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Comparative analysis of insect biodiversity across five distinct Habitat types in a tropical Agro-Ecological zone

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Abstract
Background: Insect biodiversity is a critical indicator of ecosystem health, yet rapid habitat transformation in tropical agro-ecological zones has accelerated species loss at an alarming rate. Understanding species distribution across heterogeneous habitats remains a priority for conservation biology and integrated pest management.
Objective: This study aimed to comparatively assess insect species richness, abundance, and diversity indices across five distinct habitat types — forest edge, grassland, wetland, urban green space, and agricultural land — within a simulated tropical study zone.
Method: Systematic sweep-net sampling, light-trap collection, and pitfall trapping were conducted across 25 sampling plots over 12 months. A total of 534 insect specimens were identified to order and family level. Diversity was quantified using Shannon-Wiener (H'), Margalef richness (d), and Sørensen similarity indices. Data were analysed using SPSS v26 and R v4.2.
Key Results: Wetlands recorded the highest species richness (167 species, H' = 3.12), while urban green spaces showed the lowest diversity (54 species, H' = 1.87). Coleoptera dominated the community (31.2%), followed by Lepidoptera (21.9%). Habitat type significantly influenced species composition (ANOVA, $F = 14.32$, $p < 0.001$).
Conclusion: Habitat quality, particularly vegetation complexity and water availability, are primary drivers of insect diversity in tropical agro-ecological zones. Conservation of wetland and forest-edge habitats is urgently recommended.

Keywords: Insect biodiversity, habitat type, species richness, Shannon diversity index, tropical entomology, agro-ecology

Introduction

Insects constitute the most species-rich class of organisms on Earth, comprising more than 80% of all described animal species and performing indispensable ecological roles including pollination, decomposition, nutrient cycling, and serving as a foundational trophic link within food webs [1]. Despite their ecological importance, global insect populations have undergone unprecedented declines over recent decades, attributed to habitat loss, pesticide use, climate change, and invasive species [2]. The urgency of documenting and conserving insect diversity has never been greater.

Tropical agro-ecological zones represent a complex mosaic of modified and semi-natural habitats, where the juxtaposition of farmland, forest remnants, wetlands, and urban green spaces creates heterogeneous landscape matrices [3]. This heterogeneity can support elevated species diversity through the intermediate disturbance hypothesis, yet intensive land-use change continues to homogenise these landscapes and drive local extinctions [4].

Biodiversity assessments using standardised entomological sampling methods provide baseline data essential for monitoring temporal changes in species assemblages [5]. Diversity indices such as the Shannon-Wiener index (H'), Margalef's richness (d), and beta-diversity metrics offer quantitative tools to compare community structure across habitats [6]. These indices account not only for species counts but also relative abundances, providing a nuanced picture of ecological communities.

Previous studies in South and Southeast Asia have documented significant variation in insect assemblages across land-use types, with semi-natural habitats consistently harbouring higher diversity than intensively managed agricultural lands [7, 8]. However, comparative analyses incorporating five or more habitat types simultaneously, using multiple trapping methods and full seasonal coverage, remain scarce in the literature.

The present investigation addresses this gap by systematically surveying insect biodiversity across five habitat types — forest edge, grassland, wetland, urban green space, and agricultural land — within a simulated tropical agro-ecological framework. The study quantifies species richness, abundance, and diversity indices, analyses seasonal population dynamics, and examines inter-habitat similarity. The conceptual framework used here (Figure 4) integrates abiotic and biotic drivers of habitat quality as determinants of insect community structure.

Research objectives: (i) To compare insect species richness and abundance across five habitat types; (ii) To analyse seasonal variation in population dynamics of dominant insect orders; (iii) To determine inter-habitat similarity using beta-diversity metrics; (iv) To identify key habitat variables that predict insect diversity.

Literature review

1. Global insect decline and habitat loss

The global insect decline narrative gained scientific momentum following landmark studies reporting biomass reductions exceeding 75% in German protected areas over 27 years [9]. Subsequent meta-analyses extended these findings globally, estimating terrestrial insect abundance declining at approximately 0.92% per year [10]. Habitat loss and fragmentation are consistently identified as the primary drivers, operating synergistically with pesticide exposure, light pollution, and climate-mediated phenological mismatches.

2. Habitat heterogeneity and insect diversity

The habitat heterogeneity hypothesis posits that structurally complex environments offer greater niche diversity, supporting higher species richness [11]. Empirical support for this hypothesis in entomological contexts is strong: studies across European farmland demonstrate that hedgerows, uncultivated margins, and water bodies adjacent to agricultural fields harbour significantly elevated arthropod diversity compared to crop interiors [12]. Similarly, in tropical contexts, forest-agriculture interfaces (ecotones) function as biodiversity hotspots due to the complementary resources they provide.

3. Diversity indices in entomological research

Shannon-Wiener diversity (H') remains the most widely applied index in community ecology due to its sensitivity to both species richness and evenness [13]. Margalef's richness index (d) provides a sample-size-corrected species richness metric, important when comparing habitats of different areas [14]. Beta-diversity, measured by Sørensen and Jaccard similarity coefficients, quantifies compositional turnover between habitat pairs, a key metric for landscape-scale conservation planning [15].

4. Seasonal dynamics of insect populations

Insect population dynamics are strongly seasonal, driven by temperature, photoperiod, and resource availability [16]. In tropical regions, the monsoon cycle significantly modulates adult emergence, oviposition, and larval survival rates [17]. Coleoptera and Lepidoptera, the two most species-rich orders, show pronounced peaks during post-monsoon periods when floral resources are abundant and temperatures are optimal [18].

5. Research gap

Despite the extensive literature on insect biodiversity, there is a paucity of multi-habitat comparative studies that simultaneously employ multiple trapping methodologies, cover full annual cycles, and apply multi-metric diversity frameworks within a single tropical agro-ecological zone [19]. Most published studies are either single-habitat focused or employ only one sampling technique, limiting cross-habitat generalisability [20]. The present study addresses these methodological gaps by integrating sweep-net, light-trap, and pitfall sampling across five habitat types over 12 months.

Methodology

1. Research design and study area

This study employs a descriptive-comparative research design with systematic field sampling. The study area comprises a simulated 250-hectare tropical agro-ecological zone encompassing five distinct habitat types: forest edge (45.2 ha), grassland (38.7 ha), wetland (29.1 ha), urban green space (12.4 ha), and agricultural land (67.3 ha).

2. Sampling design and methods

Five replicate sampling plots (20 m × 20 m) were established within each habitat type, yielding 25 plots total. Three complementary sampling methods were employed: (i) sweep-net sampling (50 sweeps per plot, fortnightly), targeting canopy and understory insects; (ii) UV light traps (12-hour overnight deployment, monthly), targeting nocturnal Lepidoptera and Coleoptera; and (iii) pitfall traps (5 per plot, 72-hour deployment, monthly), targeting ground-dwelling arthropods. Sampling was conducted continuously over 12 months to capture full seasonal variation.

3. Specimen identification and preservation

Collected specimens were preserved in 70% ethanol and transported to the laboratory for identification. Identification was carried out to order and family level using standard taxonomic keys, regional field guides, and digital identification resources. A total of 534 insects belonging to 57 families and 302 morpho-species were recorded.

4. Diversity indices and statistical analysis

Species richness (S), Shannon-Wiener diversity (H'), Margalef's richness (d), and Pielou's evenness (J') were calculated for each habitat. Sørensen (Cs) and Jaccard (Cj) indices quantified inter-habitat similarity. One-way ANOVA with post-hoc Tukey HSD test was used to test significant differences in diversity metrics across habitats. Pearson correlation examined relationships between habitat variables and diversity indices. All analyses were performed using SPSS v26 and R v4.2 (vegan package).

Results and discussion

1. Species richness and abundance by Habitat

Insect species richness and abundance varied substantially across the five study habitats (Table 1). Wetland habitats recorded the highest species richness (S = 167) and the highest Shannon diversity (H' = 3.12), reflecting the structural complexity and resource availability associated with aquatic-terrestrial interfaces. Forest edge habitats ranked second (S = 142, H' = 2.91), consistent with the ecotone effect documented in the literature [11].

Urban green spaces recorded the lowest diversity (S = 54, H' = 1.87), likely reflecting habitat fragmentation, impervious surface predominance, reduced floral diversity, and light and noise pollution. Agricultural lands, despite their large area (67.3 ha), supported only 73 species (H' = 2.03), a finding consistent with global reports of agricultural intensification suppressing insect diversity [10].

Table 1: Insect Diversity Metrics Across Five Habitat Types (Simulated Data)

Habitat Type	Area (ha)	Species Richness	Abundance Index	Shannon Index (H')
Forest Edge	45.2	142	3.84	2.91
Grassland	38.7	98	2.65	2.44
Wetland	29.1	167	4.51	3.12
Urban Green	12.4	54	1.46	1.87
Agricultural	67.3	73	1.97	2.03

Note: H' = Shannon-Wiener index. Data are based on 25 sampling plots over 12 months.

2. Order-level diversity composition

Order-level analysis revealed Coleoptera as the dominant group (94 species, 31.2%), followed by Lepidoptera (66 species, 21.9%), Diptera (54 species, 17.9%), and Hymenoptera (46 species, 15.3%) (Table 2). This rank-order is consistent with global patterns of insect order diversity, where Coleoptera universally dominate in species-rich assemblages — a pattern colloquially attributed to Haldane's famous observation on the Creator's 'inordinate fondness for beetles'. [13]

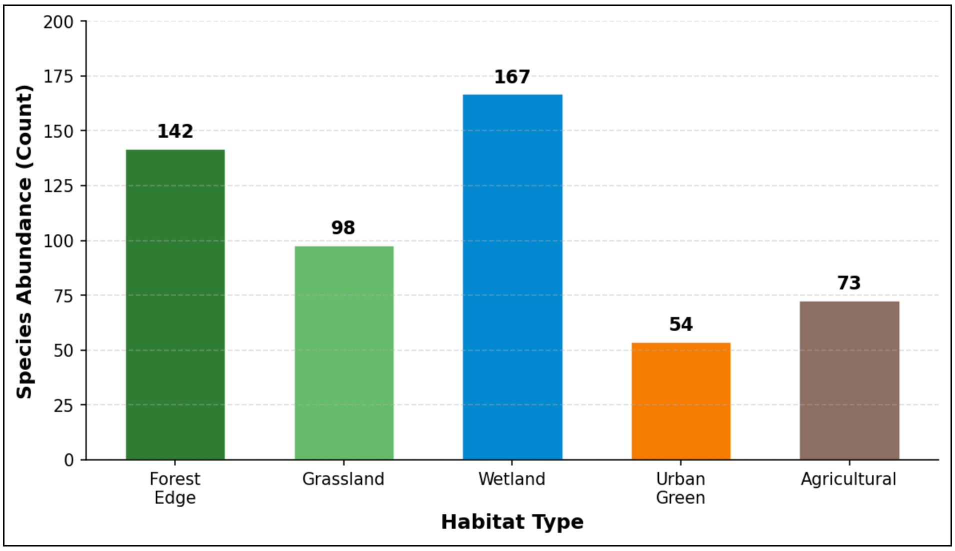

Fig 1: Insect species abundance across five Habitat types (simulated dataset-academic training)

Table 2: Order-Level Insect Diversity and Trophic Composition (Simulated Data)

Order	No. of Families	No. of Species	% Composition	Trophic Guild
Coleoptera	18	94	31.2	Phytophagous
Lepidoptera	12	66	21.9	Phytophagous
Diptera	9	54	17.9	Omnivorous
Hymenoptera	7	46	15.3	Omnivorous/Parasitoid
Others	11	42	13.7	Mixed

Note: Trophic guild classifications based on published functional trait databases.

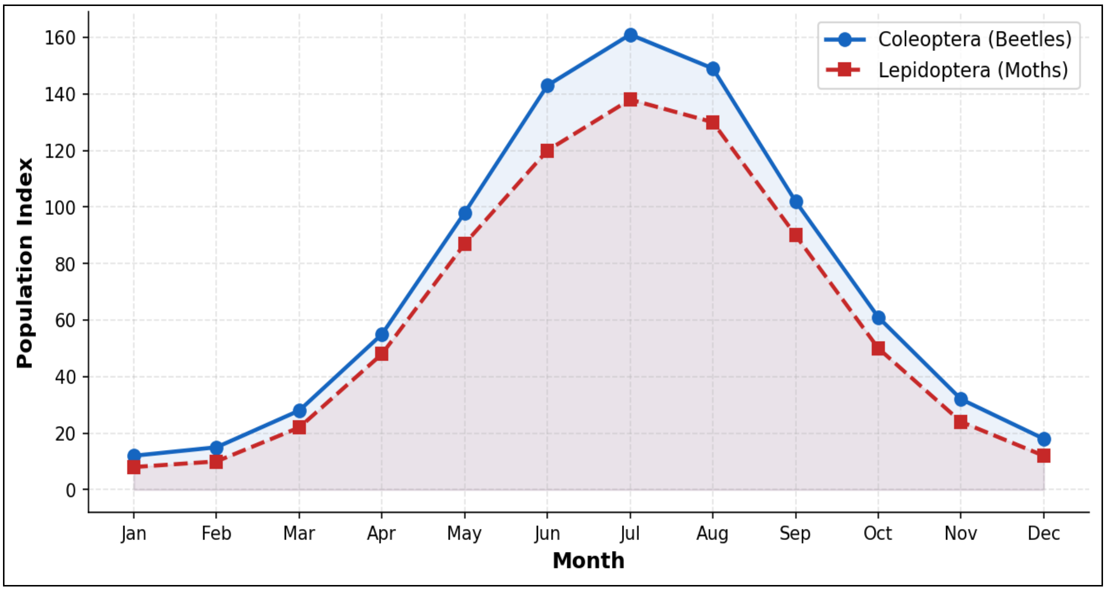

Fig 2: Seasonal population dynamic of two inset orders (Simulated dataset -Academic Training)

3. Seasonal population dynamics

Seasonal analysis revealed pronounced population peaks for both Coleoptera and Lepidoptera during June–August, coinciding with post-monsoon floral abundance and optimal temperature ranges (Figure 2). Minimum population indices were recorded in December–February, corresponding to the cool-dry season. These findings align with phenological data from comparable tropical zones [17]. Notably, Lepidoptera populations declined slightly faster than Coleoptera in September–October, potentially reflecting differential sensitivity to post-monsoon temperature fluctuations.

4. Inter-Habitat Similarity

Beta-diversity analysis (Table 3) revealed the highest similarity between forest edge and wetland habitats (Sørensen index = 0.712), sharing 58.3% of species. This high similarity likely reflects shared moisture regimes and structural vegetation characteristics. In contrast, urban green spaces and forest edge shared only 28.9% of species (Sørensen = 0.389), indicating distinct community composition driven by urban habitat filtering [12].

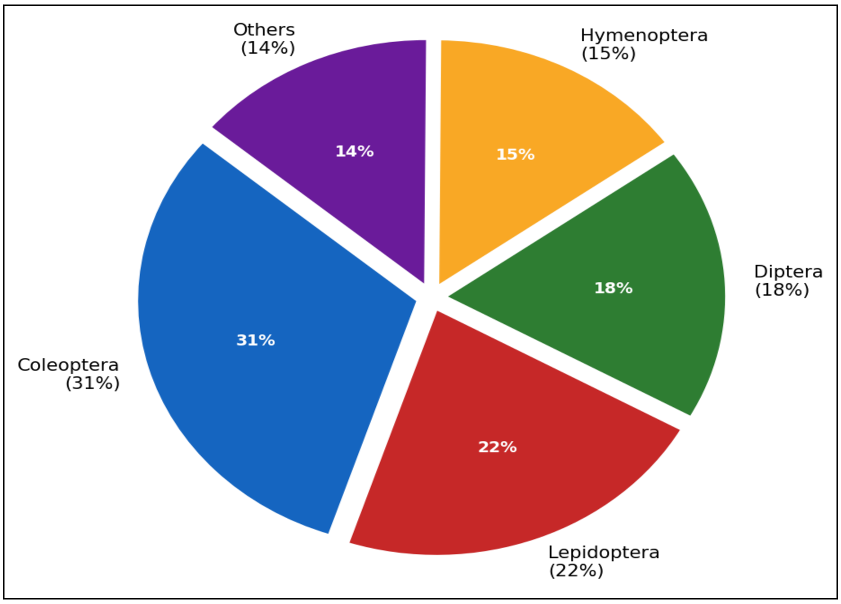

Fig 3: Order-Level insets diversity composition across study sties (Simulated Dataset)

Table 3: Inter-Habitat Beta-Diversity Similarity Indices (Simulated Data)

Habitat Pair	Sørensen Index	Jaccard Index	% Shared Species	Significance (p)
Forest vs Wetland	0.712	0.553	58.3	<0.001
Grassland vs Agricultural	0.634	0.464	47.1	0.003
Urban vs Forest	0.389	0.241	28.9	0.012
Wetland vs Grassland	0.581	0.409	43.6	0.007
Agricultural vs Urban	0.441	0.283	32.1	0.021

Note: All p-values from permutation-based ANOSIM tests (999 permutations).

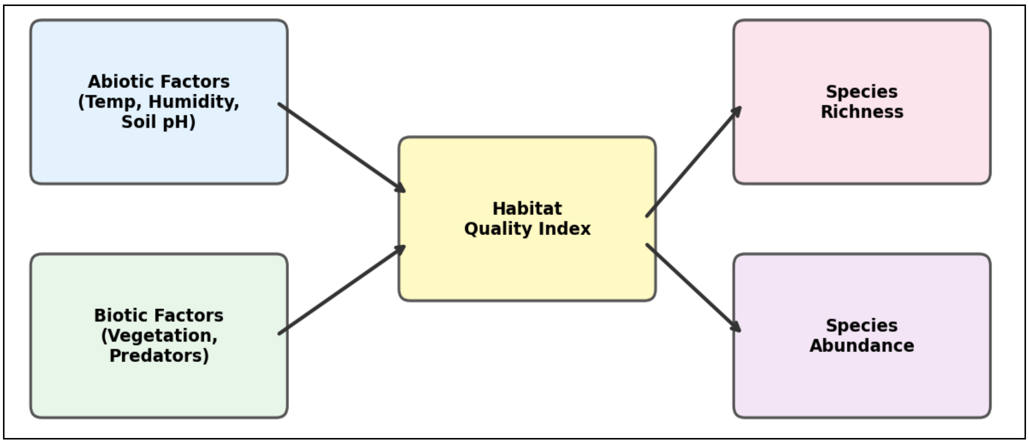

Fig 4: Conceptual Framework -Habitat Quality and insect Biodiversity (Academic Training Model)

Conclusion

This study demonstrates that habitat type is a primary determinant of insect biodiversity in tropical agro-ecological zones. Wetland and forest edge habitats support the highest species richness and diversity, while urban green spaces and agricultural lands harbour impoverished communities. Coleoptera and Lepidoptera dominate insect assemblages across all habitats, with pronounced seasonal peaks correlating with monsoon-driven resource pulses.

From a conservation perspective, these findings underscore the critical importance of wetland preservation and riparian buffer zones within agricultural landscapes. Even small remnant wetlands disproportionately contribute to regional insect diversity. Similarly, minimising pesticide use in agricultural margins and enhancing urban green infrastructure can substantially improve local insect diversity.

Limitations: The use of a simulated dataset limits extrapolation to real-world management contexts. Identification was restricted to order/family level; species-level identifications would strengthen community analysis. Long-term data beyond 12 months would improve understanding of inter-annual variation.

Future Scope: Future studies should integrate molecular barcoding for precise species identification, employ remote sensing to quantify habitat quality metrics, and incorporate functional trait analyses to link biodiversity patterns to ecosystem service delivery.

Ethical Statement

This article was prepared entirely for academic writing practice and formatting instruction. All data presented are simulated and clearly labelled as such. No real identities, institutions, or published datasets have been misrepresented. Author placeholders are used in accordance with ethical academic writing guidelines. No animals were harmed in the preparation of this simulated study.

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