Entomology

Spatial diversity of Lepidoptera and Odonata species of Village Verna

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Abstract

Goa is an extension of the Western Ghat biodiversity hotspot, a tropical, bio-diverse region in India. However, basic literature on insect species in Goa on their abundance, distribution and ecology is still lacking. Documenting biodiversity in Goa is important to provide valuable biological information in order to set up the biodiversity conservation and protection strategies to combat rapid regional habitat loss and climate change. This study provides information on the biodiversity of Lepidoptera and Odonata species in one of the small village areas of Verna in South Goa. Verna, with its undulating terrain, is rich in bio-resources but is facing habitat loss due to land use changes in recent years. A total of 181 Lepidoptera species, including 142 butterfly species from 5 families and 39 species of moth from 11 families, as well as 33 species of Odonata, including 20 species of dragonflies from 3 families and 13 species of damselflies from 4 families, were observed in this village. The study also includes the first finding of *Protosticta gravelyi* in this village. This study data of Lepidoptera and Odonata species collected through photo documentation contribute to the insect population for biodiversity monitoring in Goa.

Keywords: environment, biodiversity, insects, lepidoptera, odonata, ecology, habitat

1. Introduction

Insect groups of the orders Lepidoptera (butterflies) and Odonata (dragonflies and damselflies) are distributed in almost all habitats of the tropical ecosystem. Insect species are crucial to the sustainable functioning of the ecosystem that forms the basis of the food web on which a variety of animal species depend for their nutrition (Calvert *et al*., 1969; Hale, 1973; Bukkens, 1997; Fagan *et al*., 2002; Finke, 2004; Thomas, 2005; Oonincx and Finke, 2021) [6, 12, 5, 8, 10, 23, 19]. The insect species diversity and their community composition as well as spatial variation can support the management and conservation of ecosystem biodiversity (Westman, 1990; Franklin, 1993; Srivastava and Vellend, 2005; Boieiro *et al*., 2023) [24, 11, 22, 4]. Conserving biodiversity is extremely important in response to threats from climate change due to rising global temperatures, intensive human activities leading to land use changes for construction of roads and settlement structures, the clearing of land for agriculture, the introduction of plant species, the excessive ground water extraction and man-made forest fires have an impact on the biodiversity of the ecosystem (Hansen *et al*., 2001; Mackey *et al*., 2008; Shivanna, 2022; Boieiro *et al*., 2023) [13, 16, 21, 4]. In recent years the biodiversity of various habitats of tropical ecosystems in Goa is prone to changes due to climate change as well as political and economic reforms and rampant industrial development. Lack of documentation of many plant and animal species in this region has made it extremely difficult to initiate biodiversity conservation efforts in Goa (Fernandes, 2024) [9]. Implementation of programs and strategies to protect biodiversity is necessary and their documentation can provide valuable information for the environment and species conservation. Butterflies are the most diverse group of insects with delicate and colorfully patterned wings. Butterflies with a complex migration network mostly inhabit treetops, agricultural fields, rivers/wetlands and open landscapes. Butterflies play an important role in ecosystem maintenance, primarily as pollinators and as a bio-indicator species for maintaining the ecology of an ecosystem (Petanidou and Ellis, 1993; Allen-Wardell *et al*., 1998; Kanaujia *et al*., 2015; Medina and Cabras, 2018) [20, 1, 15, 18]. Odonata, unlike predatory instincts, act as an important bio-control agent in maintaining insect species numbers, especially in wetlands (Batzer, and Wissinger, 1996; Kanaujia *et al*., 2015; Medina and Cabras, 2018) [2, 15, 18]. In this study, we provide information on the diversity and distribution of Lepidoptera and Odonata species in different habitats of the small village of Verna of Salcete in Goa, India, with the aim of documenting insect species and providing a reference work for biodiversity conservation efforts in this village.

2. Methods

Insects in this study, mainly Lepidoptera and Odonata, were photo-documented and some were observed visiting various locations and terrains during field surveys within the village. Insect species were photo-documented using the Redmi 9 camera. The observations have been carried out throughout the year since the beginning of 2024. No live specimens of insect species were collected in this study. Lepidoptera and Odonata species were identified using Google Lens, literature and images from online sources and websites such as Indiabiodiversity.org, www.mothsofindia.org and www.inaturalist.org.

For mapping the study area, the Goa Regional Plan 2021 (RPG-2021) of Village Panchayat Verna, Salcete Taluka, obtained from the Regional Plan Division Town and Country Planning Department, Government of Goa, was used to identify the village boundary. To carry out this village mapping, field surveys were conducted at various locations using Google Maps and Android GPS logger app. The data was analyzed and

village level distribution maps were created in the QGIS platform. The village boundaries depicting the village location, elevation profile, soil mapping, and drainage pattern were marked and the data was integrated into the QGIS platform and Google Earth Pro to create complete maps of the village.

3. Study area

The study area is a small village of Verna located in the southern district of Goa in India (Fig. 1) (Fernandes, 2024) [9]. This village has an area of ~1569 hectares and geographically located at 15º 20' 24'' N and 73º 56' 24'' E (Fig. 1). The region is characterized by undulating topography that is mostly hilly, plateau terrain in north east and low lying wide plains in the west (Fig. 2). The area experiences warm and humid climate with an average rainfall of about 292.6 cm/annum received during southwest monsoon and has a mean temperature of about 27.4 ºC.

Lateritic plateaus and hilly slopes cover most of the village area. In particular, the slopes are covered by dense tropical deciduous forest, whereas the plateau forms sparsely vegetated, wide spreading grasslands (Fig. 1). The roots of the hilly areas have crowded coconut gardens, which are mainly settlement areas. Ambulor Lake is a valley reservoir lake fed by numerous surrounding springs and channels of this hilly terrain. This lake is mainly used by the locals for irrigation, fishing and agriculture. The low-land consists of wide plains covered with sandy loam and occupied predominantly by agricultural fields, but also some wetlands (Fig. 2). The cultivated land, mainly used for the seasonal rice harvest, accounts for ~11.4% of the village (approximately 179 hectares) (Fig. 2). The River Sal, which originates in these sandy plains, flows south along the village boundary in the east, is a major source of irrigation for agriculture and has its own functioning unique ecosystem (Fig. 2).

In recent years the village has experienced significant changes in its land use pattern, mainly for settlements and businesses. This has resulted to buffer zones being breached, paddy fields being deliberately filled in, forests being cut down for the lucrative teak trees, huge roads constructions being plowed through once fertile farmland. The Verna industrial area, which forms a narrow strip on a plateau, has also continued to develop rapidly in the area along the north-eastern border of the village (Fig. 2). The Sal River, which flows under hilly terrain and is fed by this plateau as well as streams and channels flowing down from this industrial area is prone to pollution due to improper disposal of industrial and household waste, leading to the destruction of centuries-old natural drainage systems. In the past, this village has been a model of sustainable living for centuries, with its rich heritage and indigenous knowledge to maintain the village ecology with minimal environmental damage. The village has an abundance of natural resources that are not documented. The hill slopes of the plateau region remain an untapped micro-biodiversity hotspot with a wide variety of plant and animal species that are the least explored. There is a need to identify, document and protect the biodiversity resources of this village before they are irreversibly damaged by human activities.

The insect survey by photo sampling was conducted in different areas and locations which are indicated in the village map (Fig. 2). The main habitats include the banks of the River Sal, mainly as weed and grass covered riverine sandy plains with coconut gardens, wetlands and paddy fields, as well as the higher lateritic hill streams and sparsely forested shrubs/grasslands of the plateau areas (Fig. 3).

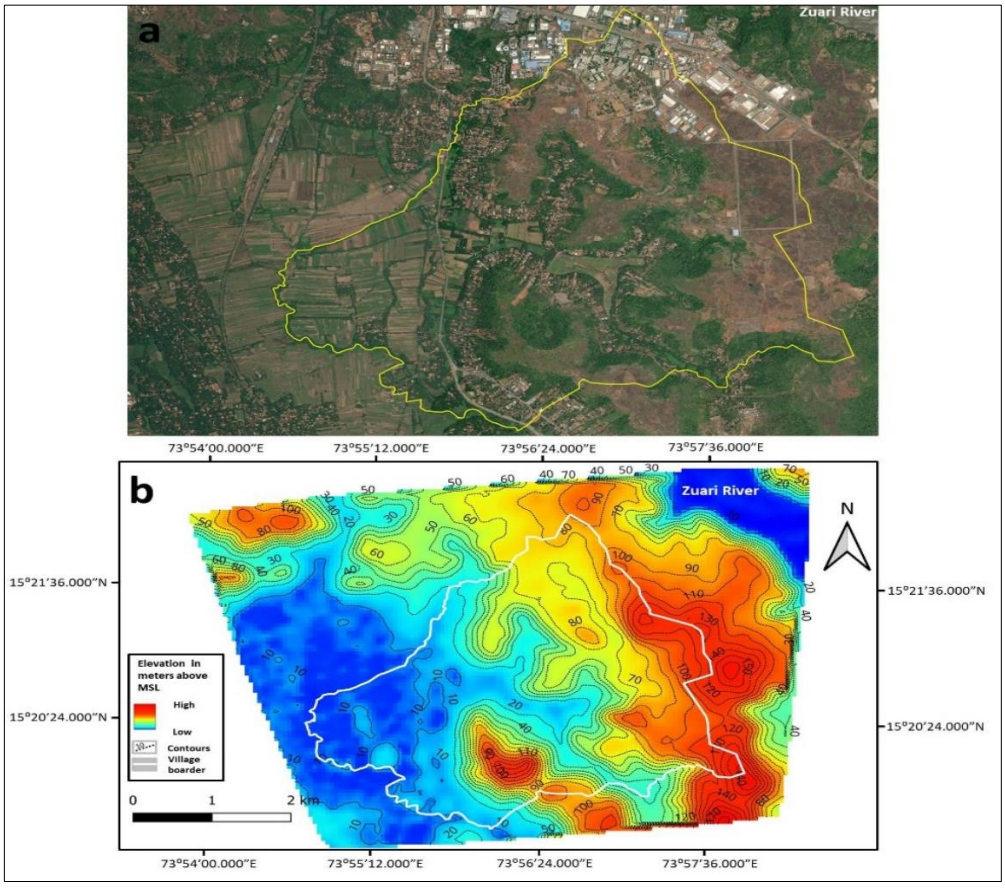

Fig 1: Verna village map a) showing satellite location map of the village, b) topography and elevation of the village

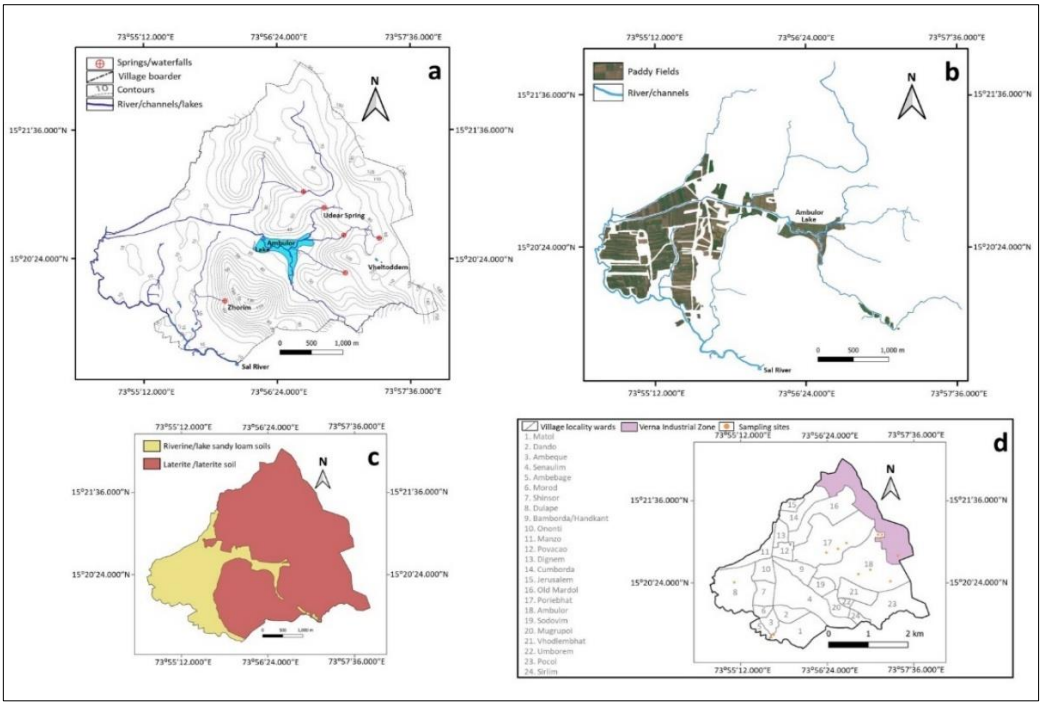

Fig 2: Verna village map a) showing drainage pattern consisting of springs, waterfall, river, lakes, streams, and channels, b) irrigation network of paddy fields by Sal river and Ambulor lake, c) surface soil map of the village, d) village locality ward map with marked industrial zone and showing the locations of the sampling areas of the village (orange dots)

Fig 3: a) Coconut canopy with underlying weeds and grasses, b) Sal river bank, c) paddy fields, d, e) grass lands in the higher plateau areas, during dry and after monsoonal rains, f) seasonally dried embankment Ambulor lake, g) monsoonal rain Mist water fall, h) natural perennial Udiar spring

4. Results

This study of insects in this village were primarily aimed to identify the diversity of Lepidoptera and Odonata species at different locations of the village to understand the ecology. Lepidoptera and Odonata species were identified and characterized into family groups on the basis of sightings and their photographic evidence. During our survey in this study, we observed a total of 214 Lepidoptera and Odonata species. Overall, we identified 181 Lepidoptera species from 16 different families and 33 Odonata species from 7 different families (Table 1 and 2).

In this insect survey, we found that Lepidoptera species of the family Nymphalidae *Junonia orithya* and *Cethosia mahratta* are only present in the higher grassland areas of the lateritic plateau of this village and are not observed in the lower sand plains (Fig. 4). Similarly, among Odonata one species of the family Platystictidae, *Protosticta gravelyi* is in low abundance found only on lateritic plateau slopes (Fig. 5). Some of the common plateau flowers that bloom in the post monsoon rains is also shown in Fig. 6.

Table 1: List of Lepidoptera species recorded in Verna, Goa

Specie Name	Family	Specie Name	Family
Byasa polla (De Nicéville, 1897)	Papilionidae	*Melanitis leda* (Linnaeus, 1758)	
Graphium agamemnon (Linnaeus, 1758)		*Melanitis phedima* (Cramer, 1780)	
Graphium doson (C. & R. Felder, 1864)		*Moduza procris* (Cramer, 1777)	
Graphium sarpedon (Linnaeus, 1758)		*Mycalesis mineus* (Linnaeus, 1758)	
Pachliopta aristolochiae (Fabricius, 1775)		*Mycalesis perseus* (Fabricius, 1775)	
Pachliopta hector (Linnaeus, 1758)		*Mycalesis visala* (Moore, 1858)	
Papilio buddha (Westwood, 1872)		*Neptis hylas* (Linnaeus, 1758)	
Papilio clytia (Linnaeus, 1758)		*Orsotriaena medus* (Fabricius, 1775)	
Papilio crino (Fabricius, 1792)		*Pantoporia hordonia* (Stoll, 1790)	
Papilio demoleus (Linnaeus, 1758)		*Parantica aglea* (Stoll, 1782)	
Papilio dravidarum (Wood-Mason, 1880)		*Parthenos sylvia* (Cramer, 1776)	
Papilio helenus (Linnaeus, 1758)		*Phalanta phalantha* (Drury, 1773)	
Papilio memnon (Linnaeus, 1758)		*Polyura athamas* (Drury, 1773)	
Papilio polymnestor (Cramer, 1775)		*Tanaecia lepidea* (Butler, 1868)	
Papilio polytes (Linnaeus, 1758)		*Tirumala limniace* (Cramer, 1775)	
Troides minos (Cramer, 1779)		*Tirumala septentrionis* (Butler, 1874)	
Belenois aurota (Fabricius, 1793)	Pieridae	*Vanessa cardui* (Linnaeus, 1758)	
Catopsilia pomona (Fabricius, 1775)		*Ypthima huebneri* (Kirby, 1871)	
Catopsilia pyranthe (Linnaeus, 1758)		*Abaratha ransonnetii* (C. Felder, 1868)	Hesperiidae
Cepora nerissa (Fabricius, 1775)		*Aeromachus pygmaeus* (Fabricius, 1775)	
Colotis amata (Fabricius, 1775)		*Ancistroides folus* (Cramer, 1775)	
Delias agostina (Hewitson, 1852)		*Ampittia dioscorides* (Fabricius, 1793)	
Delias eucharis (Drury, 1773)		*Badamia exclamationis* (Fabricius, 1775)	
Eurema blanda (Boisduval, 1836)		*Borbo bevani* (Moore, 1878)	
Eurema brigitta (Cramer, 1780)		*Borbo cinnara* (Wallace, 1866)	
Eurema hecabe (Linnaeus, 1758)		*Celaenorrhinus leucocera* (Kollar, 1848)	
Eurema laeta (Boisduval, 1836)		*Cephrenes acalle* (Hopffer, 1874)	
Hebomoia glaucippe (Linnaeus, 1758)		*Coladenia indrani* (Moore, 1865)	
Leptosia nina (Fabricius, 1793)		*Cymaenes tripunctus* (Herrich-Schäffer, 1865)	
Pareronia ceylanica (C. & R. Felder, 1865)		*Erionota torus* (Evans, 1941)	
Pareronia valeria (Cramer, 1776)		*Gangara lebadea* (Hewitson, 1886)	
Abisara bifasciata (Moore, 1877)	Lycaenidae	*Gangara thyrsis* (Fabricius, 1775)	
Acytolepis puspa (Horsfield, 1828)		*Hasora badra* (Moore, 1857)	
Arhopala amantes (Hewitson, 1862)		*Hasora chromus* (Cramer, 1782)	
Caleta decidia (Hewitson, 1876)		*Iambrix salsala* (Moore, 1865)	
Castalius rosimon (Fabricius, 1775)		*Matapa aria* (Moore, 1865)	
Catochrysops Strabo (Fabricius, 1793) *Cheritra freja* (Fabricius 1793)		*Notocrypta paralysos* (Wood-Mason & de Nicéville, 1881)	
Cupido lacturnus (Godart, 1824)		*Oriens goloides* (Moore, 1881)	
Curetis acuta (Moore, 1877)		*Parnara bada* (Moore, 1878)	
Curetis thetis (Drury, 1773)		*Pelopidas conjuncta* (Herrich-Schäffer, 1869)	
Euchrysops cnejus (Fabricius 1798)		*Pelopidas mathias* (Fabricius, 1798)	
Jamides celeno (Cramer, 1775) *Lampides boeticus* (Linnaeus, 1767)		*Pithauria stramineipennis* (Wood-Mason & de Nicéville, 1886)	
Leptotes plinius (Fabricius, 1793)		*Potanthus omaha* (H. Edwards, 1863)	
Loxura atymnus (Cramer, 1782)		*Pseudocoladenia dan* (Fabricius, 1787)	
Luthrodes pandava (Horsfield, 1829)		*Sarangesa dasahara* (Moore, 1865)	
Neopithecops zalmora (Butler, 1870)		*Spialia galba* (Fabricius, 1793)	
Prosotas dubiosa (Semper, 1879)		*Suastus gremius* (Fabricius, 1798)	
Prosotas nora (R. Felder, 1860)		*Tagiades japetus* (Stoll, 1782)	
Pseudozizeeria maha (Kollar 1844)		*Tagiades litigiosa* (Möschler, 1878)	

Rathinda amor (Fabricius, 1775)		*Taractrocera ceramas* (Hewitson, 1868)	
Spalgis epius (Westwood, 1851)		*Telicota colon* (Fabricius, 1775)	
Spindasis vulcanus (Fabricius, 1775)		*Agathia laetata* (Guenée, 1858)	Geometridae
Surendra quercetorum (Moore, 1857)		*Hyperythra lutea* (Stoll, 1781)	
Talicada nyseus (Guerin, 1843)		*Scopula emutaria* (Hübner, 1809)	
Tarucus extricates (Butler 1886)		*Araeopteron sp.* (Hampson, 1893)	Erebidae
Zesius chrysomallus (Hübner, 1819)		*Bastilla simillima* (Guenée, 1852)	
Zizeeria karsandra (Moore, 1865)		*Bocula sp.* (Guenée, 1852)	
Zizina otis (Fabricius, 1787)		*Britha biguttata* (Walker, 1866)	
Zizula hylax (Fabricius, 1775)		*Erebus ephesperis* (Hübner, 1827)	
Acraea terpsicore (Linnaeus, 1758)	Nymphalidae	*Eublemma abrupta* (Walker, 1865)	
Ariadne ariadne (Linnaeus, 1763)		*Eudocima hypermnestra* (Cramer, 1780)	
Ariadne merione (Cramer, 1777)		*Hulodes caranea (Cramer, 1780)*	
Cethosia mahratta (C. & R. Felder, 1867)		*Hypena eductalis* (Walker, 1859)	
Charaxes solon (Fabricius, 1793)		*Hypena mandatalis* (Walker, 1859)	
Cirrochroa thais (Fabricius, 1787)		*Lacera procellosa* (Butler, 1879)	
Cupha erymanthis (Drury, 1773)		*Miltochrista ila* (Moore, 1859)	
Danaus chrysippus (Linnaeus, 1758)		*Orgyia postica* (Walker, 1855)	
Danaus genutia (Cramer, 1779)		*Pantydia metaspila* (Walker, 1858)	
Discophora sondaica (Boisduval, 1836)		*Rhesala moestalis* (Walker, 1866)	
Doleschallia bisaltide (Cramer, 1777)		*Simplicia rectalis* (Eversmann, 1842)	
Dophla evelina (Stoll, 1790)		*Syntomoides imaon* (Cramer, 1780)	
Elymnias caudata (Butler, 1871)		*Thyas honesta* (Hübner, 1824)	
Elymnias hypermnestra (Linnaeus, 1763)		*Agrioglypta itysalis* (Walker, 1859)	Crambidae
Euploea core (Cramer, 1780)		*Isocentris filalis* (Guenée, 1854)	
Euripus consimilis (Westwood, 1850)		*Meroctena tullalis* (Walker, 1859)	
Euthalia aconthea (Cramer, 1777)		*Nomophila noctuella* (Denis & Schiffermüller, 1775)	
Euthalia lubentina (Cramer, 1777)		*Urola nivalis* (Drury, 1773)	
Hypolimnas bolina (Linnaeus, 1758)		*Helicoverpa armigera* (Hübner, 1808)	Noctuidae
Hypolimnas misippus (Linnaeus, 1764)		*Polytela gloriosae* (Fabricius, 1781)	
Idea malabarica (Moore, 1877)		*Progonia kurosawai* (Owada, 1987)	
Junonia almana (Linnaeus, 1758)		*Agrius convolvuli* (Linnaeus, 1758)	Sphingidae
Junonia atlites (Linnaeus, 1763)		*Endotricha flammealis* (Denis & Schiffermüller, 1775)	Pyralidae
Junonia hierta (Fabricius, 1798)		*Hypsopygia intermedialis* (Walker, 1862)	
Junonia iphita (Cramer, 1779)		*Micronia aculeate* (Guenée, 1857)	Uraniidae
Junonia lemonias (Linnaeus, 1758)		*Dysodia laevis* (Warren, 1900)	Thyrididae
Junonia orithya (Linnaeus, 1758)		*Selepa celtis* (Moore, 1858)	Nolidae
Kallima horsfieldii (Kollar, 1844)		*Canephora hirsute* (Poda, 1761)	Psychidae
Lethe europa (Fabricius, 1787)		*Plutella xylostella* (Linnaeus, 1758)	Plutellidae
Lethe rohria (Fabricius, 1787)			

Table 2: List of Odonata species recorded in Verna, Goa

Specie Name	Family	Specie Name	Family
Acisoma panorpoides (Rambur, 1842)	Libellulidae	*Copera marginipes* (Rambur, 1842)	Platycnemididae
Brachythemis contaminate (Fabricius, 1793)		*Copera vittata* (Selys, 1863)	
Crocothemis servilia (Drury, 1773)		*Protosticta gravelyi* (Laidlaw, 1915)	
Diplacodes trivialis (Rambur, 1842)		*Agriocnemis pygmaea* (Rambur, 1842)	Coenagrionidae
Lathrecista asiatica (Fabricius, 1798)		*Ceriagrion cerinorubellum* (Brauer, 1865)	
Macrodiplax cora (Kaup, 1867)		*Ceriagrion coromandelianum* (Fabricius, 1798)	
Neurothemis tullia (Drury, 1773)		*Enallagma signatum* (Hagen, 1861)	
Orthetrum luzonicum (Brauer, 1868)		*Ischnura aurora* (Brauer, 1865)	
Orthetrum pruinosum (Burmeister, 1839)		*Neurobasis chinensis* (Linnaeus, 1758)	
Orthetrum sabina (Drury, 1770)		*Pseudagrion decorum* (Rambur, 1842)	
Pantala flavescens (Fabricius, 1798)		*Pseudagrion rubriceps* (Selys, 1876)	
Potamarcha congener (Rambur, 1842)		*Ictinogomphus rapax* (Rambur, 1842)	Gomphidae
Rhodothemis rufa (Rambur, 1842)		*Vestalis gracilis* (Rambur, 1842)	Calopterygidae
Rhyothemis variegate (Linnaeus, 1763)		*Libellago indica* (Fraser, 1928)	Chlorocyphidae
Tholymis tillarga (Fabricius, 1798)		*Gynacantha dravida* (Lieftinck, 1960)	Aeshnidae
Tramea limbata (Desjardins, 1832)			
Trithemis pallidinervis (Kirby, 1889)			
Zyxomma petiolatum (Rambur, 1842)			

Fig 4: a) *Cethosia mahratta*, b) *Junonia orithya*, c) *Phalanta phalantha*, d) *Junonia lemonias*, e) *Euthalia lubentina*, f) *Ariadne ariadne*, g) *Acraea terpsicore*, h) *Elymnias caudata*, i) *Orsotriaena medus*, j) *Castalius rosimon*, k) *Rathinda amor*, l) *Zesius chrysomallus*, m) *Aeromachus pygmaeus*, n) *Ancistroides folus*

Fig 5: a) *Protosticta gravelyi*, b) *Vestalis gracilis*, c) *Libellago indica*, d) *Rhyothemis variegata*, e) *Orthetrum sabina*

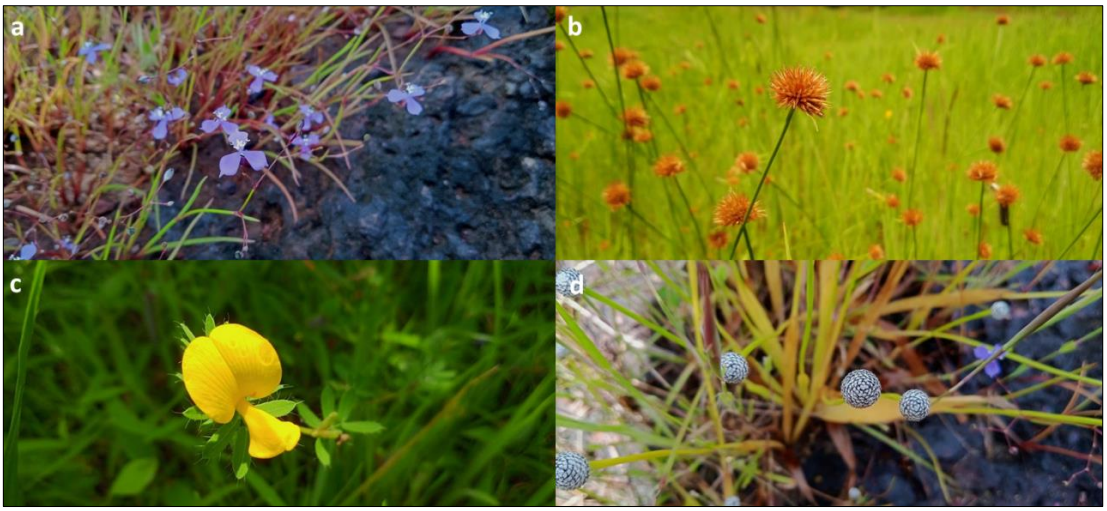

Fig 6: Common mountain flowers a) *Murdannia semiteres*, b) *Rhynchospora wightiana*, c) *Smithia sensitiva*, d) *Eriocaulon heterolepis*

5. Discussion

This study was carried out to identify insect species and study their distribution in Verna village with respect to different habitats and elevation gradient. The insect groups Lepidoptera and Odonata play an important role in the functioning of an ecosystem and their occurrence, numbers and distribution are sensitive to changes such as climate change and changes in their habitat associated with urbanization (Hansen *et al*., 2001; Thomas, 2005; Mackey *et al*., 2008; Shivanna, 2022; Boieiro *et al*., 2023) [13, 23, 16, 21, 4]. In particular, the diversity of Lepidoptera and Odonata species in Verna with its hilly terrain is characterized by a diverse habitat and species distribution over short distances. The biodiversity of Lepidoptera moth species recently reported in this village exhibits a rich abundance of taxonomic groups, suggesting that their abundance depends on monsoon rainfall (Fernandes, 2024) [9]. However, there are a number of factors related to urbanization in this region that may impact the ecology of this village. Previous studies have shown that insect diversity and species richness decrease depending on spatial extent and degree of urbanization (Blair and Launer, 1997; McKinney, 2008; Concepción *et al*., 2015; Herrmann *et al*., 2023) [3, 17, 7, 14]. This study of insect abundance and distribution in this village could help identify and monitor the impact of urbanization on the biodiversity resources of this village.

During this study, we observed mainly Lepidoptera and Odonata, species at 13 sites in Verna village, which includes various habitats such as the banks of the Sal River, and agricultural fields, but also higher lateritic plateaus and their streams, as well as industrial areas, improving the insect species inventory to collect novel data on spatial biodiversity in the village (Fig. 2 and 3). A total of 181 Lepidoptera species and 33 Odonata species were found, recorded in different areas of the village. Overall, the Lepidoptera and Odonata and other insect species found in this study are representative of the Western Ghat hotspot. There are many species that are missed in this insect survey and thus further study on insects could help fill the gap and learn more about the insect population of this village.

Insect population is shown to vary depending on the season, in particular the number and diversity of butterflies depends on the monsoon rains. A pattern is observed with the onset of monsoon in Lepidoptera species. The species *Eurema hecabe*, *Catopsilia pomona*, *Catopsilia pyranthe*, and *Cupha erymanthis* occur in abundance in the few months after the arrival of the monsoon, mainly due to mountain grass growth, while in the lower plains *Leptosia lina*, *Ypthima huebneri*, and *Melanitis leda* are abundant. Butterfly species such as *Eurema hecabe*, *Catopsilia pomona*, and *Catopsilia pyranthe*, later migrates down to the lower plain areas. The family Hesperiidae shows a uniform pattern in different locations and feeds largely on the flower nectar of small plants. Nevertheless, Hesperiidae are relatively smaller in the grasslands of the plateau areas and are commonly found as *Aeromachus pygmaeus*, *Iambrix salsala* and *Potanthus omaha*. The frequently observed and widespread butterfly species in the village mainly include *Pachliopta hector*, *Pachliopta aristolochiae*, *Papilio polymnestor*, *Euploea core*, *Graphium Agamemnon*, *Graphium doson Delias eucharis*, *Hypolimnas misippus*, *Hypolimnas bolina*, *Junonia almana*, *Junonia atlites*, *Junonia iphita*, *Neptis hylas*, *Tanaecia lepidea*, *Catopsilia pomona*, *Catopsilia pyranthe*, *Eurema hecabe*, *Leptosia lina*, *Danaus chrysippus*, *Danaus genutia*, and *Acraea terpsicore*. The junonia species shows a progressive trend from *Junonia iphita*, *Junonia atlites*, *to Junonia almana*. It is observed that the *Junonia lemonias*, and *Acraea terpsicore* are more abundant in the plateau area during the dry season spotted within the dry grasses, especially the *Junonia orithya* appears in these plateau areas during this period. *Parantica aglea* and *Euploea core* found associated are more common in the lower levels along with the other species such as *Pachliopta hector*, *Pachliopta aristolochiae*, *Papilio polymnestor*, *Graphium Agamemnon*, *Graphium doson Delias eucharis*, *Hypolimnas misippus*, *Hypolimnas bolina*, *Junonia almana*, *Junonia atlites*, *Junonia iphita*, *Neptis hylas*, *Tanaecia lepidea*, *Euthalia acanthea*, *Catopsilia pomona*, *Catopsilia pyranthe*, *Eurema hecabe*, *Leptosia lina* and *Ypthima huebneri*,. The *Elymnias caudata* is often found near coconut trees, and the *Lethe europa* is also found in areas with bamboo plantations. The Lepidoptera *Junonia orithya* and *Cethosia mahratta* also only occur in the higher plateau areas, but not in the lower plains (Fig. 4). Cicadas are more common in spring season. Butterflies are more common in open grasslands than in the dense forest canopy, particularly along the plateau slopes. The Odonata species show no variation, but the damselflies are only found near flowing streams, lakes, swamps and around the Sal River. In comparison, the Sal

riverine plain has a greater diversity of insect species than the forested plateau slopes and grasslands. One particular Odonata specie, *Protosticta gravelyi*, is not commonly observed in this village (Fig. 5). This species is found only in the streams of the densely forested plateau slopes.

Interestingly, the species diversity and distribution of Lepidoptera and Odonata species were found to vary across the different locations of the village, suggesting the need for further study into the population size of individual species as well as their seasonal variation and spatial distribution and in this village. Furthermore, it is necessary to sample additional sites and habitats of the village to identify the different species that may not be sampled in this study. Analysis of diversity and distribution of Lepidoptera and Odonata species, which are relatively common in this Verna, is common in the Western Ghat hotspot that can cope with variety of ecological condition of this village. We found that the average number of Lepidoptera and Odonata species gradually increases with species diversity at the onset of monsoon rains and is directly dependent on vegetation growth for their larval development. In winter, the adult butterflies appear to benefit from the large variety of flowers on the host plants. The Odonata rely on rainfall, which supplies the streams and recharges the aquatic ecosystem for the development of their larvae. Their number increases at the same time as predators that hunt other insects and control their population.

6. Conclusion

The study presents information on the diversity of Lepidoptera and Odonata species in the representative habitats of Verna village in Goa, which is aimed at setting a reference for documenting biodiversity resource and monitoring biodiversity in this village. The banks of the Sal River and the higher laterite plateau areas are rich in insect diversity. However, insect biodiversity in Verna is threatened by rampant urbanization, forest fires due to climate change and deforestation. The Lepidoptera and Odonata species are important bio indicators. Lepidoptera and Odonata, which show different species in this study, provide valuable information that contributes to the insect species inventory of this village, which is representative of the Western Ghat hotspot. Based on this study, some of the reported rare Lepidoptera and Odonata species in this village require recognition, monitoring and protection status.

References

1. Allen-Wardell G, Bernhardt P, Bitner R, Burquez A, Buchmann S, Cane J, *et al*. The potential consequences of pollinator declines on the conservation of biodiversity and stability of food crop yields. Conservation Biology, 1998, 8-17.
2. Batzer DP, Wissinger SA. Ecology of insect communities in nontidal wetlands. Annual Review of Entomology. 1996;41(1):75-100.
3. Blair RB, Launer AE. Butterfly diversity and human land use: Species assemblages along an urban gradient. Biological conservation. 1997;80(1):113-125.
4. Boieiro M, Antunes S, Figueiredo H, Soares A, Lopes A, Monteiro E, *et al*. Standardized inventories of lepidopterans and odonates from Serra da Estrela Natural Park (Portugal)-setting the scene for mountain biodiversity monitoring. Biodiversity Data Journal, 2023, 11.
5. Bukkens SGF. The nutritional value of edible insects. Ecology of Food and Nutrition. 1997;36:287-319.
6. Calvert CC, Martin RD, Morgan NO. House fly pupae as food for poultry. Journal of Economic Entomology. 1969;62:938-939.
7. Concepción ED, Moretti M, Altermatt F, Nobis MP, Obrist MK. Impacts of urbanization on biodiversity: the role of species mobility, degree of specialization and spatial scale. Oikos. 2015;124(12):1571-1582.
8. Fagan WF, Siemann E, Mitter C, Denno RF, Huberty AF, Woods HA, *et al*. Nitrogen in insects: implications for trophic complexity and species diversification. The American Naturalist. 2002;160(6):784-802.
9. Fernandes D. A preliminary study of moth species of verna. Journal of Applied Entomologist. 2024;4(1):29-42.
10. Finke MD. The nutrient content of insects. In: Capinara, J.L. (ed.) *Encyclopedia of entomology*. Vol 2. Kluwer Academic Publishers, Dordrecht, the Netherlands, 2004, 1562-1575.
11. Franklin JF. Preserving biodiversity: species, ecosystems, or landscapes? Ecological applications. 1993;3(2):202-205.
12. Hale OM. Dried Hermetia illucens (Stratiomyidae) as a feed additive for poultry. Journal of the Georgia Entomological Society. 1973;8:16-20.
13. Hansen AJ, Neilson RP, Dale VH, Flather CH, Iverson LR, Currie DJ, *et al*. Global change in forests: responses of species, communities, and biomes: interactions between climate change and land use are projected to cause large shifts in biodiversity. BioScience. 2001;51(9):765-779.
14. Herrmann J, Buchholz S, Theodorou P. The degree of urbanisation reduces wild bee and butterfly diversity and alters the patterns of flower-visitation in urban dry grasslands. Scientific Reports. 2023;13(1):2702.
15. Kanaujia A, Kumar A, Kushwaha S, Kumar A. Diversity of odonates (dragonflies and damselflies) and lepidopteran (butterflies) fauna of Nawabganj Bird Sanctuary, Unnao District, Uttar Pradesh, India. Advances in Bioresearch. 2015;6(2):72-78.
16. Mackey BG, Watson JE, Hope G, Gilmore S. Climate change, biodiversity conservation, and the role of protected areas: an Australian perspective. Biodiversity. 2008;9(3-4):11-18.
17. McKinney ML. Effects of urbanization on species richness: a review of plants and animals. Urban Ecosystems. 2008;11:161-176.
18. Medina MND, Cabras AA. Assessment of Odonata and Lepidoptera Fauna of the University of Mindanao Matina, Davao City, Philippines. University of Mindanao International Multidisciplinary Research Journal, 2018, 3(1).
19. Oonincx DGAB, Finke MD. Nutritional value of insects and ways to manipulate their composition. Journal of insects as food and feed. 2021;7(5):639-659.

20. Petanidou T, Ellis WN. Pollinating fauna of a phryganic ecosystem: composition and diversity. Biodiversity Letters, 1993, 9-22.
21. Shivanna KR. Climate change and its impact on biodiversity and human welfare. Proceedings of the Indian National Science Academy. 2022;88(2):160-171.
22. Srivastava DS, Vellend M. Biodiversity-ecosystem function research: is it relevant to conservation? Annu. Rev. Ecol. Evol. Syst. 2005;36(1):267-294.
23. 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.
24. Westman WE. Managing for biodiversity. BioScience. 1990;40(1):26-33.