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Comparative Assessment of Butterfly and Pollinator Diversity across Urban and Semi-Natural Ecosystems of Tripura, Northeast India

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Abstract

As a key pollinator and ecological indicator, butterflies play a crucial role in the functioning of terrestrial ecosystems. The paper provides an overall assessment of butterfly and general pollinator diversity in two ecologically distinct environments in Tripura, namely, Oxygen Park, a managed urban green space in Agartala and Silachari, a semi-natural deciduous forest in South Tripura. Field surveys were conducted during the pre-monsoon season (April-May 2024) and recorded 30 butterfly species at Oxygen Park and 30 pollinator taxa at Silachari, including 18 butterfly species. The families of dominant butterflies were Nymphalidae and Lycaenidae. The species diversity indices indicated that heterogeneity of species was higher in Silachari (H′=3.8) as compared to Oxygen Park (H′=3.1). The presence of endemic and specialist species like *Cirrochroa aoris* and *Neptis reducta* in forest habitat and presence of adaptable generalists like *Danaus chrysippus* and *Eurema hecabe* in urban green spaces falls in line with the expectancy of the species predation and feeding preferences. The results support the complementary role of the two landscapes in sustaining the community of pollinators and promote ecosystem-level conservation across the urban and nature ecosystems. The study also underlines an urgent necessity to develop integrated conservation plans with an eye on landscape level connectivity and pollination services to guarantee ecological resilience in the face of urbanisation and habitat fragmentation.

Keywords: Butterfly diversity, Conservation strategy, Pollinator ecology, Semi-natural forests, Tripura, Urban biodiversity

Introduction

The insects constitute over half of the known biodiversity in the world (May, 1992) and play significant roles in ecological services like pollination, nutrient cycle, seed dispersal and transfer of energy across trophic levels (Naeem *et al.*, 1994; Tilman, 1996). This is important particularly in tropical areas where the richness and abundance of insect population is quite outstanding (Samways, 2005; Spector, 2006). Among these, butterflies are one of the most studied insect groups in the world, because of their charismatic appearance, taxonomic clarity and susceptibility to ecological changes, which make them effective bioindicators of habitat quality and anthropogenic disturbance (Kocher and Williams, 2000; Ghazoul, 2002). Anthropogenic activities and land-use changes have a measurable impact on butterfly species richness and abundance, as reported by Agarwala and Majumder (2020).

More than 18000 species of butterflies have been characterized all over the world (Martinez *et al.*, 2003; Bonebrake *et al.*, 2010); several of which are instrumental in pollination, especially in tropical lands were the plant-pollinator associations tend to be specialized. However, according to Anonymous (2025), the present-day count of described butterfly species has reached to approx. 18,500, which reflects ongoing taxonomic efforts and discoveries. There are more than 1,500 species recorded in the Indian subcontinent, a significant percentage of these are in the Northeast, which is a part of the Indo-Burma biodiversity

Article History

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hotspot (Myers *et al.*, 2000). Despite this richness, there remains a paucity of long-term monitoring and comprehensive ecological studies on butterflies in Tripura (Lodh and Agarwala, 2015).

Moreover, the interaction of ecological resilience of butterfly communities with anthropogenic pressure has been gaining recent attention. Studies conducted by Hazarika *et al.* (2023) and Chakraborty and Dhara (2024) showed that a combination of habitat fragmentation, floral resource loss and pesticides exposure collectively affect the species turnover, especially in the biodiversity hotspots, such as the Indo-Burma region. Urban green-spaces may serve as the substitute habitats, but it is seldom sufficient as a habitat of forest-dependent and endemic taxa unless ecologically sensitive planning and green diversity is considered (Mukherjee and Hossain, 2024).

The tropical semi-evergreen, evergreen and the moist deciduous forests with bamboo breaks are the features of Tripura, which occupies only 10,491 km^2. It forms a unique ecological pathway between the Indo-Gangetic plains and the Indo-Burma region. Earlier records on butterfly species documented 76 species in Tripura (Majumder *et al.*, 2012; 2013), which is relatively lower in comparison with the neighbouring states, such as Meghalaya (104 species), Sikkim (695 species) and Assam (962 species) (Figure 1). This gap reveals that many thorough and consistent surveys are required in this region.

Probably one of the most important factors in maintenance of terrestrial ecosystems is the pollinators, especially butterflies. More than 75% of flowering plants and nearly 35% of crop production globally relies upon them to reproduce (Klein *et al.*, 2007) and thus they directly influence the food security, biodiversity and resilience of ecosystems. Nevertheless, over the past decades, it has been calculated that the number of pollinators is decreasing dramatically around the world because of the destruction of habitats, over-exploitation of agricultural pesticides, climate change and disease (Potts and Piotto, 2010). Such stressors are especially sharp in agroforestry mosaics and urbanising areas of Northeast India.

Silachari in Karbook, Gomati district of Tripura is an ecologically diverse topography that exhibits natural forest, seasonal wet lands, agricultural lands and forest-edge settlements. This mosaic provides a heterogeneous habitat that is ideal to sustain pollinator communities. However, there is little research literature on the diversity of pollinators in Tripura and the majority of earlier investigations have focused on isolated observations or protected zones of the forests (Majumdar *et al.*, 2016).

The importance of pollinators to an agro-ecosystem is widely recorded. Garibaldi *et al.* (2013) highlighted the role of habitat heterogeneity as a contributor to increasing diversity of pollinators and high crop yields. Similarly, land-use change and pesticide exposure are the two important factors that decrease the pollinator richness in Eastern India, as found by Chakrabarti *et al.* (2015; 2018) and Bhattacharya and Basu (2018). Simultaneously, Singh *et al.* (2021) acknowledged the role of indigenous communities in preserving pollinator habitats through traditional methods such as mixed cropping and forest conservation.

There are few region-specific studies that link the presence of pollinators with ecological integrity in the forests of Tripura. According to Majumdar *et al.* (2016), landscapes covered by forests support a variety of butterflies and bees communities, with the significant presence of endemic taxa. Moreover, Chakrabarti *et al.* (2015) and Kumar *et al.* (2018) indicated alarming trends in the decline of pollinators in NE India caused by pesticide residues and habitat fragmentation.

The present study aims to fill this gap by evaluating on a comparative assessment of the butterfly and general pollinator diversity in two ecologically distinct habitats: Oxygen Park (an urban green-zone in Agartala) and Silachari Forest (a semi-natural forest in South Tripura). The objectives of this study are:

i) To evaluate and compare species richness, diversity and abundance of butterflies and other insect pollinators within the forest and urban landscapes.

ii) To identify the endemic species, specialist and indicator taxa within the habitats.

iii) To understand the habitat utilisation trends and ecological forces of pollinator diversity.

iv) To provide evidence for conservation plans, restoration ecology and long-term biodiversity monitoring in Tripura.

The study contributes to the wider agenda of sustainable development by linking the conservation of biodiversity with landscape-management and ecosystem services in the Indo-Burma biodiversity hotspot.

Materials and Methods

Study Sites

Site I: Oxygen Park, Agartala (Urban Green Space)

The first study location, Oxygen Park is located in Salbagan, Gandhigram lies, within the city of Agartala, Tripura, India (Latitude 23.8818° N, Longitude 91.2872° E). It is a polycultural park developed by the Tripura Forest Department, covering about 29.6 hectares, which has both landscaped areas and semi-natural vegetation. Its distinctive vegetation contains a high variety of plant species, including *Shorea robusta* (Sal), *Careya arborea* (Khumbi), *Nymphaea lotus* (Water lily), *Sterculia villosa* (Udal), *Microcos paniculata* (Pichandi), *Bambusa bambos* (Thorny bamboo), *Swietenia mahagoni* (Mahogany), *Terminalia bellirica* (Baheda), *Artocarpus lacucha* (Dehua), *Ziziphus rugosa* (Banbarai) and *Litchi chinensis* (Litchi). Although it attracts a considerable volume of tourist activity, certain areas are quite undisturbed and can provide microhabitats for butterflies and other insect pollinators.

Site II: Silachari, Karbook Subdivision, Gomati District (Semi-Natural Forest)

The second study site is Silachari in Karbook Subdivision under Gomati District of Tripura (Latitude 23.23159° N, Longitude 91.7735° E and elevation 49 m). This region has several landscapes which include forested hills, agricultural lands and wetland edges. The floral composition consists of a mix of wild and cultivated species, which includes *Nymphaea lotus*, *Hibiscus rosa-sinensis*, *Bougainvillea glabra*, *Mangifera indica*, *Psidium guajava* and *Musa paradisiaca*. The major trees found in the canopy of this forest are *Shorea robusta*, *Tectona grandis* (Teak), *Albizia lebbeck* (Siris), *Ficus benghalensis* (Banyan) and *Azadirachta indica* (Neem). It possesses a constant source of water that comes through form a stream helping in its supply of water and it has little anthropogenic pressure making it an ideal place of conducting a research on pollinators.

Sampling Strategy and Survey Design

The field surveys were conducted during the pre-monsoon season between April and May 2024. Both sites were sampled using a standardised protocol, comprises direct observations, visual encounter surveys as well as photographic documentation on sunny days.

i) In Oxygen Park, surveys were conducted on 15 separate occasions covering all accessible microhabitats through random walks and point sampling.

ii) In Silachari, pollinator observations were conducted twice weekly using a modified Pollard Walk method along a fixed 500 m transect and random point checks. Each visit covered two time periods: morning (8:00-10:00 AM) and evening (4:00-6:00 PM).

Two observers conducted the surveys in both sites. The total sampling radius in Silachari extended approximately 20 km^2, encompassing varied habitats including forest margins and agricultural patches.

Environmental data such as ambient temperature, relative humidity and sky conditions were recorded during each sampling session using standard handheld instruments to account for abiotic influences on pollinator visibility and activity. The park site was covered using meandering transects due to its managed nature, while linear Pollard walk transects of 500 m were used in Silachari to ensure comparability with previous studies in forest ecosystems. All observations were made by the same trained observers to reduce bias.

Species Identification and Documentation

All butterfly and insect pollinator species encountered were photographed in the field using a mobile camera. Identification was done using a combination of field guides and taxonomic keys, including:

i) Evans (1932), Wynter-Blyth (1957), Corbet and Pendlebury (1992), D'Abrera (1982, 1984, 1986), Larsen (2004), Colin Smith (2006) and Kehimkar (2008).

ii) Regional reference materials such as The Faunal Wealth of Tripura - A Compilation (Tripura Forest Department).

Morphological features such as wing venation, antenna shape, colouration, scale patterns and specialised feeding/ mouthparts were used to confirm taxonomic identity. Habitat associations and floral interactions were recorded ad libitum. Species data were tabulated for comparative analysis of abundance and diversity.

1. *Cyclosia paoilionaris*

2. *Catopsila pyranthe*

3. *Pantoporia hordonia*

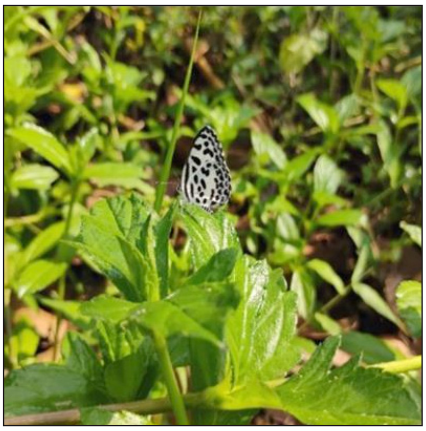
4. *Tanaecia lepidae*

5. *Athyma perius*

6. *Mycalesis mineus*

Figure 1: Continue...


7. *Mycalesis visala*

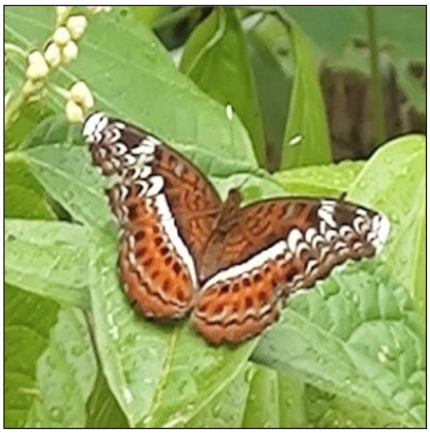

8. *Castalius rosimon*


9. *Arhopala bazalus*


10. *Junonia lemonias*


11. *Junonia iphita*


12. *Papilio nephelus*


13. *Lebadea martha*


14. *Pseudozizeeria maha*


15. *Euploea core*


16. *Hypolimnas bolina*


17. *Papilio clytia*


18. *Orsotriaena medus*

Figure 1: Continue...

19. *Rapala suffusa*

20. *Caltoris canaraica*

21. *Anthene lycaenina*

22. *Pachliopta aristolochiae*

23. *Euchrysops cnejus*

24. *Troides helena*

25. *Eurema hecabe*

26. *Charaxes athamas*

27. *Arhopala atrax*

28. *Arhopala centaurus*

29. *Ypthima baldus*

30. *Lethe europa*

Figure 1: Butterflies of Tripura

Data Analysis

The identification of the species was initially based on field observations, followed by validation with reference to authoritative sources of information including Kunte (2000) and Kehimkar (2008). Additional verification was also done through other databases such as the Butterflies of India portal and the Global Biodiversity Information Facility (GBIF).

Quantitative data analysis was conducted using R statistical software. These tools facilitated the computation of ecological indices to assess diversity and distribution patterns across the two habitats. The indices used include:

i) Shannon-Wiener Diversity Index (H'): to evaluate species richness and heterogeneity;

ii) Simpson's Dominance Index (D): to estimate the dominance of abundant species;

iii) Pielou's Evenness Index (J'): to understand species distribution uniformity.

These indices provide a multidimensional understanding of species composition and ecosystem stability, offering a robust basis for comparative interpretation between the urban (Oxygen Park) and semi-natural (Silachari) habitats.

Results and Discussion

Butterfly Diversity in Oxygen Park

During the survey conducted in Oxygen Park, a total of 30 butterfly species were recorded, which were belonging to 6 different families (Figure 2; Table 1). Among these, the family *Nymphalidae* have emerged as the most dominant in the rainforest (Figure 1), comprising 14 species (46.7%), followed by *Lycaenidae* (8 species), *Papilionidae* (4 species), *Pieridae* (2 species), *Zygaenidae* (1 species) and *Hesperiidae* (1 species). The dominance of *Nymphalidae* is in agreement with the previous studies in tropical ecosystems (Eswaran and Pramod, 2005; Padhye *et al.*, 2006; Krishnakumar *et al.*, 2007), due to polyphagous feeding habits, high dispersal capabilities and flexibility to diverse floral resources, which enables them to have a competitive advantage.

There were some prominent species like *Euploea core* and *Hypolimnas bolina* which were encountered frequently. Such species are habitat generalists that have high tolerance to anthropogenic landscapes and they tend to prefer open, sunlit habitats with ornamental and wild flowering plants. The observed richness could be due to the availability of nectar resources and host plants as well as low levels of disturbance in some sections of the park.

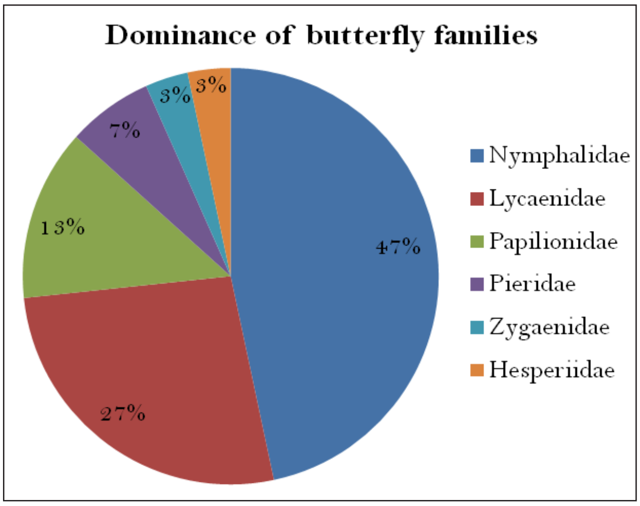


Figure 2: Butterfly family composition at Oxygen Park

Literature comparisons reveal similar dominance patterns. The current study is supported the findings of Nair *et al.* (2018), who found that the proportion of *Nymphalidae* was quite high during their survey in Lembucherra, Tripura. Similarly, Dutta *et al.* (2024) stated the *Nymphalidae* as the most dominant family in a recreational park in Diphu, Karbi Anglong. These parallels support the ecological role of this family in the managed green-spaces of Northeast India.

Pollinator Diversity in Silachari Forest

The Silachari site recorded a total of 30 pollinator taxa, which comprises 18 butterfly species, 5 beetles, 4 wasps and 3 dragonflies (Table 2; Figure 3). Such value of high taxonomic diversity shows that the pollination network within the semi-natural forest ecosystem performs effectively. The key butterfly species were *Neptis reducta*, *Hypolimnas bolina* and *Tirumala limniace* that were consistently observed across transects. These species have a reputation of existing in forests and could be commonly associated with dense understorey vegetation and indigenous flowering trees.

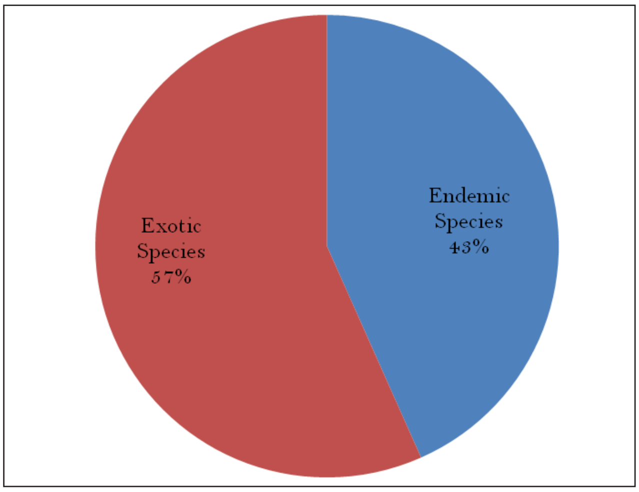


Figure 3: Endemic vs. exotic pollinators in Silachari

There were also abundant numbers of beetles (*Coleoptera*), wasps (*Hymenoptera*) and dragonflies (*Odonata*), which reflects the structural and microclimatic heterogeneity of the habitat. The presence of a nearby perennial stream likely provided essential supply of water and humidity control for larval development and adult activity.

Changes in environmental conditions, such as ambient temperature, relative humidity and seasonal floral abundance, have influenced the effect on pollinator foraging and flight activity. Rates of diversity and encounter were higher during the morning hours than evident in the evening. Continuous availability of floral resources was ensured due to the diversity of flowering plant species that include Bougainvillea, the *Mangifera indica*, the *Ficus benghalensis*, among others, thereby maintaining stable pollinator populations (Figure 4).

Table 1: Butterfly species recorded from Oxygen Park, Salbagan, Agartala, West Tripura

Sl. No.	Scientific Name	Family	Common Name	Habitat Preference
1	*Charaxes athamas*	Nymphalidae	Common Nawab	Forest Edge
2	*Ypthima baldus*	Nymphalidae	Common Five-ring	Grassland/ Shaded
3	*Lethe europa*	Nymphalidae	Bamboo Treebrown	Forest Understorey
4	*Tanaecia lepidea*	Nymphalidae	Grey Count	Forest Edge
5	*Athyma perius*	Nymphalidae	Common Sergeant	Forest Trail
6	*Pantoporia hordonia*	Nymphalidae	Common Lascar	Secondary Growth
7	*Mycalesis mineus*	Nymphalidae	Dark-brand Bush Brown	Shaded Bushes
8	*Mycalesis visala*	Nymphalidae	Long-brand Bushbrown	Forest Understorey
9	*Junonia lemonias*	Nymphalidae	Lemon Pansy	Garden/ Grassland
10	*Junonia iphita*	Nymphalidae	Chocolate Pansy	Garden Edge
11	*Euploea core*	Nymphalidae	Common Crow	Generalist
12	*Lebadea martha*	Nymphalidae	The Knight	Forest Margin
13	*Hypolimnas bolina*	Nymphalidae	Great Eggfly	Urban/ Woodland
14	*Orsotriaena medus*	Nymphalidae	Medus Brown	Dense Understorey
15	*Arhopala atrax*	Lycaenidae	Indian Oakblue	Canopy Specialist
16	*Arhopala centaurus*	Lycaenidae	Centaur Oakblue	Forest Canopy
17	*Arhopala bazalus*	Lycaenidae	Powdered Oakblue	Forest Canopy
18	*Castalius rosimon*	Lycaenidae	Common Pierrot	Urban/ Open
19	*Pseudozizeeria maha*	Lycaenidae	Pale Grass Blue	Grassland
20	*Rapala suffusa*	Lycaenidae	Suffused Flash	Forest Shrub Layer
21	*Anthene lycaenina*	Lycaenidae	Pointed Ciliate Blue	Forest Edge
22	*Euchrysops cnejus*	Lycaenidae	Gram Blue	Grassland/ Open
23	*Catopsilia pyranthe*	Pieridae	Mottled Emigrant	Open/ Garden
24	*Eurema hecabe*	Pieridae	Common Grass Yellow	Open/ Grassland
25	*Papilio nephelus*	Papilionidae	Yellow Helen	Semi-forest
26	*Papilio clytia*	Papilionidae	Common Mime	Moist Forest
27	*Pachliopta aristolochiae*	Papilionidae	Common Rose	Garden/ Forest Margin
28	*Troides helena*	Papilionidae	Common Birdwing	Primary Forest
29	*Caltoris canaraica*	Hesperiidae	Kanara Swift	Grass and Bamboo
30	*Cyclosia papilionaris*	Zygaenidae	Drury's Jewel	Moist Forest

Note: Habitat preference is categorised based on ecological plasticity observed in similar studies (Eswaran and Pramod, 2005; Kehimkar, 2008)

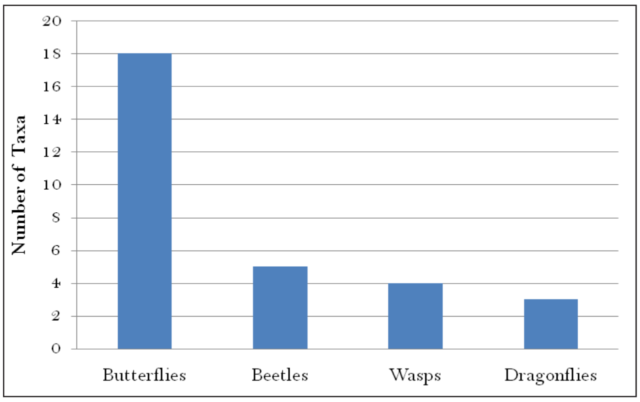


Figure 4: Pollinator group distribution in Silachari

The two sites consist of different types of ecological diversity that reflects the habitat architecture. Generalists and mobile nectar foragers occurred in all urban parkland, whereas canopy specialists, shade-loving taxa and endemic forest butterflies were favoured by the semi-natural matrix in Silachari. The fact that Silachari observed a higher evenness index (J'=0.85), further implies that the species distribution is more equitable, also suggests a reduced dominance of any single taxon and improved community stability.

Evenness Index values were 0.894 and 0.840, respectively for the two sites (Figure 5). These indices collectively show the difference in species richness and evenness between the two sites (Figure 6).

Table 2: Pollinator Species Observed at Silachari Forest, Karbook of Gomati, Tripura

Sl. No.	Scientific Name	Family	Common Name	Status	Habitat Preference
1	*Diplacodes trivialis*	Libellulidae	Ground Skimmer	Exotic	Wetlands/ Paddy Fields
2	*Brachythemis contaminata*	Libellulidae	Ditch Jewel	Exotic	Rice Field Borders
3	*Neurothemis fulvia*	Libellulidae	Fulvous Forest Skimmer	Exotic	Marshland
4	*Palpopleura juncunda*	Libellulidae	Happy Dragonfly	Exotic	Wetlands
5	*Orthetrum pruinosum*	Libellulidae	Crimson-tailed Marsh Hawk	Exotic	Streamside Vegetation
6	*Castalius rosimon*	Lycaenidae	Common Pierrot	Endemic	Open Urban Gardens
7	*Anthene Lycaenidae*	Lycaenidae	Dark Ciliate Blue	Endemic	Forest Shrub Layer
8	*Hypolimnas bolina*	Nymphalidae	Great Eggfly	Endemic	Urban/ Woodland
9	*Junonia iphita*	Nymphalidae	Chocolate Pansy	Endemic	Garden/Light Woodland
10	*Neptis reducta*	Nymphalidae	Short-banded Sailer	Endemic	Forest Glade
11	*Euthalia aconthea*	Nymphalidae	Common Baron	Endemic	Shady Forest Path
12	*Cirrochroa aoris*	Nymphalidae	Large Yeoman	Endemic	Dense Forest
13	*Delias pasithoe*	Pieridae	Redspot Jezebel	Endemic	Secondary Forest Edge
14	*Syntomoides imaon*	Erebidae	Handmaiden Moth	Endemic	Moist Forests
15	*Anticarsia gemmatalis*	Erebidae	Velvetbean Caterpillar	Exotic	Agricultural Fields
16	*Nyctemera coleta*	Erebidae	Rice Swift	Endemic	Forest Edge
17	*Xiphelmium amplipennis*	Tettigoniidae	Broad-winged Bush Katydid	Exotic	Shrubs
18	*Conocephalus malaenus*	Tettigoniidae	Black-billed Conehead	Exotic	Tall Grassland
19	*Ducetia japonica*	Tettigoniidae	Japanese Ducetia	Exotic	Forest Undergrowth
20	*Hexacentrus japonicus*	Tettigoniidae	Japanese Katydid	Exotic	Grassy Wetlands
21	*Phlaeoba antennata*	Acrididae	Antennate Grasshopper	Exotic	Grassland
22	*Xenocatantops humilis*	Acrididae	Humble Grasshopper	Exotic	Grassland
23	*Diabolocatantops pinguis*	Acrididae	Fat Devil Grasshopper	Endemic	Grassy Forest Margin
24	*Xylocopa* sp.	Apidae	Carpenter Bee	Non-endemic	Tree Canopy
25	*Apis dorsata*	Apidae	Giant Honeybee	Non-endemic	Forest Edge
26	*Polistes flavus*	Vespidae	Yellow Paper Wasp	Exotic	Human Settlements
27	*Polistes olivaceus*	Vespidae	Yellow-vented Paper Wasp	Exotic	Rural Settlements
28	*Xanthopimpla punctata*	Ichneumonidae	Yellow Pimpla	Exotic	Garden/ Fallow Areas
29	*Phyllium bioculatum*	Phylliidae	Giant Leaf Insect	Endemic	Evergreen Forest Canopy
30	*Macrocheraia grandis*	Reduviidae	Giant Assassin Bug	Endemic	Forest Edge/ Undergrowth

The comparative evaluation of two ecologically different places: Oxygen Park (urban) and Silachari Forest (semi-natural) will provide clear insight insights into habitat type, vegetation composition and anthropogenic pressures that influence pollinator communities.

Butterfly Assemblage and Habitat Association

The dominance of generalist species like *Euploea core* and *Danaus chrysippus* in Oxygen Park showed the urban adaptability of the mentioned taxa. Flexible use of host plants and resilience to fragmented habitats and high dispersal potential are attributed to their success. This is in line with findings by and Di Mauro *et al.* (2007) and Mukherjee *et al.* (2019), who identified the similar tendencies in Delhi and Kozhikode, respectively.

This ecological versatility of the family confirms because Nymphalidae were observed to be very predominant in various urban and peri-urban areas in Eastern India. This polyphagous behaviour and powerful flight capacity promote the anthropogenic colonisation and survival in the environments with ornamental plants and other anthropogenic microclimates altered by humanity.

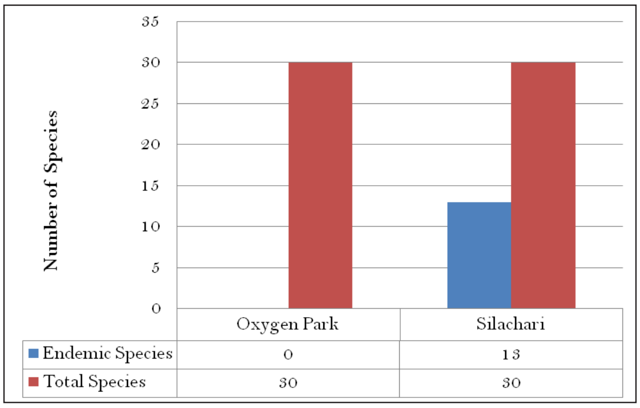


Figure 5: Representation of species belonging to different families by site

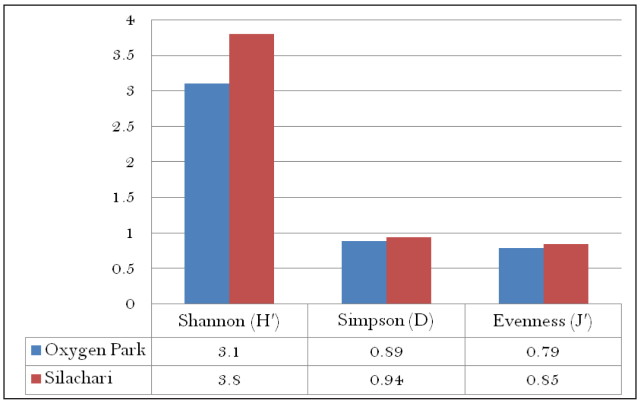


Figure 6: Comparison of diversity indices

Pollinator Diversity and Forest Structure in Silachari

Silachari's pollinator community exhibited greater taxonomic and functional diversity, underpinned by habitat complexity and native vegetation. High ecological stability and habitat fidelity is indicated by the presence of endemic and specialist butterflies, such as *Neptis reducta*. The multidimensionality of pollination services in forest ecosystems are manifested by insects belonging to multiple orders (Lepidoptera, Coleoptera, Hymenoptera and Odonata).

Other researchers like Gogoi *et al.* (2023) in Dehing Patkai and Hazarika *et al.* (2023) in Sipajhar also documented the high diversity in semi-natural and forested environments due to multi-strata vegetation, low level of disturbance and the uninterrupted supply of resources. Our observations in Silachari conform to this pattern.

Environmental Variables and Pollinator Activity

Pollinator abundance was notably influenced by diurnal variation and floral phenology. Consistent with Corbet and Pendlebury (1992) and Kehimkar (2008), morning sessions recorded higher activity, possibly due to optimal thermal and light conditions. The flowering succession of native trees and herbs also ensured spatiotemporal continuity in nectar supply.

Conservation and Urban Implications

Oxygen Park, though urban and anthropogenically maintained, demonstrated its role as a biodiversity support system. Such managed green-spaces act as urban refugia and stepping stones for pollinators. However, the comparison with Silachari underscores the importance of the irreplaceable role of semi-natural forests in supporting endemic and functionally important species.

Urban biodiversity planning should integrate the landscaping native plants, minimize the use of chemicals and encourage the ecological restoration. Meanwhile, forest habitats should be safeguarded through the anti-encroachment drives, community co-management and corridor development.

It is also noteworthy that although Oxygen Park recorded relatively high diversity, the absence of certain habitat-specific taxa like forest-dependents and host-specialists indicates ecological constraints. Similar statements were concluded by Karan *et al.* (2023) and Das *et al.* (2024) in the evaluation of human-modified landscapes in Northeast India. The presence of beetles, wasps and dragonflies in Silachari also adds the evidence on the importance of semi-natural forests in supporting a wider pollinator assemblage other than Lepidoptera, which contributes to both cross-pollination and biological control processes. This aligns with observations made by Klein *et al.* (2007) in relation to maintenance of agroforestry systems by diverse pollinator networks.

This study provides the essential baseline information for pollinator conservation, urban greening policies and long-term ecological monitoring in Tripura and the wider Northeast region.

Conclusion

This paper presents the initial comparative assessment which measures the pollinator diversities between an urban managed green space (Oxygen Park, Agartala) and a semi-natural forest ecosystem (Silachari, Gomati District) in the state of Tripura, Northeast India. A total of 30 butterfly species were documented in Oxygen Park, while 30 diverse pollinator taxa, such as butterflies, beetles, wasps and dragonflies, were recorded in Silachari. The dominance of the *Nymphalidae* family in the urban area, in addition to the repeated reoccurring presence of some species including *Euploea core* and *Hypolimnas bolina*, confirms the capability of certain taxa to handle anthropogenic environmental settings. Meanwhile, the richness and functional diversity of pollinators in Silachari support the ecological integrity and suggest the complexity of semi-natural forest systems.

The high diversity of pollinator species in Silachari is attributed due to its heterogeneous vegetation, low levels of human interference and availability of continuous floral resources. Notable species such as *Neptis reducta*, an indicator of healthy forest ecosystems, were frequently encountered and therefore, demonstrating the importance of the site requiring conservation. Pollinator activity was affected by environmental factors, *viz.*, temperature, humidity and floral abundance, with the maximum visitation peak during the morning hours. These results are consistent with regional studies in similar landscapes (Majumdar *et al.*, 2016; Gogoi *et al.*, 2023) as well as contribute to a growing understanding of pollinator dynamics in Northeast India. The presence of several insect orders that assist in the pollination processes illustrates the resilience and multidimensionality of indigenous pollination systems.

However, further studies are necessary to understand the long-term changes, population dynamics as well as the impacts of anthropogenic factors like land-use change and pesticide exposure. The formation of permanent monitoring plots, the integration of molecular approaches to ensure taxonomic accuracy and quantitative assessment of ecosystem services will strengthen the ecological foundation for pollinator conservation.

In this study, the ecological significance of the managed green-spaces in city area and the semi-natural forests in sustaining the variety of pollinator diversity are highlighted. While urban parks provide refuge for adaptable generalist species, forest ecosystems like Silachari remain irreplaceable strongholds for endemic and specialist taxa. Conservation of these pollinator habitats will not only safeguard regional biodiversity, but also ensure long-term sustainability of agricultural productivity and healthy ecosystems across the region.

Therefore there is a need to ensure that biodiversity-based land-use planning is mainstreamed in both the urban and peri-urban environment, which should incorporate ecological corridors, microhabitat niches and indigenous floral assemblages. Alternative monitoring frameworks should integrate genetic tools, seasonal data and evaluation of pollination services to improve the assessment of future pollinator communities that are resilient to climate change and rising anthropogenic pressure. The current study provides an important guideline to this kind of long-term ecological surveillance in the Northeastern region.

By promoting biodiversity-friendly landscape management and community-led conservation, Tripura can be a blueprint to integrate pollinator protection into regional development strategies and thereby may contribute to the biodiversity goals of the country and the world.

References

Agarwala, B.K., Majumder, J., 2020. Butterfly diversity assessment in protected areas in Tripura, North Eastern India. *Proceedings of the Zoological Society* 73, 68-81. DOI: https://doi.org/10.1007/s12595-019-00300-x.

Anonymous, 2025. Butterfly. In: *Wikipedia: The Free Encyclopedia* (website). Available at: https://en.wikipedia.org/wiki/Butterfly.

Bhattacharya, R., Basu, P., 2018. Pollinator limitation and crop production: Experimental observations on few economically important vegetable crops in West Bengal, India. *Proceedings of the Zoological Society* 71, 88-91. DOI: https://doi.org/10.1007/s12595-016-0189-4.

Bonebrake, T.C., Ponisio, L.C., Boggs, C.L., Ehrlich, P.R., 2010. More than just indicators: A review of tropical butterfly ecology and conservation. *Biological Conservation* 143(8), 1831-1841. DOI: https://doi.org/10.1016/j.biocon.2010.04.044.

Chakrabarti, P., Rana, S., Bandopadhyay, S., Naik, D.G., Sarkar, S., Basu, P., 2015. Field populations of native Indian honey bees from pesticide intensive agricultural landscape show signs of impaired olfaction. *Scientific Reports* 5, 12504. DOI: https://doi.org/10.1038/srep12504.

Chakrabarti, P., Sarkar, S., Basu, P., 2018. Field populations of wild *Apis cerana* honey bees exhibit increased genetic diversity under pesticide stress along an agricultural intensification gradient in Eastern India. *Journal of Insect Science* 18(3), 1-8. DOI: https://doi.org/10.1093/jisesa/iey042.

Chakraborty, D.C., Dhara, A., 2024. Butterfly diversity across Saraswati-Ganga Plains of Hooghly, West Bengal. *SAYAM* 2(2), 08-20. DOI: https://doi.org/10.63419/sayam.v2i2.62.

Colin Smith, C., 2006. *Butterflies of Peninsular India*. Prakash Books, New Delhi.

Corbet, A.S., Pendelbury, H.M., 1992. *The Butterflies of the Malay Peninsula*. Malayan Nature Society, Kuala Lumpur.

D'Abrera, B., 1982. *The Butterflies of the Oriental Region. Part I: Papilionidae, Pieridae and Danaidae*. Hill House, Victoria. pp. 1-244.

D'Abrera, B., 1984. *The Butterflies of the Oriental Region. Part II: Nymphalidae, Satyridae and Amathusidae*. Hill House, Victoria. pp. 246-534.

D'Abrera, B., 1986. *The Butterflies of the Oriental Region. Part III: Lycaenidae and Riodinidae*. Hill House, Victoria. pp. 536-672.

Das, M., Sen, M., Gan, S., Jha, B., 2024. An insight into the abundance and diversity of butterfly (Insecta: Lepidoptera) fauna in surrounding vegetation of Subhas Sarobar, Kolkata, India. Journal *of Biodiversity and Environmental Sciences* 24(5), 31-44.

Di Mauro, D., Dietz, T., Rockwood, L., 2007. Determining the effect of urbanization on generalist butterfly species diversity in butterfly gardens. *Urban Ecosystem* 10, 427-439. DOI: https://doi.org/10.1007/s11252-007-0039-2.

Dutta, D., Ahmed, G., Engti, R., Sangma, M.P., 2024. A checklist on butterfly (Insecta: Lepidoptera) fauna of the Recreation Park Cum Medicinal Garden, Diphu, Karbi Anglong. *International Journal of Entomology Research* 9(4), 117-120.

Eswaran, P., Pramod, P., 2005. Structure of butterfly community of Anaikatty hills, Western Ghats. *Zoos' Print Journal* 20(8), 1939-1942. DOI: https://doi.org/10.11609/jott.zpj.1330.1939-42.

Evans, W.H., 1932. *The Identification of Indian Butterflies*, 2nd Edition Revised. Bombay Natural History Society, Madras (Mumbai). p. 454.

Garibaldi, L.A., Steffan-Dewenter, I., Winfree, R., Aizen, M.A., Bommarco, R., *et al.*, 2013. Wild pollinators enhance fruit set of crops regardless of honey bee abundance. *Science* 339(6127), 1608-1611. DOI: https://doi.org/10.1126/science.1230200.

Ghazoul, J., 2002. The impact of logging on the richness and diversity of forest butterflies in a tropical dry forest in Thailand. *Biodiversity Conservation* 11(3), 521-541. DOI: https://doi.org/10.1023/A:1014812701423.

Gogoi, R., Chetry, A., Bhuyan, A., 2023. Diversity and species richness of butterfly in Soraipung Range of Dehing Patkai National Park, Assam, India. *The Journal of Basic and Applied Zoology* 84, 6. DOI: https://doi.org/10.1186/s41936-023-00327-9.

Hazarika, K., Saikia, D.J., Borah, M.P., 2023. A study on the diversity of butterfly species in the adjoining natural habitat of an urbanized locality of Sipajhar, Assam, India. *TWIST* 18(4), 260-264. URL: https://twistjournal.net/twist/article/view/109.

Karan, S., Acharya, R., Sen, K., Das, S.K., 2023. Study of butterfly diversity in Chilkigarh, West Bengal (India). *Entomology and Applied Science Letters* 10(4), 26-34. DOI: https://doi.org/10.51847/DczmEKgc9h.

Kehimkar, I., 2008. *The Book of Indian Butterflies*. Bombay Natural History Society, Mumbai.

Klein, A.M., Vaissière, B.E., Cane, J.H., Steffan-Dewenter, I., Cunningham, S.A., Kremen, C., Tscharntke, T., 2007. Importance of pollinators in changing landscapes for world crops. *Proceedings of the Royal Society B: Biological Sciences* 274(1608), 303-313. DOI:L https://doi.org/10.1098/rspb.2006.3721.

Kocher, S.D., Williams, E.H., 2000. The diversity and abundance of North American butterflies vary with habitat disturbance and geography. *Journal of Biogeography* 27(4), 785-794. DOI: https://doi.org/10.1046/j.1365-2699.2000.00454.x.

Kumar, A., Gill, J.P.S., Bedi, J.S., Kumar, A., 2018. Pesticide residues in Indian raw honeys, an indicator of environmental pollution. *Environmental Science and Pollution Research* 25, 34005-34016. DOI: https://doi.org/10.1007/s11356-018-3312-4.

Krishnakumar, N., Kumaraguru, A., Thiyagesan, K., Asokan, S., 2007. Diversity of papilonid butterflies in the Indira Gandhi wildlife Sanctuary, Western Ghats, Southern India. *Tiger Paper* 35(1), 1-8.

Kunte, K., 2000. *India, a Lifescape: Butterflies of Peninsula India*. Indian Academy of Sciences, Bangalore. University Press, Hyderabad. p. 254.

Larsen, T.B., 2004. *Butterflies of West Bengal and Sikkim*. World Wide Fund for Nature, New Delhi.

Lodh, R., Agarwala, B.K., 2015. Inventory of butterfly fauna (Lepidoptera: Rhopalocera) of Tripura, India, in the Indo-Myanmar biogeographical zone, with records of threatened taxa. *Check List* 11(2), 1-37. DOI: https://doi.org/10.15560/11.2.1591.

Majumder, J., Lodh, R., Agarwala, B.K., 2012. Variation in butterfly diversity and unique species richness along different habitats in Trishna Wildlife Sanctuary, Tripura, Northeast India. *Check List* 8(3), 432-436. DOI: https://doi.org/10.15560/8.3.432.

Majumder, J., Lodh, R., Agarwala, B.K., 2013. Butterfly species richness and diversity in the Trishna Wild-life Sanctuary in South Asia. *Journal of Insect Science* 13(1), 79. DOI: https://doi.org/10.1673/031.013.7901.

Majumdar, K., Choudhary, B.K., Datta, B.K., 2016. Changes of woody species diversity, horizontal and vertical distribution of stems across interior to outside within a primate rich habitat of Northeast India. *Journal of Forestry Research* 27, 787-798. DOI: https://doi.org/10.1007/s11676-016-0231-4.

Martinez, A.L., Bousquet, J.L., Warren, A.D., 2003. Biodiversity and biogeography of Mexican butterflies (Lepidoptera: Papilionoidea and Hesperioidea). *Proceedings of Entomological Society of Washington* 105(1), 209-244.

May, R.M., 1992. How many species inhabit the Earth? *Scientific American* 267(4), 76-79. DOI: https://doi.org/10.1038/scientificamerican1092-76.

Mukherjee, S., Rudra, R.P., Banerjee, S., Basu, P., Saha, G.K., Aditya, G., 2019. Correspondence of butterfly and host plant diversity: Foundation for habitat restoration and conservation. *European Journal of Ecology* 5(1), 49-66. https://doi.org/10.2478/eje-2019-0007.

Mukherjee, S.S., Hossain, A., 2024. Alteration in butterfly community structure along urban-rural gradient: with insights to conservation management. *The Journal of Basic and Applied Zoology* 85, 40. DOI: https://doi.org/10.1186/s41936-024-00391-9.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B., Kent, J., 2000. Biodiversity hotspots for conservation priorities. *Nature* 403, 853-858. DOI: https://doi.org/10.1038/35002501.

Naeem, S., Thompson, L.J., Lawler, S.P., Lawton, J.H., Woodfin, R.M., 1994. Declining biodiversity can alter the performance of ecosystems. *Nature* 368, 734-737. DOI: https://doi.org/10.1038/368734a0.

Nair, N., Giri, U., Debnath, M.R., Shah, S.K., 2018. Butterfly fauna (Lepidoptera: Rhopalocera) of Lembucherra, West Tripura, India. *Journal of Entomology and Zoology Studies* 6(2), 975-981.

Padhye, A.D., Dahanukar, N., Paingankar, M., Deshpande, M., Deshpande, D., 2006. Season and landscape wise distribution of butterflies in Tamhini, Northern Western Ghats, India. *Zoos' Print Journal* 21(3), 2175-2181. DOI: https://doi.org/10.11609/jott.zpj.1142.2175-81.

Potts, S.G., Biesmeijer, J.C., Kremen, C., Neumann, P., Schweiger, O., Kunin, W.E., 2010. Global pollinator declines: Trends, impacts and drivers. *Trends in Ecology and Evolution* 25(6), 345-353. DOI: https://doi.org/10.1016/j.tree.2010.01.007.

Samways, M.J., 2005. Butterfly houses and increasing conservation awareness. In: *Insect Diversity Conservation*. Cambridge University Press, New York. pp. 259-262. DOI: https://doi.org/10.1017/CBO9780511614163.

Singh, S., Das, B., Das, A., Devi, H.L., Godara, R.S., Sahoo, A.K., Sahoo, M.R., 2021. Indigenous plant protection practices of Tripura, India. *Journal of Ethnobiology and Ethnomedicine* 17, 50. DOI: https://doi.org/10.1186/s13002-021-00476-7.

Spector, S., 2006. Scarabaeine dung beetles (Coleoptera: Scarabaeidae: Scarabaeinae): An invertebrate focal taxon for biodiversity research and conservation. *Coleopterists' Society Monographs* 5, 71-83.

Tilman, D., 1996. Biodiversity: Population versus ecosystem stability. *Ecology* 77(2), 350-363. DOI: http://dx.doi.org/10.2307/2265614.

Wynter-Blyth, M.A., 1957. *Butterflies of the Indian Region*. Bombay Natural History Society, Mumbai.