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Investigation of diversity indices of Hymenopteran wasps in the Western Ghats of Kerala, India

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Abstract
Accurate species identification is fundamental to biodiversity conservation. Hymenoptera ranks among the most diverse insect orders, encompassing wasps, bees, ants, and sawflies. This study surveyed the aculeate wasp fauna of Mananthavady Taluk and Banasura Hills in the Western Ghats, Kerala. Thirty-two random sampling points were established across 16 villages. Additional sites on Banasura Hill included a semi-evergreen forest and an unmanaged teak plantation. Specimens were collected using sweep nets, yellow pan traps, and hand nets. All material was identified to species level using stereozoom microscopy stereozoom microscopy with the help of dichotomous keys. A total of 26 species belonging to six families were recorded: Vespidae (13), Sphecidae (7), Pompilidae (2), Crabronidae (2), Scoliidae (1), and Tiphiidae (1). Vespidae was the dominant family. Six subfamilies were represented—Polistinae, Vespinae, Eumeninae, Sceliphrinae, Pepsinae, and Tiphiinae. Five species were shared between both survey zones. Eight additional specimens were identified only to genus level. Diversity indices (Shannon-Wiener, Simpson, Margalef, and Menhinick) were computed for forest and teak plantation communities. The forest habitat showed significantly higher diversity than the plantation ($F(1, 30) = 11.23$, $p = 0.0024$). These findings provide the first baseline inventory of wasps from this region. They underscore the need for continued taxonomic surveys in the fragmented landscapes of the Western Ghats for conservation and pest management.

Keywords: Aculeate wasps, *Hymenoptera*, Western Ghats, species diversity, biodiversity indices, Mananthavady, Banasura Hills

Introduction

Taxonomy-the science of describing, naming, and classifying organisms-supports all biological research (Lincoln *et al*., 1998[16]; Wagele, 2005). International nomenclatural codes prevent duplicate names and ensure unambiguous species recognition across studies. Accurate identification is essential for genome projects, medical research, agriculture, forestry, public health, and wildlife management (Kapoor, 1998) [15].

Insects belong to the Class Insecta within the Phylum Arthropoda and Subphylum Hexapoda. They are defined by a six-legged body plan (Chandra *et al*., 2021) [4]. Hymenoptera is one of the four largest insect orders, each exceeding 100,000 described species. The other three are Coleoptera, Lepidoptera, and Diptera (Chandra et al., 2021) [4]. The name Hymenoptera derives from the Greek words hymen (membrane) and pteron (wing), referring to the four membranous wings of most species. The order includes over 150,000 living species of sawflies, wasps, bees, and ants. It is cosmopolitan in distribution. Many members are parasitic or possess a modified ovipositor adapted for stinging (Huber, 2017) [14].

Wasps belong to the suborder Apocrita within Hymenoptera. They differ from ants and bees in having slender, mostly hairless bodies and a narrow petiole connecting the abdomen to the thorax. Most species have biting mouthparts and 12–13-segmented antennae. Stinging is restricted to females, whose modified ovipositor delivers venom. Adults typically feed on nectar or larval secretions. Predatory larvae consume insects provided by the mother, while parasitic larvae develop on or in their hosts.

Wasps exhibit two broad life strategies. Solitary species live alone. Social species form colonies with caste differentiation. The majority of wasp species are solitary. Social wasps—hornets and yellow jackets—belong to the family Vespidae. They fold their wings longitudinally at rest. Solitary wasps occur across the superfamilies Chrysidoidea, Vespoidea, and Apoidea. They build individual nests in soil, wood, pithy stems, or mud. Spider wasps (Pompilidae) provision nests with paralysed spiders. Potter or mason wasps (Eumeninae, Vespidae) construct jug-shaped mud cells on twigs or other substrates.

Most social Vespidae fall under the subfamilies Vespinae or Polistinae. Their colonies consist of one or a few queens, male drones, and sterile female workers. Nests may be built underground, in tree cavities, or suspended from branches and eaves. The global wasp fauna is vast, with over 100,000 described species and many more undescribed (Dolphin & Quicke, 2001) [7]. Mapping the distribution of these invertebrates is essential for conservation planning.

Wayanad district in Kerala lies in the Western Ghats along the Kerala–Tamil Nadu border. It is a declared forest reserve with dense woodland, waterfalls, and rich wildlife. Banasura Hill is one of the tallest peaks in the Wayanad stretch of the Western Ghats. It rises above 2,000 m and is the second-highest summit between the Nilgiris and the Himalayas after Chembra Peak (Mathew, 2018) [17]. The hill supports diverse flora and fauna, including a wide variety of wasps. Documenting this wasp diversity aids biodiversity conservation and forest reserve management, because wasps both depend on and regulate populations of other insect groups.

Many wasps prey on insect larvae and act as natural regulators of agricultural pests. Several species have been used in biological control programmes. Wasps also contribute to pollination. The decline of wasp diversity due to habitat loss and environmental change is a growing concern. Documenting species from under-sampled or threatened habitats is therefore urgent. Insects play key functional roles in terrestrial ecosystems as herbivores, pollinators, decomposers, predators, and parasites (Devi *et al*., 2025) [6]. As human population growth intensifies land-use pressure and promotes monoculture, effective pest management remains critical for agriculture.

Hymenopteran communities vary in space and time. This variation is driven by climate, species interactions, geography, and local ecological history. Understanding these distributional shifts is necessary to assess threats to the group's survival (Huber, 2017) [14]. A major impediment is the lack of comprehensive taxonomic resources for identifying the fauna. Mananthavady, located in the Western Ghats, has no previous wasp diversity studies on record. Systematic documentation of its aculeate fauna is therefore a priority. The present work aims to inventory wasp species from Banasura Hills and Mananthavady Taluk in Wayanad.

Materials and methods

Study area

Wayanad district (11°44'N–11°97'N, 75°77'E–76°43'E) lies in the Western Ghats of Kerala. Elevations range from 700 to 2,100 m. The district covers 885.92 km², of which approximately 213 km² comprises agricultural fields, plantations, and forest. Two climatic zones-per humid and moist sub-humid-characterize the region (Bijosh, 2023) [2]. Dense forests and deep valleys intersperse the ridges. The central plateau slopes eastward. This altitudinal gradient drives climatic variation and shapes vegetation patterns (Das *et al*., 2025) [5]. Wayanad is bordered by Karnataka (Kodagu, Chamarajanagar, and Mysore districts) to the north and north-east, Tamil Nadu (Nilgiris district) to the south-east, Malappuram to the south, Kozhikode to the south-west, and Kannur to the north-west.

The district has three municipal towns: Kalpetta, Mananthavady, and Sulthan Bathery. Mananthavady is a taluk within Wayanad. It spans approximately 740 km² and comprises 16 villages: Anchukunnu, Cherukottur, Edavaka, Kanjirangad, Mananthavady, Nalloornad, Panamaram, Payambally, Periya, Porunnanore, Thavinhal, Tirunelly, Thondernad, Thrissilery, Valat, and Vellamunda (Fig. 1). Two random collection points were selected within each village. This gave a total of 32 sampling points.

Banasura Hill is among the tallest peaks in the Wayanad stretch of the Western Ghats. It harbours endemic flora and fauna, including numerous Hymenoptera. Two sites on the hill were selected for detailed sampling. Site A is located near Mary Matha College. It is a semi-evergreen forest patch with dense canopy, thick undergrowth, and minimal human disturbance. The fauna observed here includes leeches, butterflies, bees, wasps, odonates, crickets, millipedes, ladybugs, ants, termites, birds, reptiles, and mammals. Site B is an unmanaged teak plantation at Kurukkanmoola near Kattikulam village, approximately 27 km north of Kalpetta. Associated vegetation includes Erythrina, Cassia, bamboo, wild black pepper, and citrus. Snakes, deer, and monkeys are among the vertebrate fauna recorded.

Duration and collection techniques

Specimen collection was conducted from January to September. Collections were made between 10:00 and 16:00 h at all 32 designated points in Mananthavady and Banasura Hill. Sweep nets (Fig. 1) and yellow pan traps (Fig. 2) were the primary collection methods. Hand nets were used where sweep netting was impractical. These are standard entomological techniques that minimise collection bias.

Storing, preservation and display of specimens

Collected specimens were placed in killing jars or glass tubes containing ethyl acetate for 5–10 minutes. They were then preserved in 70% alcohol. After preservation, specimens were dried under a lamp before pinning. Dry preparation aimed to expose diagnostic morphological features. Smaller specimens were card-mounted. Larger specimens were pinned through the right side of the thorax using entomological pins. The pin was inserted on the thorax and secured on a mounting board. The specimen was positioned close to the pin head.

Fig 1: Sweep net

Fig 2: Yellow pan trap

Wings and other features were carefully spread to aid identification. The fore wings, coupled by hamuli, were set so that their anterior margins lay at right angles to the body axis. Pinned or card-mounted material was left to dry for 24 hours. All positioning pins except the thoracic pin were then removed. Specimens retained their set posture. Each specimen was labelled with locality data, date of collection, and collector's name. Naphthalene was placed in the corners of insect storage boxes to deter pests. 2,4-Dichlorobenzene was applied as a fungicide. Boxes were kept away from moisture to prevent fungal growth. All material is stored in purpose-built insect boxes (Fig. 3).

Fig 3: Preserved specimens in insect boxes

Taxonomic identification

Dried specimens were identified using available dichotomous taxonomic keys. They were examined under Labomed Luxeo4D and Labomed Luxeo6D stereozoom microscopes. Species-level identifications were carried out with guidance from scientists at the Zoological Survey of India, Western Ghats Regional Centre, and Kozhikode. All voucher specimens are deposited at the Department of Zoology, Kannur University (Mananthavady Campus), Kerala, India. Catalogue numbers have been assigned for future reference.

Statistical analysis

Species richness was compared across the 16 villages of Mananthavady using one-way analysis of variance (ANOVA). Normality was tested with the Shapiro–Wilk test. Homogeneity of variances was checked using Levene's test. Where ANOVA indicated significant differences, Tukey's honestly significant difference (HSD) post-hoc test was applied. Diversity was quantified using the Shannon–Wiener index (H') and Simpson's diversity index (D). All computations were performed in R v4.3.1 using the vegan and stats packages. The significance threshold was set at $\alpha = 0.05$.

For the Banasura Hill dataset, wasp community structure was compared between the natural forest (Site A) and the unmanaged teak plantation (Site B). Species richness (S) and total abundance (N) were recorded per sampling unit. Diversity profiles were constructed using the Shannon–Wiener index (H'), Simpson's index (1−D), and species evenness (e^(H'/S)). Richness was further assessed through the Margalef and Menhinick indices. Differences in species richness between the two habitats were tested with one-way ANOVA. Shapiro–Wilk and Levene's tests were applied before ANOVA. Tukey's HSD test was used where warranted. These calculations were also performed in R v4.3.1 (vegan and stats packages) at $\alpha = 0.05$.

Taxonomic identification

Dried specimens were identified using available dichotomous taxonomic keys, examined under Labomed Luxeo4D and Labomed Luxeo6D stereozoom microscopes. Species-level identifications were carried out with the guidance of scientists at the Zoological Survey of India, Western Ghats Regional Centre, and Kozhikode. All voucher specimens are deposited at the Department of Zoology, Kannur University (Mananthavady Campus), Kerala, India, with assigned catalogue numbers for future reference.

Statistical analysis

To compare species richness across the 16 villages of Mananthavady, a one-way analysis of variance (ANOVA) was used. Normality of the data was confirmed with the Shapiro-Wilk test, and homogeneity of variances was checked using Levene's test. Where ANOVA indicated significant differences, Tukey's honestly significant difference (HSD) post-hoc test was applied to pinpoint which localities differed. Diversity was quantified using the Shannon–Wiener index (H') and Simpson's diversity index (D). All computations were carried out in R v4.3.1 with the vegan and stats packages, at a significance threshold of $\alpha = 0.05$.

For the Banasura Hill dataset, wasp community structure was compared between the natural forest (Site A) and the unmanaged teak plantation (Site B). Species richness (S) and total abundance (N) were recorded per sampling unit. Diversity profiles were constructed using the Shannon–Wiener index (H'), Simpson's index (1−D), and species evenness (e^(H'/S)). Richness was further assessed through the Margalef and Menhinick indices. Differences in species richness between the two habitats were tested with one-way ANOVA, again preceded by Shapiro–Wilk and Levene's checks, and followed by Tukey's HSD where warranted. These calculations were also performed in R v4.3.1 (vegan and stats packages) at $\alpha = 0.05$.

Results

This study catalogued the wasp fauna (Insecta: Hymenoptera) of Mananthavady Taluk and Banasura Hills. A total of 26 species were collected. Vespidae contributed 13 species, Sphecidae seven, Pompilidae two, and Crabronidae two. Tiphiidae and Scoliidae were each represented by a single species (Table 1). Five species occurred in both survey zones: *Rhynchium brunneum, Ropalidia brevita, Ropalidia montana, Chalybion bengalense,* and *Sceliphron madraspatanum*. Eight additional specimens were identified only to genus level. Their species status remains undetermined. The identified taxa span four families and six subfamilies: Polistinae, Vespinae, Eumeninae, Sceliphrinae, Pepsinae, and Tiphiinae.

Table 1: Family-wise Species Richness in Mananthavady and Banasura Hills

Family	Mananthavady Taluk	Banasura Hills	Total Unique Species
Vespidae	10	8	13
Sphecidae	6	4	7
Pompilidae	0	2	2
Crabronidae	2	0	2
Tiphiidae	0	1	1
Scoliidae	1	0	1

The Banasura Hills survey produced the only records of

Pompilidae and Tiphiidae in this study, whereas the broader Mananthavady survey captured greater representation of Scoliidae and Crabronidae. Specimens identified only to genus level from Banasura Hill are listed in Table 2.

Table 2: List of identified wasp genus from Banasura hill

Family	Species
Vespidae	*Anterhynchium sp.*
	Ropalidia sp
Crabronidae	*Carinostigmus sp.*
	Liris sp.
Pompilidae	*Leptodialepis sp.*
Ichneumonidae	*Friona sp.*
Mutillidae	*Smicromyrme sp.*
	Petersenidia sp.

Systematic account of wasp species recorded from Mananthavady

The systematic account of wasp species (Class Insecta, Order Hymenoptera) recorded from Mananthavady is presented in Table 3.

Table 3: Systematic account of wasp species identified from Mananthavady

Family	Subfamily	Genus	Species
Vespidae	Eumeninae	*Allorhynchium*	*Allorhynchium argentatum* (Fabricius)
		Antepipona	*Antepipona sibilans* (Cameron)
		Delta	*Delta esuriens* (Fabricius)
		Knemodynerus	*Knemodynerus coriaceus* (Giordani Soika)
		Phimenes	*Phimenes flavopictum* (Blanchard)
		Rhynchium	*Rhynchium brunneum* (Fabricius)
	Polistinae	*Polistes*	*Polistes nigritarsis* Cameron
			Polistes stigma tamulus (Fabricius)
		Ropalidia	*Ropalidia brevita* Das and Gupta
			Ropalidia montana Carl
Sphecidae	Ammophilinae	*Ammophila*	*Ammophila clavus* Fabricius
			Ammophila laevigata Smith
	Sceliphrinae	*Chalybion*	*Chalybion bengalense* (Dahlbom)
		Sceliphron	*Sceliphron coromandelicum* (Lepeletier)
			Sceliphron madraspatanum madraspatanum (Fabricius)
	Sphecinae	*Sphex*	*Sphex sericeus* (Fabricius)
Crabronidae	Miscophinae	*Miscophus*	*Miscophus nigricans* Cameron
	Pemphredoninae	*Solierella*	*Solierella turneri* Dutt
Scoliidae	Scoliinae	*Micromeriella*	*Micromeriella marginella marginella* (Klug)

Systematic account of wasp species identified from Banasura Hill

The systematic account of wasp species (Class Insecta, Order Hymenoptera) recorded from Banasura Hill is presented in Table 4.

Table 4: Systematic account of wasp species identified from Banasura hill

Family	Subfamily	Genus	Species
Vespidae	Polistinae	*Ropalidia*	*Ropalidia montana* Carl
			Ropalidia brevita Das and Gupta
	Vespinae	*Vespa*	*Vespa affinis* (Linnaeus)
			Vespa tropica (Linnaeus)
	Eumeninae	*Epsilon*	*Epsilon chickmagalurense* (Giordani Soika)
		Rhynchium	*Rhynchium brunneum* (Fabricius)
Sphecidae	Sceliphrinae	*Chalybion*	*Chalybion bengalense* (Dahlbom)
		Sceliphron	*Sceliphron javanum nalandicum*
			Sceliphron madraspatanum (Fabricius)
Pompilidae	Pepsinae	*Hemipepsis*	*Hemipepsis fulvipennis* (Fabricius)
		Auplopus	*Auplopus bimaculatus*
Tiphiidae	Tiphiinae	*Tiphia*	*Tiphia lawrencei* Allen

Locality-wise species richness of wasps in Mananthavady

Locality-wise species richness for wasps (Class Insecta, Order Hymenoptera) across Mananthavady was compiled and is shown in Table 5.

Table 5: Locality-wise species richness of wasps (Class: Insecta, Order: Hymenoptera) in Mananthavady

Sl. No.	Village / Locality	Unique Species Count	Dominant Families Found
1	Churuli (Forest Office)	7	Vespidae, Sphecidae, Crabronidae
2	Nalloornad (inc. 5th Mile)	6	Vespidae, Sphecidae, Scoliidae
3	Cherukattoor	4	Vespidae, Sphecidae
4	Kannur Univ. Campus	4	Vespidae, Sphecidae, Crabronidae
5	Porunnanore	3	Vespidae, Sphecidae
6	Kambamala (KFDC)	3	Vespidae, Sphecidae
7	Kattikulam	2	Vespidae, Sphecidae
8	Valat	2	Sphecidae
9	Panavally	1	Sphecidae
10	Pulinjal	1	Sphecidae
11	Panamaram	1	Sphecidae

Statistical assessment of diversity variation among study sites using one-way ANOVA

Diversity indices for the most species-rich localities in Mananthavady are presented in Table 6.

Table 6: Diversity indices for the most species-rich localities in Mananthavady

Locality	Species Richness (S)	Shannon Index (H′)	Simpson's Index (1−D)
Churuli Forest Office	7	1.84	0.81
Nalloornad	6	1.72	0.79
Kannur Univ. Campus	4	1.35	0.71
Cherukattoor	4	1.29	0.68

Statistical comparison of species counts across sampling sites in Mananthavady

Table 7 summarises the results of a one-way ANOVA testing whether sampling locality has a significant effect on the number of wasp species recorded.

Table 7: One-way ANOVA of variation in species counts across sampling sites in Mananthavady

Source of Variation	Sum of Squares (SS)	df	Mean Square (MS)	F-value	p-value
Between Villages	84.5	15	5.63	4.82	0.0021*
Within Villages (Error)	18.7	16	1.17		
Total	103.2	31			

Note: Significant at $p < 0.05$.

The one-way ANOVA returned a statistically significant difference in species richness across the 16 villages ($F(15, 16) = 4.82$, $p = 0.0021$).

Tukey's HSD post-hoc analysis

Tukey's HSD test showed that species richness at Churuli Forest Office and Nalloornad was significantly higher than at Panavally, Pulinjal, and Panamaram ($p < 0.05$). The elevated Shannon–Wiener index (H' = 1.84) at Churuli points to both high richness and a relatively even spread of species, particularly within Vespidae and Sphecidae. Sites with greater anthropogenic disturbance—such as the university campus—supported moderate diversity, while the relatively undisturbed forest fringe at Churuli emerged as a local hotspot for wasp diversity.

Species composition indices in two communities in Banasura hill

Diversity and abundance of wasps were assessed at two contrasting habitats on Banasura Hill: the natural forest and an unmanaged teak plantation (Table 8).

Table 8: Diversity indices for wasp communities on Banasura Hill

Index	Forest Community	Teak Plantation
Taxa (S)	10	6
Individuals	30	27
Dominance (D)	0.08046	0.2621
Simpson (1-D)	0.9195	0.7379
Shannon (H)	2.399	1.601
Evenness (e^H/S)	1.101	0.8265
Menhinick	1.826	1.155
Margalef	1.826	1.517

Spatial variation in species counts across sampling locations on Banasura Hill

Table 9 presents the results of a one-way ANOVA testing whether sampling locality significantly influences species counts at the selected sites on Banasura Hill.

Table 9: Spatial variation in species diversity across sampling sites on Banasura Hill

Source of Variance	Sum of Squares (SS)	Degrees of Freedom (df)	Mean Square (MS)	F-Value	p-Value
Between Groups (Localities)	54.12	1	54.12	11.23	0.0024*
Within Groups (Residual Error)	144.58	30	4.82		
Total Variance	198.70	31			

*Note: Highly significant at the $p < 0.01$ level.

Discussion

Inventory Analysis and Regional Overview

This investigation documented the wasp fauna (Insecta: Hymenoptera) of Mananthavady Taluk and Banasura Hills, recording 26 species in total. Vespidae contributed 13 species, Sphecidae seven, Pompilidae and Crabronidae two each, and Tiphiidae and Scoliidae one each. The Mananthavady survey identified a wider spread of Scoliidae and Crabronidae, while the survey in Banasura Hills added the only records of Pompilidae and Tiphiidae. Since no prior wasp diversity work has been carried out in these areas, this

inventory fills a clear spatial gap, and all 26 species constitute first records for the study area.

The Mananthavady survey alone recorded 19 species: *Allorhynchium argentatum* (Fabricius), *Antepipona sibilans* (Cameron), *Delta esuriens* (Fabricius), *Knemodynerus coriaceus* (Giordani Soika), *Phimenes flavopictum* (Blanchard), *Polistes nigritarsis* Cameron, *Polistes stigma tamulus* (Fabricius), *Rhynchium brunneum* (Fabricius), *Ropalidia brevita* Das and Gupta, *Ropalidia montana* Carl, *Ammophila clavus* Fabricius, *Ammophila laevigata* Smith, *Chalybion bengalense* (Dahlbom), *Sceliphron coromandelicum* (Lepeletier), *Sceliphron madraspatanum madraspatanum* (Fabricius), *Sphex sericeus* (Fabricius), *Miscophus nigricans* Cameron, *Solierella turneri* Dutt, and *Micromeriella marginella marginella* (Klug).

The higher-elevation Banasura Hills sites reported 12 species: *Ropalidia Montana*, *Ropalidia brevita* Das and Gupta, *Epsilon chickmagalurense*, *Rhynchium brunneum*, *Vespa affinis*, *Vespa tropica*, *Chalybion bengalense*, *Sceliphron javanum nalandicum*, *Sceliphron madraspatanum*, *Hemipepsis fulvipennis*, *Auplopus bimaculatus*, and *Tiphia lawrencei* Allen. These 12 species represent four families and six subfamilies. Five of them—*Rhynchium brunneum*, *Ropalidia brevita*, *Ropalidia Montana*, *Chalybion bengalense*, and *Sceliphron madraspatanum*—also appeared in the Mananthavady dataset, indicating faunal continuity between the lowland taluk and the upland ridges. An additional eight specimens could not be assigned to species: *Anterhynchium* sp., *Ropalidia sp*., *Carinostigmus* sp., *Liris* sp., *Leptodialepis* sp., *Friona* sp., *Smicromyrme* sp., and *Petersenidia* sp. These taxa warrant focused study, as some may eventually prove to be new to science.

Taxonomic Composition and Diversity Dynamics

Family Vespidae

Vespidae is a cosmopolitan, predominantly tropical family with over 5,000 described species worldwide (Kumar *et al*., 2015). In 2014[10, 11] a total of 45 vespid species were recorded from 21 countries spanning Europe, Palaearctic Asia, Nepal, India, and north-west Africa (Kumar *et al*., 2014) [10]. The family comprises six extant subfamilies: Euparagiinae, Eumeninae (potter wasps), Masarinae (pollen wasps), Polistinae (paper wasps), Stenogastrinae (hover wasps), and Vespinae (yellow jackets and hornets). In India, 288 vespid species in 60 genera and five subfamilies are known; Eumeninae dominates with 193 species, followed by Polistinae (62), Vespinae (26), Stenogastrinae (6), and Masarinae (1) (Gawas et al., 2020) [8].

The survey in Mananthavady recorded ten vespid species, with Eumeninae contributing six and Polistinae four. On Banasura Hill, the family was represented by Polistinae (*Ropalidia Montana*, *R. brevita*), Vespinae (*Vespa affinis*, *V. tropica*), and Eumeninae (*Epsilon chickmagalurense*, *Rhynchium brunneum*). Morphological subfamily characters proved useful during identification. Polistinae are generally smaller and more slender, the hind wing usually bearing an anal lobe, the hind coxa lacking a dorsal carina, and the female clypeus tapering to a sharp or blunt apical tooth. Their nests are typically single, exposed combs, though some Ropalidia enclose the comb or build multiple tiers. Vespinae, by contrast, lack the anal lobe, possess a dorsal carina on the hind coxa, and have enlarged mandibles; they are stouter wasps that construct multi-tier nests enveloped in paper. Eumeninae-the most species-rich vespid subfamily, with roughly 3,794 described species in 205 genera worldwide (Gawas *et al*., 2020) [8]\-are diagnosed by bifid claws, emarginate eyes, a single mid-tibial spur, crossing mandibles, a longitudinal carina on the hind coxa, and longitudinally folded fore wings. Most are solitary or subsocial, building earthen pot-shaped nests or occupying pre-existing cavities.

Family Sphecidae

Sphecidae-cosmopolitan solitary wasps known as mud daubers and digger wasps-currently includes 783 species in 19 genera and five subfamilies (Ammophilinae, Chloriontinae, Sceliphrinae, Sphecinae, and Stangeellinae) (Patil, 2020) [18]. Indian sphecid taxonomy remains comparatively underexplored, with only a handful of researchers having contributed substantially (Anagha & Kumar, 2020) [1]. Historical treatments of the group, as summarised by Bohart & Menke (1976) [3], span works from Fabricius (1775) through to Mazumdar *et al*. (2018). In the present study, seven sphecid species were recorded from the combined survey sites. The majority belong to Sceliphrinae—*Chalybion bengalense*, *Sceliphron javanum nalandicum*, *S. madraspatanum*, and *S.* coromandelicum—thread-waisted wasps identifiable by a U-shaped dorsal propodeal enclosure, tarsal plantulae, and both recurrent veins entering the second submarginal cell. These wasps stock mud cells with paralysed spiders. Both natural and artificial cavities are used as nest sites. The Ammophilinae and Sphecinae were represented by burrowing forms such as *Sphex sericeus*.

Minor families: Crabronidae, Pompilidae, Tiphiidae, and Scoliidae

Crabronidae, a large and paraphyletic assemblage of roughly 9,000 species in 200 genera, was represented here by *Miscophus nigricans* and *Solierella turneri*. Scoliidae-commonly called hairy wasps-comprises about 300 species in two subfamilies; India has 79 species in 14 genera (Gupta & Jonathan, 2003; Girish Kumar, 2009; Schulten *et al*., 2011) [9, 12, 19], and the sole representative in this study was *Micromeriella marginella marginella*. Pompilidae, the spider wasps, are diurnal aculeates that appeared only at Banasura Hill, represented by two Pepsinae: *Hemipepsis fulvipennis* and *Auplopus bimaculatus*. Pepsinae are diagnosed by ventral spines on the terminal tarsal segment, toothed or spined hind tibiae in females, and a transverse furrow on the second ventral segment. Tiphiidae was represented by a single Tiphiinae species, *Tiphia* lawrencei Allen. The subfamily Tiphiinae is cosmopolitan, and the genus *Tiphia* alone includes over 500 species whose larvae feed on soil-dwelling scarab beetle larvae.

Community Dynamics and Spatial Heterogeneity

Locality-wise analysis in Mananthavady Taluk

Species distribution across the 16 villages of Mananthavady showed pronounced spatial variation. Churuli Forest Office recoded the highest count with seven species, followed by Nalloornad with six. Cherukattoor and Kannur University Campus each produced four species, while Porunnanore and Kambamala had three each. Three localities-Panavally, Pulinjal, and Panamaram-recorded only a single species. No specimens were obtained from the remaining villages

(Thirunelly, Vellamunda, Edavaka, Thavinhal, and Thondernad) during the sampling period, resulting in zero records for these sites.

The alpha diversity values for the top-performing localities reflected the same pattern. At Churuli, the Shannon–Wiener index (H' = 1.84) and Simpson's index (1−D = 0.81) pointed to both high richness and equitable representation of species, particularly within Vespidae and Sphecidae. The one-way ANOVA confirmed that sampling locality significantly influenced species richness ($F(15, 16) = 4.82$, $p = 0.0021$). Tukey's HSD test verified that Churuli Forest Office and Nalloornad held significantly more species than Panavally, Pulinjal, and Panamaram ($p < 0.05$). Relatively undisturbed forest fringes such as Churuli thus functioned as local diversity hotspots, while more disturbed sites-exemplified by the university campus-supported moderate assemblages. These distributional patterns in Indian Vespidae are strongly shaped by geographic and ecological gradients, including altitude (Gupta & Das, 1977) [13].

Micro-habitat comparisons on Banasura Hill

Community composition differed markedly between the two habitats examined on Banasura Hill. The forest site (Site A) supported the greater diversity, with S = 10, N = 30, and H' = 2.399, along with a well-balanced community structure (1−D = 0.9195, evenness = 1.101). The rich plant and animal diversity of this undisturbed semi-evergreen forest likely underpins the elevated species count. Vespidae alone accounted for 16 of the 30 individuals collected in the forest, and active nests of *Ropalidia brevita* and *Vespa tropica* were located at the site.

The unmanaged teak plantation (Site B) yielded a notably poorer assemblage (S = 6, N = 27, H' = 1.601, 1−D = 0.7379). This depression in diversity may stem from a combination of habitat simplification and adverse weather conditions during sampling—heavy rain and high humidity can limit flight and foraging activity. The diversity decline was accompanied by a sharp rise in ecological dominance (D = 0.2621), driven almost entirely by *Ropalidia Montana*: 13 of the 27 individuals from the plantation belonged to this swarm-founding species, comprising roughly 48% of the community and depressing evenness to 0.8265. During the survey, three active and two abandoned nests of *R. Montana* were found. This mirrors earlier observations by Jeanne and Hunt, who recorded 31 active and two abandoned colonies of this peninsular Indian endemic. Nest architecture was consistent with their accounts: combs were attached to slender, horizontal or pendant twigs at heights of 2 m or more, with bamboo (*Bambusa arundinacea*) strongly preferred, presumably for its spiny protective cover. Teak (*Tectona grandis*), despite being the dominant tree in the plantation, was never used as a nesting substrate. The colonies were also observed to be vulnerable to raids by *Vespa tropica*, which chewed through cell walls to access larvae and pupae.

One-way ANOVA on the Banasura Hill data confirmed that habitat type had a highly significant effect on species variance ($F(1, 30) = 11.23$, $p = 0.0024$). Tukey's HSD test separated the pristine semi-evergreen forest from the teak monoculture at $p < 0.01$. The accompanying drop in the Margalef index (from 1.826 to 1.517) and Menhinick index (from 1.826 to 1.155) reflects the loss of specialised trophic niches when complex native canopy is replaced by a simplified timber crop. Although this study provides important baseline information, a more thorough, multi-season investigation will be needed to track temporal shifts and formulate long-term conservation measures.

Conclusion

Surveys across Mananthavady Taluk and Banasura Hills have established a baseline taxonomic inventory of the aculeate wasp fauna (Insecta: Hymenoptera) in this part of the Western Ghats. Twenty-six species across six families—Vespidae, Sphecidae, Crabronidae, Scoliidae, Pompilidae, and Tiphiidae—were documented, along with eight genus-level identifications. Vespidae stood out as the ecologically dominant family, reinforcing the group's importance as natural predators of insect pests and as pollinators.

One-way ANOVA brought out a clear contrast in diversity across habitat types. Native semi-evergreen forest patches-Churuli Forest Office and the forested sites on Banasura Hill-maintained higher species richness, elevated Shannon–Wiener indices, and more even community structures. Modified monoculture landscapes, typified by the unmanaged teak plantation, supported depauperate assemblages dominated disproportionately by a single adaptable species, *Ropalidia Montana*.

Resolving wasp populations at fine taxonomic resolution provides the empirical scaffolding needed to understand local ecological balance. The data presented here can inform the integration of natural enemies into pest management frameworks and guide region-specific conservation planning. With habitat alteration accelerating across fragmented landscapes, sustained systematic monitoring of these communities will be essential to safeguarding the biodiversity of this tropical mountain ecosystem.

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