International Journal of Biological Innovations
http://ijbi.org.in | http://www.gesa.org.in/journals.php
https://doi.org/10.46505/IJBI.2026.8106
IJBI 8(1): 59-67 **(2026)**
E-ISSN: 2582-1032

SEASONAL DYNAMICS AND DIVERSITY PATTERN OF HEMIPTERAN ASSEMBLAGES IN MOKHADA TAHSIL, PALGHAR, INDIA

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Article Info:
Research Article
Received
30.11.2025
Reviewed
03.01.2026
Accepted
05.02.2026

Abstract: The present study elucidates the taxonomic composition, seasonal distribution, and diversity gradients of Hemipteran assemblages within Mokhada Tahsil of Palghar district, a biogeographically transitional zone situated along the eastern escarpment of northern Western Ghats. Employing standardized, stratified field-sampling protocols across pre-monsoon, monsoon and post-monsoon periods (2023-2024), a total of 54 species belonging to three suborders *namely* Heteroptera, Auchenorrhyncha and Sternorrhyncha, were documented. Heteroptera emerged as the dominant clade, representing 77.8% of species richness, with Pentatomidae alone contributing over 51.9% of the total assemblage. Alpha diversity indices revealed a pronounced seasonal gradient, with monsoon exhibiting peak species richness (S=51), Shannon–Wiener diversity (H'=3.79), and evenness (J'=0.89), indicative of community complexity under resource-replete conditions. Diversity metrics attenuated in post-monsoon (S= 46; H'=3.51) and sharply declined pre-monsoon (S=26; H'=2.68), reflecting habitat contraction and increased dominance by drought-resilient taxa. Beta diversity analysis using Bray–Curti's dissimilarity coefficients delineated compositional turnover across seasons, with the highest dissimilarity observed between monsoon and pre-monsoon (0.627), and the lowest between monsoon and post-monsoon (0.312). This investigation contributes a novel, seasonally stratified baseline inventory of Hemiptera for the Mokhada a region, underrepresented in Indian entomological literature and underscores the functional sensitivity of Hemipteran communities to monsoonal hydroclimatic cycles.

Keywords: Alpha–beta diversity, Insecta, Hemiptera, Mokhada tahsil, Seasonal diversity.

Cite this article as: Goswami M.D. and Gurav M. (2026). Seasonal Dynamics and Diversity Pattern of Hemipteran Assemblages in Mokhada Tahsil, Palghar, India. *International Journal of Biological Innovations*. 8(1): 59-67. https://doi.org/10.46505/IJBI.2026.8106

INTRODUCTION

The order Hemiptera encompasses a remarkably speciose and ecologically versatile clade within Insecta, comprising over 107,000 described species globally (Henry, 2017; Weirauch *et al.,* 2019) and approximately 6,500 species documented from India (Ambrose, 2006; Ramamurthy *et al.,* 2010). Insecta is the largest class of Kingdom Animalia (Verma and Prakash, 2020). Characterized by piercing–sucking mouthparts and hemimetabolous development, Hemipterans are taxonomically partitioned into four extant suborders Heteroptera, Auchenorrhyncha, Sternorrhyncha, and Coleorrhyncha each reflecting distinct phylogenetic trajectories (Weirauch and Schuh, 2011; Cryan and Urban, 2012; Verma, 2017). The lineage is of Paleozoic origin, with fossil records extending to the Permian, offering invaluable insights into arthropod macroevolution and territorialization

(Grimaldi and Engel, 2005). Hemiptera exhibit profound ecological roles across trophic levels. Some phytophagous families such as Aphididae, Cicadellidae, and Aleyrodidae are notorious vectors of over 200 agriculturally significant plant viruses (Nault, 1997 and Hogenhout *et al.,* 2008) while predatory taxa like Reduviidae and Nabidae serve as natural biocontrol agents in agroecosystems (Ambrose, 1999; Szczepaniec and Raupp, 2012). Aquatic Hemiptera, including Nepidae, Notonectidae, and Belostomatidae, structure freshwater trophic networks and act as bioindicators of hydrological integrity (Polhemus and Polhemus, 2008; Vatandoost *et al*., 2021).Beyond ecological services and functions, Hemipterans are pivotal in co-evolutionary research, particularly through symbiosis-driven genome reduction in Sternorrhyncha (Douglas, 2015). Seminal studies by Buchner (1965) on endosymbionts, and more recently by Hansen and Moran (2011), have uncovered intricate host–microbe interfaces. Advances in molecular phylogenetics (Dietrich, 2005; Park *et al.,* 2011; Cryan and Urban, 2012), morphological systematics (Weirauch and Schuh, 2011), and functional genomics (Elzinga and Jander, 2013) have transformed Hemipteran taxonomy into a multi-scalar discipline. Concurrently, ecological modeling studies (Bebber *et al.,* 2013) and barcoding initiatives (Foottit *et al.,* 2008; Jung *et al.,* 2011) have revealed cryptic speciation patterns and responses to climate change and perturbations. Applications extend to insecticide resistance mechanisms via gut microbiota, ecosystem health diagnostics and integrated pest management strategies (Kikuchi *et al.,* 2012; Capinera, 2013; Douglas, 2015).

Thus, Hemiptera remains central to global research agendas spanning evolutionary biology, bioindication, molecular ecology, and sustainable agriculture. Despite the ecological importance and taxonomic richness of Hemiptera, there remains a notable paucity of region-specific diversity assessments in lesser-explored landscapes such as Mokhada Tahsil, located within the ecologically sensitive zones of the Western Ghats foothills. Most existing studies in Maharashtra have concentrated on agroecosystems or protected areas, leaving semi-rural and transitional habitats largely undocumented. In this context, the present study aims to systematically document the diversity and distribution patterns of Hemipteran species in Mokhada Tahsil, thereby contributing to baseline faunistic inventories. This investigation holds significance for understanding habitat-specific assemblages, assessing ecological indicators, and informing future conservation and management strategies within this underrepresented biogeographic corridor.

MATERIALS AND METHODS

Study area

Mokhada Taluka of Maharashta (Fig.1), an undulating, predominantly tribal block on the eastern scarp of the northern Western Ghats, is centered at 19° 55' 60" N, 73° 19' 60" E and spans the head- waters of the Wagh and upper Vaitarna sub-basins. Physiographical places its mean hypsometric level at 430 MSL, with deeply incised valley floors near 60 m and weathered basaltic summits, reflecting vigorous fluvial dissection of Deccan trap terrain. Orographic interception of the south-west monsoon yields a mean annual rainfall of over 2000 mm, > 95 % of which falls between June and September, engendering flashy runoff regimes and lateritic soil development. Biogeographically, Mokhada (Palghar district of Maharashtra) lies within the North-Western Ghats Moist Deciduous Forest ecoregion, a critically endangered belt that grades locally into semi-evergreen valleys and seasonal grass–shrub mosaics on a laterite plateau, sustaining notable insect and avian endemism amid a mosaic of shifting cultivation and small holder agro-forestry.To encompass phenological turnover, fieldworks panned March 2023 to February 2024, partitioned into pre-monsoon, monsoon, and post-monsoon seasons. To comprehensively document the species richness, trophic guild representation, and seasonal turnover of Hemiptera across varied microhabitats, a multi-method, standardized field sampling protocol was employed (Table 1). This integrated approach ensured the capture of both diurnal and nocturnal taxa, as well as representatives from various ecological strata (forest, agrarian, riparian). All methods adhered to established entomological standards and were calibrated for sampling effort uniformity, enabling cross-site and temporal comparisons (Southwood and Henderson, 2000; Weirauch *et al.,* 2019).

All captured specimens were euthanized using ethyl acetate in field entomological kill jars. Specimens under 5 mm in body length were preserved in 70% ethanol, while larger taxa were air dried and pinned using entomological pins. Specimens were labelled with unique coded identifiers, linking each individual to detailed metadata, including GPS coordinates, date, time, method, and collector identity.

Species Identification

All collected Hemipteran specimens were identified based on external morphological characteristics using standard taxonomic procedures. Preliminary sorting was conducted under a stereoscopic binocular microscope (10x 40x magnification) the identified species (Table 2).

Fig. 1: Location map of study area.

Diversity Analysis

The assessment of Hemipteran diversity was conducted through a rigorous analytical framework incorporating both alpha and beta diversity metrics to capture spatial and seasonal heterogeneity across habitat types. Species abundance data were structured into community matrices and subjected to quantitative evaluation using R software (v4.4.0), employing the vegan and iNEXT packages.

1. **Alpha Diversity:** It was quantified using standard ecological indices:
   a) **Species Richness (S):** Total count of unique taxa recorded per site.
   b) **Shannon–Wiener Index (H'):** Reflects both species abundance and distributional evenness.
   c) **Simpson's Index (1–D):** Highlights species dominance and ecological concentration.
   d) **Pielou's Evenness Index (J'):** Measures uniformity of individual distribution among species.

These indices provided insights into the compositional complexity and structural equilibrium of Hemipteran assemblages across stratified habitats.

2. Beta Diversity

To evaluate between-habitat variation (-diversity), Bray-Curti's dissimilarity coefficients were computed, enabling pairwise quantification of compositional dissimilarity.

RESULTS AND DISCUSSION

The present study investigates the taxonomic composition and diversity of Hemiptera species within Mokhada Tahsil, revealing a total of 54 species distributed across three suborders: Heteroptera, Auchenorrhyncha, and Sternorrhyncha. Among these, Heteroptera emerged as the most dominant suborder, comprising 42 species and accounting for 77.8% of the total Hemipteran assemblage (Fig. 2). This high representation indicates a broad ecological amplitude and functional diversity within this group, particularly in phytophagous and predatory niches.

In contrast, Auchenorrhyncha contributed 7 species (13.0%); primarily composed of xylem and phloem feeding taxa with strong host specificity. Sternorrhyncha, with 5 species (9.3%), showed the lowest representation, reflecting their cryptic habits and potential under-detection during field sampling, notable, with 28 species representing 51.9% of all recorded species. Other contributing families in Heteroptera included Scutelleridae (7 species, 13.0

Table 1: Field Sampling Techniques adopted for the Hemiptera diversity study.

Gear/ technique	Target stratum and Taxonomic guild	Effort standardization (per visit)	Key references
Sweep net (38 cm diameter)	Herbaceous layer; Auchenorrhyncha, Miridae	100 sweeps per station	Southwood and Henderson (2000)
Beatsheet ($1 m^2$ canvas)	Shrub and lower canopy; Pentatomidae, Tingidae	25 beats/tree × 4 trees Per station	Schuh and Slater (1995)
Light trap (15 WUV, 365 nm)	Nocturnal taxa: Reduviidae, Coreidae	3 trap-nights per station per season, 19:00–22:00 hrs	Foottit and Adler (2009)
Yellow pan traps (Ø = 25 cm)	Flying Sternorrhyncha (e.g., whiteflies, aphids)	3 traps per station; exposed for 24 hours	Gullan and Cranston (2021)
Direct aspiration	Small-bodied taxa; Aphididae, Psyllidae	20 minutes of active Search per station	Upton and Chapman (2010)

The specimens were grouped into suborders Heteroptera, Auchenorrhyncha, and Sternorrhyncha based on key diagnostic traits such as wing structure, antenna morphology, and rostrum position.

Table 2: Taxonomic checklist of Hemipteran fauna recorded from the study area.

Sl. No.	Suborder	Family	Genus	Species with genus
1.	Auchenorrhyncha	Cicadellidae	*Bothrogonia*	*Bothrogonia ferruginea*
2.			*Empoasca*	*Empoasca fabae*
3.			*Idioscopus*	*Idioscopus nitidulus*
4.			*Nephotettix*	*Nephotettix virescens*
5.		Delphacidae	*Nilaparvata*	*Nilaparvata lugens*
6.			*Sogatella*	*Sogatella furcifera*
7.		Fulgoridae	*Pyrops*	*Pyrops maculata*
8.	Heteroptera	Dinidoridae	*Aspongopus*	*Aspongopus brunneus*
9.			*Coridius*	*Coridius chinensis*
10.			*Coridius*	*Coridius janus*
11.			*Cyclopelta*	*Cyclopelta siccifolia*
12.			*Megymenum*	*Megymenum distanti*
13.		Pentatomidae	*Amyotea*	*Amyotea malabarica*
14.			*Antestia*	*Antestia astrolabii*
15.			*Bagrada*	*Bagrada hilaris*
16.			*Bathycoelia*	*Bathycoelia indica*
17.			*Brochymena*	*Brochymena quadripustulata*
18.			*Capivaccius*	*Capivaccius spurcus*
19.			*Catacanthus*	*Catacanthus incarnatus*
20.			*Dalpada*	*Dalpada oculata*
21.				*Dalpada versicolor*
22.			*Degonetus*	*Degonetus serratus*
23.			*Eocanthecona*	*Eocanthecona furcellata*
24.			*Erthesina*	*Erthesina acuminata*

25.	Heteroptera	Pentatomidae		*Erthesina fullo*
26.			*Eysarcoris*	*Eysarcoris guttiger*
27.				*Eysarcoris montivagus*
28.			*Graphosoma*	*Graphosoma rubrolineata*
29.			*Halyomorpha*	*Halyomorpha halys*
30.				*Halyomorpha picus*
31.			*Halys*	*Halys_dentatus*
32.			*Megymenum*	*Megymenum parallelum*
33.			*Menida*	*Menida metallica*
34.			*Nezara*	*Nezara indica*
35.				*Nezara viridula*
36.			*Niphe*	*Niphe subferruginea*
37.			*Oplomus*	*Oplomus catena*
38.			*Piezodorus*	*Piezodorus hybneri*
39.			*Plautia*	*Plautia crossota*
40.				*Plautia stali*
41.		Scutelleridae	*Calliphara*	*Calliphara excellens*
42.			*Chrysocoris*	*Chrysocoris purpureus*
43.				*Chrysocoris stollii*
44.			*Eucorysses*	*Eucorysses grandis*
45.			*Poecilocoris*	*Poecilocoris druraei*
46.			*Scutellera*	*Scutellera perplexa*
47.			*Solenostethium*	*Solenostethium rubropunctatum*
48.		Tessaratomidae	*Tessaratoma*	*Tessaratoma javanica*
49.	Sternorrhyncha	Aphididae	*Aphis*	*Aphis gossypii*
50.			*Myzus*	*Myzus persicae*
51.		Coccidae	*Saissetia*	*Saissetia coffeae*
52.		Diaspididae	*Aspidiotus*	*Aspidiotus destructor*
53.		Psyllidae	*Diaphorina*	*Diaphorina citri*

%), Dinidoridae (6 species, 11.1%), and Tessaratomidae (1 species, 1.9%).

At the family level, the dominance of Pentatomidae (Shield Bugs) within Heteroptera was particularly most speciose, comprising 4 species (7.4%), followed by Delphacidae (2 species, 3.7%) and Fulgoridae (1 species, 1.9%. In Sternorrhyncha, the families Aphididae (2 species, 3.7%), Coccidae, Diaspididae, and Psyllidae (each with 1 species, 1.9%) were recorded (Fig. 3).

Hemipteran species documented in Mokhada Tahsil, though largely unlisted under national (Wildlife Protection Act, 1972) and global (IUCN Red List) conservation frameworks, include ecologically significant taxa such as *Catacanthus incarnatus*, *Chrysocoris stollii*, and *Diaphorina citri*, highlighting their importance as bioindicators and their potential role in biodiversity monitoring and agroecological management.

Hemipteran assemblages in Mokhada Tahsil manifest a pronounced monsoon laze ninth, registering 51 species (100% baseline), which attenuates marginally to 46 species (-9.8%) in the post-monsoon phase and plunges to 26 species (-49.0%) during the pre-monsoon interval (Table 3). Within Heteroptera, the ecologically dominant Pentatomidae exhibits an

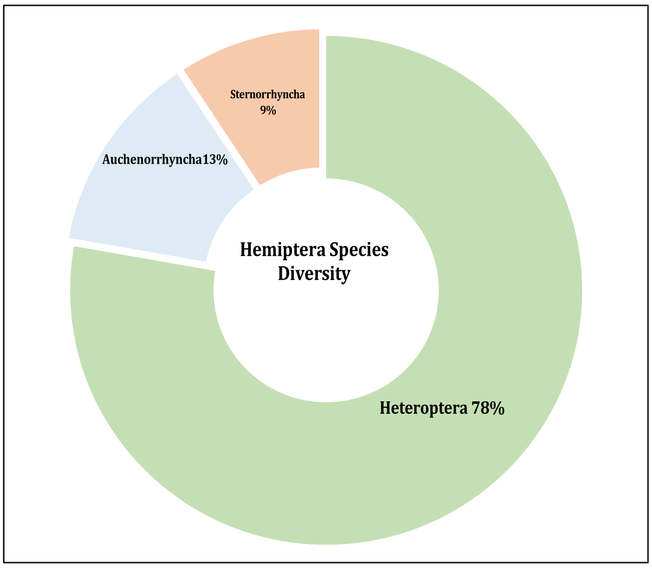

Fig. 2: Hemiptera Species Diversity in the Mokhada Tahsil.

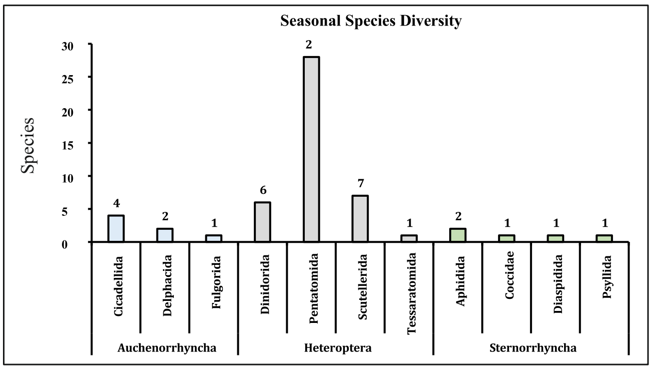

Fig. 3: Seasonal Hemiptera Species Diversity in the Mokhada Tahsil.

almost unimpaired persistence from monsoon (27sp.) to post-monsoon (26sp.) before contracting to 18sp. under pre-monsoonal aridity, while Dinidoridae and Scutelleridae follow congruently yet dramatic trajectories (6→4→3sp. and 7→7→3 sp., respectively). Auchenorrhyncha an diversity, typified by xylem- and phloem-feeding Cicadellidae (4→3→1 sp.) and Delphacidae (2→1→0 sp.)

Diversity

The alpha-diversity profile of the Hemipteran assemblage in Mokhada Tahsil exhibits a pronounced seasonally modulated gradient that mirrors the region's hydrometeorological regime. During the monsoon, luxuriant vegetative growth and sustained atmospheric humidity foster the highest species richness (S = 51) and confer a Shannon–Wiener entropy (H' = 3.79) approaching the upper theoretical limit for communities of comparable size, signifying maximal informational complexity and minimal niche overlap. A concomitant Simpson's complement (1 – D = 0.945) reveals a community configuration in which no single taxon monopolizes ecological space, while a Pielou's evenness coefficient (J' = 0.89) denotes an exceptionally equitable distribution of individuals among species an indicator of dynamic equilibrium under resource-replete conditions (Table 4).

Post-monsoon, the assemblage maintains substantial but attenuated diversity (S = 46; H' = 3.51; 1 – D = 0.926; J' = 0.86). This marginal decline reflects incipient senescence of host- plant biomass and the onset of stochastic perturbations that slightly erode evenness and amplify competitive asymmetry. Nevertheless, the community remains structurally robust, retaining high heterogeneity and buffering against dominance shifts.

Pre-monsoon, exacerbated evapotranspiration stress and dwindling trophic resources precipitate a conspicuous contraction of community breadth (S= 26) and informational entropy (H' = 2.68). The reduced Simpson's value (1 – D = 0.864) signals an emergent predominance of drought-resilient taxa, and the depressed J' = 0.80 evidences skewed abundance distributions. Collectively, these metrics illuminate a seasonal continuum in which monsoonal plenitude underwrites maximal compositional complexity, post-monsoonal conditions sustain a tempered yet still diverse mosaic, and pre-monsoonal austerity culminates in ecological simplification and heightened dominance.

Bray–Curtis Dissimilarity Coefficients

To quantify inter-seasonal beta diversity in Hemipteran assemblages of Mokhada Tahsil, Bray–Curti's dissimilarity coefficients were calculated using standardized presence– absence and relative abundance data across monsoon, post-monsoon, and pre-monsoon seasons. This metric, which ranges from 0 (complete similarity) to 1 (complete dissimilarity), effectively captures both taxonomic replacement and abundance reconfiguration between community states. The resulting dissimilarity values were organized in to asymmetrical matrix, providing pairwise comparisons between the seasonal datasets.

The lowest Bray–Curtis dissimilarity (0.312) was observed (Table 5) between monsoon and post-monsoon, reflecting high degrees of species overlap and ecological continuity. This pattern likely arises from sustained vegetational productivity and environmental stability during these two hydro climatically adjacent phases. Many species recorded during the monsoon, especially phytophagous taxa such as Cicadellidae and Pentatomidae, persist into the post- monsoon period, supported by residual soil moisture and delayed senescence of host plants.

Table 3: Seasonal Variability Diversity of Hemiptera Species.

Sub-order	Family	Monsoon	Post-monsoon	Pre-monsoon
Auchenorrhyncha	Cicadellidae	4	3	1
	Delphacidae	2	1	0
	Fulgoridae	1	1	0
	Dinidoridae	6	4	3
Heteroptera	Pentatomidae	27	26	18
	Scutelleridae	7	7	3
	Tessaratomidae	0	1	0
	Aphididae	1	2	1
Sternorrhyncha	Coccidae	1	0	0
	Diaspididae	1	1	0
	Psyllidae	1	0	0
Total		**51**	**46**	**26**

Table 4: Alpha Diversity of Hemiptera Species.

Season	Species Richness (S)	Shannon– Wiener Index (H')	Simpson's Index (1–D)	Pielou's Evenness (J')
Monsoon	51	3.79	0.945	0.89
Post-Monsoon	46	3.51	0.926	0.86
Pre-Monsoon	26	2.68	0.864	0.8

In contrast, the highest dissimilarity value (0.627) occurred between monsoon and pre- monsoon seasons. This substantial taxonomic turnover underscores the impact of abiotic stressors, including increasing temperatures, declining humidity, and resource limitations, during the pre-monsoon phase. The drying of habitats and reduction in vegetative biomass during this time selectively filter south moisture-dependent taxa, favoring a more specialized and drought- resilient subset of the Hemipteran community.

The intermediate dissimilarity (0.489) between post-monsoon and pre-monsoon denotes a transitional restructuring of the community. This period is characterized by a gradual decline in diversity and evenness as ecological conditions become more restrictive. Taxa that were abundant post-monsoon begin to decline or disappear, resulting in an assemblage increasingly dominated by a few resilient species. Overall, the Bray–Curti's dissimilarity matrix elucidates a clear gradient of compositional divergence, with maximum community turnover occurring between climatically dissimilar seasons and minimum dissimilarity between successive wet phases. These findings underscore the seasonal dynamism of Hemipteran assemblages in semi-tropical hill environments and highlight the importance of climatic periodicity in shaping beta diversity and ecological resilience.

Table 5: Bray–Curtis Dissimilarity Coefficients.

Seasonal Comparison	Bray–Curtis Dissimilarity (0–1)
Monsoon vs Post-Monsoon	0.312
Monsoon vs Pre-Monsoon	0.627
Post-Monsoon vs Pre-Monsoon	0.489

CONCLUSION

This study presents a comprehensive seasonal assessment of Hemipteran diversity in Mokhada Tahsil, revealing significant taxonomic richness and structural complexity across monsoon, post-monsoon, and pre-monsoon phases. The findings underscore the ecological preeminence of Heteroptera, particularly the Pentatomidae, which dominate species richness and persist across fluctuating hydroclimatic conditions. Alpha diversity metrics illustrate a distinct seasonal gradient, with the monsoon fostering peak richness (S = 51) and evenness (J'= 0.89), attributable to enhanced vegetative productivity and ambient humidity. Post-monsoon assemblages remain comparatively stable, whereas pre-monsoon conditions induce pronounced community contraction and taxonomic filtering, as evidenced by reduced Shannon entropy (H' = 2.68) and a sharp decline in richness (S = 26). This seasonal succession highlights the critical influence of moisture availability on community structure and the ecological resilience of drought-tolerant taxa.

Beta diversity, quantified using Bray–Curti's dissimilarity, further elucidates inter-seasonal compositional turnover, with the highest divergence observed between monsoon and pre-monsoon (0.627), and minimal differentiation between monsoon and post-monsoon (0.312). These results signify that Hemipteran community composition is tightly coupled with seasonal hydroperiodicity and that compositional dissimilarity intensifies under environmental stress. The study not only fills a vital gap in the faunistic knowledge of semi-natural landscapes within the northern Western Ghats but also emphasizes the importance of adopting stratified, multi-method sampling protocols for monitoring insect biodiversity. Importantly, the identification of taxa with potential bioindicator value (e.g., *Catacanthus incarnatus*, *Chrysocoris stollii*) provides a foundation for future conservation prioritization, integrated pest management strategies, and long-term ecological monitoring in tropical hill ecosystems.

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