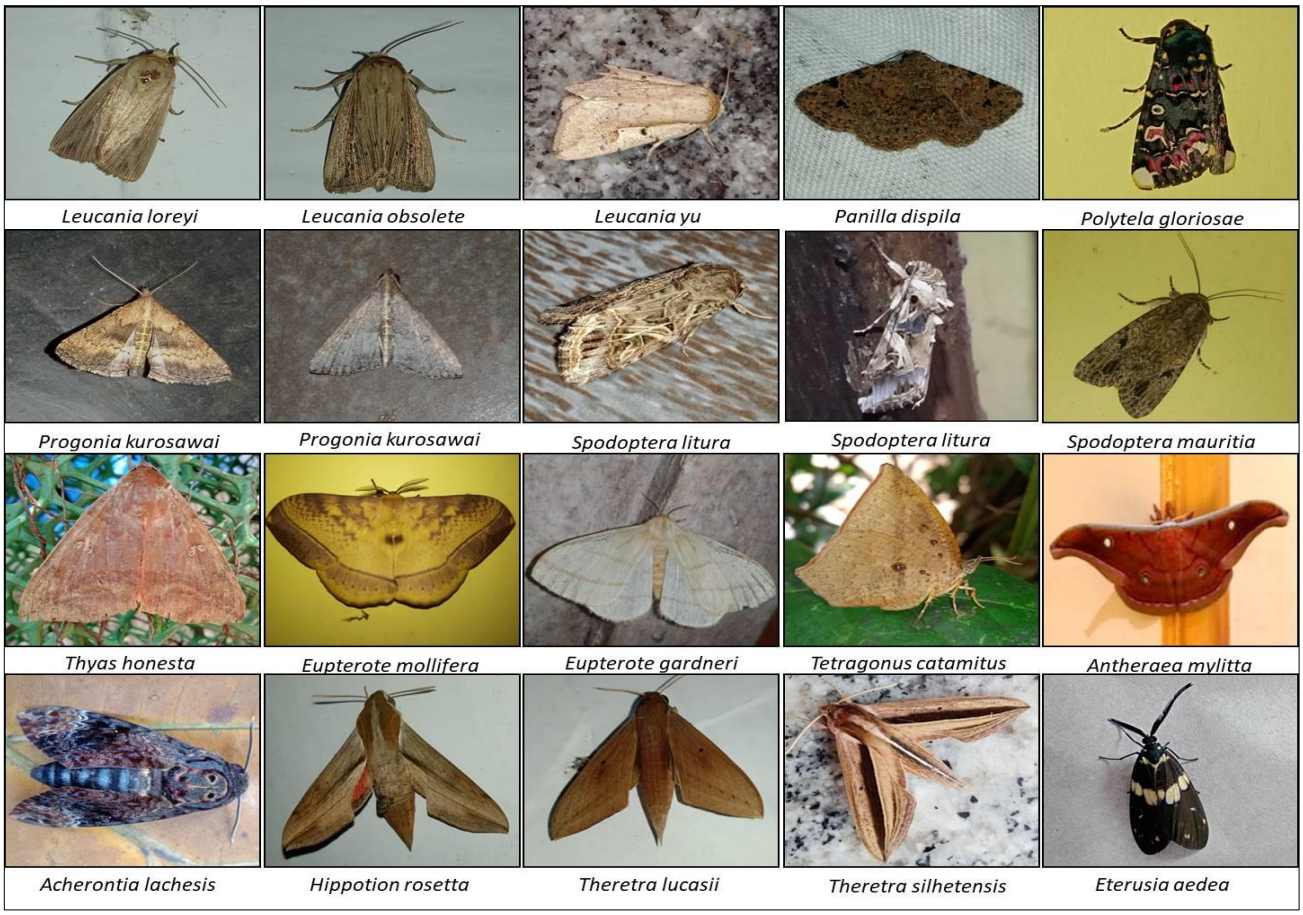

Plate 8

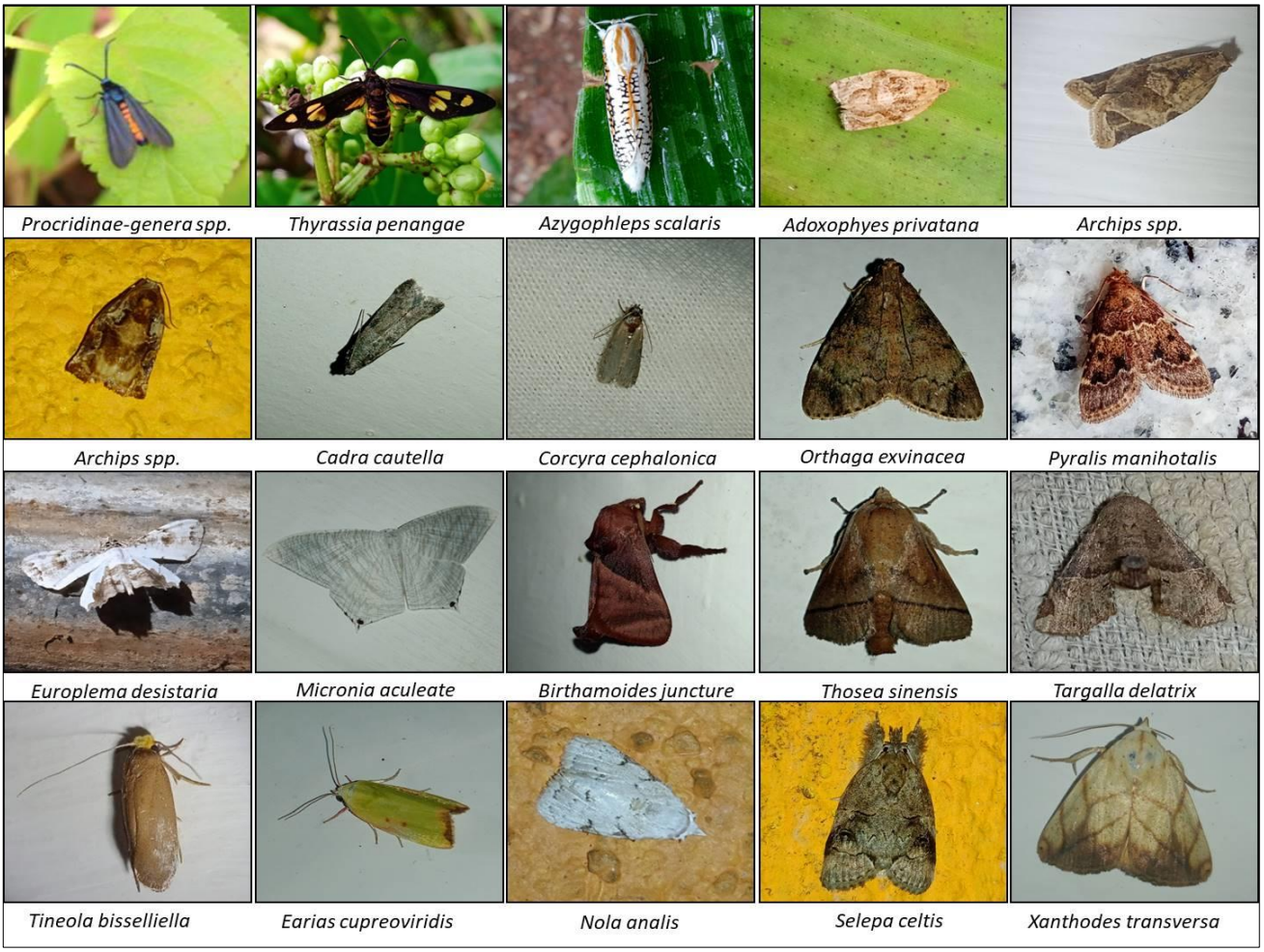

Plate 9

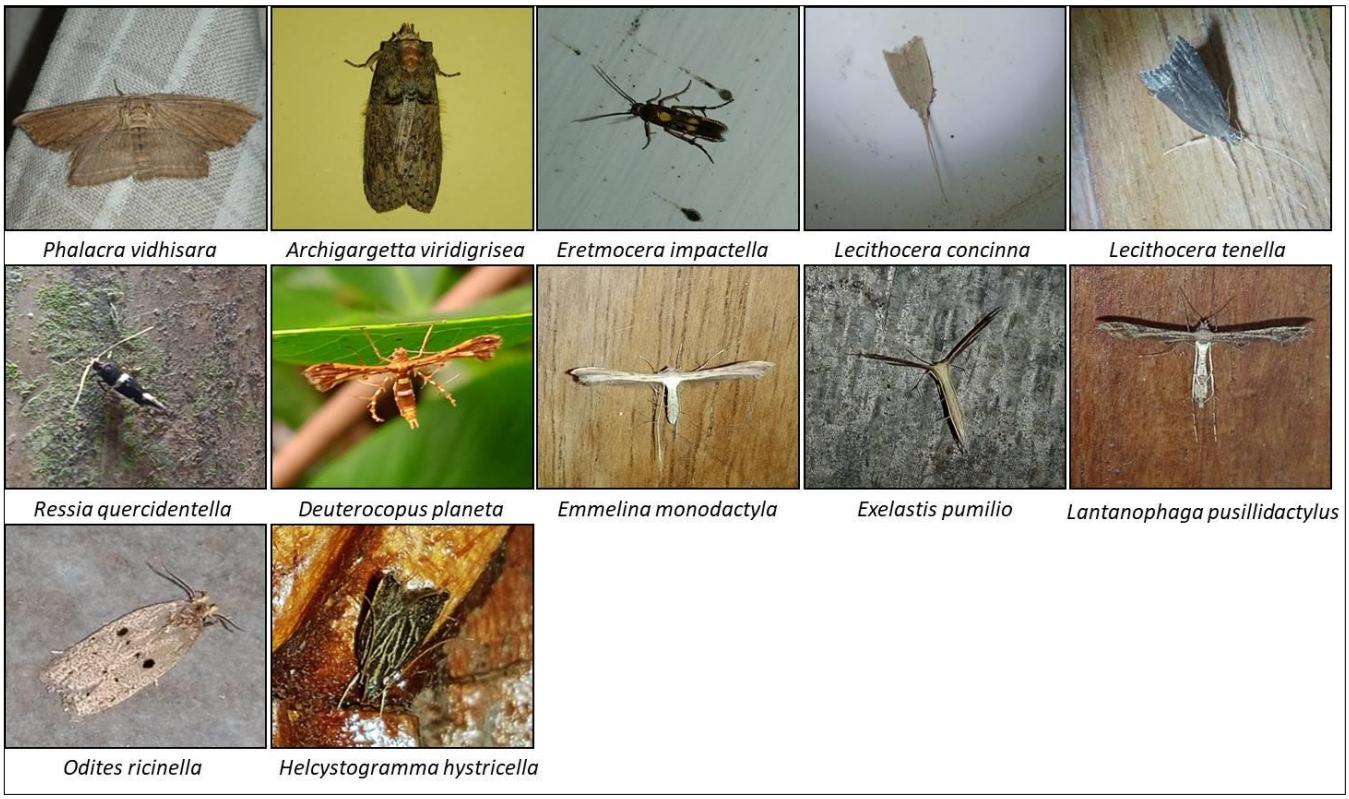

Plate 10

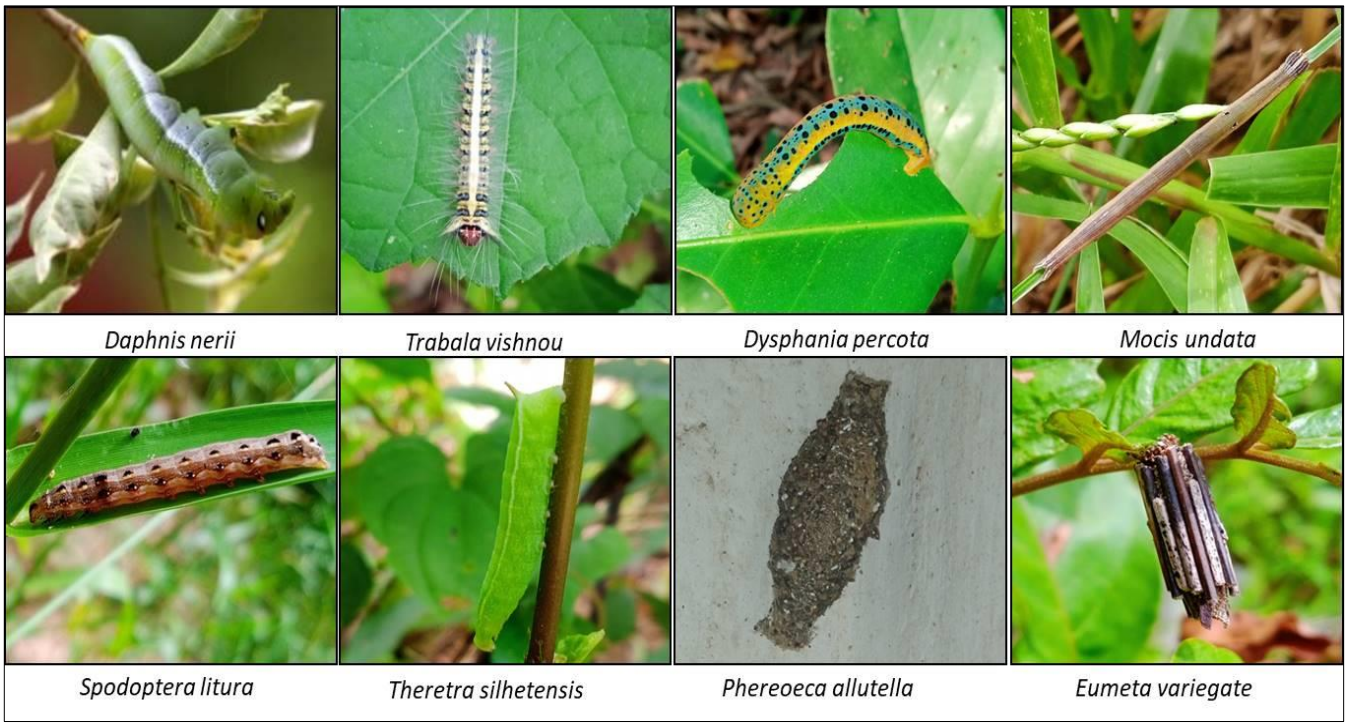

Plate 11

5. Discussion

In recent years, research into moth studies has gained momentum due to their ecological role in understanding biodiversity. Moths, from the order Lepidoptera have evolved into a taxonomic group that is particularly sensitive to climate and vegetation changes, making them an important group of insects for monitoring and assessing the effects of climate and habitat changes (Thomas, 2005) [22]. Goa has a varied topography with a variety of habitats that allow a variety of animal and plant species to thrive (Widdowson, 2009) [25]. The western coastal part of Goa forms the Konkan region, which is an uprising escarpment to the Western Ghat hill range (Radhakrishna, 1993; Gunnell and Radhakrishna, 2001; Kale and Shejwalkar, 2008; Radhakrishna et al., 2019). The Western Ghat Sahyadri hill range, which extends over 600 kilometers along eastern border of Goa, is a major hill range and an unexplored dense forest belt in the Western Ghat hotspot.

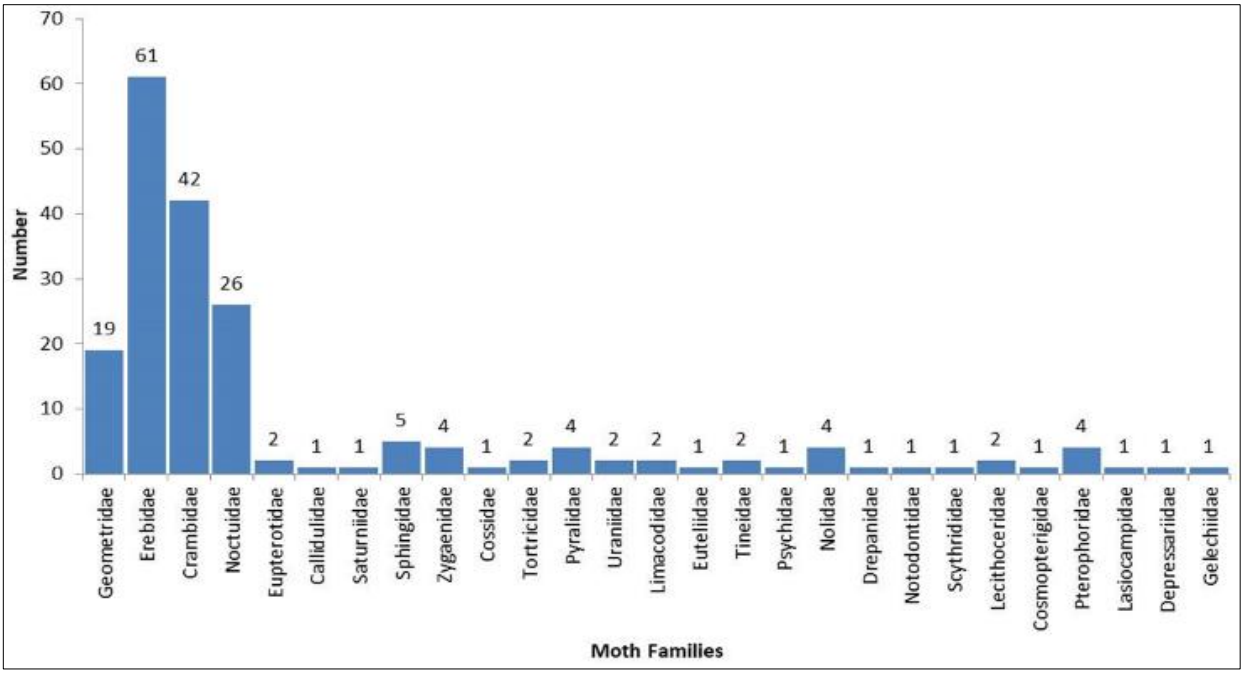

Fig 3: Species abundance of moth fauna compared to their families in Verna

Overall, Goa has a tropical monsoon climate dominated by equatorial forests. However, due to its location in the Torrid Zone and proximity to the Arabian Sea, Goa experiences a hot and humid climate almost throughout the year. These differences in climate as well as slopes, elevation, and drainage patterns influence the particular type of vegetation growth in this region. Goa is largely covered by tropical moist evergreen to wet evergreen forests with seasonal variations in growth, development and survival. In addition, there are also several mangrove areas along the coastal estuaries. The climate fluctuations in this region have a direct impact on the abundance of flora and fauna.

Moth diversity in particular has been shown in studies to play an important role in ecosystem services. Although Goa is a small Indian state, its moth diversity is said to be comparable to that of neighboring states of Maharashtra and Karnataka (Gurule and Brookes, 2021). However, the actual diversity and exploration of ground moth in Goa, as well as the nocturnal biodiversity in this ecologically rich region remains unknown. Previous studies on moths in Goa are extremely rare. A recent attempt to identify the moth species in Goa has revealed interesting insights into the diversity of moth species inhabiting in this tropical ecosystem (Gurule and Brookes, 2021). However, the University of Goa campus study shows the moth diversity in the higher laterite plateau region.

This study is the first report on moth diversity of Sal River in Goa. The study focuses on the taxonomy, distribution and ecological role of Sal River moths in Verna and provides valuable insect data for biodiversity research in Goa. The study area consists of a region of dense coconut plantation in a riverine area located at the foot of the plateau hills in Verna. The Sal River, which meanders through the flat sandy plains, is home to a wide variety of plants and creates a unique habitat for various species of moths. The Sal river plan is a unique, vast extensive low lying flat area distinct in this region, lithologically covered with sandy loam soil and used almost exclusively for the cultivation of rice and other ruby crops in this region. A total of 189 moth species were found and many of them were observed during day walks in the grasses of coconut plantations. However, most moth species were seen at night, visiting the tube lights in nearby settlement house walls. While some species overlap with previous studies, the discovery of several species such as *Tetragonus catamitus*, *Dysphania percota*, *Biston strigaria*, and *Acherontia lachesis* demonstrates the importance of local investigations (Gurule and Brookes, 2021). Of these 193 moth species 27 moth families were recorded, with the Erebidae, Crambidae, Noctuidae and Geometridae being the most speciose. Nearly 32% of moth species were Erebidae (61), indicating a dominant moth family group in this region. The family Crambidae includes 42 individuals representing 22%, and has a moderately large number of moths with larvae, which are graminoids that feed on grasses. The family Noctuidae, which represents a significant group of moth species with 13% and many individuals, are potential crop pest in this region. With 10% individuals, the Geometridae represent a fairly significant moth species population in this region. Apart from 3% of the Sphingidae moths, which functions primarily as nectar feeders and pollinators, the remaining individuals of the moth family are insignificant with less than 5 individuals.

There appears to be a direct connection between moth species and the rich natural plant species of the Sal Riverine plain. This study shows a correlation between the abundance and diversity of moths and the diverse plant species that live in this region. The delicate balance between these organisms is pivotal, and any disruption, such as habitat loss, overexploitation, and the looming threat of global climate change, could lead to the extinction of moth species. The Sal Riverine plain is characterized by a wide variety of plant species, including the predominant *Cocos nucifera* plantation and others such as *Barringtonia acutangula, Leea indica, Carallia brachiate, Pandanus tectorius, Alstonia scholaris, Holigarna arnottiana, Caryota urens, Streblus asper, Ixora coccinea, Memecylon wightii, Lannea coromandelica, Mangifera caesia, Phyllanthus reticulatus, Macaranga peltata, Ceiba pentandra, Careya arborea, Garcinia indica, Ficus benghalensis, Ficus racemosa,*

Tectona grandis, Mimusops elengi, Cinnamomum malabatrum, Thespesia populnea, Bridelia retusa, Antidesma ghaesembilla, Zanthoxylum rhetsa, Terminalia catappa, Ziziphus mauritiana, Lantana camara, Bambusa bambos and Syzygium caryophyllatum. This exploration shows the ecological interactions of different moth species with specific plant hosts. For example, *Dysphania percota* is the most widespread species, often confused with butterflies due to its daytime visibility, largely due to the widespread presence of Carallia brachiata, a tree species on which its larvae feeds extensively. The larvae of *Polytela gloriosae* thrive on the leaves of *Hymenocallis littoralis*, which flourish after the first monsoon rain, while the larvae of *Asota caricae* feed on Ficus plant species that are only sporadically present in the coconut plantation. *Deuterocopus spp.* is a common moth finds nectar mainly on plant species of the genus *Leea indica*. *Thyas honesta* a dominant moth that emerges at night, is probably due to the common occurrence of plant species such as *Barringtonia acutangula* as fresh mangrove and *Careya arborea* which are commonly found along the Sal River channel, as the moth larvae are known to feed on these plant species. *Barringtonia acutangula* is also an excellent plant species for erosion control. It's long, shallow spreading roots protect the soil from erosion. *Agathia laetata* is also a seasonally recurring moth, possibly due to the common plant *Ichnocarpus frutescens*, a weed vine that moth larvae are known to feed on. The presence of the moth *Thalassodes quadraria* in this region could be due to the plant species *Mangifera caesia* widespread in this region. *Eudocima materna, Eudocima phalonia* and *Eudocima hypermnestra* are seasonal fruit piercing moths that occur in this region primarily due to the introduced abundance of fruit tree species such as *Anacardium occidentale, Averrhoa carambola, Carica papaya, Psidium guajava, Musa × paradisiaca* and *Mangifera caesia.*

The grass ecosystems in this region support variety of moth species, with particular emphasis on families such as Crambidae, Geometridae, Erebidae and Noctuidae. Among these, the Crambidae stand out, accounting for a significant proportion of 22%, of all recorded species. The dominant moth species within the family Crambidae include *Bocchoris inspersalis, Bradina admixtalis, Maruca vitrata, Glyphodes bicolor, Diaphania indica, Chabulina onychinalis, Sameodes cancellalis, Eurrhyparodes tricoloralis, Hahncappsia pergilvalis, Herpetogramma basalis, Herpetogramma licarsisalis, Herpetogramma phaeopteralis, Marasmia poeyalis, Metoeca foedalis, Nausinoe perspectata, Parapoynx fluctuosalis, Spoladea recurvalis, Sufetula sunidesalis, and Tatobotys biannulalis.* Geometridae moths in grasses are dominated by species such as *Scopula emissaria, Scopula ornate, and Scopula umbilicata*. Meanwhile, Erebidae grass moths show diversity with species such as *Bocula diffisa, Dichromia sagitta, Eilema caniola, Eublemma anachoresis, Eublemma cochylioides, Euproctis chrysorrhoea, Euproctis similis, Grammodes geometrica, Hypena laceratalis, Miltochrista semifascia, Mocis frugalis, Mocis undata, Nygmia icilia, Perina nuda, Mecodina agrestis, Rivula sericealis, Spirama helicina, Syntomoides imaon, and Trigonodes hyppasia*. In addition, Noctuidae moths in grasses include species such as *Amyna axis, Chrysodeixis acuta, Dierna patibulum, Gesonia obeditalis,* and *Anomis flava*, which contribute to the overall richness of moth species in the ecosystem. Other common grass moths include *Lecithocera tenella,* and *Acontia crocata.*

Aroa spp. is a common morning flying moth. While *Argina astrea* may be due to the presence of the widespread *Crotalaria retusa*. *Nola analis* and *Hulodes caranea* are also common moths that visit the light source on the house wall in the evening hours. Another species of moth, *Pyralis manihotalis,* is found near chicken coops. *Cyana peregrine* and *Artena dotata*, whose presence in this ecosystem is probably due to the presence of the introduced plant species *Terminalia catappa* on which their larvae are known to feed and which contribute to the complex web of ecological relationships. Furthermore, Sphingidae species, particularly *Theretra lucasii* and *Theretra silhetensis*, emerge as the most frequently observed members of their family, while *Hippotion rosetta* exhibits the characteristic behavior of resting on fence nets in the morning.

Moth diversity in this region also shows a seasonal trend, with the highest species richness observed during the high rainy season and the lowest during the dry season, consistent with findings of prior studies (Fig. 2) (Wolda, 1988; Pinheiro et al., 2002). The high species richness in this region is due to the onset of rains from May to June, which results in lush vegetation that provides numerous food sources for the moth larvae. This pattern also reflects observations in butterfly populations and highlights the important role of climate, location, and monsoon in the emergence of moth species, their variation and abundance. The Sal River, which flows through the area, and the weirs prove to be a vital source of water, maintaining greenery and encouraging moth abundance during the extended season that lasts until March. A noticeable decline in moth abundance during the summer months (March to May) appears to be associated with a severe dry season, consistent with previous studies (Janzen and Schoener, 1968; Wolda, 1977). This comprehensive investigation reveals the complex interplay of climate, topography, and hydrology in shaping moth community dynamics in the Sal Riverine ecosystem of this region.

This investigation also examines the pervasive influence of moth species on agricultural crops in Verna and their role as major crop pests. The study identifies several moth species that pose a threat from sowing to harvest, potentially damaging important crops. The most well-known crop-damaging moths in this region include *Sylepta derogate* and *Helicoverpa armigera*, which attack *Abelmoschus esculentus*, while *Agrostis ipsilon* and *Helicoverpa armigera*, majorly affect *Vigna unguiculata,* and *Spodoptera frugiperda*, known for its damage to *Citrullus lanatus var. lanatus*. *Diaphania indica* is emerging as a major pest for *Cucurbita pepo* and *Cucumus sativus L.*, while *Anadevidia peponis* targets *Trichosanthes cucumerina*, and *Lagenaria siceraria*, posing a significant challenge to cultivation. Furthermore, *Spodoptera litura* is identified as a significant threat to *Allium cepa*.

This study in Verna, examines moth species, contributing to the overall insect diversity of Goa. Biodiversity is crucial to Goa sustainable development and represents its natural wealth. However, insects and plants worldwide are at risk from habitat loss, overexploitation, pollution, overpopulation and climate change. To address this issue, the current study emphasizes the need for additional research to identify, document and protect various insects in Verna. This investigation is an attempt to

develop strategies to protect biodiversity in Goa to address challenges such as habitat loss and climate change and to ensure conservation of the invaluable insect diversity that supports the ecological strength of the region and to protect coastal habitats in Goa.

6. Conclusion

The study assesses moth diversity and species composition in the ecosystem of Verna, Goa. A comprehensive moth collection in Verna yields a total of 193 species from 27 families, most of which were attracted to light during nocturnal observation. Of these, 183 species were photographed and presented in the current work. In particular, the family Erebidae was found to be the most diverse family in the study area. This study contributes to a better understanding of moth ecology in Goa by expanding the known species of moths and improving our understanding of their ecological roles in local ecosystems.

References

1. Brakefield PM, Liebert TG. Evolutionary dynamics of declining melanism in the peppered moth in The Netherlands. Proceedings of the Royal Society of London. Series B: Biological Sciences. 2000;267(1456):1953-1957.
2. Chandra KA, Nema DK. Insecta: Lepidoptera: Heterocera (Moths). Fauna of Madhya Pradesh (including Chhattisgarh), State Fauna Series. Zoological Survey of India. 2007;15(1):347-418.
3. Cho S, Mitchell A, Mitter C, Regier J, Matthews M, Robertson RO. Molecular phylogenetics of heliothine moths (Lepidoptera: Noctuidae: Heliothinae), with comments on the evolution of host range and pest status. Systematic Entomology. 2008;33(4):581-594.
4. Eisner T, Alsop R, Ettershank G. Adhesiveness of spider silk. Science. 1964;146(3647):1058-1061.
5. Fitt GP. The ecology of Heliothis species in relation to agroecosystems. Annual Review of Entomology. 1989;34(1):17-53.
6. Fullard JH. *Comparative hearing: insects*. Published by Springer New York, New York, NY, 1998, 279-326.
7. Goto K, Yagi S, Oku J, Tomura S, Yamaguchi D, Hirowatari T. Surveys on detritivorous moths using bait traps in Japan. Journal of Asia-Pacific Biodiversity. 2021;14(3):386-398.
8. Gunnell Y, Radhakrishna BP. Sahyādri: The Great Escarpment of the Indian Subcontinent, No., 2001, 47 (Published by Geological Society of India).
9. Janzen DH, Schoener TW. Differences in insect abundance and diversity between wetter and drier sites during a tropical dry season. Ecology. 1968;49(1):96-110.
10. Kale VS, Shejwalkar N. Uplift along the western margin of the Deccan Basalt Province: Is there any geomorphometric evidence? Journal of Earth System Science. 2008;117:959-971.
11. Kennedy JS, Marsh D. Pheromone-regulated anemotaxis in flying moths. Science. 1974;184(4140):999-1001.
12. Kent KS, Harrow ID, Quartararo P, Hildebrand JG. An accessory olfactory pathway in Lepidoptera: the labial pit organ and its central projections in Manduca sexta and certain other sphinx moths and silk moths. Cell and Tissue Research. 1986;245:237-245.
13. Kingsolver JG. Thermoregulation and flight in Colias butterflies: elevational patterns and mechanistic limitations. Ecology. 1983;64(3):534-545.
14. Macgregor CJ, Pocock MJ, Fox R, Evans DM. Pollination by nocturnal Lepidoptera, and the effects of light pollution: a review. Ecological Entomology. 2015;40(3):187-198.
15. Neil TR, Shen Z, Robert D, Drinkwater BW, Holderied MW. Moth wings are acoustic metamaterials. Proceedings of the National Academy of Sciences. 2020;117(49):31134-31141.
16. Neil TR, Shen Z, Robert D, Drinkwater BW, Holderied MW. Thoracic scales of moths as a stealth coating against bat biosonar. Journal of the Royal Society Interface. 2020;17(163):20190692.
17. Pierce NE. Predatory and parasitic Lepidoptera: carnivores living on plants. Journal of the Lepidopterists' Society. 1995;49(4):412-453.
18. Pinheiro MHO, Monteiro R, Cesar O. Levantamento fitossociologico da floresta estacional semidecidual do Jardim Botanico Municipal de Bauru, Sao Paulo. Naturalia. 2002;27:145-164 [In Portuguese].
19. Radhakrishna BP. Neogene uplift and geomorphic rejuvenation of the Indian Peninsula. Current Science, 1993, 787-793.
20. Sinu PA, Mallick S, Mandal P, Talukder TK. Egg-laying pattern of Hyposidra talaca (Lepidoptera: Geometridae) in Northeastern Indian tea plantations: implications for pest management. International Journal of Tropical Insect Science. 2013;33(1):8-13.
21. Sonak SM. Khazan ecosystems of Goa: Building on indigenous solutions to cope with global environmental change. Published by Springer Science & Business Media, 2013.
22. Thomas JA. Monitoring change in the abundance and distribution of insects using butterflies and other indicator groups. Philosophical Transactions of the Royal Society B: Biological Sciences. 2005;360(1454):339-357.
23. Vaughan N. The diets of British bats (Chiroptera). Mammal Review. 1997;27(2):77-94.
24. Warren MS, Bourn NA. Ten challenges for 2010 and beyond to conserve Lepidoptera in Europe. Journal of Insect Conservation. 2011;15:321-326.
25. Widdowson M. Evolution of laterite in Goa. Proceedings of natural resources of Goa: a geological perspective. Geological Society of Goa, Miramar Goa, 2009, 35-68.
26. Wilson WG, Harrison SP, Hastings A, McCann K. Exploring stable pattern formation in models of tussock moth populations. Journal of Animal Ecology. 1999;68(1):94-107.
27. Wolda H. Fluctuations in abundance of some Homoptera in a neo tropical forest. Geology, Ecology and Tropical Science. 1977;3:229-257.

28. Wolda H. Insect seasonality: why? Annual Review of Ecology and Systematics. 1988;19(1):1-18.
29. Yack JE, Fullard JH. Ultrasonic hearing in nocturnal butterflies. Nature. 2000;403(6767):265-266.
30. Zeng J, Xiang N, Jiang L, Jones G, Zheng Y, Liu B, et al. Moth wing scales slightly increase the absorbance of bat echolocation calls. PLoS One. 2011;6(11):e27190.