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Cover: Long-tailed Shrike *Lanius schach* resting on a dry branch after courtship. Digital illustration on Procreate. © Aakanksha Komanduri.

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ARTICLE

Altered nocturnal vocal activity patterns in Tropical Kingbird *Tyrannus melancholicus* (Passeriformes: Tyrannidae) at a site with artificial lighting

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Abstract: Artificial lighting at night (ALAN) modifies the vocal activity patterns of numerous birds. In this study, we evaluated the impact of ALAN on the vocal activity patterns of the Tropical Kingbird *Tyrannus melancholicus* on María Madre Island, located in the state of Nayarit, Mexico. Vocalizations were recorded using autonomous Song Meter Micro recorders at one site with ALAN and another without. We analyzed sound spectrograms to quantify vocalizations and performed behavioural observations. Our results showed differences in vocal activity between the ALAN site and the non-illuminated site. The ALAN site had higher total vocal activity, producing 3,947 vocalizations with at least one vocalization in every recording, compared to 228 distributed across 40% of the recordings at the non-ALAN site. Tropical Kingbirds at the ALAN site also had a substantially longer and earlier-shifted period of pre-dawn vocalization activity, from 0200 h to 0500 h, compared to a very brief period around 0500 h at the site without ALAN, as well as vocalizations throughout the night compared to a brief peak around twilight with no nocturnal vocalizations. Finally, we observed that individuals at the ALAN site continued to forage into the night, displaying increased agonistic interactions such as chases, wing-fluttering, and physical confrontations. Our results suggest that artificial light significantly alters the activity pattern of the Tropical Kingbird, extending its vocal and foraging activity. Our study could contribute to understanding the effects of light pollution on insectivorous birds in island environments and shows the importance of reducing the impacts of artificial light in natural habitats.

Keywords: ALAN, behaviour, insectivorous birds, islands, light pollution, nocturnal foraging, vocalization.

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INTRODUCTION

Increasing urbanization in economically developing regions has often resulted in substantial increases in artificial lighting at night (ALAN) (Cinzano 2003; Hölker et al. 2010). ALAN adversely affects ecosystems by modifying natural light regimes, a phenomenon called "ecological light pollution" (Longcore & Rich 2004). This affects terrestrial and marine habitats globally through both direct illumination and indirect reflection of sky glow (Spoelstra & Visser 2013). However, the effects and consequences of light pollution on biodiversity, ecosystems, and ecological and evolutionary processes remain poorly understood (Dominoni 2015).

Most organisms are subject to circadian cycles that are regulated by natural light cycles (Arendt 1998; Bell-Pedersen et al. 2005). Light pollution alters these cycles in numerous species by interfering with the natural light regimes that regulate their biological rhythms (Cassone 2014). Beyond disrupting sleep and activity patterns, ALAN can also have detrimental effects on behaviour, reproduction, and even survival (Raap et al. 2015). Desynchronization of the circadian clock due to artificial light can have consequences at the physiological and biochemical levels, altering processes such as hormone secretion and immune responses, which potentially compromises organisms' ability to adapt to their environment and perform activities that are essential for their survival (Gaston et al. 2013).

In addition to the direct negative effects of artificial night-time lighting, ALAN can alter the foraging activity of insectivorous by attracting arthropods, thereby providing a consistent food source for insectivorous species. Opportunistic nocturnal feeding has been observed at locations where ALAN leads to nighttime arthropod activity, primarily in some species of amphibians (Perry et al. 2008), reptiles (Garber 1978; Amadi et al. 2021; Baxter-Gilbert et al. 2021), and birds (Santos et al. 2010; Ortiz 2013).

In avian species, one of the most frequently reported effects of light pollution is the alteration of vocal activity patterns and feeding behaviour, which in some instances has been found to impact reproduction and survival (Longcore & Rich 2004; Dominoni et al. 2013; Dominoni 2015). While birds commonly exhibit marked vocal peaks at dawn and dusk (Gil & Llusia 2020), ALAN can substantially modify these vocalization rhythms. In species such as Eurasian Blue Tit *Cyanistes caeruleus*, European Robin *Erithacus rubecula*, Eurasian Blackbird *Turdus merula*, Great Tit *Parus major*, and American Robins *Turdus migratorius*, an advancement in the onset of morning song and an extension of vocal activity after dusk have been observed in illuminated environments (Miller 2006; Kempenaers et al. 2010; Da Silva et al. 2014). However, most of these studies have focused solely on identifying the first and last vocal events of the day, without examining song patterns across the full 24-hour cycle, limiting our understanding of continuous vocal activity (Dominoni 2015). Moreover, ALAN has been shown to affect not only vocal rhythms but also foraging behaviours. Although some species are typically diurnal, the Northern Mockingbirds *Mimus polyglottos* have been observed utilizing the visibility provided by ALAN to continue to feed their offspring after dusk (Stracey et al. 2014), and the Eurasian Blackbird has been observed using artificial lighting to forage at night in urban areas (Russ et al. 2015). It has been documented that in anthropogenically altered locations, some visual-hunting waders demonstrate increased activity in illuminated areas, increasing their ingestion rate by 83% (Santos et al. 2010). Illuminated areas may also attract avian species to degraded habitats near urban areas where they may be subject to fitness costs such as increased predation by domestic & feral dogs and cats, lower quality nesting habitats, and noise & chemical pollution, among others.

The Tropical Kingbird *Tyrannus melancholicus* (Image 1), a passerine bird of the family Tyranidae, is widely distributed, ranging from the southwestern United States to southern Argentina (Stouffer et al. 2024). In Mexico, this species is resident from southern Sonora, including the Islas Marías on the west coast and from central Tamaulipas on the east coast extending southward along both coasts, including the Yucatán Peninsula, and inland throughout the central region of the country (Stager 1957; Howell & Webb 1995). Both sexes vocalize throughout the day, mostly while perched but also occasionally during flight. A distinctive dawn song, characterized by a series of brief notes and delicate ascending trills, is typically performed from shortly before dawn until sunrise and does not resume for the remainder of the day (Skutch 1965; Smith 1966). Additionally, these birds emit social calls that are perceived as high-pitched, thin warbles that exhibit contextual variations (Skutch 1965). The Tropical Kingbird feeds primarily by aerial hunting of flying insects, with frequent returns to the same perch after capturing prey (Fitzpatrick 1980). While foraging habits are predominantly diurnal, there are anecdotal reports of Tropical Kingbirds hunting insects at night in artificially illuminated areas in Brazil (Sick & Teixeira 1981; Stouffer et al. 2024). Nevertheless, the influence of ALAN on the

Image 1. Tropical Kingbird *Tyrannus melancholicus* perched while searching for food at night (~0200 h) in the Islas Marías Biosphere Reserve, Mexico. © David Ramírez Adame.

activity patterns of this species remains unclear, and the specific effects on vocal activity in less anthropized insular populations, such as those inhabiting isolated regions like Islas Marías, have yet to be elucidated.

Given that artificial illumination continues to expand into remote regions, it is crucial to understand its effects on avian populations. To address this, we compared the vocal activity of the Tropical Kingbird at locations with and without artificial nocturnal lighting in an island population that is not exposed to other aspects of urbanization. We hypothesized that ALAN induces an extension of vocal activity during nighttime hours, thereby altering the natural activity patterns of this species.

METHODS

During July and August 2024, we conducted field research on María Madre Island (21.634° N, 106.541° W; Image 2) with the main objective of studying the Elf Owl *Micrathene whitneyi*. María Madre is the largest island in the Islas Marías archipelago, situated within the Islas Marías Biosphere Reserve in Nayarit, Mexico. The climate is arid, with moderate precipitation occurring from June to October and an average annual temperature of 24.9°C. In the Islas Marías, during the sampling period, sunrise occurred at approximately 0500 h and sunset around 1900 h. The island exhibits four distinct vegetation types: medium sub-deciduous forest, low deciduous forest, crassicaulous scrub with low thorny forest, and coastal dune associations (Sánchez-Mejorada 1984; CONANP

Image 2. Location map of the study site on María Madre Island, Nayarit, Mexico.

2021). Furthermore, the island has an urbanized area, consisting of paved roads, houses for tourists and island personnel, as well as some areas designated for naval bases.

During our field trips on the island, we noted that individuals of Tropical Kingbird inhabiting the urbanized area exhibited nocturnal activity. Consequently, we designed an observational study to be conducted at two sites with contrasting lighting conditions. The first site was situated in an area with consistent ALAN, where multiple lamps are activated at dusk and remain on until dawn, providing approximately 10 hours of continuous artificial illumination each night. These lamps are positioned at 30 m intervals. The second recording location was established in the territory of a Tropical Kingbird, approximately 410 m from the nearest lamp in an area without ALAN (Image 2). We implemented the same recording protocol at both sites using autonomous Song Meter Micro recorders model SM-MIC (Wildlife Acoustics, Inc., Maynard, USA) with built-in omnidirectional microphones. Recorders were mounted at 2 m height on tree branches within Tropical Kingbird territories, carefully positioned to avoid disturbance. The recording protocol consisted of 10 min recording periods followed by 10 min intervals without recordings, continuing until a complete 24-hour cycle was achieved at both sites. The recordings were made continuously, with one day of separation between both recording sets and a similar lunar phase (last quarter) at both sites. All recordings were made in WAV format at 44.1 kHz/16-bit resolution.

The vocal activity pattern of Tropical Kingbird was characterized by quantifying the number of vocalizations from 72 recordings per site, corresponding to a complete 24-hour recording cycle. Data were extracted through systematic visual inspection of spectrograms configured with a Hann window, 256 points, 90% overlap, and a discrete Fourier transform size of 512 samples, using Raven Pro 1.6 software (Yang 2024). Vocalizations were identified and counted by manually selecting all clear acoustic events across the 24-hour cycle. Each detection was verified aurally and visually by two independent observers to minimize false positives. Vocalizations were manually identified and categorized as either dawn songs or social calls (Figure 1; Audio 1; Audio 2). Dawn songs are apparently produced only by males and defined as long, ascending trills composed of stereotyped sequences of multiple syllables, typically emitted during pre-dawn hours, and characterized by slightly longer and more grating notes. Social calls are high-pitched, thin, and emitted by both sexes, consisting of short, repeated notes (Howell & Webb 1995; Stouffer et al. 2024). Circular charts were constructed utilizing the "ggplot2" package (Wickham 2016) of R Software R 4.4.2 (R Core Team 2024) to visualize the frequency distribution of dawn songs and social calls over a 24-hour cycle. Subsequently, acoustic activity patterns were statistically compared using the Mardia-Watson-Wheeler circular nonparametric test (Zar 1998) using Oriana 4.02 software (Kovach 2013).

In addition to the recordings, to document the nocturnal behaviour of Tropical Kingbirds, direct observations were conducted during six nights at sites with ALAN, simultaneously, were performed these six same nights walks at sites without ALAN, between 1800 h and 0200 h, with a single walk conducted per site.

RESULTS

At the site with ALAN, 100% of recordings contained at least one Tropical Kingbird vocalization, totaling 3,947 vocalizations, of which 1,040 were dawn songs, and 2,907 were social calls. In contrast, at the site without ALAN, 40% of recordings contained vocalizations, for a total of 228 vocalizations, of which 13 were dawn songs and 215 were social calls. During the sampling period, we observed that the territories were generally occupied by a single individual; however, at the site with ALAN, more agonistic interactions between individuals were observed, including chases, wing-fluttering, and physical confrontations.

At the site with ALAN, dawn songs were recorded from 0200–0500 h, exhibiting a peak around 0300 h (Figure 2A). In contrast, at the site without ALAN, dawn song activity was more temporally concentrated, occurring primarily near dawn at approximately 0500 h (Figure 2B). Statistical analysis revealed significant differences in dawn song emission patterns between the site with ALAN compared to the site without ALAN ($W = 26.145$, $P < 0.001$).

Social call patterns exhibited notable differences between the sites with and without ALAN. At the artificially illuminated location, social calls occurred throughout the 24-hour cycle, with heightened activity during nighttime hours and a peak after sunset (1900 h; Figure 2C). In contrast, in the site lacking artificial light, social calls were less frequent, limited to daytime hours, and primarily concentrated around twilight periods, with peak activity observed before sunset at 1800 h (Figure 2D). Statistical analysis revealed significant differences between the two sites ($W = 56.456$, $P < 0.001$).

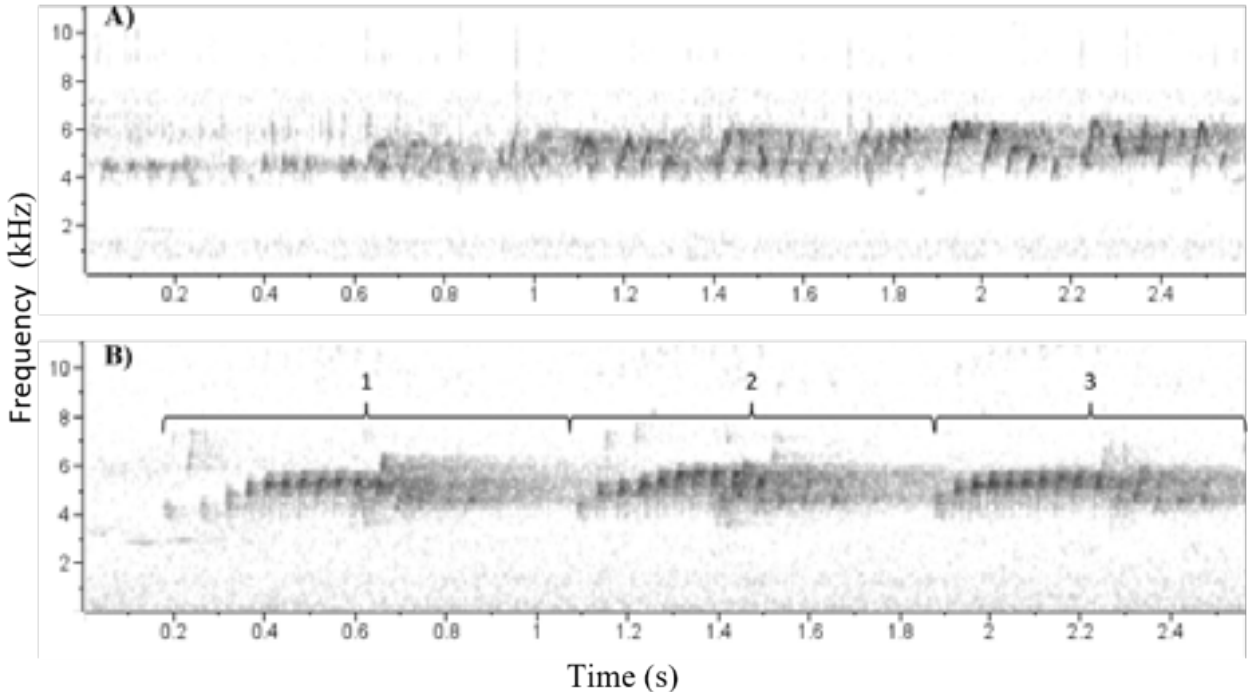

Figure 1. Spectrograms of the Tropical Kingbird vocalizations recorded during study period: A—One dawn song vocalization | B—Three social calls.

Our field observations at ALAN site revealed that Tropical Kingbirds foraged at night, frequently pursuing insects drawn to the light sources (Video 1). These feeding behaviours were recorded from dusk until 0200 h, covering the entire period during which field surveys were conducted. Additionally, these birds displayed agonistic behaviours towards conspecifics. In contrast, during six nighttime surveys at locations without ALAN, we did not observe feeding behaviours or detect any vocalizations of Tropical Kingbird after nightfall.

DISCUSSION

The results of this study show clear differences in vocalization patterns, both in dawn songs and in social calls, of the Tropical Kingbird between a site with ALAN and a site without ALAN. At the site with ALAN, an earlier onset of dawn singing and a longer duration of vocal activity were observed, in contrast to the site without ALAN, where vocal activity was more concentrated at dawn. This difference was statistically significant. Such shifts in the timing of morning song in the presence of ALAN have been reported in other bird species exposed to similar conditions. For instance, previous studies have documented that artificial light can advance the onset of vocal activity and extend its duration in urban birds, which can in turn affect key processes such as reproductive success and disrupt circadian rhythms (Kempenaers et al. 2010; Da Silva et al. 2015).

Regarding social calls, we observed significantly higher activity at the site with ALAN, with calls recorded throughout the 24-hour cycle, including a peak in vocal activity after sunset and a high concentration of calls during the night. In contrast, at the site without ALAN, social calls were considerably less frequent and were only recorded during daylight hours, peaking before sunset. This difference in the temporal pattern of social calls was statistically significant, reinforcing evidence that artificial night lighting substantially alters vocal communication in this species on María Madre Island. While our findings partially align with previous studies that have documented increased nocturnal vocalizations in birds exposed to artificial light (Da Silva et al. 2014; Dominoni et al. 2015; Ursino et al. 2022), most of those studies report this phenomenon only within narrow time windows, shortly before or after sunset. In contrast, the present study documents extended nocturnal vocal activity lasting throughout the night.

Furthermore, we observed nocturnal foraging behaviour at the site with ALAN, including active pursuit of insects attracted to the light and increased agonistic interactions between individuals, such as chasing, fluttering, and physical confrontations. These

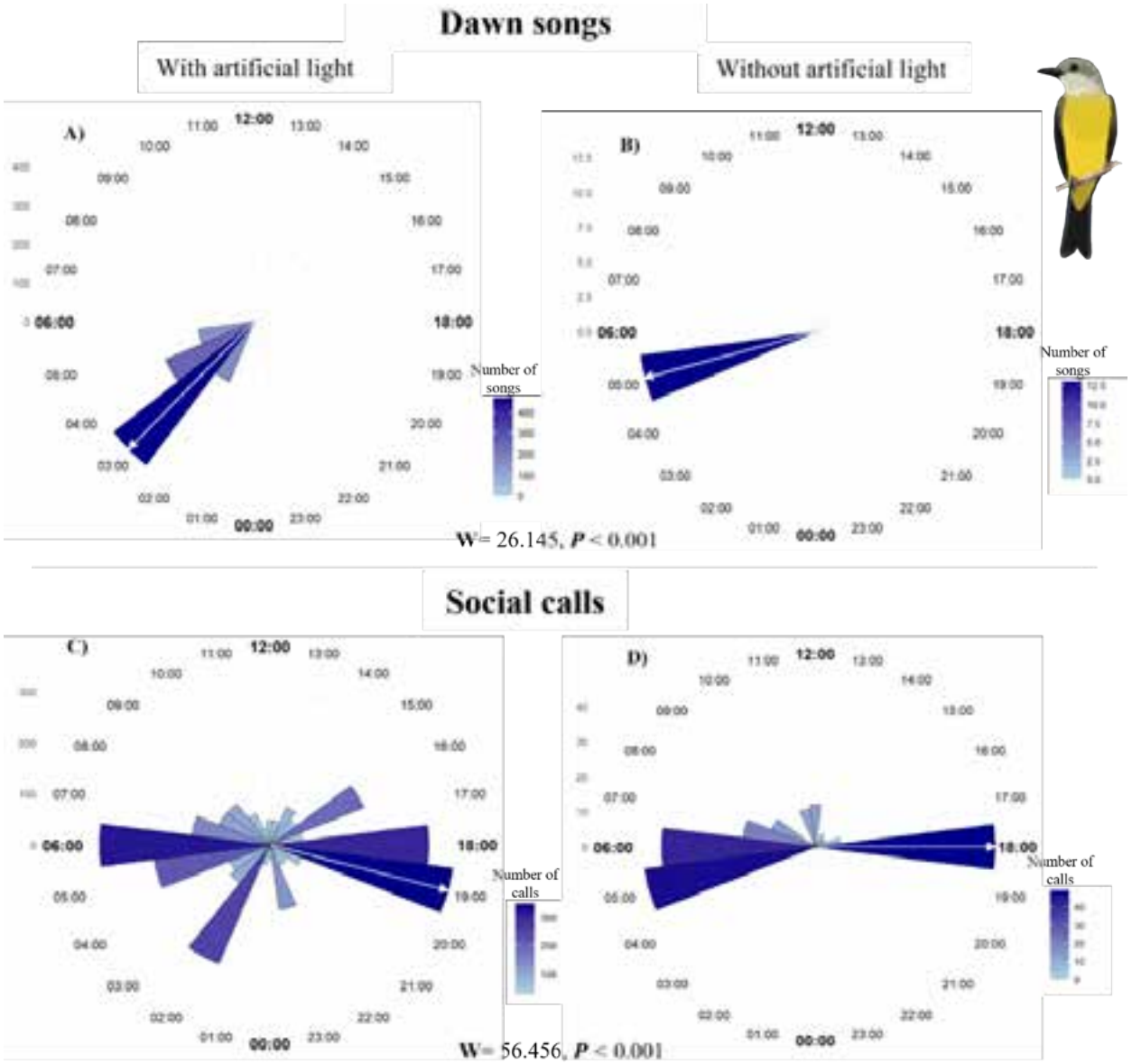

Figure 2. Vocal activity patterns of the Tropical Kingbird in a continuous 24-hour cycle. The color intensity represents the relative frequency of vocalizations, and the white arrow indicates the peak of vocal activity: A—Dawn songs with artificial light | B—Dawn songs without artificial light | C—Social calls with artificial light | D—Social calls without artificial light.

behaviours were not observed during nighttime hours at the site without ALAN, where individuals remained vocally and behaviourally inactive after sunset. This type of behaviour is consistent with observations in other bird species, in which opportunistic nocturnal foraging induced by ALAN has been documented, facilitated by the attraction of insects to light sources (Santos et al. 2010; Stracey et al. 2014; Russ et al. 2015). These studies indicate that ALAN can extend birds' foraging activity beyond the daytime period, altering natural foraging patterns.

Although the Tropical Kingbird is widely distributed across the American continent and is common even in urban areas with high levels of artificial light (Stouffer et al. 2024), records of nocturnal vocal activity in this species are scarce in the literature. To date, there is only a single isolated report of nocturnal vocal activity from a continental population, where individuals were observed feeding on insects and emitting social calls from 2300 h to 2400 h (Sick & Teixeira 1981). Therefore, the more pronounced and extended response to ALAN observed in this study could potentially be intensified by the ecological conditions of an insular environment.

Previous work has shown that island species

often exhibit greater behavioural plasticity and niche expansion (Scott et al. 2003; Losos & Ricklefs 2009; Dufour et al. 2024). These traits have been associated with the evolution of relatively larger brains in island populations, which facilitates the adoption of new foraging strategies and space use (Sol et al. 2005; Cnotka et al. 2008; Sayol et al. 2018). In this context, the high levels of nocturnal activity recorded in our study could be interpreted as an adaptive strategy by which birds exploit the abundance of insects attracted by artificial light, a resource that would otherwise be unavailable under natural conditions.

A potential limitation of the study is the limited sampling effort, the lack of quantification of the number of individuals per site, along with the absence of data on the reproductive status of the birds during the brief sampling period, which could influence vocal activity and foraging patterns of the individuals. Furthermore, our results establish a foundation for developing conservation strategies aimed at mitigating the impact of artificial illumination on species susceptible to human-induced environmental changes.

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Spanish Resumen (español): La iluminación artificial nocturna (ALAN, por sus siglas en inglés) modifica los patrones de actividad de numerosas especies de aves, alterando su comportamiento y actividad vocal. En este estudio, evaluamos el impacto de la ALAN en los patrones de actividad vocal del Tirano Pirirí (*Tyrannus melancholicus*) en la Isla María Madre, ubicada en el estado de Nayarit, México. Las vocalizaciones de esta especie se registraron en un sitio con ALAN y otro sin ALAN, utilizando grabadoras autónomas Song Meter Micro. Analizamos los espectrogramas para cuantificar las vocalizaciones y realizamos observaciones de comportamiento. Nuestros resultados mostraron diferencias claras en la actividad vocal en el sitio con ALAN en comparación con el sitio no iluminado. El sitio con ALAN presentó una mayor actividad vocal total, con 3,947 vocalizaciones con al menos una en cada grabación, en contraste con 228 vocalizaciones distribuidas en el 40% de las grabaciones en el sitio sin ALAN. Los Tiranos Piriríes en el sitio con ALAN tuvieron un período de vocalización previo al amanecer sustancialmente más prolongado y adelantado, de 0200 h a 0500 h, en comparación con un período muy breve alrededor de las 0500 h en el sitio sin ALAN, así como vocalizaciones a lo largo de toda la noche, en contraste con un breve pico al anochecer sin vocalizaciones nocturnas. Finalmente, observamos que los individuos en el sitio con ALAN continuaron forrajeando durante la noche, mostrando también un aumento en las interacciones agonísticas, como persecuciones, aleteos y confrontaciones físicas. Nuestros resultados sugieren que la luz artificial altera significativamente el patrón de actividad del Tirano Pirirí, extendiendo su actividad vocal y de forrajeo. Este estudio podría contribuir a comprender los efectos de la contaminación lumínica en aves insectívoras en ambientes insulares y muestra la importancia de reducir los impactos de la luz artificial en los hábitats naturales.

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ARTICLE

Importance of integrating multiple criteria in breeding habitat management for urban frogs and toads (Amphibia: Anura) in Jakarta City, Indonesia

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Abstract: This study assessed the local and landscape factors that support breeding habitats for native frog species in Jakarta, the capital city of Indonesia. We surveyed 25 wetlands categorized into two management states and varying local and landscape features. Our results revealed that frog species exhibit diverse habitat preferences for breeding; some species prefer constructed or managed environments, some depend on more natural or minimally managed habitats, and one species was highly linked with vegetation cover and light intensity. These findings emphasize the need to incorporate multiple criteria when designing strategies to support breeding habitats for all native frog species in Jakarta. We also explored specific factors influencing breeding site selection, providing insights into the drivers of breeding habitat preferences in urban environments.

Keywords: Anthropogenic, conservation, green infrastructure, landscape ecology, native, urban wetland.

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Author contribution: MIN contributed to conceptualizing ideas and hypotheses, designing methodology, conducting investigations, analyzing data, and writing manuscripts. IH helped in providing field data (investigation), statistical analysis, and data visualization. AS contributed to detailing the research ideas and methods, validating results, and refining the discussion. RK added insight into the manuscript, refining the methodology, and validating the results.

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INTRODUCTION

Urban environments are experiencing a high degree of land-use changes to support ever-increasing human populations and economies. As a result, natural habitats that support native wildlife species are unsustainably degraded in terms of both quality and quantity (Wang & Kintrea 2021; Pereira et al. 2022). Only a few native species can tolerate these dramatic changes and would likely persist in the remaining remnant patches of habitats (Callaghan et al. 2021; Hahs et al. 2023). Frogs are considered key-stone species living in urban environments (Hutto Jr & Barrett 2021). The ongoing degradation of natural habitats has driven even the most resilient of frogs to cope with degraded habitats left over by humans, known as constructed habitats (Scheffers & Paszkowski 2013). Although utilizing degraded and constructed habitats poses greater risks to the survival of the frogs, finding an isolated or inaccessible natural habitat is more costly considering the risks of bypassing unsuitable urban matrixes (Klop-Toker et al. 2016; Watchorn et al. 2023).

The utilization of urban habitats by frogs is not only to find prey and seek shelter, but they also utilize these areas as breeding habitats to find mates and reproduce (Watchorn et al. 2023). Breeding habitats for frogs are usually unique with certain characteristics that probably might not always be obtained in their foraging habitats (Băncilă et al. 2017; Nakanishi et al. 2020). Male frogs find a mate by vocalizing sporadically to get attention from the females that could be at some distance (Wells 1977). Thus, a greater chance of getting a mate is influenced by the greater efficacy of acoustic signals (Gridi-Papp et al. 2006; Simmons et al. 2013). The trade-off of choosing high-quality habitats persisting in isolation can be compensated for by selecting medium or low-quality habitats but gaining better access for movements and dispersal. The quality of the aquatic habitat used by frogs to deposit eggs is also pivotal to ensure the development and survival of their offspring. However, the presence of ubiquitous disturbances and fragmentation in urban environments is highly reducing the access of urban frog populations to find suitable habitats for breeding. Thus, frogs need to compensate for the risks of finding a suitable breeding habitat by choosing a novel habitat in an urban environment. Instead of considering multiple factors in their breeding decision, they are constrained to settle down for few fundamental criteria in selecting a breeding habitat in the urban environment (McCaffery et al. 2014; Băncilă et al. 2017).

Previous studies have reported that frogs could utilize constructed or managed habitats (Simon et al. 2009; Holzer 2014; Hutto Jr & Barrett 2021) either foraging or breeding even though the preferences are highly associated with the level of synurbism. Synurbic species are usually well adapted to substantial changes made by humans, thus the potential risks are negligible (Feoktistova et al. 2020). However, some urban areas have retained many nature-dependent or seminatural species that require habitats with low disturbances and changes (Scheffers & Paszkowski 2013). In general, there are so many factors considered by frogs to choose their breeding habitat in urban environments, which generally can be classified into two categories based on their role, specifically local and landscape factors. Local factors are strongly linked to the quality of breeding habitats, encompassing the key parameters that frogs require to ensure breeding success and support the growth and survival of their offspring. Landscape factors relate to the extent of human interference at breeding sites, which influence the environmental conditions preferred by certain frog species. In urban environments, frogs are likely face trade-offs when selecting breeding habitats, as areas that offer both suitable local and landscape conditions are scarce (Pope et al. 2000). As a result, we expect that frogs will select breeding habitats based on the most influential conditions available in urban environments, in an effort to minimize the cost of finding ideal habitats. The selection may likely vary in all species found in the city since each species of frog has a different fundamental niche and sensitivity level.

Jakarta is one of Indonesia's major urban centres that supports a vast and densely packed human population spread across various districts. The urban landscape exhibits marked disparities in the distribution of green spaces. Central regions, typically characterized by extensive urbanization, contain minimal natural areas. In contrast, peripheral zones often feature substantial green spaces, with some areas maintaining access to semi-natural habitats (Ardiansyah et al. 2018; Hwang et al. 2020). A tiny body of research studying frog diversity exists in some parts of the city, reporting a quite diverse frog composition in such suboptimal habitat patches. Approximately, nine species of frogs have been documented in this city, displaying different habitat preferences (Rushayati et al. 2023). Till date, no study has exclusively focused on the breeding activities of Jakarta frogs. Thus, this study attempted to examine the breeding site selection of frogs within these urban environments, focusing on some remaining patches of green areas in Jakarta City.

MATERIALS AND METHODS

Sampling Sites

A total of 25 wetlands were surveyed sporadically in 2022 and 2023 encompassing a diverse urban landscape in Jakarta, Indonesia. The study areas covered private areas, parks, fishing sites, and vacant lots. We conducted frog surveys at the beginning of the rainy season when many frogs started breeding activities. These areas were categorized into two distinct groups based on their levels of management intensity, allowing for a comparative analysis of how human intervention influences habitat suitability. In addition, we assessed the factors that contribute to the attractiveness of these habitats for breeding, shedding light on how urban green spaces, despite varying degrees of modification, continue to play a crucial role in supporting wildlife, particularly frogs.

Breeding survey

Breeding activities and frog abundance were determined using an acoustic approach from 1900–2100 h WIB. Most urban frogs in the city of Jakarta are selective breeders that vocalize exclusively in their breeding sites or period, they would not produce calls outside those constraints. Thus, the acoustic survey is reliable for assessing the breeding habitat of frogs in Jakarta. Some areas, such as private lands, were also difficult to access and explore at night for conducting visual search, utilizing an acoustic survey was best for these circumstances. If available, we also incorporated mating calls for some species of frogs to ascertain that the sites surveyed were utilized by frogs for breeding activities. Frogs were identified acoustically using a database provided by Xeno-Canto (Xeno-canto Foundation, 2026), frog voices of Borneo (Inger et al. 2017), and other information sources from previous studies, such as (Márquez & Eekhout 2006; Kurniati et al. 2010). The number of individual frogs in each site was estimated using the method outlined by Scheffers & Paszkowski (2013). We used an 180^0-point count for 10 minutes to detect the vocalization and count the number of males calling within 50 m. Based on our preliminary surveys, 10 minutes of observation is adequate to detect nearly all species in the city of Jakarta. We used 20 minutes pre-observation to ensure there were no undetected or cryptic species that did not emit calls during observation.

Local and landscape variables

We measured six local and five landscape variables for all surveyed sites. We recorded all local variables directly in the field at the time when frogs were sampled to ensure that all variables represent the exact condition of their breeding habitat. Six local variables comprised of one management state and five water chemistry parameters. Management state was classified into managed and unmanaged sites following the description proposed by Garcia-Gonzalez & Garcia-Vazquez (2011). We defined 'unmanaged sites' as areas that were not subject to any form of management or control. In contrast, 'managed sites' were those where vegetation, particularly surface vegetation, is frequently mowed, and leaf litter is regularly cleared. To accurately classify all sites into proper categories, we carried out day surveys (immediately after night surveys) to quantify management state as well as water chemistry parameters. Water chemistry parameters measured in this study were turbidity, temperature, salinity, pH, and total nitrogen using LAQUA NO3 2000-S ION NITRATE/PH/ORP/TEMP. METER. All five water chemistry parameters were measured randomly at three distinct locations within a single site. Five landscape variables recorded were normalized difference vegetation index (NDVI), normalized difference water index (NDWI), normalized difference building index (NDBI), land surface temperature (LST), and light intensity. Landscape variables were mapped within 1 km of the surrounding site by creating a buffer and the data were extracted using zonal statistic plugin. NDVI, NDWI, and NDBI were extracted from Landsat 8 L2SP taken at or near the time when the survey was conducted. LST and light intensity respectively were extracted from Terra/MODIS provided by NASA at 0,1 degrees of resolution and VIIRS night-time lights provided by Earth Observation Group (EOG). All landscape variable analyses were performed using QGIS 3.38.

Data analysis

The number of calling individuals per site was used to characterize male abundance and were organized into two distinct categories of site management (managed and unmanaged). In order to determine which local and landscape variables are the best predictors for breeding occurrence in 25 surveyed wetlands, we used a generalized linear regression model (GLM) with a binomially distributed error term and a logit link function in R 4.4.1 using lme4 package. We tested five local and four landscape models consisting of nine multivariate models. Models were evaluated using Akaike's information criterion adjusted for small samples (AICc) to determine the best variables that predict the occurrence of breeding activities. The smallest value of ΔAICc was chosen as the top model, while the value of

ΔAICc <2 was considered as the best predictive model. Since some species of frog were very rare such that their sightings sample size does not entertain running statistical analyses, we ran this model evaluation only on three common frogs with adequate sighting frequencies obtained in our study.

RESULTS

This study recorded six species of frogs that utilize the remnant green areas of Jakarta as their breeding habitat. The most common or generalist species that occupied urban wetlands for breeding were *Duttaphrynus melanostictus*, *Hylarana nicobariensis*, and *Polypedates leucomystax*. In contrast, others were found in a deficient number of detections (Table 1). *Duttaphrynus melanostictus* was considered more generalist in terms of their utilization of breeding sites, it was found breeding in unmanaged and managed sites. Most other frog species were also found using these two habitats but were more likely to breed in unmanaged habitats (Figure 1). Only one species, *Fejervarya limnocharis*, was found utilizing unmanaged habitat exclusively for breeding.

The occupancy of *H. nicobariensis* was best predicted by NDVI (Normalized Difference Vegetation Index) and light, which were consistently identified as the most influential landscape predictors. These two factors appeared in three out of the four top models evaluated, highlighting their significance in determining habitat preference. On a more localized scale, pH levels and total nitrogen were identified as the most important predictors influencing *H. nicobariensis* occupancy, as detailed in Table 2. This suggests that while local variables play a role, the species tends to prioritize landscape-level features when selecting breeding sites, as evidenced by models with ΔAICc values of less than two, indicating strong model performance. The interplay between landscape and local variables underscores the complexity of habitat selection for this species, with landscape factors exerting a stronger influence.

For *D. melanostictus*, local variables played a more significant role in predicting their occupancies compared to landscape variables, as shown in Table 3. Among these local variables, pH and total nitrogen were identified as the strongest predictors, explaining the selection of breeding sites with a ΔAICc of less than two, indicating robust model performance. Interestingly, NDVI (Normalized difference vegetation index), while not the best predictor, also appeared as a landscape-level predictor for *D. melanostictus*, similar to its role in the occupancy models for *H. nicobariensis*. Despite

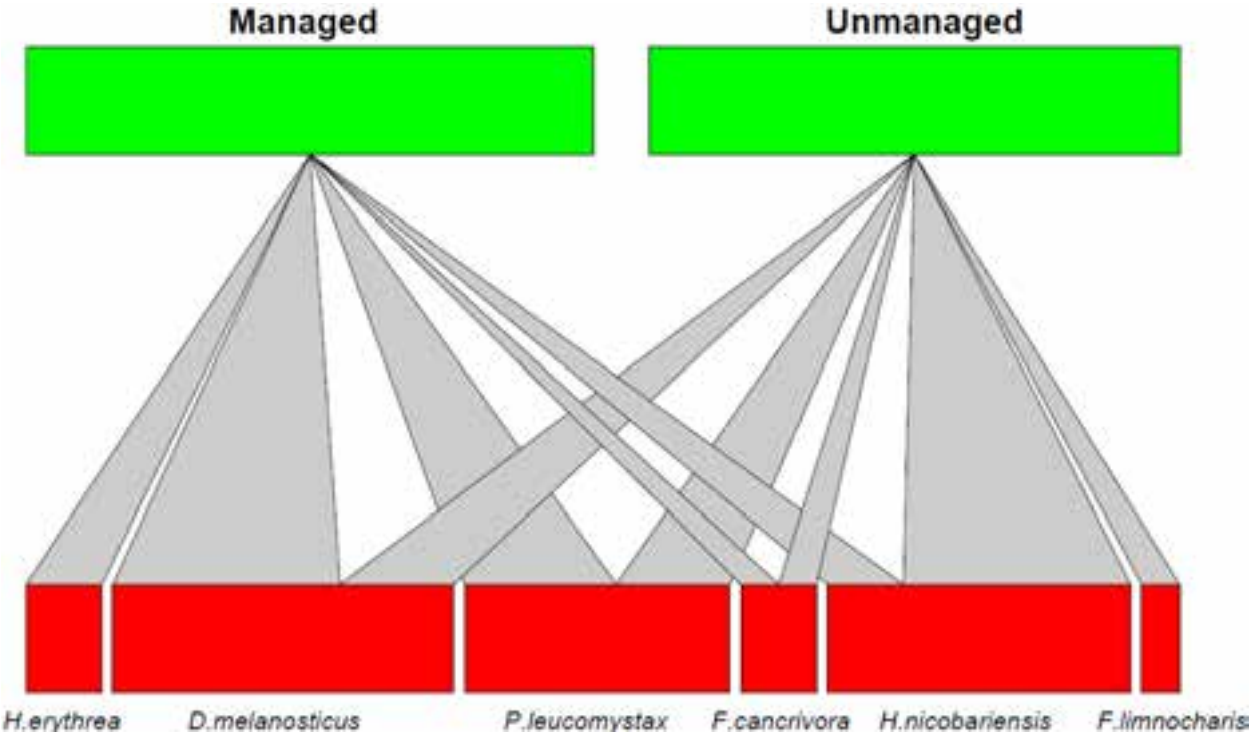

Figure 1. Anuran occupancies in two distinct types of habitats depicting the adaptive selection of some species in selecting breeding sites (managed and unmanaged).

Table 1. Occupancy and abundance of six anurans organized based on site management types.

Species	Type	N	Occ[a]	% Occ[b]	Abundance[c]
D. melanostictus	Unmanaged	28	3	14.28	3.11
	Managed	26	6	28.57	2.16
F. cancrivora	Managed	1	1	4.76	0.08
	Unmanaged	1	1	4.76	0.11
F. limnocharis	Unmanaged	3	1	4.76	0.33
	Managed	0	0	0	0
H. erythrea	Managed	6	2	9.52	0.5
	Unmanaged	0	0	0	0
H. nicobariensis	Unmanaged	63	6	28.57	7
	Managed	18	2	9.52	1.5
P. leucomystax	Unmanaged	18	3	14.28	2
	Managed	11	4	19.04	0.91

[a]—Occurrences of anuran species | [b]—Percent occurrences between two management types | [c]—Mean abundance based on two management types.

its presence, NDVI was not considered a top predictor for *D. melanostictus*, emphasizing the species' stronger reliance on local environmental factors over broader landscape features when choosing breeding habitats. This distinction highlights the varying degrees of influence between local and landscape variables on different species' habitat preferences.

As expected for *P. leucomystax*, pH and total nitrogen were the best predictor variables explaining this species' occupancy. However, our models demonstrated that landscape variables were also important variables to consider. Four of five models revealed the inclusion of NDVI, LST, and light as the best-explained predictors for breeding site selection by *P. leucomystax* **(**Table 3).

DISCUSSION

Frog surveys in the city of Jakarta have not been conducted intensively, making scientific data on frogs in this city scarce. This study provides important information to fill the gap in the species that inhabit Jakarta's urban ecosystem and breeding site selection, which can be used as baseline information to enhance urban biodiversity in Jakarta. By selecting 25 sites of breeding sites across urban landscapes, we found six species of frogs residing in Jakarta. Most of the frogs are generalist and synurbic species that are capable of utilizing urban habitats and matrices (Iskandar 1998), only one species (*H. erythrea*) which is considered exceptional since this frog is usually found in rural areas.

Our findings demonstrated that most species were capable of using both managed and unmanaged sites for breeding, as only *F. limnocharis* was obtained exclusively in unmanaged sites. However, species that utilized both types of sites showed different occupancies on those sites. *Duttaphrynus melanostictus* is found more often in managed sites, whereas *H. nicobariensis* is found in unmanaged sites. *Duttaphrynus melanosticus* is a synurbic toad that favours a human-modified environment. This species is capable of using man-made structures for foraging and breeding. In the context of breeding habitat, *D. melanostictus* can utilize areas that contain many human populations and less vegetated areas or natural habitats (Bickford et al. 2010), including stormwater ponds, in the middle of the city. Seemingly, this toad's tadpole fundamentally has developed adaptive features to cope with urban disturbances such as shortening the larval periods (Mahapatra & Mahapatra 2015; Mogali 2017; Saidapur 2025). In line with our findings which found undemanding features of the habitat chosen by *D. melanostictus* to breed. This frog only considers pH and total nitrogen as a fundamental requirement for breeding. *Duttaphrynus melanostictus* would thrive in water bodies with a neutral to slightly alkaline due to the essential pH for optimal egg development and larval survival (Rout et al. 2019). Total nitrogen is another critical factor, as it affects the nutrient availability in breeding sites. Higher nitrogen levels can enhance algal growth, thus providing adequate food for tadpoles to grow more quickly in the changing environment of urban city (Edirisinghe & Amarasinghe 2011).

Hylarana nicobariensis is commonly found in disturbed areas (Inger & Stuebing 1997), favouring swampy areas in urban environments (Kurniati & Hamidy 2017). This frog is typically abundant in the city's fringe, but some manage to survive around the city centre. The breeding habitat used by this frog in urban is a bit more complex than *D. melanostictus* or even somewhat in contrast, even though they can occupy the same habitat on some occasions. The dependency of this frog on swampy areas characterized by the lower rate of human frequentation is the reason why this frog has a greater connection with NDVI and other landscape parameters associated with the lower level of human frequentation. The quality of landscape features is probably linked with other landscape-derived features, such as moisture. Previous study highlighted the importance of moist environments for the breeding and survival of *H. nicobariensis*, indicating that inhabiting swampy areas with higher NDVI is beneficial to maintaining acceptable

Table 2. Occupancy models for nine predictor variables observed for *Hylarana nicobariensis*.

Variable categories	Predictors	K	AICc	Delta_AICc	AICcWt	Cum.Wt	LL
Landscape	NDVI+Light	3	27.91	**0**	0.53	0.53	-10.25
	NDVI+LST+Light	4	30.12	2.2	0.17	0.7	-9.81
	LST+Light	3	30.91	3	0.12	0.82	-11.75
	NDVI+NDWI+NDBI+LST	5	32.93	5.01	0.04	0.96	-9.46
Local	pH+TN	3	31.3	3.39	0.1	0.92	-11.95
	Sal+pH+TN	4	34.39	6.48	0.02	0.98	-11.95
	Type+Sal+pH+TN	5	34.86	6.95	0.02	1	-10.43
	Type+Turbid+Sal+pH+TN	6	38.82	10.91	0	1	-10.41
	Type+Turbid+Temp+Sal+pH+TN	7	38.86	10.95	0	1	-8.12

Table 3. Occupancy models for nine predictor variables observed for *Duttaphrynus melanostictus*.

Variable categories	Predictors	K	AICc	Delta_AICc	AICcWt	Cum.Wt	LL
Local	pH+TN	3	30.75	**0**	0.58	0.58	-11.67
	Sal+pH+TN	4	33.04	2.29	0.18	0.76	-11.27
	LST+Light	3	35.03	4.28	0.07	0.91	-13.81
	Type+Sal+pH+TN	5	36.49	5.74	0.03	0.95	-11.25
	Type+Turbid+Temp+Sal+pH+TN	7	41.39	10.64	0	1	-9.39
Landscape	NDVI+Light	3	34.63	3.88	0.08	0.85	-13.61
	NDVI+LST+Light	4	36.82	6.07	0.03	0.97	-13.16
	Type+Turbid+Sal+pH+TN	6	37.68	6.93	0.02	0.99	-9.84
	NDVI+NDWI+NDBI+LST	5	40.25	9.5	0.01	1	-13.13

Table 4. Occupancy models for nine predictor variables observed for *Polypedates leucomystax*.

Variable categories	Predictors	K	AICc	Delta_AICc	AICcWt	Cum.Wt	LL
Local	pH+TN	3	33.2	**0**	0.35	0.35	-12.89
	Sal+pH+TN	4	36.28	3.09	0.08	0.91	-12.89
Landscape	LST+Light	3	33.85	**0.65**	0.26	0.61	-13.22
	NDVI+Light	3	34.1	**0.9**	0.23	0.83	-13.34
	NDVI+LST+Light	4	36.86	3.66	0.06	0.97	-13.18
	NDVI+NDWI+NDBI+LST	5	39.15	5.95	0.02	0.98	-12.58
	Type+Sal+pH+TN	5	39.75	6.56	0.01	1	-12.88
	Type+Turbid+Sal+pH+TN	6	43.7	10.51	0	1	-12.85
	Type+Turbid+Temp+Sal+pH+TN	7	47.9	14.7	0	1	-12.64

moisture (Basukriadi et al. 2021; Laurence et al. 2023).

Polypedates leucomystax probably is a fussy breeder in the urban city of Jakarta. Previous studies have documented the capability of this frog to utilize urban structures (Kuraishi et al. 2013; Shahrudin 2016). However, the quality of the man-made structures utilized by this frog is significantly different from *D. melanostictus*. *Polypedates leucomystax* favours aged or senescent stagnant water with a low level of disturbances or modification to breed. Aged ponds often have stable water conditions, which are conducive to the growth of algae and microorganisms that serve as food sources for *P. leucomystax* larvae (Sandifer et al. 1993). In addition, our findings also highlighted the importance of landscape

factors in defining the breeding selection of this frog. *Polypedates leucomystax* is a tree frog, though this frog can adapt to man-made structures for laying eggs, *P. leucomystax* needs green areas to facilitate movement and other activities, especially for finding mates since this frog is solitary (Shahrudin 2016; Simon et al. 2022). Therefore, green connectivity is an important factor in supporting the breeding activities of *P. leucomystax* in urban environments.

Even though three common frog species documented in this study exhibit variation in preference for managed and unmanaged habitats, management criteria are not the best predictor explaining the habitat selection for breeding. Management state is probably not strongly associated with the local and landscape parameters required by frogs. Some managed habitats are capable of providing the resources and environmental conditions required by frogs to carry out breeding activities and safe habitats for the tadpoles. In contrast, unmanaged habitats in urban areas are probably not always safe for sensitive species to breed. Some of them are subjected to high exposure to water pollution such as heavy metals, or have potential risks of predators, especially fish. Most of the unmanaged habitats are linked strongly to wilderness habitats that are suitable for some other cryptic frogs that rely on low levels of ecological reset and enrichment.

Other frogs that are found in lower detection probably have similar basic requirements to other common frogs. Some of them (*F. cancrivora* and *F. limnocharis*) showed strong dependencies on paddy fields or related areas that were seemingly limited only to the urban periphery (Iskandar 1998; Kurniati 2006; Kurniati et al. 2010). In order to manage these species to persist in Jakarta, building paddy fields or related habitats scattered in the city of Jakarta is encouraged as well as providing connectivity among these areas. For *H. erythrea*, we recognized the challenging issue for urban planners and designers to maintain this frog. This frog is very sensitive to human disturbances and extreme temperatures, making this frog usually found in natural or rural areas located especially at medium levels of elevation. Temperature is likely the important factor that explains the presence of this species in Jakarta (Widyasamratri et al. 2019; Siswanto et al. 2023) since human disturbances are ubiquitous in Jakarta and the city's geographic location is at a low elevation. Therefore, urban planners and designers need to deal with urban heat islands as a general effort to maintain many areas in the city of Jakarta that are suitable for frog breeding and foraging activities.

Our findings indicate that all common frog species residing in the urban landscape of Jakarta share different fundamental needs for their breeding habitats. Therefore, urban planning must take into account multiple criteria to ensure these habitats are preserved or created. Addressing these ecological requirements is essential not only for the survival of amphibian populations but also for achieving broader sustainable urban development goals, where biodiversity and natural habitats are integrated into the city's growth plans (Sedayu et al. 2024).

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ARTICLE

Rediscovery of the endemic and threatened Jewel Damselfly *Rhinocypha togeanensis* van Tol & Günther, 2018 (Insecta: Odonata: Chlorocyphidae) in Indonesia, with notes on its habitat loss and the urgent need for conservation action

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Abstract: *Rhinocypha togeanensis* van Tol & Günther, 2018 (Insecta: Odonata: Chlorocyphidae) is a damselfly species endemic to Batudaka Island, Togean Archipelago, Indonesia. Since its discovery over 25 years ago, no further records of its presence have been made. This study documents its rediscovery, current distribution, and the state of the habitat of *R. togeanensis* in Sungai Tanimpo. Surveys were conducted at 12 sites, and several environmental parameters were recorded at each locality. A total of 18 individuals were observed along its type locality, Sungai Tanimpo, where the habitat comprised primary forest along the riverbank. Numerous perches were available, such as foliage and small twigs. This species prefers the stream's upper reaches in the forested area with lower air temperatures and good illumination. Since no individuals were found at the exact type locality of this species, the preliminary impression was that *R. togeanensis* has experienced habitat reduction due to deforestation and other human activity, suggesting that urgent conservation measures are needed to preserve this endangered species. According to current knowledge, it is one of the endangered damselfly species in the world.

Keywords: Conservation, diversity, deforestation, endemic fauna, freshwater habitat, habitat protection, Indonesia, Sulawesi, Togean Islands, Wallacea.

Abstrak: *Rhinocypha togeanensis* van Tol & Günther, 2018 (Odonata: Zygoptera: Chlorocyphidae) merupakan capung endemik yang tersebar hanya di Pulau Batudaka, Kepulauan Togean. Selama lebih dari 25 tahun setelah ditemukan pertama kali pada 1994 dan 1999, belum pernah ada laporan terbaru terkait status populasi dan distribusinya. Penelitian ini bertujuan untuk melaporkan penemuan kembali, distribusi dan kondisi habitat *R. togeanensis* di Sungai Tanimpo. Survei dilakukan pada 12 titik menggunakan jaring serangga. Pengambilan data lingkungan dilakukan meliputi suhu, kelembapan dan intensitas cahaya serta kondisi habitat. Total sebanyak 18 individu ditemukan di Sungai Tanimpo dengan mikrohabitat berupa vegetasi alami dan ranting serta batang kayu di sepanjang aliran sungai. Spesies ini hanya ditemukan di wilayah mendekati bagian hulu sungai dengan tutupan hutan yang baik serta suhu yang lebih rendah. Kami tidak menemukan *R. togeanensis* di type locality nya sehingga mengindikasikan adanya penurunan kualitas habitat akibat aktivitas manusia dan deforestasi sehingga perlu adanya upaya konservasi untuk menyelamatkan spesies ini. Oleh karenanya, spesies ini menjadi salah satu spesies capung paling terancam di dunia.

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INTRODUCTION

Odonata (dragonflies and damselflies) are well-known for their significance in ecosystem assessment and environmental monitoring. Certain groups of damselflies, especially members of the family Chlorocyphidae, are good bioindicators as they are very sensitive to landscape change, especially the loss of vegetation cover along the riverbank (Da Silva Junior et al. 2023). Many Indonesian chlorocyphids are at a high risk of extinction due to extensive human activities, including the expansion of land given over to agriculture, especially in the small islands where the damselflies rely on undisturbed, clear running water and other pristine microhabitats (Harahap & Shahroni 2024). Several smaller islands in Indonesia host a high percentage of endemic species (Lupiyaningdyah 2020; Dow et al. 2024), but at the same time, species diversity in these islands usually suffers disproportionately from anthropogenic pressures (Clausnitzer et al. 2009; Cleary et al. 2025). The study of Odonata in Indonesia has mainly focused on their taxonomy and systematics, while their ecology, behaviour, and other conservation-related studies are limited, especially in Sulawesi (Dow et al. 2024). One of the essential topics suggested by these researchers was broadly assessing population status and mapping the distribution of dragonflies in Indonesia that could be used as a template for conservation action and management planning (Lupiyaningdyah 2020). Sulawesi is a unique island, with remarkable biodiversity patterns owing to its composite geological history, and it is widely recognised as a diversity hotspot for Odonata (van Tol 1987).

Sulawesi hosts a moderately high diversity of the suborder Zygoptera with 59 species (Dow et al. 2024), including 50 species in the northern arm (Van Tol 1987). Three genera of Chlorocyphidae are endemic to Sulawesi: *Disparocypha* Ris, 1916 (Günther 2020), *Sclerocypha* Fraser, 1949 (Günther 2019), and *Watuwila* van Tol, 1998 (van Tol 1998). In addition, two widespread genera are also represented on Sulawesi: *Libellago* Selys, 1840 and *Rhinocypha* Rambur, 1842. Van Tol & Günther (2018) published a revision of the genus *Rhinocypha* on Sulawesi and adjacent islands and reported eight species from the island, several closely related. Five of the species were new to science, including *Rhinocypha togeanensis* from Togean Island in Sulawesi.

Rhinocypha togeanensis van Tol & Günther, 2018 was first collected in 1994 and 1999 by the last author (AG). This species was found only in one locality, Sungai Tanimpo, South of Wakai Village, Batudaka Island. During the first fieldwork in 1994, AG and F. Randow found about 80 individuals on 13–14 August 1994 along the stream between the (former) beginning of the undisturbed rainforest and the waterfall. Above the waterfall, the population density increased further. In August 1999, the lower reaches of the stream had already been significantly disturbed by deforestation. Below the waterfall, only eight males could be observed. Above the waterfall, in the section up to a narrow gorge, about 25 individuals were encountered.

In the following two decades, no further records of this species were reported. Günther (2008) noted the importance of clear streams in healthy forests for successful reproduction in most *Rhinocypha*. Anthropogenic activities in smaller islands like Batudaka result in particularly serious habitat loss to agriculture (van Tol & Günther 2018; Jati et al. 2024); modification of river flow for recreational purposes poses another serious threat. A survey of population size and distribution is needed since the habitat condition has evidently changed a lot since the original 1994 observations. This study provided a record of the rediscovery of *Rhinocypha togeanensis*, and its current distribution around its type locality in Sungai Tanimpo, Batudaka Island. In addition, the present study also provides the current condition of the habitat of *R. togeanensis* in Sungai Tanimpo along with the profound changes that have occurred to natural habitats in Batudaka Island, Togean Archipelago, in the last ca. 30 years.

MATERIALS AND METHODS

Study site

Several field investigations were conducted in Sungai Tanimpo ['sungai' (Indonesian: river/stream)] in the south of Wakai Village, located in Batudaka Island (244 km^2), one of the islands in the Togean Archipelago (Figure 1), Tojo Una-Una Regency, Central Sulawesi Province. This archipelago lies in Gorontalo Bay and is separated from the main island by a deep-water strait (200–4,000 m), suggesting that these islands were never connected to the Sulawesi main island, even with significant sea level fluctuations that occurred during the past million years (Nugraha & Hall 2018). Geologically, Batudaka Island was formed during the Pliocene to Pleistocene, and is dominated by limestone and interbedded sediments, a formation known as Celebes Molasse (Cottam et al. 2011). The island of Batudaka is dominated by lowland tropical rainforest and mangroves. Well before modern times, some parts near the coastal area were

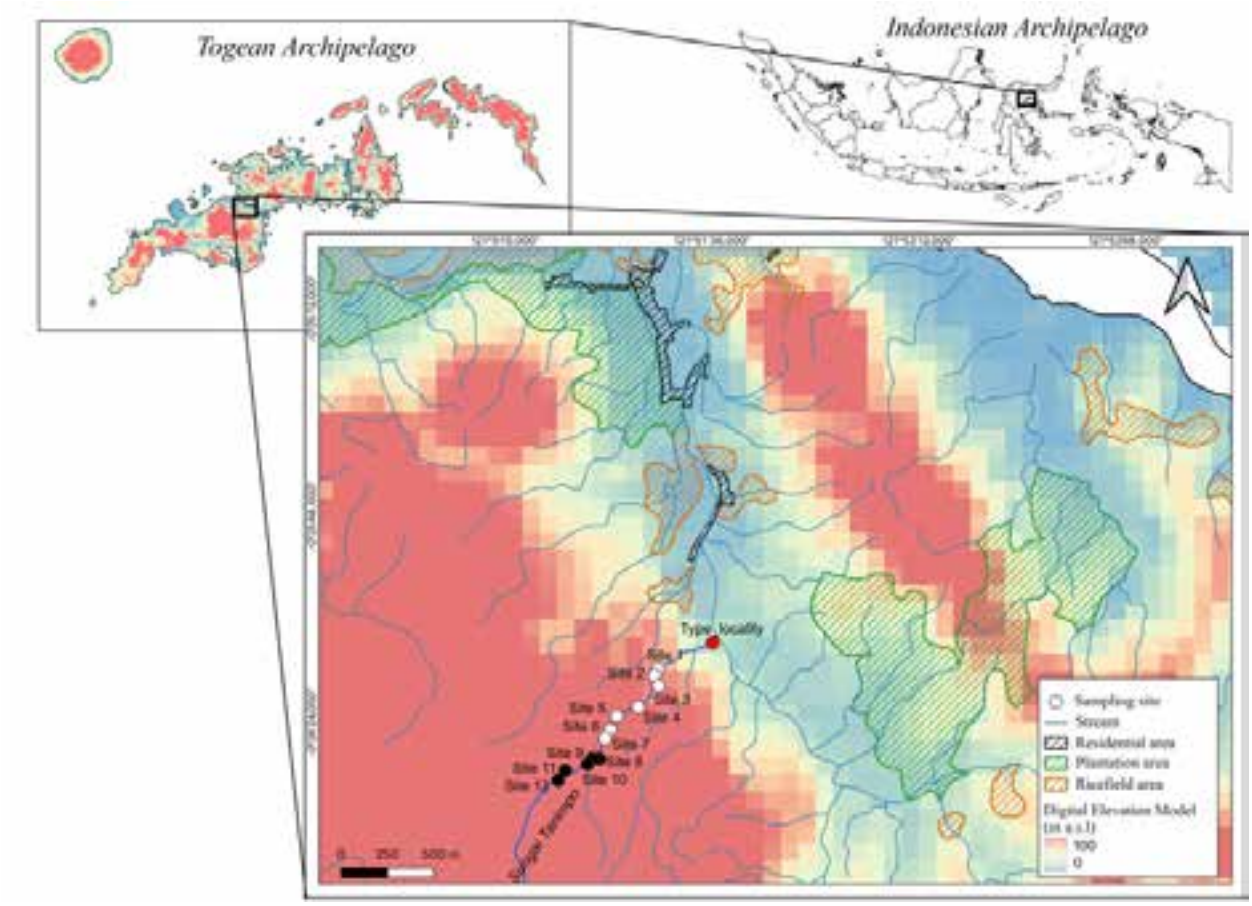

Figure 1. The map of the study site shows the land-use surrounding Sungai Tanimpo, the habitat of *Rhinocypha togeanensis* in Batudaka Island, Togean Archipelago. Red circle: type locality in 1994 and 1999; white circle: *R. togeanensis* absent; black circle: *R. togeanensis* present.

converted into agricultural plantations, including clove and coconut, which are typical crops suitable for an area with low precipitation (monthly precipitation 203–445 mm in 2022) (Jati et al. 2024).

Survey of *Rhinocypha togeanensis*

The second author (DD) conducted the preliminary survey at the type locality on 12 October 2023, followed by the first author (MA). The survey on the population and distribution of *R. togeanensis* was conducted on 15–16 November and 17–20 December, 2024, in Sungai Tanimpo, starting from the lower reaches at an altitude of 78 m in the agricultural area up to 153 m in the forested area. Since this river is vital for the local community in Wakai Village, the upper reaches were used as a source of drinking water. Thus, Sungai Tanimpo has an important role in sustaining the local environment. This stream flows from a hilly area with dense tropical forest vegetation to a coastal area in Wakai before emptying into Gorontalo Bay, forming a transitional ecosystem supporting freshwater species. In its upper reaches, Sungai Tanimpo is characterised by a fast-flowing shallow stream, with several small waterfalls, cascades, and pools along the stream. The stream bottom is composed mainly of gravel and rocks.

Individuals of *R. togeanensis* were identified by 'catch and release' method (Balzan 2012; Fernandez 2024) and one individual collected in their habitat along the Sungai Tanimpo using an aerial net. We searched for this damselfly in 12 sites, including its type locality in Air Terjun Tanimpo ['air terjun' (Indonesian: waterfall)] (van Tol & Günther 2018). The individuals collected were directly identified in the field based on key identification provided by van Tol & Günther (2018). The photographs of *R. togeanensis* were made using a Canon EOS 200D camera with a 70–300 mm lens. Only one individual was preserved for further detailed examination using a stereomicroscope. The environmental parameters, including air temperature (°C), relative humidity (%) and light intensity (lux), were measured using a digital thermohygrometer. The coordinates of each site were recorded using a global positioning system (GPS) Garmin

GPSmap 78s. The distribution map of *R. togeanensis* was made using QGIS 3.36 Maidenhead (QGIS.org 2026).

RESULTS

This study rediscovered *Rhinocypha togeanensis* in its natural habitat after the last record in 1999 (more than two decades ago) (Image 1). Specimens were found at localities somewhat contracted more upstream from the location where *R. togeanensis* was found for the first time in Air Terjun Wakai (van Tol & Gunther 2018) (Figure 1). During the survey, no individual was observed in the type locality (red circle in Figure 1), but they were present approximately 2 km, far more inland in the remaining pristine forest. The stream section where this species was observed was located beyond a narrow gorge with dense forest cover and less anthropogenic activity.

In this study, since the focus was on rediscovery and updating the current population of *R. togeanensis*, only one specimen was collected. In fact, only one individual (male) was preserved for morphological examination under a stereomicroscope to avoid population depletion of this endangered species. The species identification was verified directly by the last author (AG), who collected this species in 1994 and 1999. Based on one male, the specimen agreed well with the original description of *R. togeanensis* by van Tol & Günther (2018), especially in black colour of head, without any blue markings; black mandible; thorax with velvet black colour, pronotum black; abdomen with black dorsum and blue markings on the lateral part, S9 and anal appendages black; wings with dark brownish black, anterior part of wings dark brown, wings with blue metallic colour (Image 2). The specimens have no well-defined blue annulae thus differing from *R. virgulata* (van Tol & Günther 2018).

A total of 12 sites in Sungai Tanimpo, Batudaka Island, were surveyed. *R. togeanensis* was recorded at only five sites, all of which were located in primary forest and relatively far from the residential and agricultural area. Around 18 individuals were recorded in the stream located beyond a narrow gorge rarely visited by humans. In this study, the sex of *R. togeanensis* were not recorded, hence, the functional sex ratio cannot be stated (Table 1).

In the lower reaches, near the residential and agricultural area (sites 1–7), not a single individual of *R. togeanensis* was observed but they appeared in forested area hiding in the narrow gorge (high approximately 5 m) (Image 3A). Beyond the narrow gorge, the area became a well-preserved primary forest with little human activity (Image 3B,C). Areas favoured by *R. togeanensis* in this area tended to support vegetation located approximately 0.6 m above the water surface and twigs along the riverbank. When disturbed, the damselflies occasionally moved to the higher part of the tree branches. It was primarily found on riverbanks exposed to direct sunlight (Table 1).

The distribution of *R. togeanensis* is associated with small, swift-running streams in the upper reaches (> 100 m). The environmental parameters in Sungai Tanimpo, where *R. togeanensis* was found, included lower air temperature 26.7–26.8°C (sites 8–12) and higher relative humidity > 96%, i.e., characteristics of a closed canopy of the primary forest. The light intensity ranged from 694–8117 lux. The stream in the habitat of *R. togeanensis* was approximately 3 m wide with a rocky and gravel bottom and shallow riffles (Image 3C). In this part, there are some cascades or pools with a rocky

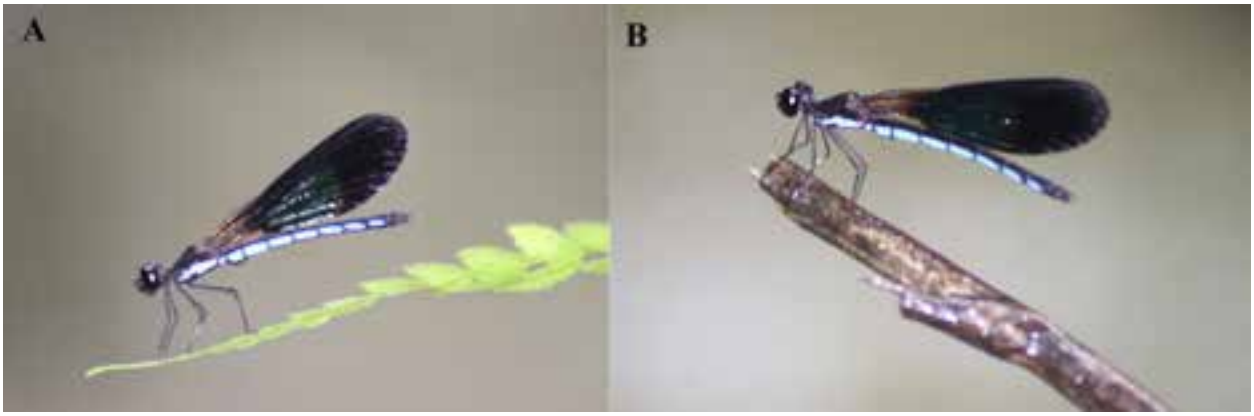

Image 1. *Rhinocypha togeanensis* at Sungai Tanimpo showing preferred perches: A—on leaves | B—on branch. © Muhammad Amiruddin.

Table 1. Environmental variables, elevation and population abundance recorded in 12 sampling sites during this study.

Sampling site	Temperature (°C)	Relative humidity (%)	Light intensity (Lux)		Elevation (m)	Number of individuals
			min.	max.		
Site 1	32.2	89.6	217	254	78	0
Site 2	32.4	74.1	155	164	82	0
Site 3	28.5	84.6	632	986	85	0
Site 4	31	84.4	4307	4735	87	0
Site 5	32.3	78.7	869	1305	91	0
Site 6	29.3	92.4	1688	2317	98	0
Site 7	30.1	80.3	718	842	113	0
Site 8	26.8	96	1007	1407	136	4
Site 9	26.7	96.4	1022	1421	139	3
Site 10	26.7	97.2	900	1185	146	4
Site 11	26.8	97.5	694	916	151	3
Site 12	26.8	98.3	4137	8117	153	4
	Total					18

Image 2. A male of *Rhinocypha togeanensis* van Tol & Gunther, 2018 from Sungai Tanimpo, Batudaka Island, Togean Islands. © Muhammad Amiruddin.

bottom. The surrounding vegetation was dominated by primary forest.

DISCUSSION

This study confirmed that *Rhinocypha togeanensis* still occurs in its habitat in Sungai Tanimpo, although there is a significant contraction in occupied habitat to the undisturbed forested area upstream. After more than two decades, although there has been extensive development in human settlement and expansion of agriculture, this study is the first survey to rediscover this endemic damselfly in its wild habitat (Image 1).

Since the survey only successfully recorded 18 individuals in Sungai Tanimpo, it is assumed that *Rhinocypha togeanensis* might now have a small population size and a very small area of occurrence, making it vulnerable to extinction. In 1994, over 80 individuals were observed in the area below the waterfall, where the species was no longer present in the current survey. And above the waterfall, the species was even more common. By 1999, the population size in the lower reaches of the stream had already decreased considerably due to the loss of suitable habitats (A. Günther, pers. obs. 24–28 August 1999). It cannot be ruled out that lower numbers in the upper part could be a sampling artefact (different time/season, etc.), or it might be that the loss of the healthy downstream population might be adversely affecting the upstream population as well.

Rhinocypha togeanensis was listed as 'Endangered' with IUCN Red List criteria B1ab(ii,iii) without any available data on population status (Dow 2021). This study contributes to the preliminary update on the population of this endangered and endemic damselfly in Togean Islands. It is strongly suggested that the threatened status of this species should be elevated to Critically Endangered (CR) to gather more conservation actions for this species in the future. Current data suggest that this is one of the most threatened damselfly species in the world.

The habitat of *R. togeanensis* in Sungai Tanimpo is now highly disturbed, especially in the lower reaches of the stream. According to the observations, deforestation and disturbance of the surrounding forests and the

Image 3. Habitat of *Rhinocypha togeanensis* in Sungai Tanimpo. A—a narrow gorge in front of the forested area where this species was found | B&C—primary forest around the gorge with cascades and streamflow showing natural vegetation along the riverbank.

introduction of sand and soil into the stream represent the greatest threats to the survival of the species. No individuals of *R. togeanensis* were found near human settlements or agricultural areas (cacao plantation) up to Air Terjun Tanimpo, where this species was previously found. The habitat seems to have now been reduced to the upper part of the stream in forested areas. In some situations, damselflies (Zygoptera) have been reported to have a different community structure according to land change, thus sensitive to disturbance (Monteiro-Júnior et al. 2014). Since the natural flow of Sungai Tanimpo relies on the forested area upstream, deforestation or land use surrounding Sungai Tanimpo could affect that annual flow and water turbidity and cause problems to aquatic organisms that depend on a healthy stream. In addition, Sungai Tanimpo has also now become popular for recreational activities, especially at the waterfall. It is likely that in the future, the habitat of *R. togeanensis* inside the narrow gorge will also become a recreational site. To date, human activity in this area has only been for the regional drinking water supply (PDAM), affected by installing a long pipe from this area to the human settlement.

This study highlights the conservation priority of *Rhinocypha togeanensis*, an endemic and Endangered damselfly. Conservation issues in the Togean Islands have been known for several endemic large vertebrates, such as *Babyrousa togeanensis* (Jati et al. 2024) and *Tarsius niemitzi* (Supriatna et al. 2020), including the adverse effects of deforestation for small-scale agriculture and human settlement. Aquatic invertebrates, such as dragonflies and damselflies, are not only found in streams during their larval stage (Monteiro-Júnior et al. 2014), but also in the riparian vegetation and perhaps the subcanopy as adults (de Oliveira-Junior et al. 2017). Many chlorocyphids might ascend to the subcanopy to forage, where they tend to disappear for a day, then return to the breeding site, and there is some evidence that this time is spent feeding, as some species, for example, *Libellago* spp., will travel quite long distances (1–2 km) to forage (Albert G. Orr pers. communication). The presence of human activities for recreation in the stream or waterfall could alter the structure of the habitat, such as the removal of logs, driftwood, and

branches lying in the stream that become a vital site for mating and oviposition (Günther 2008; van Tol & Günther, 2018).

Possible conservation measures for *R. togeanensis* include restoring gallery forests along the stream's lower reaches and preventing runoff from agricultural land. Community outreach programs and education for visitors and the local community will be important steps in providing adequate information regarding this species and its habitat. In addition, searching for other permanently flowing streams hosting the species is needed. The high endemicity of damselflies in Sulawesi should be an incentive for extraordinary conservation efforts to ensure their long-term existence in Sulawesi.

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Author contribution: Muhammad Amiruddin, Diky Dwiyanto and André Günther designed the study, performed data collection and data analysis, and wrote the manuscript. Diky Dwiyanto, Nuranisa Nuranisa, and Jusriadi Jusriadi wrote and revised the manuscript. Nur Khasanah and André Günther supervised and revised the manuscript. All authors reviewed and approved the final manuscript.

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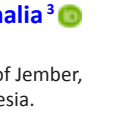

ARTICLE

The dragonfly (Odonata) community structure at Sukamade Resort, Meru Betiri National Park, Indonesia

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Abstract: Sukamade Resort, located within Meru Betiri National Park, is a conservation management area. Dragonflies have significant diversity and extensive spread, and their presence in conservation areas is linked to the availability of ecological resources such as abundant vegetation near aquatic habitats. This study ascertained the composition of the dragonfly community in Sukamade Resort at four sampling sites to provide data for conservation area management. Of the 17 species recognized, *Orthetrum sabina* and *Pseudagrion microcephalum* had the greatest population density across all locales. The diversity index indicated a moderate level, the Margalef index demonstrated low requirements, the dominance index was low, and evenness was high. The important value index (IVI) indicates that *Neurothemis ramburii*, *Orthetrum sabina*, and *Libellago lineata* had the highest ecological importance (IVI = 0.38). Canonical correspondence analysis indicates that *Pseudagrion microcephalum*, *Zyxomma obtusum*, *Ischnura senegalensis*, *Diplacodes trivialis*, and *Trithemis festiva* are associated with air humidity characteristics at the Great Estuary location. It is concluded that the presence of dragonflies is influenced by habitat factors such as aquatic substrate composition, abiotic parameters (light, temperature, humidity), and riparian vegetation. Protecting riparian habitats and maintaining good water quality are crucial for the conservation of dragonflies, which reflect healthy ecological conditions and support the sustainability of aquatic ecosystems.

Keywords: Abiotic, abundance, conservation, diversity, ecosystem, environmental, forest, habitat, tropical.

Resort Sukamade, yang terletak di dalam Taman Nasional Meru Betiri, merupakan kawasan pengelolaan konservasi. Capung memiliki keanekaragaman yang signifikan dan persebaran yang luas, serta keberadaannya di kawasan konservasi terkait dengan ketersediaan sumber daya ekologis seperti vegetasi yang melimpah di dekat habitat perairan. Penelitian ini bertujuan untuk mengetahui komposisi komunitas capung di Resort Sukamade pada empat lokasi pengambilan sampel guna menyediakan data bagi pengelolaan kawasan konservasi. Dari 17 spesies yang teridentifikasi, *Orthetrum sabina* dan *Pseudagrion microcephalum* memiliki kepadatan populasi tertinggi di seluruh lokasi. Indeks keanekaragaman menunjukkan tingkat sedang, indeks Margalef menunjukkan kebutuhan rendah, indeks dominansi rendah, dan indeks kemerataan tinggi. Indeks nilai penting (INP) menunjukkan bahwa *Neurothemis ramburii*, *Orthetrum sabina*, dan *Libellago lineata* memiliki kepentingan ekologis tertinggi (INP = 0,38). Analisis korespondensi kanonik menunjukkan bahwa *Pseudagrion microcephalum*, *Zyxomma obtusum*, *Ischnura senegalensis*, *Diplacodes trivialis*, dan *Trithemis festiva* berasosiasi dengan karakteristik kelembapan udara di lokasi Muara Besar. Disimpulkan bahwa keberadaan capung dipengaruhi oleh faktor-faktor habitat seperti komposisi substrat perairan, parameter abiotik (cahaya, suhu, kelembapan), serta vegetasi riparian. Perlindungan habitat riparian dan pemeliharaan kualitas air yang baik sangat penting bagi konservasi capung, yang mencerminkan kondisi ekologis yang sehat serta mendukung keberlanjutan ekosistem perairan.

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Author contribution: AR: Conceptualization, supervision, and revision of the manuscript and manuscript writing. WS: Methodology, validation, and data analysis. DAA: Data collection, analysis, and manuscript writing.

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INTRODUCTION

Meru Betiri National Park is a conservation management area that includes Sukamade Resort, a lowland forest. Dragonflies exhibit specific habitat preferences within the region. Dragonflies exhibit significant diversity and a wide distribution across various habitats (Kalkman et al. 2008). The presence of dragonflies in conservation areas is intricately linked to the availability of natural elements essential for their life cycle, particularly robust and diverse aquatic environments. Dragonflies exhibit considerable variability in their distributions, contingent upon the prevailing environmental conditions and habitat types in a given locale. Consequently, examining dragonfly communities across many habitats and conservation areas is crucial for comprehending the interplay between dragonfly species and their ecosystems and developing more effective conservation measures. Furthermore, conducting inventories is essential to ascertain the composition and abundance of species within an ecosystem, facilitating the examination of diversity, abundance, dominance, and evenness, which collectively depict community structure (Navarro et al. 2018).

Dragonflies have a crucial function in the ecosystem as bioindicators of aquatic quality and environmental contamination (Virgiawan 2016; Yuditaningtyas et al. 2022; Datto-Liberato et al. 2024). Furthermore, they function as predators and pest management agents (Lino et al. 2019). The availability of water and vegetation influences the presence of dragonflies. The nymph stage occurs in aquatic environments, while adults remain near the water (Nasirianda & Irvine 2017; Da Silva-Méndez et al. 2022). The research by Orlofske et al. (2024) shows that several river dragonfly larval taxa in the mountains co-occur; yet, during emergence, specific species may react differently to distinct stream characteristics. Certain adult dragonfly species prefer flowing rivers, particularly those with moderate to gentle currents. Dragonflies are distributed along streams about light intensity and canopy cover (French & McCauley 2018).

The research by Chovanec et al. (2015) established a dragonfly association index that correlates rivers with dragonflies to evaluate the ecological condition of rivers. Conservation zones with robust vegetation surrounding water habitats also affect the presence of dragonflies. The varied forest structure and dense vegetation can influence the distribution and quantity of dragonflies (O'Malley et al. 2020). Thick foliage offers refuge, roosting, foraging, and breeding opportunities. Dragonfly populations are typically more abundant in conservation areas with substantial vegetation cover along riverbanks. The advantageous and varied environmental conditions create an optimal ecosystem for dragonflies, enabling them to efficiently reproduce and fulfil their ecological functions (Hykel et al. 2020). The composition of the substrate also influences water quality (Vanderzwalmen et al. 2022).

The substrate of a river influences odonate makeup. Organic substrates, such as leaf litter and riparian zones, exhibit greater richness than inorganic substrates like rocks and gravel. Perron & Pick (2020) research indicates that water quality significantly affects the nymphal phase (Perron et al. 2020). Additionally, a correlation exists among riparian vegetation, water quality, and land cover, which may yield high-quality habitats for dragonflies. O'Malley et al. (2020) assert that dragonfly conservation through river habitat management must encompass the protection of riparian habitats alongside the preservation of water habitats and their quality. Riparian ecosystems characterized by diverse and dense plant life offer optimal habitats for dragonfly populations, but sparser and more open vegetation is also conducive to their presence. This study fills the knowledge gap by providing baseline data on the structure and diversity of dragonfly communities in Sukamade Resort, Meru Betiri National Park, which has not been widely studied. This study offers novelty by comprehensively analyzing habitat variables that can collectively affect dragonfly communities. This study provides an innovative methodology in the Meru Betiri National Park context by applying the dragonfly association index to assess ecological conditions. The study results are expected to be a strong scientific basis for more effective management and formulation of conservation policies, especially in efforts to protect habitats and support the sustainability of the ecological function of dragonflies as bioindicators of environmental quality and control agents. Based on this background, this study will analyze the composition, diversity, and structure of dragonfly communities in the Sukamade Resort Area, which will later become basic data for policymaking in managing the conservation area of Meru Betiri National Park.

MATERIALS AND METHODS

Study area

This study was conducted from June to August 2024 in Sukamade Resort, Meru Betiri National Park (TNMB) (Image 1). The approach employed for determining

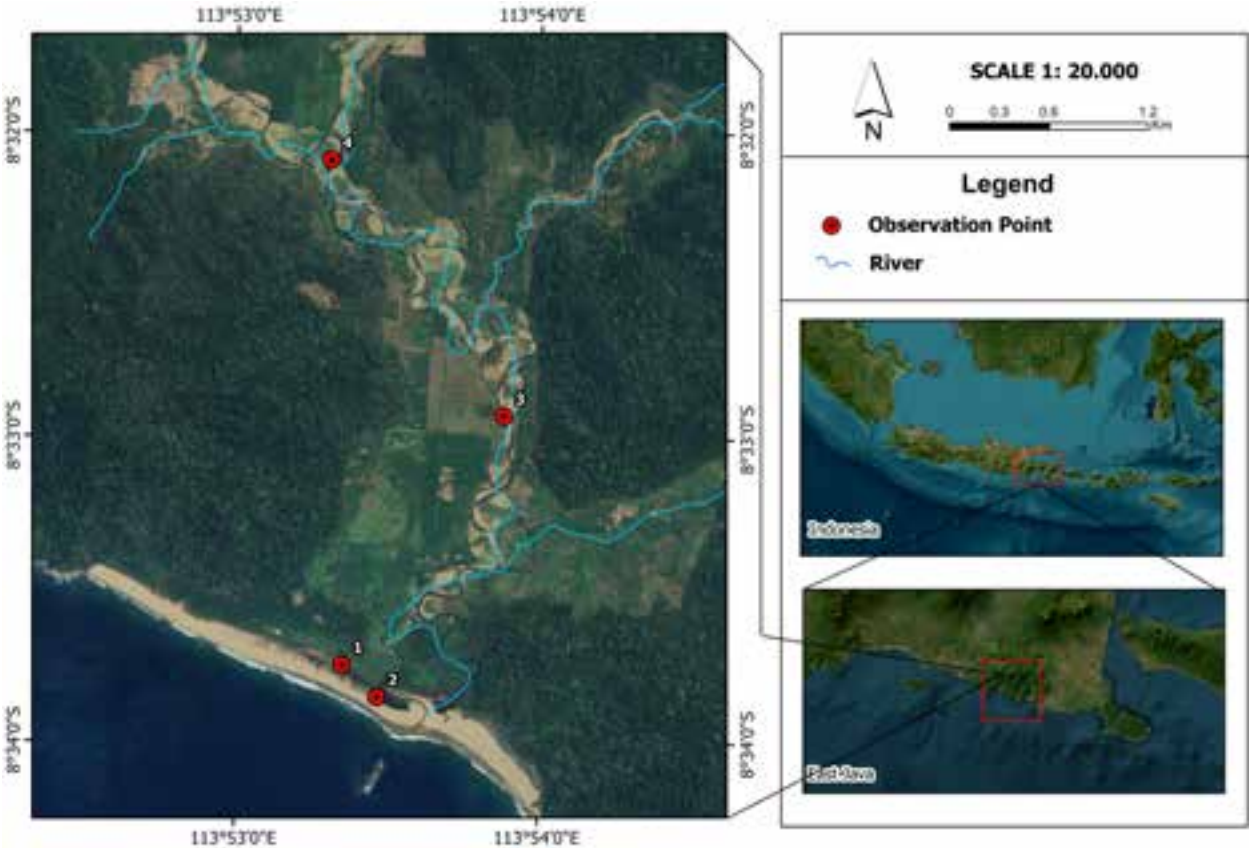

Image 1. Research location Sukamade Resort, Meru Betiri National Park.

sampling points was purposive sampling. Data collection on dragonflies was conducted throughout the river flow and categorized into four locations: great estuary, small estuary, Getean River, and Hamlet River.

Dragonfly data collection

The study employed the road sampling technique, which involved traversing a sampling area of 100 m in length and 10 m in width at each research site. Samples were collected using the sweeping technique (Rohman et al. 2024). Field data were gathered on different days, with each sampling session repeated three times. Sampling was conducted between 0600 h and 1700 h Western Indonesian Time (WIB). The parameters recorded included the species of dragonflies encountered and the number of individuals per species. Species identification was carried out by examining the morphological characteristics of each individual, guided by standardized identification keys. The identification process relied on validated scientific references, including identification manuals published by Orr (2005), Kalkman & Orr (2013), Orr & Kalkman (2015); Setiyono et al. (2017).

Substrate composition measurement

The composition of the water substrate was determined on a 1 m^2 plot located near the water's edge at the beginning, middle, and end of the transect. The substrate composition listed includes: mud, sand, rocks, gravel, plant substrate, leaf litter, and twigs or tree trunks.

Measurement of abiotic factors

The abiotic parameters examined include air temperature, light intensity, humidity, and wind speed.

Instruments and materials

Sweep net, stationery, ruler, styrofoam, needles, insect needles, cardboard paper, cotton, cardboard, papilot paper, syringe, camera, 5 watt yellow light, lux meter, thermohygrometer, anemometer, killing jar, and Garmin GPSmap 60CSx. The dragonflies that had been obtained were then dried and preserved and identified.

Data analysis

Assessment of conservation status according to the International Union for Conservation of Nature (IUCN)

Red List of Threatened Species (https://www.iucnredlist.org). Data analysis utilizing PAST4.09 software: Shannon-Wiener diversity index (H'), evenness (E), and dominance (D). The IVI was calculated for dragonfly communities based on their density, frequency, and dominance, which was utilized to evaluate the significance of species at each location.

The Shannon-Wiener diversity index (H') (Odum 1996) can be calculated using the formula:

$$H' = -\sum\{\left(\frac{ni}{n}\right) In \left(\frac{ni}{n}\right)\}$$

Information:

H' = Shannon-Wiener diversity index

ni = Number of individuals of type i

N = Number of individuals of all types

The evenness index (E/evenness) is used to determine the evenness of the number of individuals who form a community (Magurran 2004) as follows:

$$E = \frac{H'}{Ln\ S}$$

Information:

E = Evenness index

H' = Shannon-Wiener diversity index

S = Number of species found

Species dominance is determined using the Simpson's index using the formula:

$$D = \sum_{i-l}^{s} (\frac{ni}{n})^2$$

Information:

D = Dominance index

ni = Number of individuals of type i

N = Number of individuals of all types

The similarity index (Iss) is used to determine the similarity of species between locations as follows:

$$Iss = \frac{2C}{A+B} x\ 100$$

An importance value index (IVI) was determined for dragonfly communities based on their density, frequency and dominance, which was used to assess the importance of the species present at each location.

$$\text{Density} = \frac{\text{The number of species}}{\text{Area of measuring}}$$

$$\text{Relative density} = \frac{\text{Species density}}{\text{Density of all species}} \times 100\%$$

$$\text{Frequency} = \frac{\text{The number of plots containing a s}}{\text{The sum of all plots}}$$

$$\text{Relative frequency} = \frac{\text{Species frequency}}{\text{Frequency of all species}} \times 100\%$$

$$\text{Dominance} = \frac{\text{Species dominance}}{\text{Dominance of all species}}$$

$$\text{Relative dominance} = \frac{\text{Species dominance}}{\text{Dominance of all species}} \times 100\%$$

IVI = Relative Density (%) + Relative Frequency (%) + Relative Dominance (%)

Environmental parameters (abiotic) were analyzed using canonical correspondence analysis (CCA) to demonstrate the impact of abiotic factors on dragonfly presence in a habitat.

RESULTS

Dragonfly Diversity at Sukamade Resort, Meru Betiri National Park

A total of 133 individuals representing 17 dragonfly species from six families were documented (Table 2): *Neurothemis ramburii*, *Orthetrum sabina*, *Orthetrum pruinosum*, *Diplacodes trivialis*, *Zyxomma obtusum*, *Onychothemis culminicola*, *Potamorcha congener*, *Trithemis festiva*, *Libellago lineata*, *Ischnura senegalensis*, *Agrocnemis pygmaea*, *Agrocnemis femina*, *Pseudagrion microcephalum*, *Pseudagrion pruinosum*, *Pseudagrion rubriceps*, *Prodasineura humeralis*, and *Eupaea variegata*. *Orthetrum sabina* and *Pseudagrion microcephalum* had the greatest abundance across all locations. The family Libellulidae comprised eight dragonfly species, the family Coenagrionidae included six species, and the families Chlorocyphidae, Protoneuridae, and Euphaeidae each contained one species.

The Libellulidae had the highest proportion of species (47%), followed by the Coenagrionidae (35%), Chlorocyphidae, Protoneuridae, and Euphaeidae families with 6% each (Figure 1). This signifies that Libellulidae predominates in all locations and is the most prevalent family across diverse ecosystems.

Dragonfly index parameters

Figure 2 illustrates the computation of data analysis employing the diversity index, Margalef index, dominance index, and evenness index at Sukamade Resort of Meru Betiri National Park (MBNP). The variety index is valued at 1.99. The diversity index (H') is categorized as moderate ($1 \leq H' < 3$) based on the criteria. The subsequent index

Table 1. Description of the four research locations in Sukamade Resort, Meru Betiri National Park.

	Location	Coordinates		Elevation (m)	Description
		Latitude	Longitude		
1	Great Estuary	-8.562	113.889	29	The large river estuary has a width of 35 m with lentic brackish water conditions. This area is dominated by *Sonneratia griffithii* tree vegetation, which reaches heights of over 5 m, as well as riparian plants such as *Axonopus compressus.*
2	Small Estuaries	-8.564	113.891	27	The river with a smaller estuary has a width of 6 m and lentic water conditions. This area is dominated by *Sonneratia griffithii* tree vegetation, with heights exceeding 5 m, riparian plants such as *Axonopus compressus.*
3	Getean River	-8.548	113.898	31	The river, which has a smaller estuary, has a width of 15 m and lotic water conditions. This area is dominated by *Calliandra surinamensis* tree vegetation and riparian plants such as *Cymbopogon schoenanthus.*
4	Hamlet River	-8.534	113.888	33	The river, which has a smaller estuary, has a width of 9 m and lotic water conditions. This area is dominated by *Albizia chinensis* tree vegetation and riparian plants such as *Arachis hypogaea L*.

parameter is the Margalef index, which has a value of 2.18. Sukamade Resort exhibits a low species richness index, with R values below 2.5. The dominance index (D) of dragonflies in the Small Estuary is 0.24, categorizing it as low (D < 0.5). The species uniformity index (Evenness) of dragonflies in the Hamlet River is the greatest at 0.92, followed by the Geaten River at 0.84, the Great Estuary at 0.78, and the Small Estuary at 0.77, indicating a high level of uniformity (E > 0.6).

Figure 3 illustrates the relative abundance of dragonflies at Sukamade Resort in MBNP, indicating that at the Great Estuary (36.96) and Small Estuary (45) sites, the species *Pseudagrion microcephalum* exhibits the highest abundance. Conversely, at the Getean River site, the species *Orthetrum sabina* shows the highest abundance (30.77), and similarly, at the Hamlet River site, *Orthetrum sabina* also has the highest abundance (28.57).

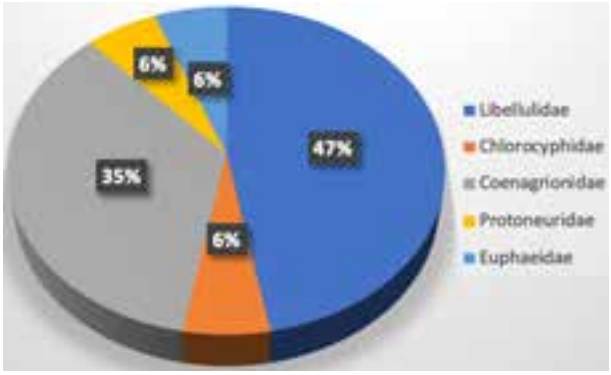

Figure 1. Dragonfly family composition at Sukamade Resort, Meru Betiri National Park.

Important value index dragonfly

The relevance index evaluation at the four locations encompassed Great Estuary, Small Estuary, Geean River, and Hamlet River (Figure 4). The initial site (Great Estuary) exhibited three species with the highest importance index: *Potamarcha congener*, *Ischnura senegalensis*, and *Pseudagrion microcephalum*, with an IVI of 0.34. The second site, Small Estuary, *Onychothemis culminicola*, exhibited the greatest significance index at 0.45. The Getean River exhibited that *Neurothemis ramburii*, *Orthetrum sabina*, and *Libellago lineata* possessed the highest importance index of 0.38. The Hamlet River exhibited the highest significance score of 0.4, attributed to *Potamarcha congener* and *Prodasineura humeralis*.

Measurement of substrate composition

The measurement of aquatic substrate composition in estuarine and riverine areas reveals significant variations depending on environmental characteristics and the dominant sources of organic and inorganic materials. In the Great Estuary, the aquatic substrate consists of inorganic materials such as sand, rocks, and gravel and organic materials such as plant substrates, leaf litter, twigs, or woody debris. A similar composition is observed in small estuaries, which are dominated by sand, rocks, gravel, plant substrates, leaf litter, and twigs or woody debris. This indicates that small and large estuaries share comparable sedimentation dynamics and organic material inputs. In contrast, the substrate composition in the Getean River is predominantly characterized by fine mud and twigs or woody debris, reflecting intensive sedimentation processes and organic material input from riparian vegetation. In the Hamlet River, the aquatic substrate primarily consists of mud and leaf litter, highlighting the influence of leaf decomposition and the accumulation of fine sediments. These variations in substrate composition underscore the diverse environmental processes and material sources shaping aquatic ecosystems in different locations. Further studies are needed to explore the

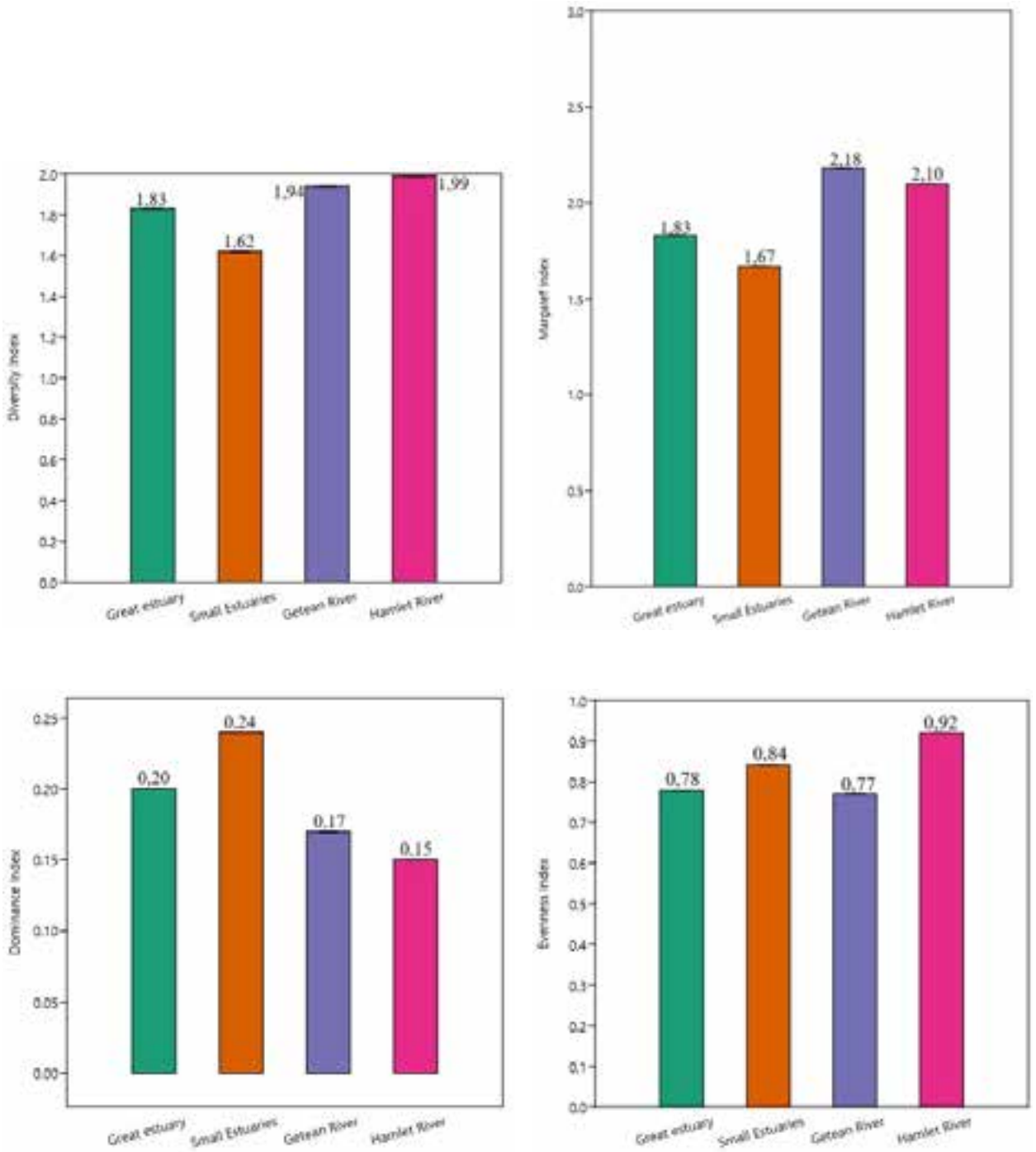

Figure 2. Diversity, Margalef, dominance, and evenness index parameters at Sukamade Resort, Meru Betiri National Park.

ecological implications of these substrate variations on aquatic biodiversity and ecosystem functions.

Abiotic parameters at Sukamade Resort, MBNP

The light intensity parameter ranged 2054.3–81866.7 lux. Compared to other sites, the Getean River exhibited the maximum intensity at 81,866.7 lux. Air temperature ranged 27.4–33.7 °C. This temperature range is ideal for insects. The air temperature in Getean River was higher (33.7°C) than other locations. Air humidity ranged 67–81.8. Humidity was lower at Getean River (67) than other locations. Wind speed ranged 0–2.3 (Table 3).

Table 2. List of dragonflies found in Sukamade Resort, Meru Betiri National Park.

	Suborder	Family	Species	Protection and conservation status of the species			Relative abundance				
				IUCN	CITES	NS	Great Estuary	Small Estuaries	Getean River	Hamlet River	Total
1	Anisoptera	Libellulidae	*Neurothemis ramburii* (Nr)	LC	NA	NP	17,39	10	23,08	10,71	22
2	Anisoptera	Libellulidae	*Orthetrum sabina* (Os)	LC	NA	NP	19,57	20	30,77	28,57	33
3	Anisoptera	Libellulidae	*Orthetrum pruinosum* (Op)	LC	NA	NP	0,00	5	0,00	0,00	1
4	Anisoptera	Libellulidae	*Diplacodes trivialis* (Dt)	LC	NA	NP	4,35	0	0,00	0,00	2
5	Anisoptera	Libellulidae	*Zyxomma obtusum* (Zo)	LC	NA	NP	6,52	5	0,00	0,00	4
6	Anisoptera	Libellulidae	*Onychothemis culminicola* (Oc)	LC	NA	NP	0,00	15	0,00	0,00	3
7	Anisoptera	Libellulidae	*Potamarcha congener* (Pc)	LC	NA	NP	6,52	0	0,00	7,14	5
8	Anisoptera	Libellulidae	*Trithemis festiva* (Tf)	LC	NA	NP	4,35	0	0,00	0,00	2
9	Zygoptera	Chlorocyphidae	*Libellago lineata* (Ll)	LC	NA	NP	0,00	0	15,38	7,14	8
10	Zygoptera	Coenagrionidae	*Ischnura senegalensis* (Is)	LC	NA	NP	4,35	0	0,00	0,00	2
11	Zygoptera	Coenagrionidae	*Agriocnemis pygmaea* (Ap)	LC	NA	NP	0,00	0	2,56	0,00	1
12	Zygoptera	Coenagrionidae	*Agriocnemis femina* (Af)	LC	NA	NP	0,00	0	5,13	0,00	2
13	Zygoptera	Coenagrionidae	*Pseudagrion microcephalum* (Pm)	LC	NA	NP	36,96	45	12,82	7,14	33
14	Zygoptera	Coenagrionidae	*Pseudagrion pruinosum* (Pp)	LC	NA	NP	0,00	0	0,00	3,57	1
15	Zygoptera	Coenagrionidae	*Pseudagrion rubriceps* (Pr)	LC	NA	NP	0,00	0	2,56	0,00	1
16	Zygoptera	Protoneuridae	*Prodasineura humeralis* (Ph)	NE	NA	NP	0,00	0	5,13	25,00	9
17	Zygoptera	Euphaeidae	*Eupaea varigeata* (Ev)	NE	NA	NP	0,00	0	2,56	10,71	4

Note: IUCN: NE—Not Evaluated | DD—Data Deficient | LC—Least Concern | NT—Near Threatened | VU—Vulnerable | EN—Endangered | CR—Critically Endangered | EW—Extinct in the Wild and Extinct. CITES: NA—Not Appendix | A.I—Appendix I | A.II—Appendix II | National Status (NS): P—protected | NP—not protected (P.106 /MENLHK /SETJEN /KUM.1/12/2018).

Canonical corresponding analysis

Canonical correspondence analysis categorizes dragonflies into four quadrants. Quadrant 1 indicates that the species *Pseudagrion microcephalum*, *Zyxomma obtusum*, *Ischnura senegalensis*, *Diplacodes trivialis*, and *Trithemis festiva* are associated with air humidity characteristics at the Great Estuary location. Quadrant two species, *Potamarcha congener*, *Eupaea variegata*, *Prodasineura humeralis*, and Pseudagrion pruinosum, exhibited a correlation with wind speed at the Hamlet River site. Quadrant three includes *Orthetrum sabina*, *Neurothemis ramburii*, *Libellago lineata*, *Pseudagrion rubriceps*, *Agriocnemis pygmaea*, and *Agriocnemis femina*, which are connected with water temperature and light intensity at the Getean River. Quadrant four species of *Orthetrum pruinosum* and *Onychothemis culminicola* are associated with the proximity of tiny estuaries (Figure 5).

Table 3. Abiotic parameters at Sukamade Resort, Meru Betiri National Park.

	Parameters	Great Estuary	Small Estuaries	Getean River	Hamlet River
1	Light intensity (lux)	2054.3 ± 102.9	45500 ± 2351.6	81866.7 ± 62185.7	45966.7 ± 5718.7
2	Air temperature (°C)	29.5 ± 0.5	27.4 ± 0.6	33.7 ± 1.5	30.7 ± 0.6
3	Air humidity	81.8 ± 2.8	77.3 ± 3.2	67 ± 8.5	69.3 ± 3.8
4	Wind speed (m/s)	0 ± 0.0	0.1 ± 0.3	0.8 ± 0.1	2.3 ± 0.1

Plant diversity in Sukamade Resort, Meru Betiri National Park

Eighteen (18) plant species were found in Sukamade Resort, Meru Betiri National Park (Table 4). Nine tree

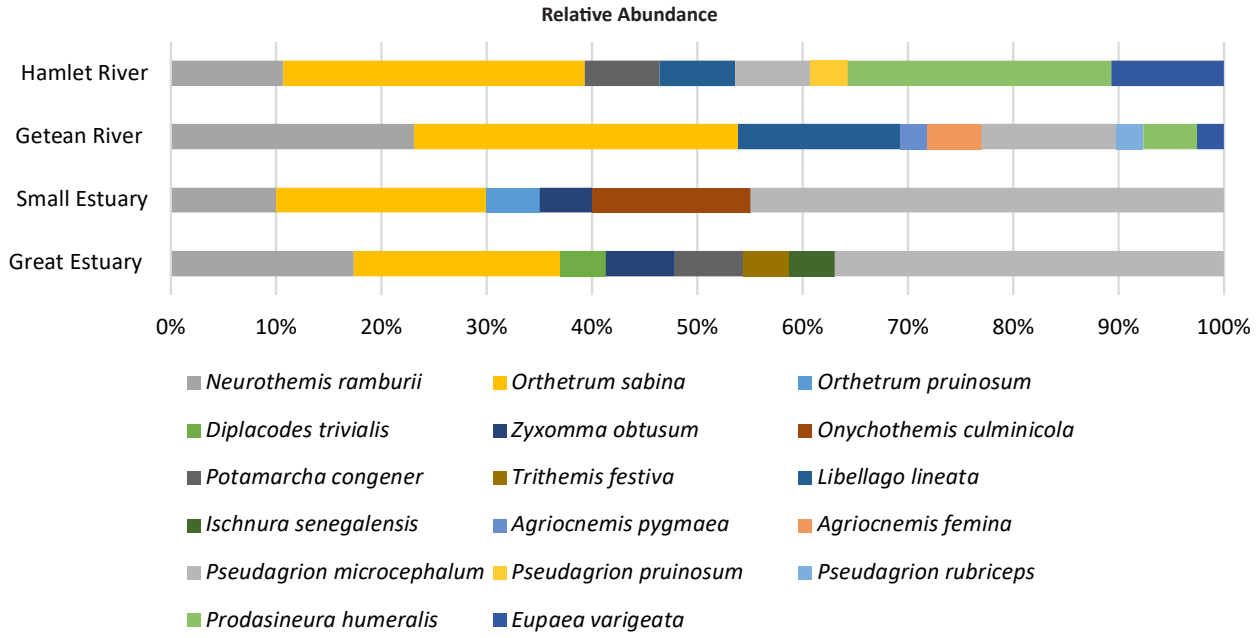

Figure 3. Relative abundance of dragonflies at Sukamade Resort, Meru Betiri National Park.

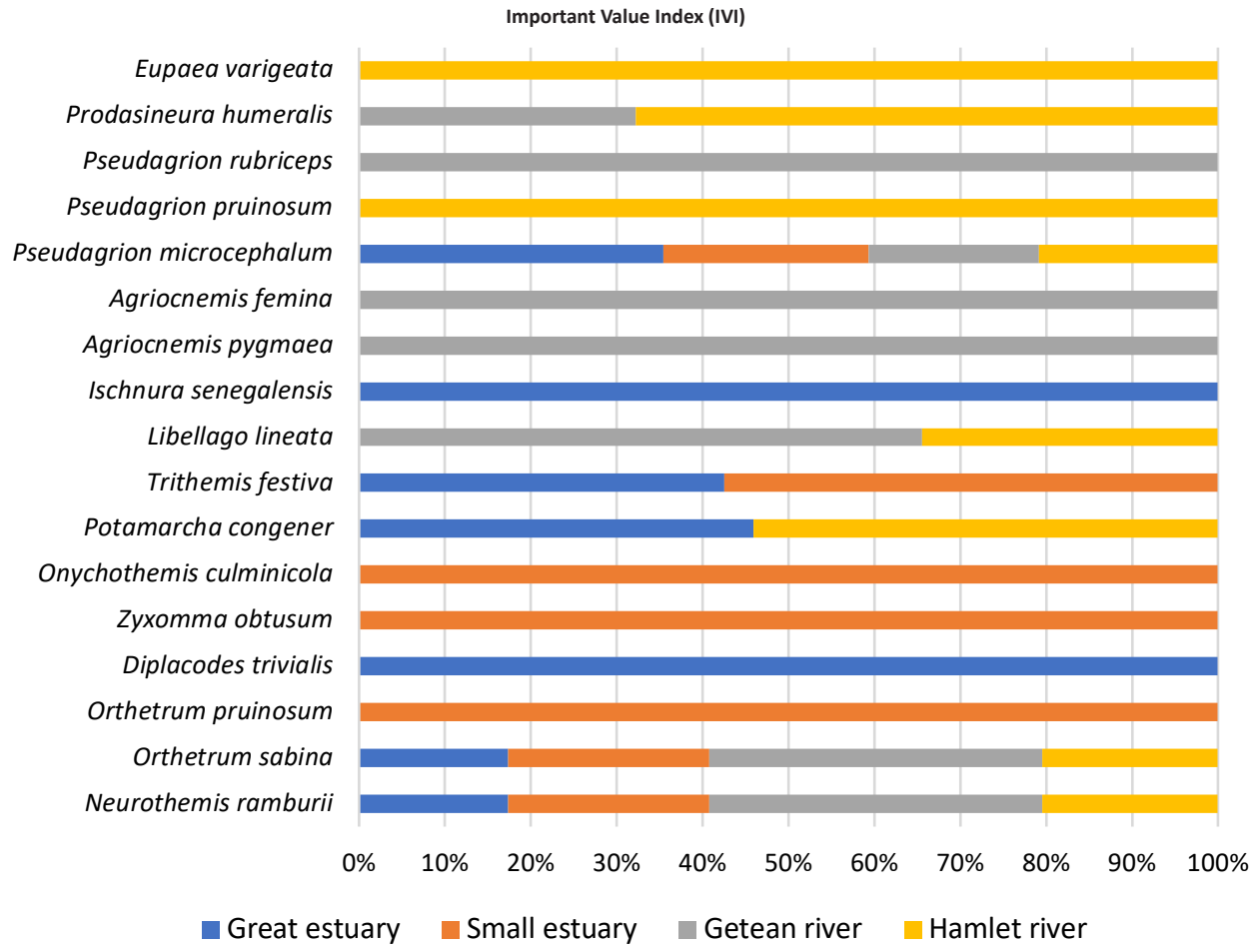

Figure 4. Dragonfly importance index at Sukamade Resort, Meru Betiri National Park.

Table 4. List of plant diversity in Sukamade Resort, Meru Betiri National Park.

	Plants	Family	Species	Great Estuary	Small Estuaries	Getean River	Hamlet River
1	Trees	Pandanaceae	*Pandanus tectorius*	12	38	0	0
2	Trees	Calophyllaceae	*Calophyllum inophyllum*	14	24	0	0
3	Trees	Fabaceae	*Albizia chinensis*	0	0	0	55
4	Trees	Fabaceae	*Cassia alata* L.	0	0	32	29
5	Trees	Fabaceae	*Calliandra surinamensis*	0	0	145	42
6	Trees	Moraceae	*Ficus elastica*	0	0	0	25
7	Trees	Lythraceae	*Sonneratia griffithii*	78	49	0	0
8	Trees	Musaceae	*Musa paradiciaca*	0	0	0	18
9	Trees	Arecaceae	*Cocos nucifera*	0	0	0	19
10	Riparian	Convolvulaceae	*Ipomoea indica*	0	16	23	0
11	Riparian	Amaranthaceae	*Celosia argentea*	0	0	25	0
12	Riparian	Ranunculaceae	*Ranunculus repens*	0	0	24	0
13	Riparian	Zygophyllaceae	*Tribulus terrestris*	0	0	28	0
14	Riparian	Apocynaceae	*Wrigtiya Antidysenterica*	0	64	0	23
15	Riparian	Poaceae	*Cymbopogon schoenanthus*	95	86	55	48
16	Riparian	Poaceae	*Axonopus compressus*	128	93	0	0
17	Riparian	Fabaceae	*Arachis hypogaea* L.	0	0	0	225
18	Riparian	Verbenaceae	*Stachytarpheta jamaicensis*	0	0	53	75

and riparian species were identified. Hamlet River is the location with the highest number of plant species (10 species). Followed by the Getean River (8 species), Small Estuaries (7 species), and Great Estuary (5 species).

DISCUSSION

Seventeen species of dragonflies were documented at Sukamade Resort, Meru Betiri National Park (Table 1). According to IUCN statistics, two species are classified as 'Least Concern': *Orthetrum sabina* and *Pseudagrion microcephalum*. According to CITES classification, the species *Orthetrum sabina* and *Pseudagrion microcephalum* are not listed in the Annexures. The national status of the species *Orthetrum sabina* and *Pseudagrion microcephalum* has not been documented as protected. The *Orthetrum sabina* species were observed roosting in riparian zones and huge trees adjacent to the Getean River. Berliani et al. (2024) identified the *Orthetrum sabina* species in riverine environments, natural habitats, and rice paddies. As per Rohman et al. (2024) *O. Sabina* is also present in utilization woods. *Pseudagrion microcephalum* was observed mating in the vicinity of the Great Estuary. This species is also present in streams (Salsabiela et al. 2022). Moreover, both species (*Orthetrum sabina* and *Pseudagrion microchepalum*) inhabit regions following lakes (Gultom 2022).

The Libellulidae family has the largest contribution, followed by Coenagrionidae. Both families exhibit a broad distribution in proximity to streams, rice fields, agricultural areas, freshwater environments, parks, and gardens (Rohman & Faradisa 2020; Salsabiela et al. 2022; Berliani et al. 2024). Their high adaptability to various environmental conditions and dependence on freshwater resources make Libellulidae and Coenagrionidae groups often found in these locations. Their presence reflects good ecological conditions and confirms their important role as bioindicators of environmental health, especially in monitoring water quality and the sustainability of aquatic ecosystems. Recent studies have shown that these two families have a significant ecological role in maintaining the balance of the food chain, both as predators and as prey for other organisms (Kehar et al. 2025; Palacino-Rodríguez et al. 2020).

Data analysis indicates that the diversity index parameter (H') is categorized as moderate ($1 \leq H' < 3$) (Magurran 2004). Dharmawan et al. (2022) demonstrated a moderate diversity index value in the national plant Alas Purwo at Pancur Resort. Hastomo et al. (2019) indicate a low diversity index value at the Kuningan

Resort of Mount Ciremai National Park. The Margalef index registers a value of 2.18. Sukamade Resort exhibits a low species richness index (R < 2.5) according to the standards established by Magurran (2004). Hastomo et al. (2019) demonstrated a low Margalef index value at the Kuningan Resort of Mount Ciremai National Park. The dominance index (D) of dragonflies in the Small Estuary is 0.24, categorizing it as low (D < 0.5). Nafisah & Soesilohadi (2021) indicate a low dominance index value in natural forests and tourist locations. The Evenness index for the four locations indicates a high level of homogeneity (E > 0.6). Nafisah & Soesilohadi (2021) indicate a high evenness index value in natural forests and tourist locations. According to Susanto et al. (2023), the degree of regularity in aquatic ecosystems is high.

The Great Estuary critical index study revealed three species with the highest importance index: *Potamarcha congener*, *Ischnura senegalensis*, and *Pseudagrion microcephalum*, with an IVI of 0.34. All three species exhibit extensive distribution. *Potomarcha congener* predominantly flies in open terrain and is capable of migration. Astuti et al. (2022) indicate that *P. congener* inhabits both agricultural and forested regions. *I. senegalensis* and *P. microcephalum* exhibit habitat traits associated with moving waters (rivers and irrigation systems) and stagnant waters (reservoirs, swamps, rice fields, and ponds). As per Nicolla et al. (2021), *I. senegalensis* inhabits both canopied and non-canopied environments. The second Small Estuary site, *Onychothemis culminicola*, possesses the greatest significance index of 0.45. Zulhariadi et al. (2024) indicate that the species inhabits areas surrounding ponds. Potential within aquatic ecosystems. In the Getean River, there are three species, namely *Neurothemis ramburii*, *Orthetrum sabina* and *Libellago lineata*. possess the greatest significance index of 0.38. As per Salsabiela et al. (2022), *O. Sabina* exhibits a broad dispersion. The three species inhabit areas surrounding rivers, irrigation systems, rice paddies, and ponds. The fourth location, Hamlet River, possesses the greatest significance score of 0.4, attributed to *Potamarcha congener* and *Prodasineura humeralis*. Salsabiela et al. (2022) indicate that *P. congener* species inhabit areas adjacent to streams with dense vegetation and near wells. The extensive distribution across several environments enables these species to attain the highest Important Value Index. Furthermore, assistance is available from nutritional resources and shelters. The existence of the three dragonfly species is contingent upon water availability. Dragonflies rely highly on aquatic environments, particularly during the nymph stage (Salsabiela et al. 2022). Moreover, variations in altitude can influence the distribution of certain dragonfly species (Table 1).

Aquatic substrate composition plays a critical role in determining the presence and abundance of dragonfly nymphs (Odonata), the aquatic phase of the dragonfly life cycle. Dragonfly nymphs typically inhabit waters with substrates that provide shelter and food sources, such as organic materials (leaf litter, twigs, or woody debris) and plant substrates. In the Great Estuary and small estuaries, the presence of sand, rocks, and gravel, along with organic materials, creates ideal habitats for dragonfly nymphs, as these substrates offer spaces for shelter from predators and areas for foraging. In the Getean River and Hamlet River, the dominance of mud and organic materials such as twigs or leaf litter also supports the life of dragonfly nymphs, albeit with different characteristics. Mud can serve as a suitable substrate for nymphs more tolerant of fine sediment conditions, while leaf litter and twigs provide detritus and microorganisms as food sources. According to Worthen & Horacek (2015), species are distributed differently across various sediment types. Family Gomphidae are commonly found in sand, while Family Cordulegastridae prefer a mixture of sand and cobbles. Family Gomphidae also tend to dominate in cobbles and coarse sediments, whereas family Aeshnidae favour coarse sediments. The average size of nymphs varies among species, and these habitat preferences contribute to differences in average size across sediment types. Overall, variations in aquatic substrate composition influence the distribution and abundance of dragonfly nymphs, with each substrate type providing distinct habitat conditions for specially adapted nymph species.

The Getean River exhibited the highest intensity of abiotic parameters measured at 81,866.7 lux, signifying exceptionally significant sunshine exposure relative to other sites. The Getean River features riparian vegetation along its banks, interspersed with open spaces. The Great Estuary exhibited the lowest intensity at 2054.3 lux (see Table 3). This site is characterized by vegetation and a canopy, resulting in increased shade and shelter. The air temperature varied between 27.4°C and 33.7°C. This temperature range is optimal for insects. The air temperature at Getean River was elevated at 33.7°C compared to the other locations. This location has a higher temperature than others due to its open space, which allows unimpeded light intensity. The intensity of light correlates with temperature; elevated light intensity facilitates dragonfly mobility, particularly in flight, due to its association with the wing veins (Liu et al. 2022). Air humidity varied between 67 and 81.8. The

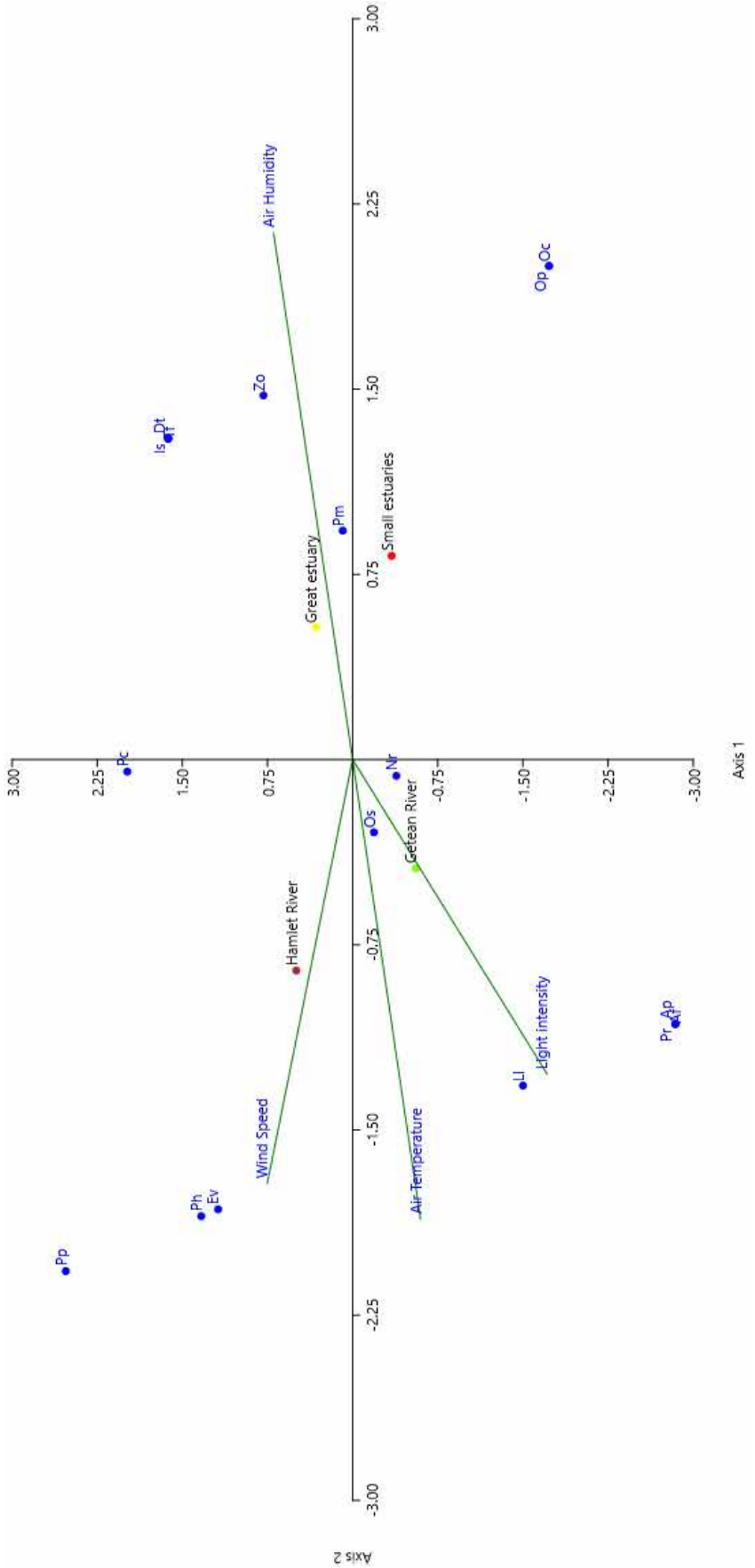

Figure 5. Canonical corresponding analysis at Sukamade Resort, Meru Betiri National Park.

air humidity at the Getean River (67) was lower than at other locations. Low air humidity will impact dragonfly motility (Susanto et al. 2024). Wind speed varied 0–2.3. This range signifies that the wind is not very strong, facilitating the movement of dragonflies.

Canonical Correspondence Analysis indicated that five dragonfly species (*Pseudagrion microcephalum*, *Zyxomma obtusum*, *Ischnura senegalensis*, *Diplacodes trivialis*, *Trithemis festiva*) had a positive correlation with the water humidity parameter in the Great Estuary. Rohman et al. (2023) demonstrated a positive association between various dragonfly species *Diplacodes trivialis* and air humidity (Figure 6).

Vegetation investigation reveals the presence of 18 plant species at Sukamade Resort, Meru Betiri National Park (Table 3). Nine varieties of trees located along riverbanks provide shade over the water. Zulhariadi et al. (2022) indicated that dragonfly diversity correlates with alterations in land cover along the river. Moreover, escalating land cover alterations may result in numerous dragonfly species' extinction. Water bodies that offer diverse riparian habitats can sustain dragonflies. Dragonflies frequently utilize riparian areas for roosting. Cheri (2020) asserts that the structure of dragonfly communities is significantly connected with riparian-specific vegetation factors. Dragonflies exhibit sensitivity to riparian conditions in stream habitats within the Nearctic area. O'Malley et al. (2020) assert that the development of dragonfly populations is linked to aquatic and terrestrial influences. Diversity primarily pertains to terrestrial variables such as canopy cover and slope. Therefore, proposals for the National Park regarding river habitat management for dragonfly conservation should encompass the protection of riparian habitats while preserving aquatic habitats and their quality.

CONCLUSIONS

The researchers identified seventeen species of dragonflies. The dragonfly population exhibited variability across the four locations. The Shannon-Wiener diversity index (H') is defined as a medium, the Margalef index indicates low criteria, the dominance index falls within the low category, and evenness is high. Canonical correspondence analysis (CCA) indicated that five dragonfly species correlated with the air humidity parameter (Quadrant 1). The findings of our investigation demonstrate a correlation between the existence of dragonflies and vegetation in the forest. Consequently, the significance of the forest in Sukamade Resort of TNMB as a protection zone, particularly for dragonfly habitats, is paramount.

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ARTICLE

Butterflies (Lepidoptera: Rhopalocera) of Mahananda Wildlife Sanctuary, West Bengal, India: a preliminary checklist

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Abstract: The present study from Mahananda Wildlife Sanctuary records a total of 98 butterfly species among which 66 species are found as 'first-time records' from the sanctuary. Therein, eight butterfly species are scheduled under the Wild Life (Protection) Amendment Act, 2022 and two are enlisted in the IUCN species list (2016). Nymphalids were recorded at the highest frequency (45.92%) whereas Riodinids are rarest (2.04%).

Keywords: Darjeeling, lepidopteran-diversity, new species records, Nymphalidae, protected area, Riodinidae, Terai.

Bangla: পশ্চিমবঙ্গের হিমালয়-পাদদেশ অঞ্চলে অবস্থিত মহানন্দা অভয়ারণ্যে ২০২৪ সালের মার্চ থেকে সেপ্টেম্বর মাস পর্যন্ত একটি সমীক্ষা চালিয়ে ছয়টি পরিবারের অন্তর্গত ৯৮টি প্রজাতির প্রজাপতিকে নথিভুক্ত করা হয়েছে যার মধ্যে ৬৬টি প্রজাতির এই অভয়ারণ্যে প্রথম দেখা মিলেছে। এদের আটটি প্রজাপতি প্রজাতি 'বন্যপ্রাণ সংরক্ষণ সংশোধিত আইন' (২০২২) এবং দুটি 'আইইউসিএন-এর প্রজাতি তালিকাভুক্ত' (২০১৬)। প্রজাপতিগুলির মধ্যে নিম্ফ্যালিডি পরিবারের প্রজাতি সংখ্যাই সর্বাধিক (৪৫.৯২%) এবং রিওডিনিডি-র প্রজাতি সংখ্যা সর্বনিম্ন (২.০৪%)।

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INTRODUCTION

Butterflies (Lepidoptera: Rhopalocera) are 'day-flying lepidopterans', belonging to the world's second largest insect order under the Class Insecta (Wendimu et al. 2024). These widespread creatures are found almost in every ecological stratum and perform diverse ecological functions in nature. Butterflies act as bio-indicators for a healthy environment and pollinate many flowering plants, thus serving a wide range of ecological benefits (Sinha et al. 2019).

The northern sub-Himalayan part of West Bengal is extremely biodiverse; a handful of studies were reported on butterfly diversity, records, and its ecology from this region. Chakraborty et al. (2023) recorded a few butterfly species from Buxa Tiger Reserve (BTR). Only two studies have been conducted from the Neora Valley National Park (Roy et al. 2012; Sengupta et al. 2014). Pradhan & Khaling (2020) recorded butterfly diversity from an organic tea plantation garden of the Darjeeling hills, and a single work from the University of North Bengal campus have been reported (Saha et al. 2023) till date. Approximately, 256 species of butterflies have been recorded from Darjeeling district, of which the family Nymphalidae is the most diverse (114 species), followed by Lycaenidae (52 species), Pieridae (28 species), Hesperiidae (28 species), Papilionidae (27 species), and Riodinidae (7 species) (Roy et al. 2012; Sengupta et al. 2014; Pradhan & Khaling 2020; Saha et al. 2023).

Singhal & Chowdhury (1996) provided the first comprehensive record of biodiversity from Mahananda Wildlife Sanctuary (MWS), documenting 170 species of plants (39 trees, 55 herbs, 54 shrubs, and 22 climbers) and 329 species of animals (32 mammals, 253 birds, 9 reptiles, 6 amphibians, and 27 lepidopterans). No systematic study on butterfly diversity has been conducted in MWS to date. Only a baseline study on the flora and fauna of MWS is available (Singhal & Chowdhury 1996), conducted collaboratively by the Wildlife Wing, Forest Department, Government of West Bengal; the West Bengal Forest Development Corporation Ltd.; and the Nature, Environment & Wildlife Society (NEWS). In the survey report by Singhal & Chowdhury (1996), 27 species of butterflies were listed along with other wildlife taxa approximately 30 years ago, providing only rudimentary information on the butterfly fauna of MWS. There are several protected forests in India where butterfly diversity data was recorded because of its pivotal role as pollinators in all the habitats (Sengupta et al. 2014; Gogoi et al. 2023; Choudhury et al. 2024). Therefore, the present study was undertaken in MWS to generate an updated checklist of butterfly species, providing baseline information to facilitate future studies on their diversity, abundance, distribution, and conservation within this protected area.

MATERIALS AND METHODS

MWS along its four ranges, namely, Sukna or East, West, North, and South Range, is expanded over the foothills of central Himalaya and parts of Terai plains (26.798°–26.925° N, 88.393°–88.558° E) of West Bengal (Figure 1). It falls under one of the most species-rich regions in the Indian subcontinent. Hydrologically, the sanctuary is influenced by the Mahananda River system, with the Teesta River defining its eastern margin. The sanctuary encompasses an area of about 161 km², with elevations ranging approximately 150–1,300 m (MWS Management Plan 2012–2022). Most of the habitats of the sanctuary are hilly mountains with precipitous to moderate slopes. The sanctuary contains temperate to tropical climate which give rise evergreen tropical, sub-tropical and deciduous forest and even grasslands in its different parts. Along the two rivers, MWS has characteristic thin watercourses or streams generated from the Himalayan mountains and monsoon rains, innervating the whole sanctuary, are lifelines to its numerous bioresources and wildlife. The sanctuary is situated in the trans-boundary between highly biodiverse 'Doars' in the eastern side and Darjeeling Himalaya in its extreme northern side.

The perennial and non-perennial watercourses of MWS serve as lifelines to the wildlife that often visit the places for water and leave their droppings on the shores. The natural bleach and mineral salts are accumulated on the rocks and sandy shores from the algae. The forest soil also shows a variation of sandy loam, coarse sand or 'slit' type texture and color from light brown to dark brown, contains different grades of mineral salts and organic matters (MWS Management Plan 2012–2022). These attributes of several spots of Mahananda habitat attract the butterflies to puddle inside the sanctuary for the accumulation of salts, minerals, and amino acids, essential for their physiological and reproductive functions.

For this study, opportunistic surveys were carried out on sunny days from 0800 h to 1200 h, occasionally in the dawn for capturing specific butterflies, between March–September 2024, in the sanctuary. Due to permanent occupancy of mega-mammals, like elephants, butterflies were solely documented by direct sighting and random

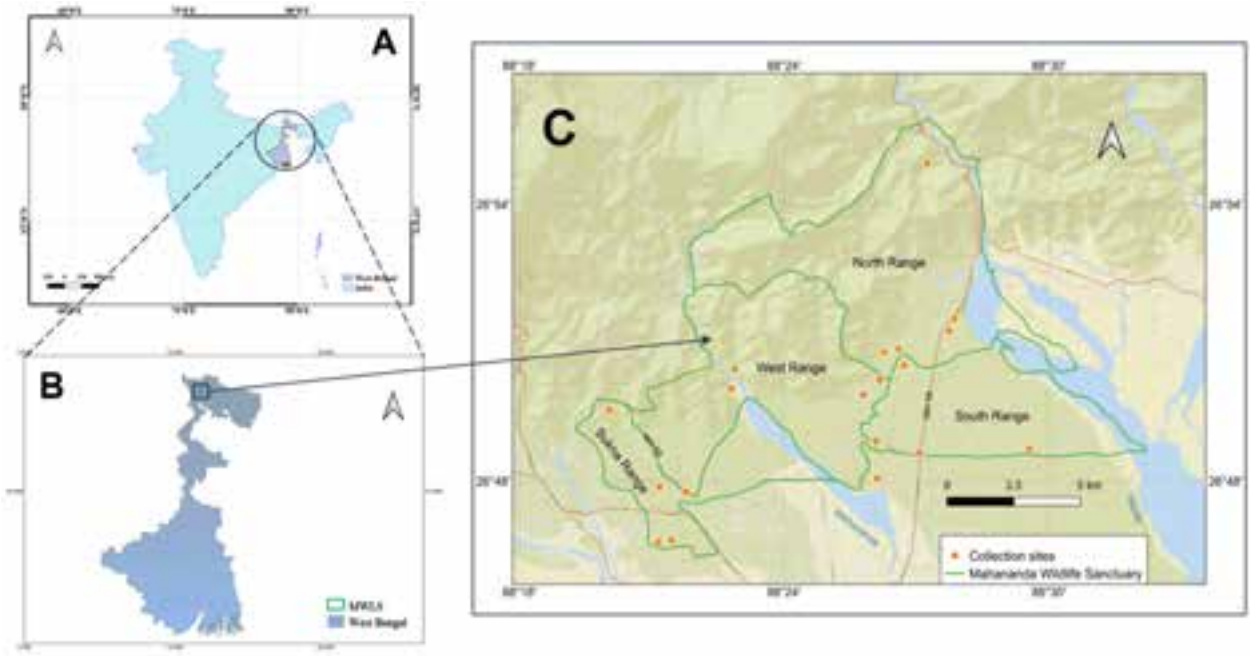

Figure 1. Study area map: A—West Bengal within India | B—Location of the study area within West Bengal | C—Mahananda Wildlife Sanctuary.

walks (Murugesan et al. 2013; Upadhyay et al. 2023) near the water courses, roadsides, range office compounds, plantation forests and sometimes in forest core areas (Image 6). Butterflies were photographed in their natural habitat using a digital camera (NIKON P-900), and common species were identified based on their body and wing color patterns, and designs on the spot. All species were later verified using published literature (Mukherjee & Mondal 2020), standard books (Evans 1932), field guide books (Smetacek 2017; Sinha et al. 2019), and from some relevant websites (https://www.ifoundbutterflies.org; https://www.inaturalist.org) (Kunte et al. 2026; iNaturalist 2026). All photo plates and data charts were prepared in the MS-PowerPoint 2019 and MS-Excel 2019, respectively.

RESULTS

In this study, a total of 98 butterfly species, representing 66 genera across all six extant families, were recorded from MWS. Among these, 86 species were photographed during the survey (Images 1–5). Detailed information on all 98 species is presented in Table 1.

The family-wise distribution of species in the sanctuary was as follows: Riodinidae–2 species (2.04%), Hesperiidae–8 species (8.16%), Papilionidae–9 species (9.18%), Pieridae–12 species (12.24%), Lycaenidae–22 species (22.45%), and Nymphalidae–45 species (45.92%) (Table 1, Figure 2). Four families, namely, Papilionidae, Pieridae, Lycaenidae, and Nymphalidae, were recorded in all four ranges of the sanctuary, whereas Hesperiidae was absent from the northern range. Riodinidae was recorded exclusively in the eastern (Sukna) range (Table 1; Figure 3). Among all families, Nymphalidae was the most species-rich and abundant, while Riodinidae was the least abundant, represented by only two species.

Butterfly species were observed within an altitudinal range of 161–576 m in MWS, with 91 out of the 98 species found occurring below 200 m, ranging from sub-tropical and tropical to moist forests (Table 1).

Of the 98 recorded species, eight are listed under the Wildlife (Protection) Amendment Act, 2022. Two species, Orchid Tit *Hypolycaena othona* and Grey Count *Tanaecia lepidea*, are included in Schedule I; five species, Danaid Eggfly *Hypolimnas misippus*, Long-banded Silverline *Spindasis lohita*, Great Evening Brown *Melanitis zitenius*, White-bar Bushbrown *Mycalesis anaxias*, and Blue Oakleaf Butterfly *Kallima horsfieldi*, are included in Schedule II; and a single species, Common Crow *Euploea core*, is included in Schedule IV (Table 1). Under the IUCN Red List (2016), two species—Common Imperial *Cheritra freja* and Plain Tiger *Danaus chrysippus*—are classified as 'Least Concern' (Table 1), whereas the remaining species have not been assessed.

Table 1. Checklist of butterflies recorded from Mahananda Wildlife Sanctuary (March–September, 2024).

Scientific name	Common name	Habitat type	Collection locality	Elevation (m)	Red List status	WPAA, 2022 status
Family 1. Riodinidae (2 species)						
Zemeros flegyas Cramer, 1780*	Punchinello	TPF; FROC	ER; ER	184; 197	NL	NM
Abisara bifasciata Moore, 1877*	Double-banded Judy	TPF	ER	181	NL	NM
Family 2. Hesperiidae (8 species)						
Seseria sambara Moore, 1866*	Notched Seseria	LHWMF	WR	177	NL	NM
Gerosis bhagava Moore, 1866*	Yellow-breasted Flat	FROC	ER	197	NL	NM
Pseudocoladenia dan Fabricius, 1787*	(Himalayan) Fulvous Pied Flat	FROC	ER	197	NL	NM
Sarangesa dasahara Moore, 1866*	Indian Common Small Flat	FROC	ER	197	-	-
Burara gomata Moore, 1866*	Pale Green Awlet	FROC	ER	197	NL	NM
Pelopidas agna Moore, 1865*	Bengal Obscure Branded Swift	FROC	SR	186	-	-
Oriens gola Moore, 1877*	Common Dartlet	FROC	ER	197	NL	NM
Iambrix salsala Moore, 1866*	Chestnut Bob	FROC	ER	197	NL	NM
Family 3. Papilionidae (9 species)						
Graphium agamemnon Linnaeus, 1758§	Tailed Jay	SPF -	SR; Golaghat, 1995	162	NL	NM
Graphium antiphates Cramer, 1775*	Five-bar Swordtail	LHWMF; FROC	WR; ER	177; 197	NL	NM
Graphium doson Felder, 1864*	Common Jay	LHWMF	WR	177	NL	NM
Graphium sarpedon Linnaeus, 1758§	Common Bluebottle	LHWMF; FROC -	WR; ER; Golaghat, 1995	177; 197; -	NL	NM
Papilio nephelus Boisduval, 1836*	Yellow Helen	LHWMF; FROC; LHDMF; LHDMF	WR; ER; NR; NR	177; 197; 235; 190	NL	NM
Papilio memnon Linnaeus, 1758*	Great Mormon	FROC LHDMF	ER; NR	197; 190	NL	NM
Papilio polytes Linnaeus, 1758§	Common Mormon	FROC; LHDMF; LHDMF; LHDMF; FROC; FROC; LHWMF	NR; NR; NR; NR; ER; SR; WR; Hatisar, 1995	195; 317; 228; 190; 197; 186; 177	NL	NM
Papilio demoleus Linnaeus, 1758¥	Lime butterfly	-	Andheri, 1995	-	NA	NM
Pachliopta aristolochiae Fabricius, 1775¥	Common Rose	-	Sukna, 1995	-	NL	NM
Family 4. Pieridae (12 species)						
Pieris canidia Linnaeus, 1768*	Asian Cabbage White	FROC; LHWMF	ER; WR	197;184	NL	NM
Leptosia nina Fabricius, 1793§	Psyche	FROC & roadside	ER; Jogijhora, 1995	197	NL	NM
Eurema blanda Boisduval, 1836*	Three-spot Grass Yellow	LHWMF; FROC & roadside	WR; ER	177; 197	NL	NM
Eurema hecabe Linnaeus, 1758§	Common Grass Yellow	LHWMF - -	WR; Golaghat, 1995; Hatisar, 1995	177; -	NL	NM
Catopsilia pomona Fabricius, 1775*	Lemon Emigrant	FROC	ER	197	NL	NM
Ixias pyrene Linnaeus, 1764§	Yellow Orange-tip	LHWMF -	WR; Banderjhola, 1995	177; -	NL	NM
Hebomoia glaucippe Linnaeus, 1758*	Great Orange-tip	LHWMF; WMF	WR; SR	184; 174	NL	NM
Cepora nerissa Fabricius, 1775*	Common Gull	LHWMF; Roadside	WR; ER	177; 197	NL	NM

Scientific name	Common name	Habitat type	Collection locality	Elevation (m)	Red List status	WPAA, 2022 status
Delias descombesi Boisduval, 1836§	Red-spot Jezebel	FV -	NR; Kokhlong, 1995	195; -	NL	NM
Appias lyncida Cramer, 1777§	Chocolate Albatross	LHWMF; Roadside; LHDMF -	WR; ER; NR; Chewa, 1995	177; 184; 228; -	NL	NM
Appias olferna Swinhoe, 1890*	Eastern Striped Albatross	Roadside; FROC; LHWMF	ER; ER; WR	184; 197; 177	NL	NM
Delias hyparete Linnaeus, 1758¥	Painted Jezebel	-	Kuhi, 1995	-	NL	NM
Family 5. Lycaenidae (22 species)						
Arhopala centauruns Fabricius, 1775*	Centaur Oakblue	FROC	ER	197	NL	NM
Arhopala sp.	Oakblue Butterfly	TPF	ER	184	NL	NM
Castalius rosimon Fabricius, 1775*	Common Pierrot	FROC	ER	197	NL	NM
Cheritra freja Fabricius, 1793*	Common Imperial	LHWMF; FROC	WR; ER	177; 197	**LC**	NM
Curetis sp.	Sunbeam	FROC	NR	195	NL	NM
Spalgis epius Westwood, 1851*	Apefly	FV	ER	576	NL	NM
Talicada nyseus Guerin, 1843*	Indian Red Pierrot	LHWMF; FROC	WR; ER	184; 197	NL	NM
Heliophorus epicles Godart, 1824*	Purple Sapphire	LHWMF	WR	184	NL	NM
Pseudozizeeria maha Kollar, 1844*	Pale Grass Blue	LHWMF; FROC	WR; ER	177; 197	NL	NM
Jamides alecto C. Felder, 1860*	Metallic Cerulean	LHWMF; FROC	WR; ER	177; 197	NL	NM
Jamides bochus Stoll, 1782*	Dark Cerulean	FROC	ER	197	NL	NM
Jamides celeno Cramer, 1775*	Common Cerulean	LHWMF; FROC -	WR; ER; WR	184; 197; 177	NL	NM
Catapaecilma major Druce, 1895*	(Himalayan) Common Tinsel	SPF	SR	161	NL	NM
Catochrysops strabo Fabricius, 1793*	Forget-me-not	FROC	ER	197	NL	NM
Hypolycaena erylus Godart, 1824*	Common Tit	Sal forest	SR	161	NL	NM
Hypolycaena othona Hewitson, 1865*	Orchid Tit	FROC	ER	197	NL	**Sch-I**
Spindasis sp.	Silverline	FROC	ER	197	-	-
Spindasis lohita Horsfield, 1829*	Long-banded Silverline	SPF	SR	161	NL	**Sch-II**
Prosotas nora C. Felder, 1860*	Common Lineblue	FROC	ER	197	NL	NM
Leptotes plinius Fabricius, 1793*	Zebra blue	FROC	ER	197	NL	NM
Chilades pandava Horsfield, 1829*	Plains Cupid	FROC	ER	197	NL	NM
Loxura atymnus Stoll, 1780*	Yamfly	FROC	ER	197	NL	NM
Family 6. Nymphalidae (45 species)						
Cirrochroa aoris Doubleday, 1847*	Large Yeoman	TPF; FROC; FROC	NR; SR; ER	186; 164; 197	NL	NM
Junonia iphita Cramer, 1779§	Chocolate Pansy	LHWMF; LHWMF; FROC -	WR; WR; ER; Latpanchor, 1995	184; 177; 197; -	NL	NM
Junonia hierta Fabricius, 1798*	Yellow Pansy	LHWMF	WR	184	NA	NM
Junonia lemonias Linnaeus, 1758*	Lemon Pansy	LHWMF	WR	177	NL	NM
Danaus genutia Cramer, 1779§	Striped Tiger	LHWMF; FROC; FROC	WR; ER; Rhyeum, 1995	184; 197; -	NL	NM
Danaus chrysippus Linnaeus, 1758§	Plain Tiger	LHWMF; FROC -	WR; ER; Golaghat, 1995	184; 197; -	**LC**	NM

Scientific name	Common name	Habitat type	Collection locality	Elevation (m)	Red List status	WPAA, 2022 status
Parantica aglea Stoll, 1782*	Glassy Tiger	LHWMF; WMF	WR; SR	177; 184	NL	NM
Tirumala septentrionis Butler, 1874*	Dark Blue Tiger	LHWMF	WR	184	NL	NM
Euploea sp.	Crow Butterfly	LHWMF; LHWMF; FROC	WR; WR; ER	184; 177;197	NL	NM
Euploea core Cramer, 1780[§]	Common Crow	FROC; WMF; Forest road -	ER; WR; SR; Sukna, 1995	197; 184; 164; -	NL	**Sch-IV**
Melanitis zitenius Herbst, 1796*	Great Evening Brown	LHWMF	WR	291	NL	**Sch- II**
Chersonesia risa Doubleday, 1848*	Common Maplet	LHWMF	WR	179	NL	NM
Kallima inachus Doyere, 1840*	Himalayan Orange Oakleaf	WMF	WR; SR	184; 174	NL	NM
Lethe confusa Aurivillius, 1898[§]	Banded Treebrown	FV; FV	ER; ER; Panchanai, 1995	184; 576; -	NL	NM
Mycalesis anaxias Hewitson, 1862*	White-bar Bushbrown	FROC	ER	197	NL	**Sch-II**
Mycalesis visala Moore, 1858*	Long-branded Bushbrown	WMF	ER	181	NL	NM
Orsotriaena medus Fabricius, 1775*	Oriental Medus Brown	FROC	ER	197	NL	NM
Mycalesis perseus Fabricius, 1775*	Common Bushbrown	FROC	ER; SR	197;162	NL	NM
Charaxes bharata C. & R. Felder, 186[7]§	Indian Nawab	FROC	ER; Golaghat, 1995	197; -	NL	NM
Tanaecia jahnu Moore, 1858*	Plain Earl	FROC	ER	197	NL	NM
*Tanaecia lepidea Butler, 1868**	Grey Count	FROC	ER	197	NL	**Sch-I**
Tanaecia julii Lesson, 1837*	Common Earl	FROC	ER	197	NL	NM
Euthalia aconthea Cramer, 1777*	Common Baron	FROC	ER	197	NL	NM
Neptis clinia susruta Moore, 1872*	Himalayan Sullied Sailer	FROC	ER	197	NL	NM
Athyma inara Westwood, 1850*	Color Sergeant	FROC	ER	197	NL	NM
Pantoporia hordonia Stoll, 1790*	Common Lascar	FROC	ER	197	NL	NM
Neptis miah miah Moore, 1858*	East Himalayan Small Yellow Sailer	FROC	ER	197	NL	NM
Athyma perius perius Linnaeus, 1758*	Oriental Common Sergeant	FROC	ER	197	NL	NM
Lasippa viraja Moore, 1872*	Yellowjack Sailer	FROC	ER	197	NL	NM
Neptis sp.	Sailer	LHWMF	WR	177	-	NM
Lebadea martha Fabricius, 1787*	Knight	FROC	ER	197	NL	NM
Phalanta phalantha Drury, 1773[§]	Common Leopard	LHDMF; LHWMF; -	NR; WR; Sukna, 1995	228; 184; -	NL	NM
Charaxes psaphon imna Westwood, 1847*	Indian Plain Tawny Rajah	FROC	ER	197	NL	NM
Hypolimnas bolina Linnaeus, 1758*	Great Eggfly	FROC	ER	197	NL	NM
Elymnias hypermnestra undularis Drury, 1773*	Himalayan Palmfly	FROC	ER	197	NL	NM
Ypthima baldus Fabricius, 1775[§]	Common Five-ring	FROC; SPF	ER; Panchanai, 1995	197; -	NL	NM
Ypthima huebneri Kirby, 187[1]§	Common Four-ring	FROC; LHDMF	ER; Upper Ghoramara, 1995	197; -	NL	NM
Aglais caschmirensis Kollar, 18[4]4§	Indian Tortoiseshell	FROC	ER Sukna 1995a,b	197; -	NL	NM
Symbrenthia lilaea Hewitson, 1864*	Northern Common Jester	FROC	ER	197	NL	NM
Charaxes bernardus Fabricius, 17[9]3¥	Tawny Rajah	-	Hatisar, 1995	-	NL	NM
Cyrestis thyodamas Doyere, 1840[¥]	Map Butterfly	-	Jogijhora, 1995	-	NL	NM
Hypolimnas misippus Linnaeus, 1764[¥]	Danaid Eggfly	-	Golma, 1995	-	NA	**Sch-II**

Scientific name	Common name	Habitat type	Collection locality	Elevation (m)	Red List status	WPAA, 2022 status
Tirumala limniace Cramer, 177[5]¥	Blue Tiger Butterfly	-	Sukna, 1995	-	NL	NM
Neptis hylas Linnaeus, 175[6]¥	Common Sailer	-	Golaghat, 1995	-	NL	NM
Kallima horsfieldi Kollar, 184[4]¥	Blue Oakleaf Butterfly	-	Latpanchor, 1995	-	NA	**Sch-II**

ER—East range | FROC—Forest range office compound | LC—Least Concern | LHDMF—Lower hill dry mixed forest | LHWMF—Lower hill wet mixed forests | NA—Not applicable | NL—Not listed | NM—Not mentioned | NR—North range | Sch—Schedule | SPF—Sal Plantation forest | SR—South range | TPF—Teak Plantation Forest | WMF—Wet mixed forest | WPAA—Wildlife (Protection) Amendment Act, 2022 | WR—West range.
*Species identified in this study represent new records.
§Species found in both the previous records and this study;
¥Species found in the previous records but not in this study

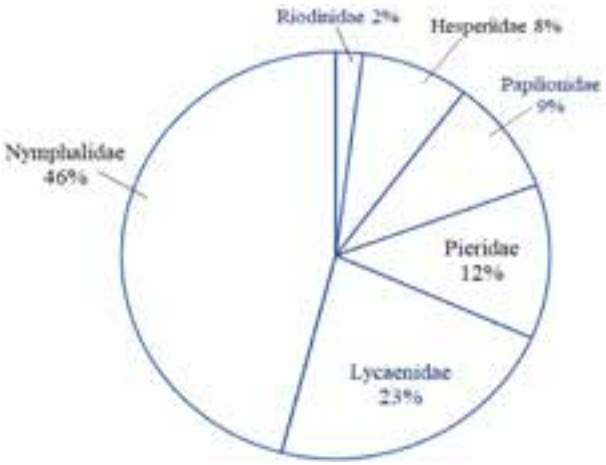

Figure 2. Percentage composition of six butterfly families from Mahananda Wildlife Sanctuary.

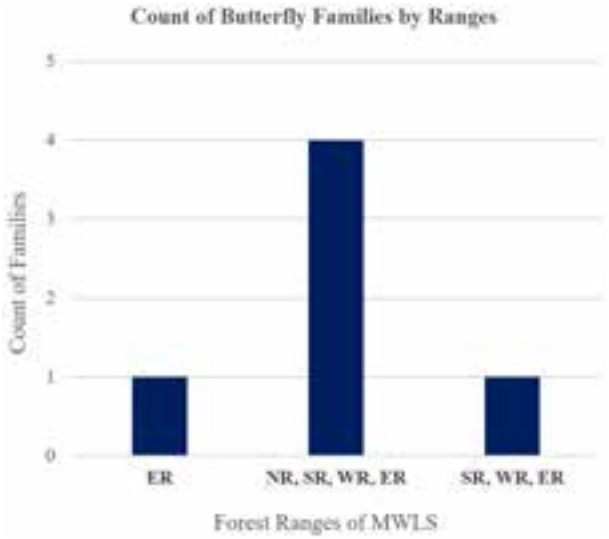

Figure 3. Presence-absence data of the six butterfly families across the ranges of Mahananda Wildlife Sanctuary: ER—East range | NR—North range | SR—South range | WR—West range.

DISCUSSION AND CONCLUSION

Out of 98 species, 18 were found both this study and in the record of Singhal & Chowdhury (1996). Whereas, nine other species of previous record were absent during this study. Amongst 66 species were first-time recorded from the sanctuary in this study: Nymphalidae–27 species—*Cirrochroa aoris*, *Junonia hierta*, *Junonia lemonias*, *Parantica aglea*, *Tirumala septentrionis*, *Melanitis zitenius*, *Chersonesia risa*, *Kallima inachus*, *Mycalesis anaxias*, *Mycalesis visala*, *Orsotriaena medus*, *Mycalesis perseus*, *Tanaecia jahnu*, *Tanaecia lepidea*, *Tanaecia julii*, *Euthalia aconthea*, *Neptis clinia susruta*, *Athyma inara*, *Pantoporia hordonia*, *Neptis miah miah*, *Athyma perius perius*, *Lasippa viraja*, *Lebadea martha*, *Charaxes psaphon imna*, *Hypolimnas bolina*, *Elymnias hypermnestra undularis*, *Symbrenthia lilaea*; Lycaenidae–19 species—*Arhopala centaurus*, *Castalius rosimon*, *Cheritra freja*, *Spalgis epius*, *Talicada nyseus*, *Heliophorus epicles*, *Pseudozizeeria maha*, *Jamides alecto*, *Jamides bochus*, *Jamides celeno*, *Catapaecilma major*, *Catochrysops strabo*, *Hypolycaena erylus*, *Hypolycaena othona*, *Spindasis lohita*, *Prosotas nora*, *Leptotes plinius*, *Chilades pandava*, and *Loxura atymnus*; Hesperiidae–eight species—*Seseria sambara, Gerosis bhagava, Pseudocoladenia dan, Sarangesa dasahara, Burara gomata, Pelopidas agna, Oriens gola, Iambrix salsala*; Pieridae–six species—*Pieris canidia*, *Eurema blanda*, *Catopsilia pomona*, *Hebomoia glaucippe*, *Cepora nerissa*, and *Appias olferna*; Papilionidae–four species—*Graphium antiphates, Graphium doson, Papilio nephelus*, and *Papilio memnon*; and Riodinidae–two species—*Zemeros flegyas* and *Abisara bifasciata*. Records of the majority butterfly species (91 species) within a 162–200 m range of MWS is corroborated with Priya (2024).

In India, about 500 Nymphalid species are found, among which 45 species are now found from MWS.

Image 1. Family Riodinidae (1–2); Hesperiidae (3–10); Papilionidae (11–17); Pieridae (18–20). © Ratnadeep Sarkar & Priyanka Rai.

Image 2. Family Pieridae (21–27) & Lycaenidae (28–39). © Ratnadeep Sarkar & Priyanka Rai.

Image 3. Family Lycaenidae (40–48) Nymphalidae (49–59). © Ratnadeep Sarkar & Priyanka Rai.

Image 4. Family Nymphalidae (60–78). © Ratnadeep Sarkar & Priyanka Rai.

Image 5. Family Nymphalidae (79–86). © Ratnadeep Sarkar & Priyanka Rai.

As other studies from the region (Roy et al. 2012; Sengupta et al. 2014; Pradhan & Khaling 2020; Saha et al. 2023), here only the highest number of species is from Nymphalidae and the lowest number from Riodinidae. Their dominance in MWS may be due to its habitat preferences and larval host as well as nectar plants among the vast floral diversity in the foothills of the Himalaya (Sengupta et al. 2014; Pradhan & Khaling 2020). With 98 butterfly species, several of protected under WPA, 1972 and the IUCN species list (2016), the MWS can be considered an important reserve of butterflies in the transition zone between the peninsular Indian sub-region and Indo-Malayan sub-region of the Oriental region.

With 98 species, although this work is the first of its kind in the record of butterflies, not only from MWS but also from any protected forests of the Darjeeling District, this study demands systematic, long-term investigation for the record of more butterfly species as well as a survey on its nectar and host plants and precise efforts for the introduction of conservation and management practices for the butterfly fauna in MWS.

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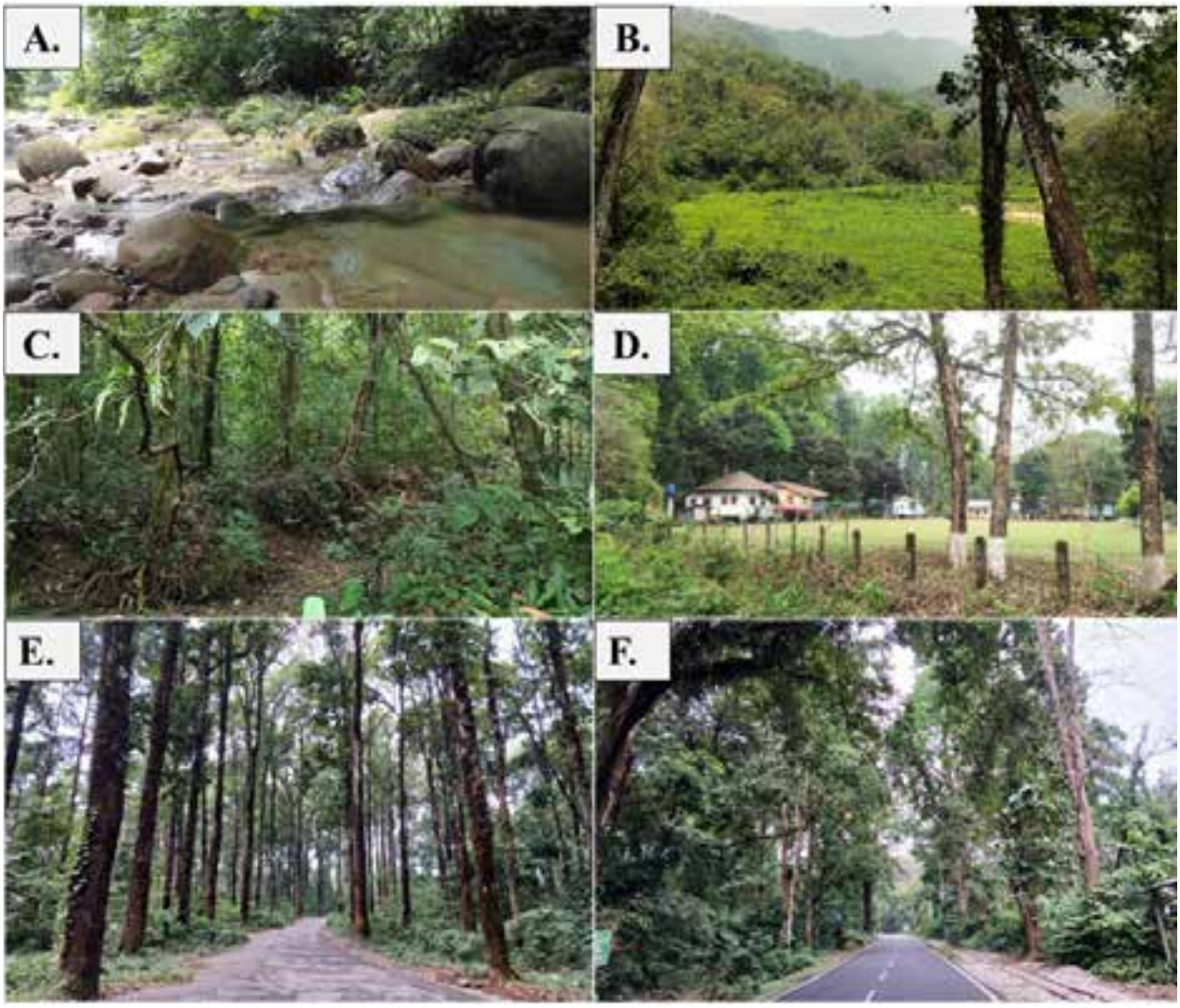

Image 6. Study sites: A—Watercourses inside the sanctuary | B—Lower hill dry mixed forest | C—Lower hill wet mixed forest | D—Forest range office compound | E—Sal Plantation forest | F—Hill cart road innervating the sanctuary. © Ratnadeep Sarkar.

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OPEN ACCESS

COMMUNICATION

A preliminary study to investigate behavioural differences among elephants residing near the Buttala-Kataragama and Habarana roads in Sri Lanka, where they are regularly fed by passing motorists

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Abstract: This study examined the behavior of wild Sri Lankan Elephants *Elephas maximus* living in districts near Buttala-Katragama road (B035) and Habarana road (A11). Elephants at B035 were observed to be more attracted to food given by motorists than those at A11, who were more interested in feeding on surrounding vegetation, strolling, and crossing the road. Motorists travelling the B035 route were also observed to be more likely to feed elephants than those travelling the A11 route, despite the latter having the most traffic.

Keywords: Asian Elephants, behavioural plasticity, conservation, Elephant cognition, Elephants' food solicitation, ethology, road ecology, Sri Lanka, wildlife-human negative interaction.

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INTRODUCTION

Wild elephants showing an interest in food given by humans is not new (Muthukumarana 2017). In Sri Lanka, places have been identified where some elephants could be said to be "addicted" to getting food directly from people travelling through the area. These places include Somawathiya, Sithulpawwa, Udawalawe, Buttala-Katragama road, Habarana road, and Kebaliththa in Yala Block IV. Of these, the Buttala-Katragama road (B035) and Habarana road (A11) are significant since both cut through protected forest patches. The Buttala-Katragama road goes through Yala National Park-Blocks III, IV, and V, the latter connecting with Lunugamwehera National Park, which connects with Vetahirakanda Nature Reserve and thereby Udawalawe National Park. The Habarana road runs adjacent to Minneriya National Park and a jungle corridor that connects to Kaudulla National Park (Image 1).

On either side of these two roads, sign boards have been erected informing travelers of the presence of elephants and advising not to feed them. Both roads are heavily used by motorists, and incidents have been reported when vehicles have collided with elephants, and when elephants are said to have attacked motorists. In Buttala-Katragama road, elephants have been reported to take food by force by blocking the road and using their trunks to grab food from inside vehicles. This act may damage the vehicle but the animals do not seem to intentionally attack the passengers.

Study objective

To identify which population of elephants is more "addicted" to human-provided snacks. Features of "snack addicts" include:

1. They linger near or on the road for long periods of time, extending to several hours.

2. They show little interest in feeding on nearby vegetation.

3. They show considerable interest in passing vehicles, with responses including approaching them and lifting their trunk next to windows to accept food.

There were previous reports that elephants on Buttala-Kattaragama (BK) road are more interested in buses than other vehicles, since they are more confident in getting food from riders therein. Thus, one aim of this study was to examine this aspect. Another goal was to check whether musth periods were associated with aggressive responses to motorists.

Evaluation

Records come from the years 2013–2019, during which a survey recorded 203 elephant encounters on BK Road, and 145 in Habarana. When an elephant or a group of elephants was sighted, their behaviour was assessed against the ethogram and related criteria, and the relevant data were documented. Each sighting was classified as a "case," with observation duration varying according to the elephants' proximity and visibility. The mean observation time per case was 97.5 ± 82.5 minutes on BK and 70 ± 60 minutes (113 days) on Habarana (109 days). Twenty-seven behavioural criteria were checked for both the populations (Table 1 & 2), and observations also indicated more traffic on Habarana road relative to BK road. Recent observations seem to indicate a similar behaviour pattern.

Additionally, traffic was monitored for 20 days on both the BK and Habarana roads. Specifically, the number of vehicles passing per minute was recorded. The mean traffic values were then calculated separately for each road (Tables 1 and 2).

Buttala-Katragama elephants' analytical data

From the behaviour criteria, the behaviour that was observed the most was "Staying on the middle of road for long times". In all the other sightings, except in one herd, elephants had an interest in staying on the road. But herds seem to prefer staying off the road compared to the individual males. This also clarifies that most of the "addicts" were males. It is also remarkable that bachelor herds were absent, and male elephants that were within a range of 55 m were not cooperative with each other for a long time.

In the few herds observed, the number of individuals ranged from 2–5 individuals. Per herd there were at least one each of the following: infant, juvenile, and sub-adult. The adult number ranged from 1–2 individuals. These were basically small herds and since the research was based upon sightings, sometimes the same herd might get counted on different occasions.

Out of the elephants that exhibited aggression towards motorists, only one of them was in musth condition. None of the members in any herd showed any signs of aggression.

The types of vehicles that gave food were (in descending order): van n = 80, three-wheeler n = 56, car n = 54, bus n = 51, truck or lorry n = 33, SUV n = 25, motorcycle n = 9, cab n = 8 and tractor n = 1. However, it was remarkable to notice that out of the four incidents of force grabbing, three were from buses, while only one was from a three-wheeler. It should be mentioned

Table 1. Behavioural criteria noted at Buttala-Katragama.

Cases / Incidents	n
Shows any nervous feelings towards vehicles (tries to flee away from the motorists)	10
Any signs of aggression towards vehicles (try to mock attack the motorists)	9
Interested in feeding on surrounding vegetation	16
Staying in the middle of the road for long times	174
Shows any aggression towards any other male elephants	3
Herds (Adult-female/may have a juvenile or infant male)	6
Adult male	197
Juvenile (male)	1
Sub-adult (male)	48
Number of elephants exhibiting temporal gland secretion	9
People getting out of the vehicle (to give food/watch or photograph)	25
Engagement of nearby resources such as water	1
Elephants staying at side of the road but people are feeding them	3
Elephants taking food by force	4
Number of times when another elephant was present within a radius of approximately 55 m	12
Interested in strolling along the road	6
Number of times when herds were detected to beg for food from the motorists	5
Total number of vehicles that gave food to elephants	115
Average number of vehicles passed an elephant per 1 min	2.56338

that those buses were filled with passengers going on a pilgrimage. The three-wheeler incident happened to a foreigner who had rented a three-wheeler and was passing by that road.

Habarana elephants' analytical data

From the behaviour criteria, the behaviour that were observed the most were "Interested in Strolling Along the Road", "Interested in Feeding on Surrounding Vegetation", and "Crossing the Road and Entering Forest (without strolling)".

All the elephants that were interested in strolling along the road were male elephants. In this behaviour, they may stroll along the road and enter to the side of the forest. Sometimes they strolled more than 1 km in distance.

Out of the 26 herds that were encountered during the course of the study, about 22 herds were interested in feeding on the surrounding vegetation. This vegetation is the flora present at road side, basically 15 m away from the road. About 17 herds crossed the road without strolling. The remaining nine herds may have crossed before the encounter. There were two bachelor herds that quickly crossed the road.

The number of herd members ranged 3–70 individuals per herd, including multiple herds getting together to form a kinship herd. Usually in a herd, there would be less than 15 individuals, so having a greater number than that means these are likely kinship herds (Prasad 2004). Per herd the infant number ranged from 1–15 individuals, while juveniles ranged 1–26, sub-adults 1–17, and adults 1–12. There was one kinship herd with two adult males.

Out of the elephants that exhibited aggression towards motorists, not a single musth elephant belonged to that criterion. About four herds did exhibit aggression towards the motorists.

The types of vehicles that gave food were (in descending order): car n = 3 and bus n = 1.

DISCUSSION

The bulk of begging elephants' diet is not the food they get from humans along the road. Those foods are morsels that they have a special interest in. The foods that were given consists of fruits, vegetables, baked goods and sweetmeats. This preliminary study shows that the elephants at the BK are the most "addicted" ones when compared with the Habarana population. This fact is clearly proven since the majority of elephants at BK were interested in standing on the road pathway for a long period of time. Unlike the Habarana elephants, the elephants at BK did not show much interest in strolling along the road, feeding on surrounding vegetation, or even crossing the road without strolling. The motorists travelling through the BK road were the ones that were more interested in giving food to elephants when compared with Habarana.

In BK, the motorists from vans, three wheelers, cars, buses, and truck or lorry were the ones that fed elephants. Though it was known by some that elephants at BK showed a special interest in buses rather than other vehicles, yet motorists from vans, three wheelers, and cars gave more food to the elephants. Despite that, it is concerning that forced grabbing of food was mostly on buses. A probable hypothesis could be that since all the buses subjected to force grabbing are pilgrimage buses, those buses are usually filled with lots of snacks. Due to the fact that elephants possess a remarkably strong olfactory sense, they may be able to detect it (Bates et al. 2007; Plotnik et al. 2019). That could trigger them to grab the food. If not, perhaps it could be due to elephants' high cognition capabilities; they might have

learnt that they get more food from buses, so targeting buses would be more beneficial and promising.

There wasn't much relationship between aggression and the musth period of the elephants. In BK even the small rate of aggression shown from one elephant towards another elephant was mainly because of dominance while getting snacks from the motorists. From the rate of aggression shown to motorists, about five of the motorists behaved in a risky manner near the presence of the elephants. This means either the passengers got out from the vehicle or the vehicle drove closely to the elephant. In one case a motorist provoked the elephants to exhibit aggressive signs. In that particular incident, the elephant was standing at the roadside feeding on vegetation when a vehicle approached. The occupants lowered the window and began shouting at the animal. In response, the elephant performed a mock charge as a defensive reaction. It did not damage the vehicle or injure any passengers. Nevertheless, such reckless human behaviour could easily have resulted in a tragic outcome.

In BK there were nearly 20 individual male elephants that followed the habit of begging. Some are frequently engaged in this behaviour while others only do it occasionally. From the earliest times until today there is one bull elephant in his prime with a broken tail that is more frequently seen begging for food. This elephant, named "Buttala Raja", is more placid towards the motorists, but sometimes exhibits aggression towards

Table 2. Behavioural criteria noted at Habarana.

Cases / Incidents	n
Shows any nervous feelings towards vehicles (tries to flee away from the motorists)	1
Any signs of aggression towards vehicles (try to mock attack the motorists)	10
Interested in feeding on surrounding vegetation	73
Staying in the middle of the road for long times	2
Herds (adult females /may have a juvenile or infant male/with kinship herds)	26
Adult male	133
Sub-adult (male)	11
Number of elephants exhibiting temporal gland secretion	8
People getting out of the vehicle (to give food/watch or photograph)	12
Engagement of nearby resources such as water	5
Elephants staying at side of the road but people are feeding them	2
Number of times when another elephant was present within a radius of approximately 55 m	4
Interested in strolling along the road	93
Kinship herds	2
Quickly crossing the road & entering forest (without strolling)	27
Locals feeding elephants	1
Males testing strength in the middle of the road	1
Bachelor herd	4
Bachelor herd (only two together)	3
Standing behind an electric fence or high slope	7
Total number of vehicles that gave food to elephants	4
Average number of vehicles passed an elephant per 1 min	10.333

Image 1. A bull elephant crossing the road in Habarana. © Tharindu Muthukumarana.

other male elephants over food given by motorists. In Yala NP there is a young elephant named "Gemunu" that has a habit of forcibly stopping safari vehicles and getting food from them for consumption. But generally, "Buttala Raja" did not exhibit such behaviour. During the curfew time due to the Covid-19 pandemic, "Buttala Raja" was not seen on the road as much but was frequently spotted at the Wildlife office near the Galge entrance. This was mainly due to the deserted road. In the same time period elephants did cross the Habarana road as usual. Yet almost every minute a vehicle passed. This situation indicates that the Habarana road carries heavier traffic than the BK road, which may partly explain the higher mortality from elephant–vehicle collisions reported in Habarana compared to BK. Although elephants along BK display stronger food-soliciting behaviour and often remain in the middle of the road for prolonged periods, the Habarana population is at greater risk of being struck by vehicles due to the higher traffic volume (Department of Wildlife Conservation 2018).

Some motorists that travel on the BK road take some food with the aim of giving it to an elephant. A main reason for this to happen is that certain people believe that if food is not given to the elephants, they may not let the motorists pass. In Yala Block IV there is a religious site with a tamarind tree called Kebiliththa Devalya. In here a lot of offerings are made to the Kataragama God. Because of these activities a wild male elephant named "Madhu" comes to this site frequently with the aim of getting fed by the pilgrims.

CONCLUSION

In Habarana, more than a decade ago there was a young male elephant that was "addicted" to food given by the motorists. Just like the BK elephants, this elephant would stay on the road and approach motorists with the aim of getting food from them. This elephant was frequently seen near a road-side shop. Motorists even used to stop near this shop and buy foods for this elephant. Later this elephant was translocated to another place by the wildlife officers. Relative to this study, this incident leaves us with the question that "if this young elephant wasn't translocated, would there have been more young male elephants that would have followed the begging pattern of the initial elephant?"

Because of a high frequency of traffic and of a higher accident mortality due to vehicle-elephant collisions in Habarana, it would be better to have a strategy to mitigate this issue. Solutions such as building flyovers can be time consuming, and science should be utilized in the building process. As a short-term strategy, ground surveillance to monitor the traffic, something similar to what is done on Kaziranga's National Highway 37 in India, might have some positive feedback at least for the time being. In more extreme cases speed bumps could be considered.

Since this research shows that some buses that carry pilgrims are vulnerable to force grabbing, it would be better if the respective authorities promoted an alternative route for reaching their destination. This type of action could ease the friction between elephants on the road and the motorists. Moreover, this is a preliminary study, and further research is needed to obtain more details about those elephants.

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COMMUNICATION

Impact analysis of SMS-triggered elephant activity alert lights

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Abstract: Human-elephant negative interactions typically arise when elephants enter human settlements in search of food, water, migratory routes, or other resources. Each year, accidental encounters with elephants in areas near reserve forests result in the deaths of hundreds of people. To address this challenge, the Bannerghatta National Park Forest Department has implemented a solution based on a straightforward conflict management approach, utilizing an SMS-based light and sound alert system to notify locals of elephant activity. To help reduce the risk of such encounters, 40 SMS-triggered elephant activity alert lights have been strategically placed across four ranges. We have partnered as the technology provider for this initiative. This paper presents an overview of the system's hardware architecture, the site selection process, the implementation strategy, and an evaluation of its technical performance and effectiveness over an eight-month period. This large-scale implementation of an elephant alert system offers valuable insights into potential usage in other conflict-prone areas.

Keywords: Accidental encounters, Bannerghatta National Park, forest department, human-elephant negative interactions, implementation strategy, socio-economic issue, sound alert system.

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Author contribution: SD: Conceptualisation, methodology, resources, supervision, project administration, writing – original draft. SCSR: Investigation, data curation, field deployment, performance analysis. SA: Methodology, investigation, system development and implementation. SKR: Validation, formal analysis, writing – review & editing, correspondence.

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INTRODUCTION

Human-elephant negative interaction is a significant socio-economic issue in many parts of the country, particularly near reserve forest areas (Shameer et al. 2024; Natarajan et al. 2025), where ongoing habitat degradation has led to increasing elephant intrusion into settlements in search of food, water, and other necessities. Large-scale degradation of forests and the expansion of human settlements into traditional elephant corridors have intensified these interactions (Wilson et al. 2015; Majumder 2022). Elephant intrusions often lead to property damage and injuries/fatalities of humans (Talukdar et al. 2024) and elephants alike. Providing early alerts of potential elephant activity could help to prevent such incidents and reduce the risks to both humans and elephants (Borah et al. 2020; Ramkumar & Deb 2021; Deb et al. 2025). In most cases, information concerning elephants leaving the forest comes from forest guards, watchers, local residents, and other spotters, many of whom have field experience in predicting elephantmovements (Ramkumar & Deb 2022). The challengeis to effectively communicate this information to the those in the local community who may be at risk of encountering elephants (Borah et al. 2020). In this context, the SMS-triggered elephant alert lights offer a highly effective approach to warn of local elephant activity and prevent potential conflicts.

Recognizing the need for such a system, the Bannerghatta National Park Forest Department has launched a project to install elephant activity alert lights (EAAL) at sensitive locations across four ranges of the park to improve human-elephant interaction management. As the technology partner, we have provided the design, installation, and maintenance support for 40 such system units. These EAAL units feature a PCB controller unit, GSM modem, battery, solar panel, light, buzzer, and other components. In collaboration with the forest department, 40 suitable locations were identified, and units were installed on 6 m (20 ft) iron poles for long-range visibility. The installation was completed in March 2024, and all of the units are now operational. This manuscript provides an overview of the project to date.

Design Architecture and Steps

The EAAL system hardware architecture comprises four primary subsystems: a controller unit, a light & buzzer unit, a power supply unit, and a communication module as shown in Figure. 1. The controller unit is equipped with a microcontroller that stores the program and integrates two relay switch modules to operate the light & buzzer unit. The system is programmed to activate the light & buzzer unit for varying durations upon receiving specific coded SMS messages, enabling short (10 min), medium (60 min), and long-duration (6 h) alerts as needed. The system also provides a stop code which needs to be communicated with the system to interrupt and stop the alert instantaneously. The light & buzzer unit consists of a 12 V waterproof module with two bright red lights and a compact 90 dB buzzer. The power supply unit features six 3 V rechargeable batteries in a parallel-series configuration, charged by a 12 V, 5-watt solar panel, ensuring a stable 12 V output and uninterrupted operation for 18–24 hours on a single charge. The communication module includes a GEM modem with a SIM slot, facilitating connectivity with the controller unit. The controller unit PCB is uniquely designed, while the system program has been developed based on inputs from key project stakeholders, including forest department staff and local residents, to align with the project's specific requirements. Figure 2 shows different steps of EAAL hardware system design.

Implementation Strategy

The EAAL system is designed to alert local residents about elephant movements, allowing them to take timely safety measures. To maximize its effectiveness, the system units are installed in or near human settlements at the forest boundary, preferably on elevated ground along frequently used paths. During field surveys, appropriate installation sites are chosen, often at village entrances or exits in high-conflict zones. The site selection process considers input from local villagers and forest officials. During installation, the system's functionality is thoroughly explained and demonstrated to the community. The system is triggered when a specific SMS code is received from any sender. As such, the contact number for the system and the activation code are shared with the designated forest guard and a few authorized local individuals. Each designated range is equipped with 10 system units. To ensure quick and direct communication regarding system-related issues, four WhatsApp groups, specific to each range, have been established, involving rangers, forest guards, and local community members. Pictures of system installation in collaboration with the forest department team and local residents are given in the Figure 3.

System Performance & Result Analysis

The performance of the EAAL system is significantly impacted by the strength of the mobile network and the positioning of the units for optimal long-range visibility.

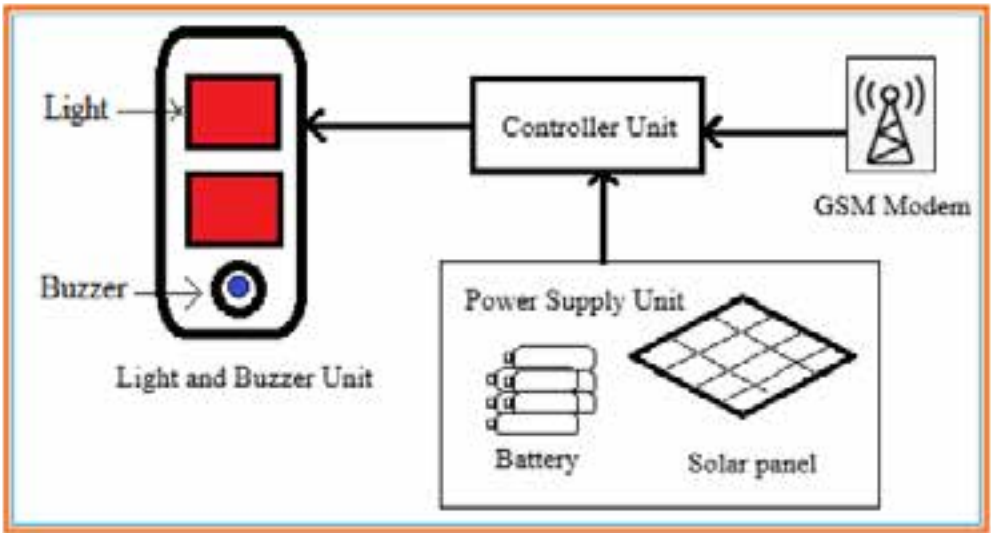


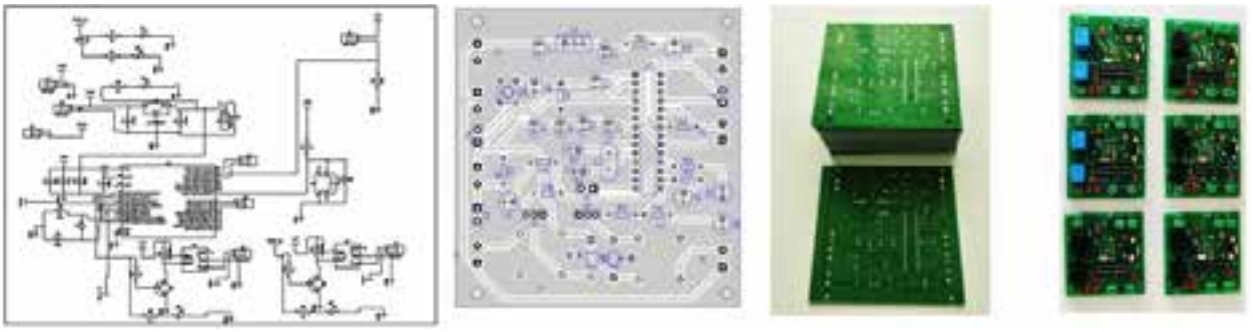
Figure 1. The architecture of the EAAL system.

Table 1. Range-wise numbers of unit with respect to network strength and suitable location.

	Range	Numbers of unit w.r.t network strength			Numbers of units w.r.t suitable location		
		Low network	Moderate network	Standard network	Village entry/ exit	Village inside	High-land/ open area
1.	Harohalli	3	5	2	4	3	3
2.	Bannerghatta	1	3	6	2	7	1
3.	Kodahalli	7	2	1	2	2	6
4.	Anekal	5	3	2	3	2	5

While some sites are strategically located for visibility from human settlements and elephant intrusion paths, they may suffer from weak mobile network coverage. Based on the current analysis, the network strength parameter is categorized according to call connectivity percentage: call connectivity of 80% or above is considered a strong network, 50–80 % connectivity is classified as a moderate network, and connectivity below 50% is regarded as a weak network. Therefore, choosing the best installation site requires balancing location suitability with network strength, necessitating careful optimization. To understand how this factor influences system performance, an evaluation of each unit's location in relation to mobile network strength has been conducted for all installed units, as shown in Table 1. The table indicates that the Bannerghatta Range, being near a major city, benefits from excellent mobile network coverage, with only one unit located in a low-network area. In contrast, Kodahalli, located at the interstate border, faces poorer network performance, with seven units in low-network zones. Harohalli and Anekal rank second and third, respectively, in terms of network weakness. However, system locations on elevated or open terrain offer superior long-range visibility and stronger mobile network connections, making them ideal for such light-based alert systems. Although Kodahalli has weak network coverage, its remote and sparsely populated nature makes it suitable for more system installations. On the other hand, Bannerghatta, which is densely populated, has most of its system units within the village itself. The other two ranges, Harohalli and Anekal, present intermediate conditions for system installation suitability.

As a real-time system, response time is crucial in determining performance, along with the number of failed triggering. Thanks to a strong mobile network, the Bannerghatta system units have an average response time delay of seven seconds, with three failed triggering, as shown in Figure 4. In contrast, the Kodahalli units, impacted by slow mobile connectivity, experience a higher average response time delay of 20 seconds, with seven failed triggering per unit. The other two ranges,



Schematic of the circuit | PCB layout | Fabricated PCBs | Finished circuit

Assembling light sound units | A working EAAL circuit unit | A glowing EAAL

Figure 2. Different design steps of EAAL from scratch to the entire module.

Table 2. Range-wise system performance analysis.

	Range	Number of system trigger	Number of units out of range in days			Number of units suffered malfunction	
			+50	+100	+150	Count	Cause of malfunction
1.	Harohalli	10+	2	3	0	3	Circuit damaged (1 no) ant nests (1 no), water infiltration (1 no).
2.	Bannerghatta	30+	2	0	0	1	Light damaged due to water (1 no).
3.	Kodahalli	5+	1	4	6	4	Circuit damaged (2 no), a tree branch fell (1 no), and the pole was knocked down by strong winds (1 no).
4.	Anekal	7+	2	4	4	2	Circuit damaged (1 no), water infiltration (1 no).

Harohalli and Anekal, exhibit intermediate performance, with Harohalli ranking second and Anekal in third place.

Over the eight-month period of April–December 2024, the system's performance was analyzed based on the number of systems triggering via SMS, the number of units experiencing network failures, and the number of malfunctions, as presented in Table 2. Due to the quality of the network, the Bannerghatta system units were triggered more frequently, as shown in the table, compared to the other ranges. The data on triggerings, failed attempts, and units going out of network, was collected from forest officials assigned to each unit and updated on an ongoing basis through a WhatsApp group. Less than 20% of the system units malfunctioned during this phase, and these issues were primarily due to weather conditions and other factors, rather than circuit failures.

Although there are only four circuit failures, these circuits have been thoroughly investigated, and it has been determined that the 5 V relay switch is causing momentary high power consumption from the 5 V regulator during switching, leading to regulator damage due to overheating. As a result, the next generation of the EAAL system will be designed with a 12 V relay, powered directly from the battery, bypassing the regulator. To address the mobile network failure issue, the simplest solution is to restart the system to restore the network connection. Therefore, in the first phase of system maintenance, the units will be equipped with external hanging switches for easy restarts, which has significantly reduced the occurrence of systems going out of network.

During the installation and maintenance phases of the system, a survey was conducted to evaluate its impact on the local community, asking the simple question: "Do you think this system is useful and will have an impact?"

Bannerghatta Range Harohalli Range Anekal Range Kodahalli Range

Figure 3. Installation of forty EAAL across all four ranges of Bannerghatta NP.

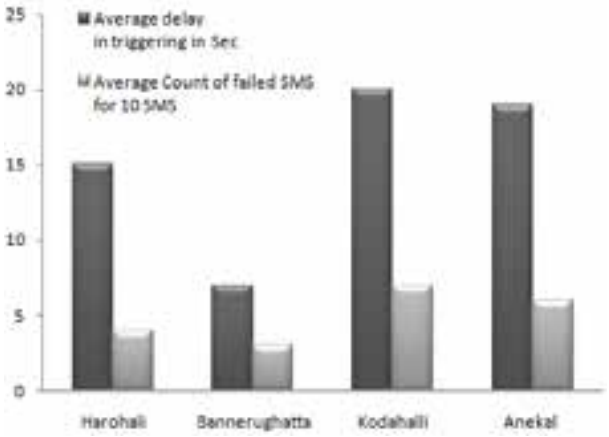


Figure 4. Range-wise average system response delay time with the number of failed SMS.

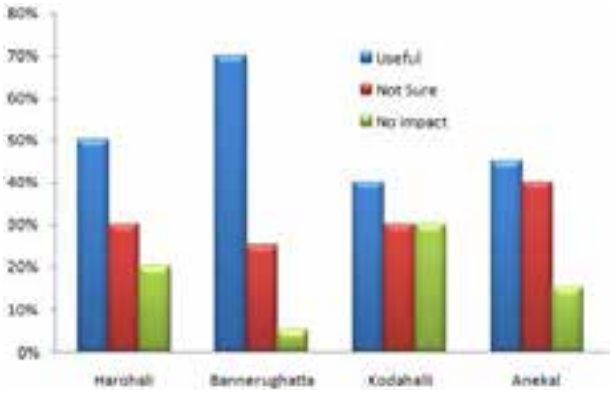


Figure 5. Range-wise local community response on system utility.

The sample sizes for Bannerghatta, Harohalli, Kodahalli, and Anekal were 100, 60, 50, and 30, respectively. The responses are shown in Figure 4 and Figure 5. Residents of Bannerghatta, a more developed and technology-friendly area, had a clear understanding of the system's benefits and gave positive feedback. However, in Harohalli and the other ranges, the responses were more mixed. This was due to a lack of technical understanding of the system and a preference for a deterrent system rather than an elephant alert system.

CONCLUSION

This research provides a comprehensive overview of a simple yet effective method for managing human-elephant conflict through a large-scale pilot project. The main goal is to alert local communities about elephant activity using an SMS-operated light and sound alarm system called 'Elephant Activity Alert Lights,' allowing them to take safety precautions. A total of 40 units of this system have been installed across four ranges of Bannerghatta National Park as part of a forest department initiative, with our technical support. The system is uniquely designed, and this paper outlines its architecture, design process, algorithm, and operation in detail. For the system to be effective, two critical factors—mobile network availability and long-distance visibility—must be considered. This paper includes detailed tables and graphs showing how these factors influence the system's performance and suggests possible ways to optimize it. The system's performance over an eight-month period is analyzed, including the number of times the system was triggered via SMS, the number of units experiencing network failures, and the frequency of malfunctions. These findings are presented with accompanying graphs and tables. Additionally, some technical issues observed during this period are

discussed, and potential solutions for correcting them are identified. Local feedback on the system's usefulness on the ground is also gathered and presented. Given the significant socioeconomic and dangerous impact of human-elephant conflicts in many parts of India, this project, as detailed in this paper, will serve as a valuable reference for implementing similar solutions in other conflict-prone areas.

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COMMUNICATION

Report of phimosis in an Andean Bear *Tremarctos ornatus* (Mammalia: Carnivora: Ursidae) and ultrasonographic description of the male genitourinary system

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Abstract: The Andean Bear is classified as 'Vulnerable' by the IUCN Red List of Threatened Species. Unfortunately, there is still a lack of data on the species' reproduction and reproductive pathologies. General anesthesia was administered to assess the health of a 16-year-old male individual weighing 161 kg, housed in a zoological institution. Anesthesia was induced using ketamine (7 mg/kg; im), butorphanol (0.2 mg/kg; im), midazolam (0.3 mg/kg; im), and dexmedetomidine (0.007 mg/kg; im). It was maintained with 1% isoflurane. During the clinical evaluation, a phimosis condition, secondary to a traumatic injury, was observed for the first time in this species. Ultrasonography of the reproductive system revealed the left testicle measured 3.87 x 2.27 cm and the right testicle measured 3.66 x 2.16 cm. Both testicles exhibited irregular hyperechoic areas. The prostate measured 1.77 x 3.11 cm. The penile urethra measured approximately 0.5 cm, and the penile bone, an elongated structure, measured 4 x 0.8 cm.

Keywords: Accessory glands, animal welfare, captive management, conservation medicine, one conservation, preputial trauma, reproductive pathology, Spectacled Bear, testicular parenchyma.

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Author contribution: AP Bom-Conselho: Conceptualization, data curation, formal analysis, investigation, methodology, project administration, resources, writing – original draft, writing – review & editing. AC Belsitoc: Investigation, writing – original draft; AC Trindade & CAT Cruvinel: Investigation. PN Jorge-Neto: Writing – review & editing; CS Pizzutto: Investigation, methodology, supervision, visualization, writing – review & editing.

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INTRODUCTION

The Andean Bear *Tremarctos ornatus* is a species in the Ursidae family, classified as 'Vulnerable', regarding its risk of global extinction (Velez-Liendo, X. & S. García-Rangel 2017) . Endemic to South America (Ruiz-Garcia 2003; Cueva et al. 2018, 2024), the Andean Bear measures approximately 1.5–1.8 m in height, with females weighing up to 60 kg and males up to 140 kg (Hohendorff & Giacomini 2014; Collins 2015). However, these weight ranges may vary in both wild and captive individuals without compromising their health parameters or biochemical evaluations. This species is commonly kept in zoological institutions worldwide, with records dating back to the 19th century (New York N.Y. Board of Commissioners of the Central Park 1867; Gould 1871). There is a lack of information, however, especially regarding reproduction and reproductive pathologies in this species.

Phimosis is a reproductive pathology that typically affects juveniles and, less frequently, adult animals (De Vlaming et al. 2019). Characterized by the inability to expose the penis through the prepuce due to a reduced preputial orifice (Volkmann 2023), there are reports of phimosis in various mammalian species, both domestic and wild (Ali et al. 2016; Martel-Arquette & Mans 2016; Kane et al. 2021). However, to date, there are no reports of phimosis in Andean Bears.

Ultrasonography is a highly useful imaging technique for the reproductive evaluation of domestic and exotic animals. Its applications include assessing the reproductive system of males and females, monitoring gestation, confirming reproductive pathologies, tracking ovulation and the estrous cycle in females, and aiding in semen collection, artificial insemination, ovum pick-up, and embryo transfer (Hildebrandt et al. 2000; Pugliesi et al. 2018; Silvatti et al. 2020; Araújo et al. 2022; Gazendam et al. 2023; Requena et al. 2023). This examination has enormous potential for use in zoological institutions and free-ranging animals, not only as a tool for general health assessment but also for the application of reproductive biotechnologies for conservation purposes (Pizzutto et al. 2021). For this, it is essential to understand the normal reproductive system patterns of the Andean Bear.

This study aims to report the first case of phimosis in an Andean Bear and describe the ultrasonographic findings of the genitourinary system in this species.

MATERIALS AND METHODS

The study details the results of clinical assessments conducted by veterinary professionals. These assessments fall under zootechnical practices and, therefore, did not necessitate approval from an animal use ethics committee (MCTIC 2023). Adhering to ethical standards for the assisted reproduction of wild animals (Pizzutto & Jorge-Neto 2023), the treatment and use of experimental animals were in full compliance with Brazilian laws, guidelines, and policies regarding animal welfare.

A 16-year-old male Andean Bear, weighing 161 kg, housed at a zoological institution (Rio de Janeiro, RJ, Brazil; lat. -22.904° , long. -43.229°), underwent an annual medical check-up for health assessment. The animal was fasted for 12 hours before anesthesia. An anesthetic dart gun was used, containing ketamine (7 mg/kg), butorphanol (0.2 mg/kg), midazolam (0.3 mg/kg), and dexmedetomidine (0.007 mg/kg). Anesthesia was maintained with 1% isoflurane.

A complementary examination of the abdominal and pelvic regions was performed using a GE Logiq E R8 ultrasound machine in two-dimensional mode, with high-frequency linear and microconvex multifrequency transducers ranging from 7–13 MHz, to assess the animal's general health and reproductive status. A breeding soundness examination was also performed.

RESULTS

Clinical evaluation revealed a narrowing of the preputial ostium, characterized as phimosis, preventing penile exposure (Image 1A,B). Based on the clinical history, the phimosis was secondary to preputial trauma. Clinical pathology tests showed values within the normal range for the Andean Bear. The animal did not present other clinical abnormalities; however, semen collection was not possible.

On palpation, the testicles were firm, and ultrasonography showed regular contours and symmetrical sizes, measuring 3.87 x 2.27 cm for the left testicle (LT) (Image 2A) and 3.66 x 2.16 cm for the right testicle (RT) (Image 2B). The mediastinum testis was poorly defined, and the parenchyma was hypoechoic and slightly heterogeneous due to the presence of small, irregular hyperechoic areas in both testicles, with the largest measuring 0.35 x 0.18 cm in the left testicle (Image 2C). In the pelvic region, at the topography of the accessory glands, in close contact with the caudal

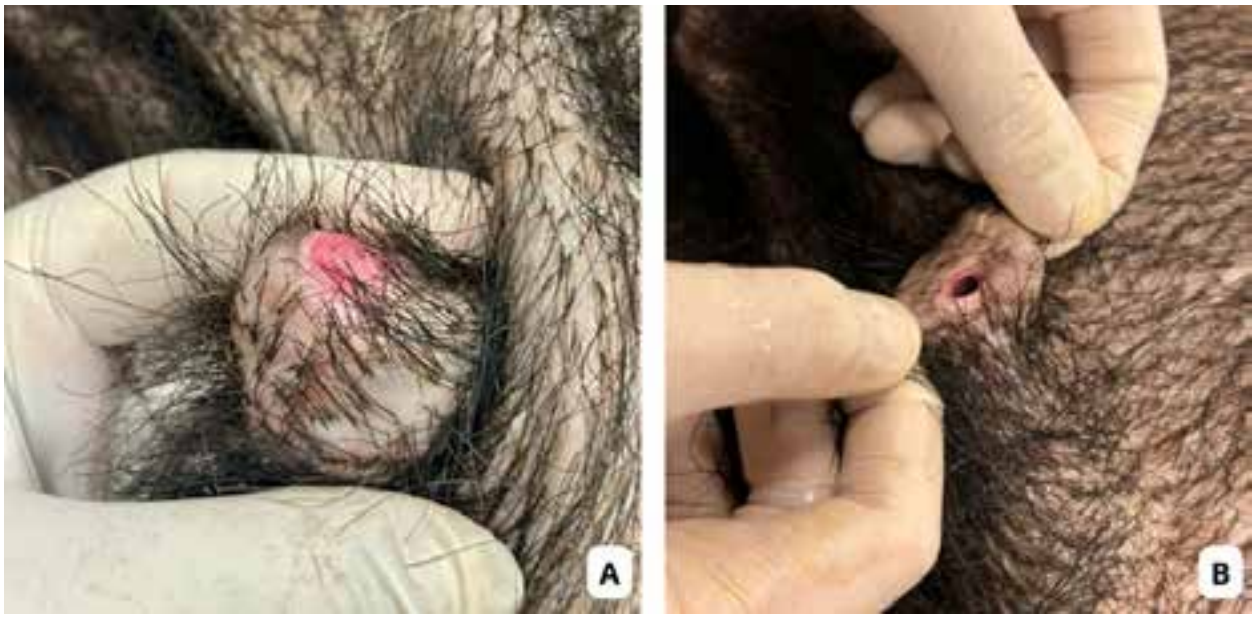

Image 1. A—Phimosis, preventing penile exposure | B—Narrowing of the preputial ostium. © Personal archive of Aléxia P. Bom-Conselho. 2024.

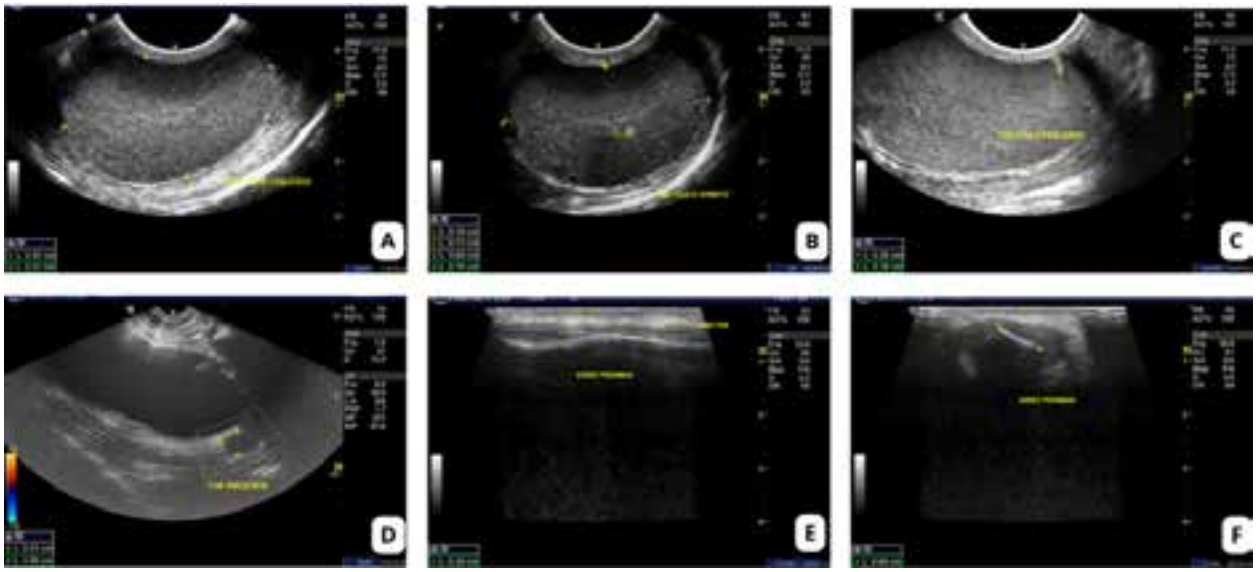

Image 2. A—Left testes | B—Right testes | C—Irregular hyperechoic areas in left testes | D—Prostate topography | E—Penile urethra | F—Penis bone. © Personal archive of Aléxia P. Bom-Conselho. 2024.

bladder wall, a hypoechoic structure with regular contours and an oval shape in the longitudinal section was observed, measuring 1.77 x 3.11 cm (Image 2D). The penile bone (Image 2E,F) is an elongated structure measuring approximately 4.0 x 0.8 cm, it is almost completely inside the gland and has a ventral groove that houses the urethra.

The urinary bladder was filled with anechoic liquid content, with a normoechoic, slightly irregular, and normothickened wall for the Andean Bear, measuring 0.45 cm. The penile urethra was empty and measured approximately 0.5 cm (Image 2E). The kidneys were symmetrical, measuring 9.41 cm on the left and 9.83 cm on the right, elongated and multilobed, with regular contours and typical architecture. Diffuse echogenic points were observed in the renal parenchyma.

DISCUSSION

Phimosis in adults is reported as secondary to trauma, lacerations, inflammatory processes, scarring, neoplastic conditions, excessive cleaning, licking, and other factors (De Vlaming et al. 2019; Madhesh et al. 2019), leading to inflammation, ostium narrowing, and phimosis. Andean bears have a strong tendency towards stereotypy in captivity (Lima et al. 2022), including excessive masturbation, which, according to the animal's history, possibly caused the lesion leading to the current condition. Despite the phimosis, the animal did not present other clinical abnormalities, such as stranguria, which is common in these cases. The bladder wall irregularity was related to insufficient filling at the time of the examination, as clinical pathology tests were within the normal range for the Andean Bear. Surgical intervention was not performed during the check-up, and clinical follow-up was planned for the following days, without ruling out the possibility of surgery, which is generally recommended for phimosis reversal in small animals.

In ultrasonography, the left testicle measured 3.87 x 2.27 cm and the right 3.66 x 2.16 cm, consistent with the literature, with the left averaging 3.16 x 2.44 cm and the right 3.19 x 2.55 cm (Talavera et al. 2021). As previously reported, the mediastinum testis in the Andean Bear is poorly defined (Talavera et al. 2021). The amorphous hyperechoic points found may be related to fibrosis or dystrophic mineralization, subject to histopathology for confirmation.

The prostate's function is to produce fluids for the first and third fractions of the ejaculate. It is important to know the normal dimensions of the prostate in Andean bear to monitor the animal's health, as affections in the accessory glands, such as hyperplasias, neoplasias, and prostatitis, are common in other mammals, especially humans and dogs, potentially compromising the individual's quality of life and health (Alves et al. 2010; Christensen 2018). For pharmacological semen collection, it is important to know the depth at which the urethral catheter should be inserted to reach the prostate, promoting semen recovery and avoiding urine contamination by reaching the bladder (Jeong et al. 2019; Araújo et al. 2020, 2021; da Silva et al. 2022; Deco-Souza et al. 2024). Ultrasonographic visualization of the urethral probe could confirm the prostate image; however, the individual's phimosis prevented urethral catheterization.

According to the ultrasonographic examination, it is possible that the prostate of Andean bears has an oval shape in the longitudinal section and is located at the neck of the urinary bladder, surrounding the caudal urethra, similar to dogs, measuring 1.77 x 3.11 cm in the evaluated Andean Bear. Transrectal ultrasonographic images of the prostate of a bear of the species *Ursus thibetanus* (Jeong et al. 2019) coincide with the images found for the species *T. ornatus*; however, the study does not provide gland measurements for interspecific comparison. Although there are studies describing the ultrasonographic topography of the abdominal and pelvic organs in *T. ornatus* (Cahua & Sato 2012; Talavera et al. 2021), no description of the prostate was found, which may be related to the difficulty of visualizing the gland due to its proximity to the pelvis or bladder filling, hindering visualization.

CONCLUSION

Phimosis can affect Andean Bears, as it does other mammals, and this is the first report. The testicular measurements (LT 3.87 x 2.27 cm and RT 3.66 x 2.16 cm) obtained by ultrasonography are consistent with the literature (LT 3.16 x 2.44 cm and RT 3.19 x 2.55 cm). The accessory gland in the pelvic region is located caudal to the bladder wall, with a hypoechoic appearance, regular contour, and oval shape in the longitudinal section, measuring 1.77 x 3.11 cm. Further studies are needed for comparison and determination of prostate normality.

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COMMUNICATION

Assessing avifaunal diversity and anthropogenic impacts on Ladhwaya Pond, Gwalior, India

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Abstract: Village ponds serve as important micro-wetland habitats that support diverse avifauna yet are subject to anthropogenic pressures. The present study assessed the avifaunal diversity and seasonal variations in Ladhwaya Pond, Tekanpur, Gwalior (Madhya Pradesh), India, during 2024–2025 using point count and line transect methods. A total of 52 bird species belonging to 33 families and 17 orders were recorded, comprising resident and migratory species. Passeriformes was the dominant order, followed by Columbiformes and Charadriiformes. Diversity indices revealed the highest species diversity during winter (ShannonWiener H' = 1.563; Simpson index = 0.826), indicating the pond's seasonal importance as a refuge for migratory and water-dependent birds. Most species (98.1%) were categorized as 'Least Concern', while one 'Near Threatened' species, the Asian Woolly-necked Stork was documented, emphasizing the conservation value. Field observation indicated that grazing, unregulated fishing, agricultural runoff, and human disturbance significantly influenced habitat quality and bird assemblages, favouring disturbance-tolerant generalist species over sensitive taxa. The study highlights the ecological role of small rural wetlands in sustaining local and migratory bird populations and underscores the urgent need for habitat restoration, disturbance regulation, and community-based conservation measures to maintain avifaunal diversity in such anthropogenically pressured pond ecosystems.

Keywords: Anthropogenic disturbance, aquatic avifauna, conservation, diversity, ecological role, habitat quality, rural ponds, small wetlands, village pond, wetland birds.

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Author contribution: RL contributed to manuscript preparation and scientific writing, conducted field surveys, and performed species identification. He also participated in data collection, interpretation of results, and critical revision of the manuscript for intellectual content. NPG carried out surveys, photography and identification of birds. SS carried out surveys, identification of birds, collecting data. AJ conducted field surveys, performed systematic documentation and identification of avifaunal species, and contributed to data analysis and manuscript preparation. RKG significantly contributed to the conceptualization and design of the study. He was actively involved in field surveys, data collection, and species identification. RJR provided academic guidance, supervised the research work, and critically reviewed the manuscript.

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INTRODUCTION

Birds are one of the most prominent animal groups in the world because of their remarkable splendour, melodious calls, easy recognition, and liveliness (Wenny et al. 2011; Brusatte et al. 2015). Birds are found in different habitats like grasslands, forests, rivers, wetlands, crop fields and urban areas (Byju et al. 2023a; Singh & Tiwari 2024). As pollinators, seed dispersers, insect predators, and environmental health indicators, birds are essential to ecosystems (Sekercioglu 2006). The aquatic avifauna supports nutrient cycling, insect population management, and ecological balance, and hence, it is essential to the conservation of wetland ecosystems (Byju et al. 2025a). Bird populations around the world have significantly declined due to intensifying anthropogenic activities, such as habitat destruction, pollution, and climate change (BirdLife International 2022). Due to urbanization, water pollution, and habitat fragmentation, wetland-dependent bird species have seen significant losses worldwide (Davidson 2014; Rashiba et al. 2022). The Ramsar Convention on Wetlands states that since 1970, around 35% of the world's wetlands have disappeared, which directly impacted the diversity of aquatic birds (Finlayson et al. 2017). Several recent studies from Indian wetlands have demonstrated that even small village ponds function as critical refugia for resident and migratory waterbirds, though they are increasingly affected by land-use change and human disturbance (Byju et al. 2023b).

India, home to over 1,376 bird species, with wetlands supporting a substantial proportion of migratory waterbirds, has also witnessed a similar trend (Praveen & Jayapal 2025). Lamba et al. (2024) reported a sharp decline in several wetland bird populations, attributing the decline to increased pollution, habitat destruction, and unregulated human activities (Byju et al. 2024a). In Madhya Pradesh, wetlands and other water bodies serve as essential habitats for diverse avifauna, including migratory and resident bird species (Rahmani 2012). The region's rich biodiversity is under threat due to agricultural expansion, water pollution, and unregulated fishing. Ladhwaya Village, near Tekanpur in Gwalior District, represents a microcosm of these broader conservation challenges. Despite its ecological significance, the wetland ecosystems in the region have received limited scientific attention, necessitating urgent research to document avifaunal diversity and to assess the impact of anthropogenic pressures. Hence, the present study was conducted in Ladhwaya Pond located in Ladhwaya Village near Tekanpur in Gwalior District on avifaunal diversity and anthropogenic influence on it.

Study area

Ladhwaya pond is situated (25.5915° N and 78.1323° E) in Ladhwaya Village near Tekanpur in Gwalior District, Madhya Pradesh, India (Image 1). The pond covers approximately 5 ha with an average depth of 2.5 m and is primarily rain-fed/perennial. The surrounding land use comprises agriculture and grazing fields, influencing nutrient influx and habitat structure. The climate of Ladhwaya is classified as subtropical, featuring three distinct seasons: summer, monsoon, and winter. Summers, extending from late March to early July, are notably hot, with average high temperatures reaching up to 41°C (106°F) in May. The monsoon season spans from late June/early July to early October, during which the region receives annual rainfall of, averaging 750 mm. Seasonal variations in the area are pronounced, influencing both the natural environment and human activities.

Methods

Field visits were made once in the first week of every month from March 2024–February 2025 in early morning (0700–1000 h) and evening hours (1700–1900 h). The point count and line transect methods were followed for observation of bird species. Four different points were established to cover the water body, and two line transects, 500 m long (Bibby et al. 2000; Archana et al. 2024), were used to collect data to evaluate the avifaunal diversity in Ladhwaya Pond. Avifaunal identification was made by using field guides (Grimmett et al. 2011). Photographs of birds were taken using a DSLR camera, Nikon D-60, for documentation and verification. Nikon Action EX 8 x 40 CF binoculars were used for observation of birds. To understand anthropogenic influences on avifaunal diversity, disturbance factors like grazing, human presence, and land-use changes were documented by personal observation. Species diversity indices such as Shannon-Weiner diversity index (H') and Simpson's diversity index (D), species richness, evenness, and relative abundance were calculated by statistical analysis using PAST statistical software (Hammer et al. 2001). Anthropogenic activities in the study area were assigned a grading scale of 0–5. The most negative influential activities were given a value of 5, and the lowest value, 'zero' (0), through personal observations.

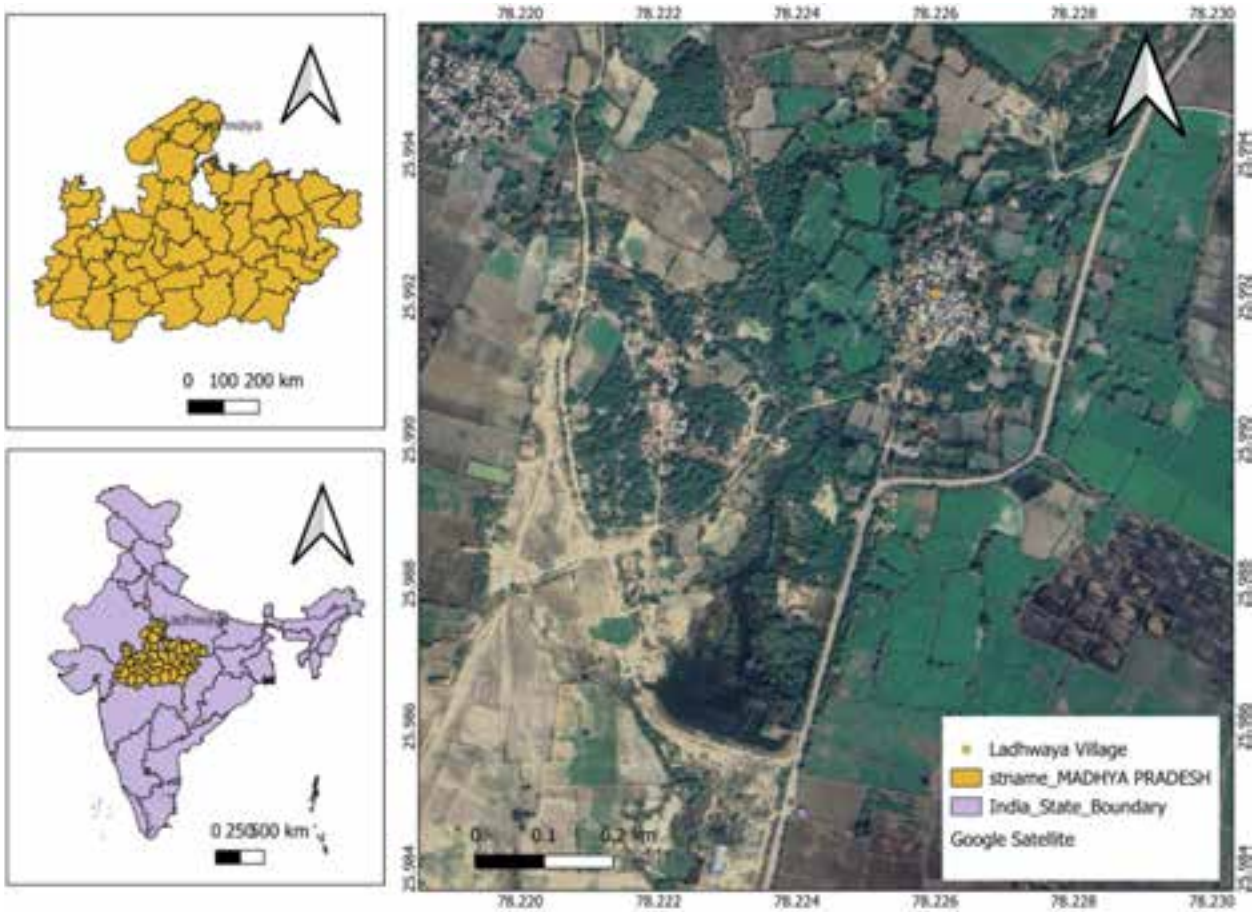

Image 1. Ladhwaya Pond, Tekanpur, Gwalior.

RESULTS

A total of 52 species of aquatic birds representing 33 families and 17 orders were observed in Ladhwaya Pond during the study period (Table 1). The birds are presented with their scientific name, Red List status, and residential status. Order Passeriformes was dominantly represented with 13 species, while Columbiformes had six species, Charadriiformes had five species, Coraciiformes had four species, Galliformes and Pelecaniformes had three species each, Cuculiformes, Gruiformes, Ciconiiformes, Suliformes, Bucerotiformes, and Piciformes had two species each, followed by Caprimulgiformes, Accipitriformes, Strigiformes, and Psittaciformes with one species each.

Among the families, Columbidae was the dominant with six species, followed by Phasianidae and Ardeidae with three species each. Alcedinidae, Anatidae, Cuculidae, Rallidae, Charadriidae, Ciconiidae, Phalacrocoracidae, Megalaimidae, Sturnidae, Muscicapidae were recorded with two species each, Apodidae, Recurvirostridae, Jacanidae, Scolopacidae, Accipitridae, Strigidae, Upupidae, Bucerotidae, Meropidae, Coraciidae, Psittacidae, Dicruridae, Corvidae, Cisticolidae, Pycnonotidae, Leiotrichidae, Nectariniidae, Estrildidae, Passeridae, and Motacillidae with one species each were documented in the study area. In the present study, the Red List status of the total recorded species was classified as 'Least Concern' 51 (98.1%) species and one 'Near Threatened' (1.9%) species (Figure 1). The ecological significance of Ladhwaya Pond as a vital resting place and breeding ground for bird fauna is highlighted by the presence of resident, local migratory and migratory species. Based on residential status, approximately 51.92 % of the species were residents, 36.53% were local migrants, and the remaining species 11.53% were migrants (Figure 2).

Metrics such as species richness, Shannon-Wiener diversity, Simpson Index, and species evenness were derived from the aggregated data across the rainy, winter, and summer seasons. Among the three seasons, the winter season exhibited the highest Shannon diversity

Table 1. List of avian species recorded from Ladhwaya Pond with their taxonomic position, conservation, and residential status.

	Order	Family	Scientific name	Bird name	Red List status	Residential status
1.	Anseriformes	Anatidae	*Dendrocygna javanica*	Lesser Whistling-Duck	LC	LM
2.			*Anas poecilorhyncha*	Indian Spot-billed Duck	LC	M
3.	Galliformes	Phasianidae	*Pavo cristatus*	Indian Peafowl	LC	R
4.			*Ortygornis pondicerianus*	Grey Francolin	LC	R
5.			*Perdicula asiatica*	Jungle Bush-Quail	LC	R
6.	Columbiformes	Columbidae	*Columba livia*	Rock Dove	LC	R
7.			*Streptopelia decaocto*	Eurasian Collared Dove	LC	R
8.			*Streptopelia tranquebarica*	Red Collared Dove	LC	M
9.			*Spilopelia chinensis*	Spotted Dove	LC	R
10.			*Spilopelia senegalensis*	Laughing Dove	LC	R
11.			*Treron phoenicopterus*	Yellow-footed Green-Pigeon	LC	LM
12.	Cuculiformes	Cuculidae	*Centropus sinensis*	Greater Coucal	LC	LM
13.			*Eudynamys scolopaceus*	Asian Koel	LC	R
14.	Caprimulgiformes	Apodidae	*Apus affinis*	Little Swift	LC	R
15.	Gruiformes	Rallidae	*Gallinula chloropus*	Common Moorhen	LC	LM
16.			*Amaurornis phoenicurus*	White-breasted Waterhen	LC	R
17.	Charadriiformes	Recurvirostridae	*Himantopus himantopus*	Black-winged Stilt	LC	M
18.		Charadriidae	*Charadrius dubius*	Little Ringed Plover	LC	LM
19.			*Vanellus indicus*	Red-wattled Lapwing	LC	R
20.		Jacanidae	*Metopidius indicus*	Bronze-winged Jacana	LC	LM
21.		Scolopacidae	*Actitis hypoleucos*	Common Sandpiper	LC	LM
22.	Ciconiiformes	Ciconiidae	*Anastomus oscitans*	Asian Openbill	LC	LM
23.			*Ciconia episcopus*	Asian Woolly-necked Stork	NT	LM
24.	Suliformes	Phalacrocoracidae	*Microcarbo niger*	Little Cormorant	LC	M
25.			*Phalacrocorax fuscicollis*	Indian Cormorant	LC	M
26.	Pelecaniformes	Ardeidae	*Egretta garzetta*	Little Egret	LC	M
27.			*Ardeola grayii*	Indian Pond-Heron	LC	R
28.			*Ardea purpurea*	Purple Heron	LC	LM
29.	Accipitriformes	Accipitridae	*Milvus migrans*	Black Kite	LC	R
30.	Strigiformes	Strigidae	*Athene brama*	Spotted Owlet	LC	R
31.	Bucerotiformes	Upupidae	*Upupa epops*	Eurasian Hoopoe	LC	R
32.		Bucerotidae	*Ocyceros birostris*	Indian Grey Hornbill	LC	LM
33.	Coraciiformes	Meropidae	*Merops orientalis*	Asian Green Bee-eater	LC	LM
34.		Alcedinidae	*Halcyon smyrnensis*	White-throated Kingfisher	LC	R
35.			*Ceryle rudis*	Pied Kingfisher	LC	R
36.		Coraciidae	*Coracias benghalensis*	Indian Roller	LC	LM
37.	Piciformes	Megalaimidae	*Psilopogon haemacephalus*	Coppersmith Barbet	LC	LM
38.			*Psilopogon zeylanicus*	Brown-headed Barbet	LC	LM
39.	Psittaciformes	Psittacidae	*Alexandrinus krameri*	Rose-ringed Parakeet	LC	R
40.	Passeriformes	Dicruridae	*Dicrurus macrocercus*	Black Drongo	LC	LM
41.		Corvidae	*Corvus splendens*	House Crow	LC	R
42.		Cisticolidae	*Prinia inornata*	Plain Prinia	LC	R
43.		Pycnonotidae	*Pycnonotus cafer*	Red-vented Bulbul	LC	R

	Order	Family	Scientific name	Bird name	Red List status	Residential status
44.	Passeriformes	Leiotrichidae	*Argya striata*	Jungle Babbler	LC	R
45.		Sturnidae	*Sturnia pagodarum*	Brahminy Starling	LC	R
46.			*Acridotheres tristis*	Common Myna	LC	R
47.		Muscicapidae	*Copsychus saularis*	Oriental Magpie-Robin	LC	R
48.			*Saxicola maurus*	Siberian Stonechat	LC	LM
49.		Nectariniidae	*Cinnyris asiaticus*	Purple Sunbird	LC	R
50.		Estrildidae	*Euodice malabarica*	Indian Silverbill	LC	LM
51.		Passeridae	*Passer domesticus*	House Sparrow	LC	R
52.		Motacillidae	*Motacilla maderaspatensis*	White-browed Wagtail	LC	LM

Aberration: LC—Least Concern | NT—Near Threatened | LM—Local Migrant | M—Migrant | R—Residential.

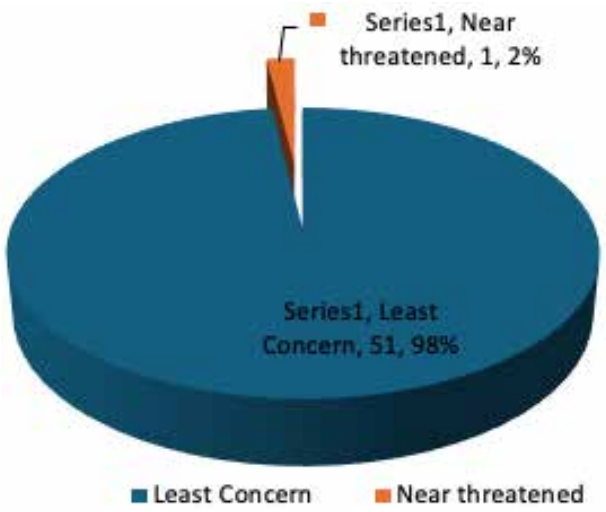

Figure 1. IUCN Red List status of recorded species.

index value (H' = 1.563), followed by the rainy season (H' = 1.228) and the summer season (H' = 0.209). The Simpson diversity index also showed its highest value in the winter season (0.826), summer season (0.699) and rainy season (0.495). In terms of species evenness, the summer season recorded the highest value (0.481), while the rainy season had a value of 0.172, and the winter season had the lowest at 0.093 (Figure 3).

During the present study, anthropogenic impacts through the grading system (0–5) showed that Ladhwaya Pond was highly affected during winter season. The highest levels of sewage impact are recorded at a value of five followed by weed abundance, agriculture with value of four, grazing, grass cutting, fishing, human presence, cattle wading with value of three, water extraction and construction with value of two and it was less affected in rainy season while winter season was moderate. The excessive use of the pond for various purposes affected the environment of the water body.

DISCUSSION

The present study recorded 52 bird species belonging to 33 families and 17 orders from Ladhwaya Pond, reflecting a moderately diverse avifaunal assemblage for a small pond wetland ecosystem. Such patterns are commonly reported from small village wetlands where edge vegetation, surrounding agricultural fields, and open water collectively influence bird assemblages. Similar mixed guild dominance has been documented in Indian wetland complexes where passerines utilize peripheral vegetation while true waterbirds occupy open water and marsh zones (Rahmani 2012). Comparable trends in species composition and habitat-use heterogeneity have also been highlighted in other inland wetlands experiencing anthropogenic habitat modification, where generalist passerines increase in proportion relative to specialist waterbirds (Byju et al. 2024b).

The dominance of Columbiformes (six species) further indicates strong terrestrial–wetland interface usage, suggesting that Ladhwaya Pond is not only a feeding site but also a roosting and nesting landscape influenced by nearby human settlements. Such family-level dominance patterns are typical of semi-urban and rural wetlands where granivorous and omnivorous species adapt to anthropogenic food resources (Boora & Kumar 2023). In contrast, the presence of Charadriiformes (five species) and Pelecaniformes (three species) reflects the functional importance of shallow mudflats and open-water zones, which provide foraging opportunities for waders and piscivorous birds. This structural heterogeneity in microhabitats is crucial

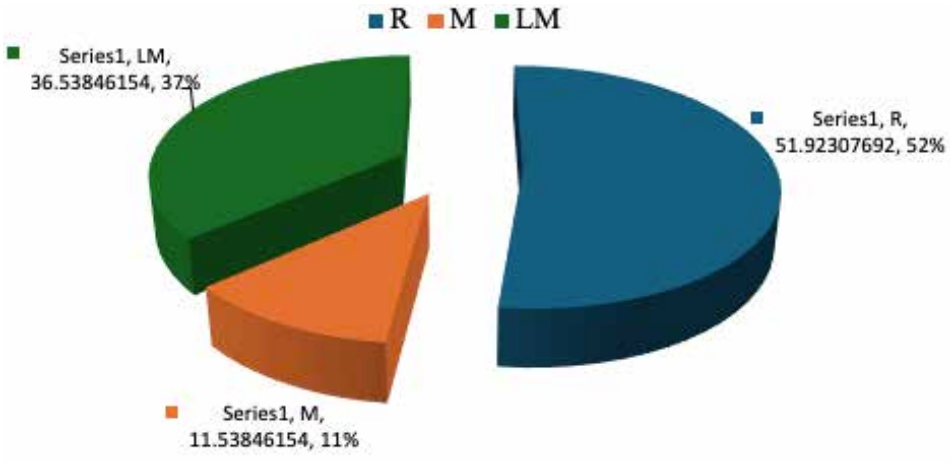

Figure 2. Residential status of recorded species.

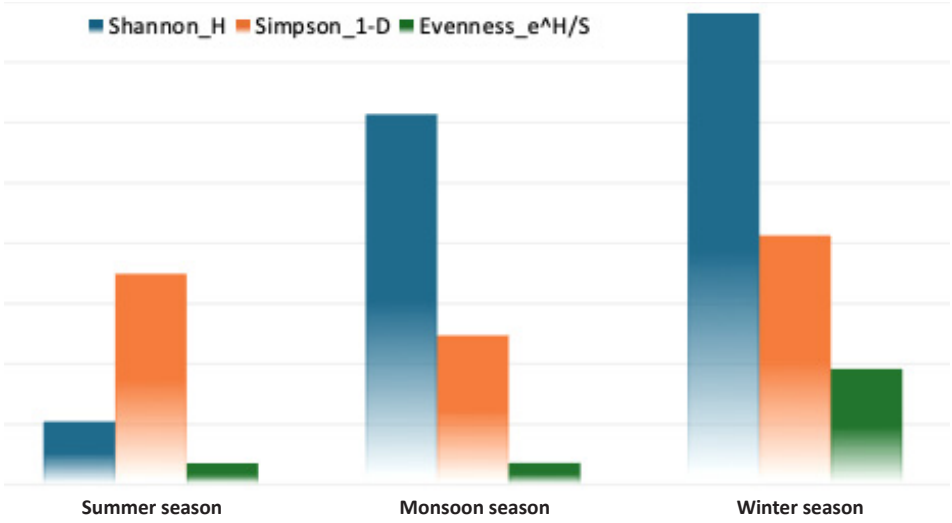

Figure 3. Seasonal diversity index of recorded species.

for sustaining guild diversity, a phenomenon similarly observed in seasonal wetlands across India (Anand et al. 2023; Byju et al. 2025a).

Family-level analysis revealed Columbidae as the most dominant family, followed by Phasianidae and Ardeidae. The prominence of Columbidae indicates strong adaptation to anthropogenic landscapes and the availability of food subsidies from surrounding agriculture and human habitation. On the contrary, the representation of Ardeidae underscores the ecological role of the pond as a foraging ground for herons and egrets, which depend on shallow aquatic zones rich in fish and invertebrates (Aarif et al. 2025). The occurrence of Anatidae, Rallidae, Scolopacidae, and Recurvirostridae, though with fewer species, further confirms the wetland's significance as a seasonal refuge for water-associated birds. Such assemblage structures align with findings from inland wetlands of central and southern India, where waterbird diversity is closely linked to hydrological regimes, vegetation complexity, and anthropogenic disturbance gradients (Jha & McKinley 2015; Lodhi et al. 2017). Long-term observations from Indian wetland ecosystems have also shown that moderate disturbance often results in a shift towards generalist and adaptable families, while specialist taxa decline, leading to biotic homogenization (Byju et al. 2025b,c).

The conservation status pattern in the present study, with 98.1% 'Least Concern' species and only one 'Near Threatened' species, suggests that the pond presently supports common and adaptable taxa. While this may indicate ecological resilience, it may also reflect early

signals of habitat simplification, where disturbance-sensitive species are gradually replaced by generalist species. Similar patterns of declining representation of conservation-priority waterbirds have been reported from wetlands undergoing land-use transformation and hydrological alteration in India (Byju et al. 2025d). Therefore, the dominance of 'Least Concern' species should not be interpreted as the absence of conservation concern, but rather as an indicator of increasing anthropogenic filtering of avifaunal communities.

Seasonal diversity analysis showed the highest Shannon diversity and Simpson index during winter, confirming that Ladhwaya Pond serves as an important seasonal habitat for migratory and winter-visiting birds. The influx of migratory waders, ducks, and other wetland species during winter is a well-documented phenomenon in Indian wetlands, driven by favorable climatic conditions, water availability, and food abundance (Rahmani 2012). Relatively lower diversity during summer corresponds with reduced water levels and elevated temperatures, which limit habitat suitability and food resources. Similar seasonal peaks in winter diversity have been observed across inland and coastal wetlands of India, highlighting the significance of small wetlands as stopover and wintering grounds (Mathibalan et al. 2026). The higher evenness recorded during summer, despite low species richness, indicates a more uniform distribution of a few resident species, suggesting reduced niche overlap and competitive exclusion during resource-scarce periods.

The disturbance grading results indicate that anthropogenic pressure was highest during summer, coinciding with peak bird congregation. Activities such as grazing, fishing, agricultural runoff, and frequent human presence likely disturb foraging and roosting behaviour, leading to altered species composition and reduced abundance of disturbance-sensitive taxa. Studies across Indian wetland landscapes have consistently demonstrated that chronic anthropogenic disturbance modifies habitat structure, reduces water quality, and reshapes avian community composition (Byju et al. 2024a).

Increasing anthropogenic utilization poses a serious threat to habitat quality and the long-term sustainability of bird diversity. Therefore, conservation strategies focusing on habitat restoration, regulation of human activities, and maintenance of hydrological regimes are essential to sustain the ecological integrity of this rural wetland ecosystem, as emphasized in recent wetland conservation assessments across India (Rashiba et al. 2022; Byju et al. 2025b). In the current study, it was noted through a grading scale that Ladhwaya Pond experienced a significant impact during the winter season, while it was less affected comparing the winter season to both the monsoon and summer seasons. The extensive utilization of the pond for various purposes has adversely affected the Ladhwaya Pond.

CONCLUSION

Ladhwaya Pond functions as a seasonally important wetland supporting diverse avifaunal assemblages despite anthropogenic pressures. The observed dominance of disturbance-tolerant species and reduced sightings of sensitive taxa indicate ongoing habitat stress. Long-term monitoring and habitat restoration are essential to prevent ecological simplification, as demonstrated in other Indian wetlands facing similar pressures.

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COMMUNICATION

New record of invasive moth *Phalera* cf. *bucephala* (Linnaeus, 1758) (Lepidoptera: Notodontidae) on *Salix alba* (Salicaceae) from Ladakh, India

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Abstract: The Suru Valley of district Kargil, UT Ladakh, India is part of the Trans-Himalayan region. Over the past two decades, the region has been experiencing climate change, resulting in outbreaks of many invasive insect species in the area. The present study documents a new invasive moth *Phalera* cf. *bucephala* (Linnaeus, 1758) on *Salix alba* and its biology in the region. This species is polyphagous, infesting a wide range of plant species, including those of the genus *Salix*. Observations indicate that adults emerge in late June, with females laying eggs within 2–3 days. After an incubation period of 10–15 days, larvae hatch in July and pupate in August and September. The insect overwinters in the pupal stage underground, beneath decomposing leaves, grasses, and debris. There are four larval stages, all of which are active feeders, leading to complete defoliation of the host plant within 30 days of emergence. Currently, *P.* cf. *bucephala* is confined to the Suru Valley of district Kargil but may potentially spread to neighbouring areas.

Keywords: Alien invasive species, climate change, insect outbreaks, Kargil, forest, plant defoliation, polyphagous pest, Suru Valley, Trans-Himalaya.

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Author contribution: MH identified the insect species up to the species level, captured photographs of insect specimens and study sites, and prepared the manuscript along with NFK. BA and MA assisted in collecting insect specimens, preparing the manuscript, photo editing in Photoshop, and related tasks.

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INTRODUCTION

The Suru Valley of Kargil is situated in the Trans-Himalayan region of the cold arid desert of Ladakh, India. This valley extends widely along the sides of the Suru River and its tributaries, from Minjee Village to Parkachik Village. It is renowned for the cultivation of willow and poplar plants, which are crucial for both firewood and construction purposes. Locally, willow branches, known as Kralboo, are extensively used in roofing just below the mud slab in traditional Ladakhi architecture. Both fresh and dried leaves, as well as tender twigs, are used as fodder for livestock during early spring and periods of grass shortage. These uses underscore the significant economic value of willow and poplar plants in the region (Hussain et al. 2024). In recent years, the Ladakh region has been experiencing insect pest outbreaks on many economically important plants, including willow and poplar species (Raghuvanshi 2016; Hussain et al. 2021a,b, 2024). These outbreaks are likely to be influenced by climate change and other environmental factors (Johnson & Haynes 2023; Tabassum et al. 2024). Over the past two decades, these infestations have been increasingly documented (Raghuvanshi 2016; Hussain et al. 2024). According to a literature review, six invasive species—Brown Tail Moth *Euproctis chrysorrhoea* Linnaeus, 1758; Migratory Locust *Locusta migratoria migratorioides* (Linnaeus, 1758); Spotted-wing Drosophila *Drosophila suzukii* (Matsumura, 1931); Giant Willow Aphid *Tuberolachnus salignus* Gmelin, 1790; Aspen Leaf Miner *Phyllonorycter populifoliella* (Treitschke, 1833); and *Pheosia albivertex* (Hampson, 1983)—have been recorded in the region (Kumar et al. 2009; Raghuvanshi et al. 2016; Hussain et al. 2021b, 2024). In the current study, *P.* cf. *bucephala* has been recorded in the Suru Valley of Kargil, Ladakh, India.

The genus *Phalera* causes various degrees of infestation to a variety of trees and shrubs, including willow, poplar, sessile oak, apple, mountain ash, and walnut, causing complete defoliation to the host plant (Bochniarz 2022). The genus is primarily distributed across the Palearctic, Oriental, Australian, Central Asian, and Ethiopian regions, including Korea and China, and can be found at altitudes of up to 2,200 m (Schintlmeister 2008; Wu & Fang 2012; Bochniarz 2022). Worldwide, the genus encompasses approximately 87 species, with 11 species previously recorded in India (Smetacek 1999; Chandra et al. 2018; Singh 2019). This new record brings the total number of documented *Phalera* species in India to 12.

MATERIALS AND METHODS

The survey was conducted in the Suru Valley area of the Trans-Himalayan region of Kargil, UT Ladakh, from June 2021 to August 2023 (Figure 1). The entire stretch was thoroughly inspected, and spatial information about collection sites was recorded using a Garmin hand-held eTrex 32X device (Table 1). To study the biology, the insect was cultured in the zoology laboratory at the University of Ladakh using a technique adapted from the culture of the invasive insect *Pheosia albivex* recorded from Kargil, with some modifications (Hussain et al. 2024). Larval stages were collected by hand from host plants and brought to the laboratory for further study. Specimens were sorted and kept in clean plastic jars (2 × 2 × 3 ft) covered with muslin cloth. They were fed fresh leaves, with twigs inserted in wet sand in a flowerpot covered with muslin cloth or mosquito netting. The culture was refreshed daily. Mature fourth instar larvae were transferred to a jar filled with dry soil, covered with rotten leaves and plant debris, to facilitate pupation. The jars were left undisturbed at room temperature until the adults emerged in June and July of the following year. Adults were sorted by sex based on morphological characteristics and allowed to mate in a large chamber covered with mosquito netting (Hussain et al. 2024). Gravid females were provided with fresh host plant leaves for egg-laying. Adult specimens were identified using keys provided by Wu & Fang (2012) and Dolinskaya (2016). Photographs of eggs, instars, and adults were taken with a stereo zoom microscope (Leica S9i) and a Canon 500D DSLR camera. The images were later edited using Adobe Photoshop 7.0.

RESULTS

Phalera* cf. *bucephala (Linnaeus, 1758)

Material examined: Three males and two females were collected from Khachan, near the trout fish farm in Khachan, Kargil, Ladakh (Geolocation: 34.365° N, 74.969° E, elevation—2,880 m, 23.vii.2021). The specimens were identified as *Phalera* cf. *bucephala* (Linnaeus, 1758) (Figure 2A; Image 1D) and deposited in the Zoology Museum, University of Ladakh on 10 October 2023.

Diagnostic characters

Adult: The body measures 3–3.5 cm in length. Males have feathery, bi-pectinate antennae, while females have filiform antennae. The forewings are grey with a large dark brown patch near the apex and narrow dark

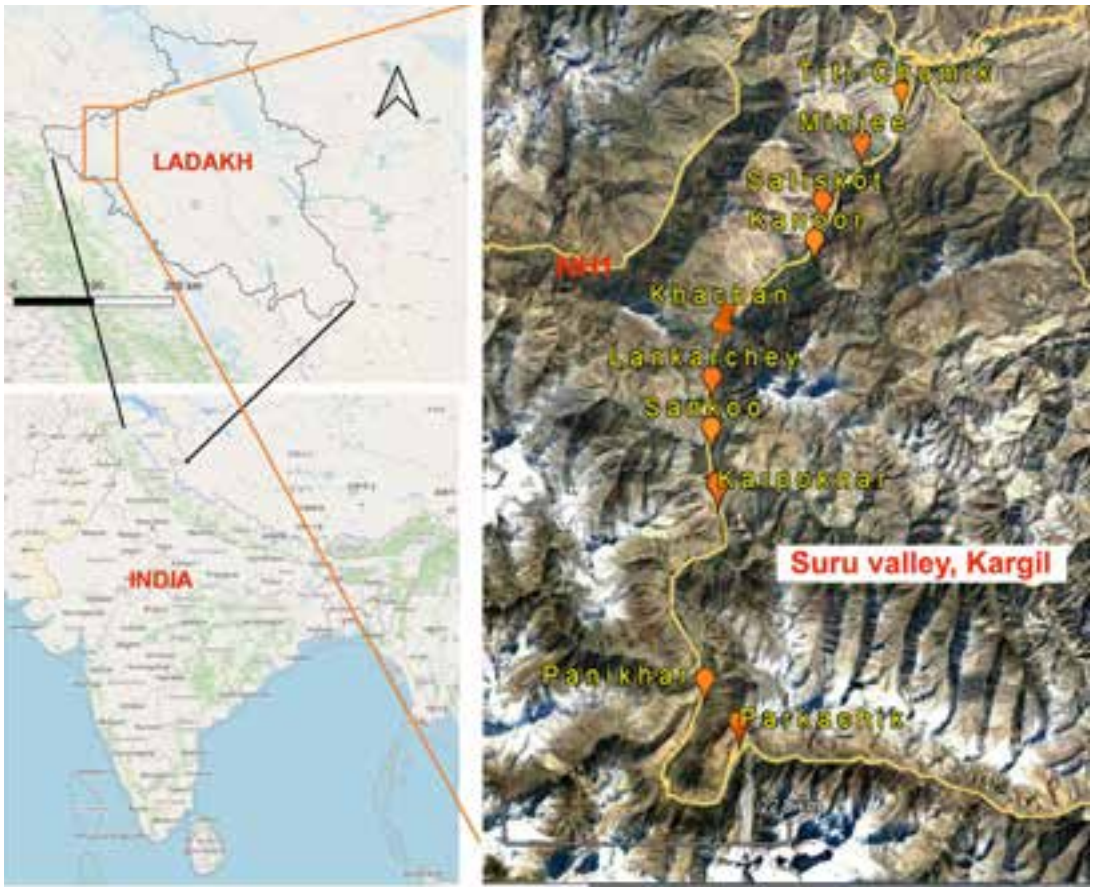

Image 1. Map of study area, Suru Valley of Kargil, Ladakh, India. (Source: QGIS and Google Earth Pro).

bands. The hind wings are creamy white. The thorax is hairy, buff, and grey, and the abdomen is brown. The buff-tip moth exhibits minimal sexual dimorphism, though females tend to be larger and have a bulging abdomen before laying eggs; male genital part, uncus large dome-shaped, apex pointed and highly sclerised, well developed, forming "C" shaped arch on the 1/3 area from the outer side air, saccus processes reduced, juxta enlarged with processes, valva brought with one processes and small hairs (Figure 2D,E; Image 1D).

Egg: Creamy white, spherical with a single black spot at the apex, and a flat base for better adhesion to leaf surfaces. Eggs are 0.8–1 mm in diameter and laid in clusters of 100–150. They hatch in 15–20 days in late July (Figure 2B).

Larvae: *Phalera* cf. *bucephala* represents four larval stages. Newly hatched larvae are slightly yellowish, later turning black with yellow patterns, and measure 0.8–1 cm in length. The body is covered with white hairs, and the head is black. Each thoracic segment has distinct markings, and the last abdominal segments have a brown band. Siblings live in groups, held together by fine threads secreted by the larvae (Figure 2D; Image 1A). Second instar larvae measure 1.5–2 cm, and the third and fourth instar larvae grow to 3–5 cm in length (Figure 2F). Except for newly hatched larvae, all the

Table 1. Sample collection sites, Suru Valley, Kargil, Ladakh.

	Sample collection sites	Geo-location	Altitude (in m)
1	Titi-Chumik	34.523° N, 76.131° E	2,735
2	Minjee	34.487° N, 76.1° E	2,769
3	Saliskot	34.428° N, 76.052° E	2,831
4	Kanoor	34.417° N, 76.05° E	2,827
5	Khachan	34.365° N, 74.969° E	2,880
6	Lankarchey	34. 326° N, 75.96° E	2,929
7	Sankoo	34.281° N, 75.962° E	2,983
8	Karpokhar	34.241° N, 75.97° E	3,071
9	Panikhar	34.092° N, 75.94° E	3,287
10	Parkachik	34.093° N, 75.991° E	3,585

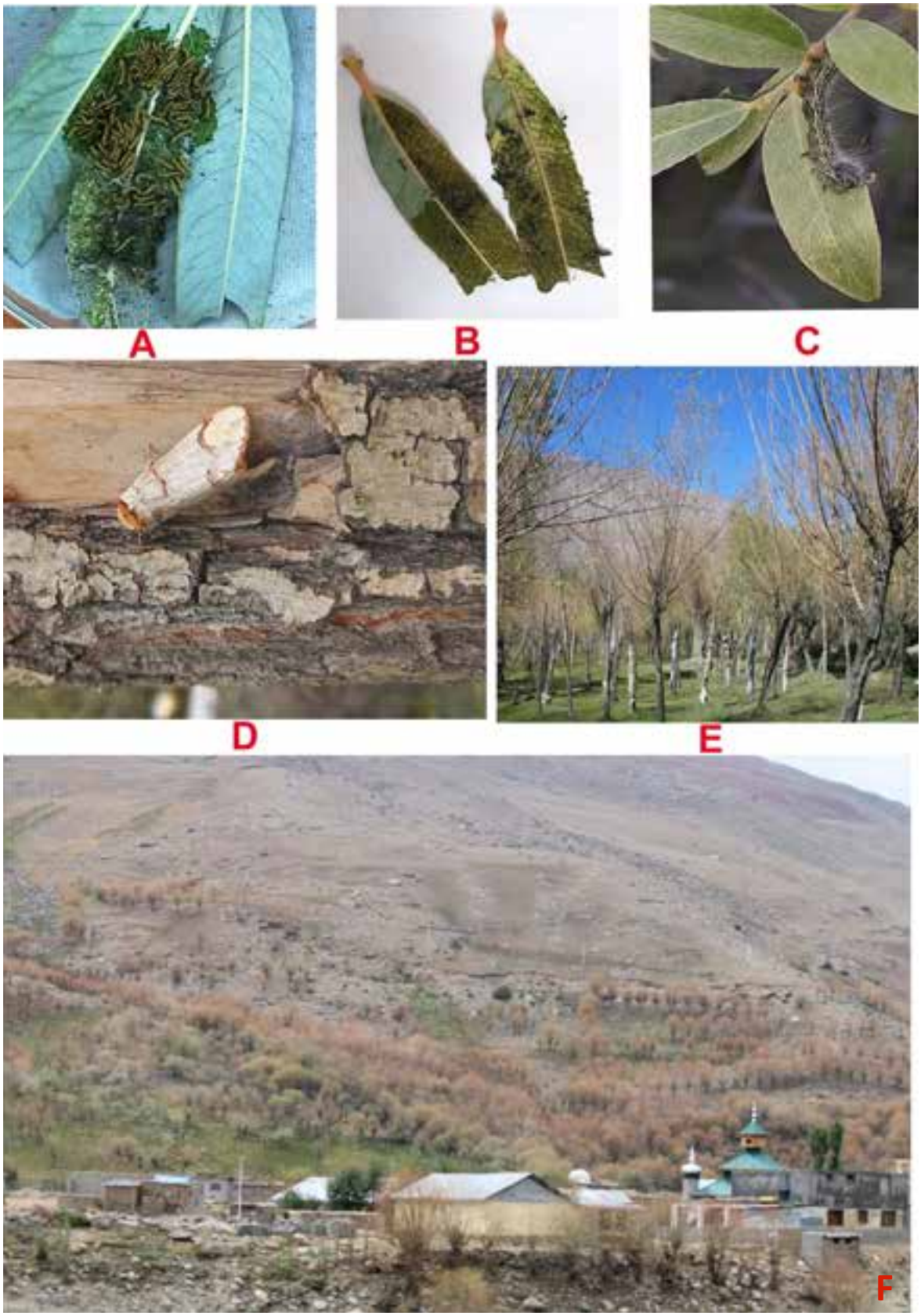

Image 1. *Phalera* cf. *bucephala*: A—newly hatched larvae feeding on the lower surface of the host plant leaves | B—lower surface of host plant leaves scrapped by 1st instar larvae | C—3rd instar larvae on leaf of host plant | D—adult resembling the trunk of host plant | E—defoliated host pants at the study sites, Khachan fish farm | F—defoliated host pants in a study sites, Panikhar. © Mohd Hussain.

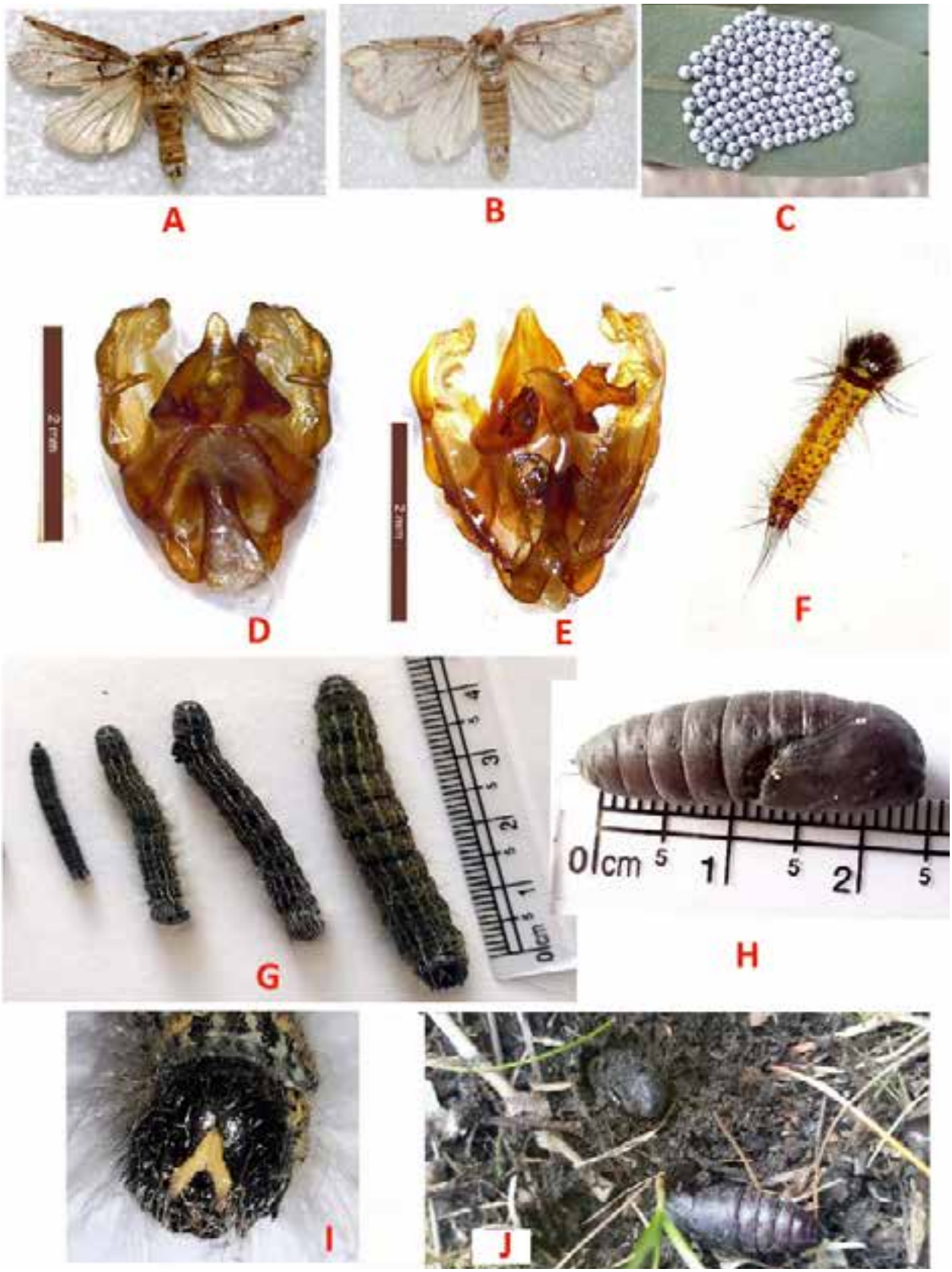

Image 2. *Phalera* cf. *bucephala*: A—adult male | B—adult female | C—eggs on the under surface of host plant leaf | D—male genetilia, Dorsal view | E—male genetilia, ventral view | F—newly hatched 1st instar larvae | G—1st to 4th instar larvae | H—Pupae | G & J—pupae under the ground | I—4th instar larvae head. © Mohd Hussain.

larval stages are black with yellow pattern, rows of white lines running from anterior to posterior end, which are prominently visible in the third and fourth larval stages, body hairy with white hairs (Figure 2F; Image 1C). The head is black with a characteristic inverted "Y" shape line on the anterior head (Figure 2F).

Pupa: *P.* cf. *bucephala* overwintered in pupal stage. Pupae purple-brown in colour, measuring 2.5 cm in length. Pupation occurs under the ground at a depth of 3–4 inches in September, no cocoon formation (Figure 2E,G).

Biology: *P.* cf. *bucephala* is univoltine, completing one generation per season in the study area. Adults emerge from pupae in mid-June and are active until August, with peak abundance in July. Females lay eggs soon after copulation, in clusters of 100–150 (Figure 2B). The first instar larvae hatch after 10–15 days and go through four developmental stages in 40–45 days (Figure 2F). Mature larvae leave the host plant to pupate and overwintered under rotten leaves and plant debris (Image 1E,G).

Host: *P.* cf. *bucephala* is polyphagous, preferring plants from the Rosaceae, Salicaceae, and Fagaceae families (Wu & Fang 2012; Hausmann & Scalercio 2016; Morozov et al. 2016; Morimoto & Pietras 2020). In this study, it was recorded on *Salix alba* in the Suru Valley of Kargil, UT Ladakh, India.

Nature of Damage: Only the larval stage feed on the leaves of the host plant causing complete defoliation by mid-August (Image 1E,F). Newly hatched larvae scrape from the under surface of the leaves for 2–3 days, then eat from the margins toward the midrib, leaving only the veins (Figure 2A–C).

Distribution: *P.* cf. *bucephala* has been documented in China, Korea, Russia, Europe, Africa, and Italy (Wu & Fang 2012; Hausmann & Scalercio 2016; Morozov et al. 2016). This study records its presence in India from the Trans-Himalayan region of Kargil, UT Ladakh, India, where it is well-distributed from Minjee to Parkachik Village of Suru Valley.

DISCUSSION

The Suru Valley, located in the Trans-Himalayan region of Kargil, Ladakh, boasts rich biodiversity, with numerous insect species documented in the valley so far (Behera 2014). Ladakh is experiencing a warming trend due to climate change, resulting in the presence of many invasive insects in the region (Chevuturi et al. 2018; Hussain et al. 2021a, 2024). Recently, Hussain et al. (2024) recorded an invasive insect pest on *Populus alba* in the Dyanguchey Village of the Suru Valley. In the present study, a new invasive moth species, *P.* cf. *bucephala*, has been recorded from the valley on *Salix alba*. Therefore, this area in the Ladakh region provides ideal conditions for the introduction and succession of insect species. The genus *Phalera* comprises approximately 87 species worldwide and is well-distributed in the Palearctic region, including China, Mongolia, Korea, Russia, Europe, and northeastern Africa (Wu & Fang 2012; Morozov et al. 2016; Bochniarz 2022; ADW: Phalera: Classification 2024). In India, the genus has been documented in the eastern Himalayan region and its surrounding areas; however, it is the first time the genus is being recorded from Trans-Himalaya, Kargil Ladakh (Chandra et al. 2018). The larvae of *P.* cf. *bucephala* feed on the leaves of various trees and shrubs, including willow, poplar, sessile oak, apple, mountain ash, and walnut, causing complete defoliation within a short period (Bochniarz 2022). Upon reaching maturity, the larvae leave the host plant and crawl in masses on the ground for pupation, causing a nuisance in the study area during crop harvesting in July and August. In Ladakh, the host plant, *Salix alba* holds great economic value locally, with its branches (Kralboo) widely used in house construction for roofing under the mud slab. The leaves and tender twigs are used as fodder for livestock in early spring during grass shortages. During the survey, it was observed that the insect covers the entire valley from Minjee to Parkachik. Therefore, it may be declared an invasive pest and timely control measures should be implemented. The insect is polyphagous, and without timely control measures, it may spread to other areas, including fruit-growing regions like Kargil City, Shilikchey, Hardas, and other adjoining areas of the Kargil District.

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COMMUNICATION

Diversity and distribution of wasps and bees (Insecta: Hymenoptera: Vespidae, Apidae) in the Gauhati University Campus, Kamrup Metro, Assam, India

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Abstract: The diversity and distribution of wasps and bees in the Gauhati University campus, Kamrup Metro, Assam was investigated in four different habitats: campus gardens, grasslands, residential areas, and areas adjacent to wetlands. Specimens were observed or collected from March 2022 to February 2023. A total of 23 species were recorded from five subfamilies; Polistinae, Eumeninae, and Vespinae under the family Vespidae, Apinae, and Xylocopinae under the family Apidae. The most abundant subfamily was Polistinae (44%) and the least Xylocopinae (8%). Shannon-Weiner diversity index values indicated the highest diversity in residential areas (3.4) followed by gardens (3.3), grasslands (2.2), and areas adjacent to wetlands (2.0). Species abundance exhibited seasonal variations, peaking during the monsoon months.

Keywords: Apinae, diversity indices, eumeninae, habitat, northeastern India, polistinae, seasonal variation, species abundance, vespinae, xylocopinae.

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Author contribution: BK: Field data collection, conceptualization, methodology, investigation, data curation, writing - original draft. JD: Field data collection, formal analysis. MKS: Validation, Writing - review and editing. PKS: Supervision, visualization, validation, writing - review and editing.

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INTRODUCTION

The wasps in the family Vespidae (Hymenoptera), commonly known as paper wasps, potter wasps, pollen wasps, yellow jackets, hornets, and hover wasps (Gawas et al. 2020), are a specialized group of insects. Globally, this family consists of about 5,000 species (Varghese & Kumar 2023), with 288 species reported in India (Mazumdar et al. 2021). This cosmopolitan family consists of six subfamilies: Polistinae, Eumeninae, Euparagiinae, Masarinae, Stenogastrinae, and Vespinae, of which only Euparagiinae is not reported in India (Gawas et al. 2020). Mazumdar et al. (2021) reported 116 species of Vespidae under four subfamilies from six northeastern states of India, including Assam. The family Apidae (Hymenoptera) comprises bees, and there are approximately 25,000 named species globally (Gupta 2014). Some of the earliest literature available on the diversity and distribution of wasps and bees from the Indian subcontinent were by Bingham (1897), Das & Gupta (1983, 1989). In the last decades, many studies were conducted from various regions of India. Some of those studies include (Kumar 2010, 2013, 2018; Kumar & Nguyen 2010; Kumar & Srinivasan 2010; Kumar & Lambert 2010; Kumar & Carpenter 2013, 2018; Kumar & Sharma 2013, 2014, 2015; Kumar et al. 2014, 2016, 2017, 2019; Gawas et al 2020; Mazumdar et al. 2021; Varghese & Kumar 2023). From the Indian state of Assam, no consolidated works on Vespidae wasps have been reported (Mazumdar et al. 2021).

Vespid wasps forage for fuel, water, and resources to construct their nests (Lima & Prezoto 2003). Their primary food source is insects, which account for 90–95% of the prey gathered (Gobbi & Machado 1986). The aggregation arrangement of social wasps is mostly clustered, indicating that they are extremely territorial insects with populations exhibiting significant species concentration in the same area (Richards 1971). Wasps contribute vital ecosystem services as bioindicators (de Souza et al. 2010), pollinators, predators, and biocontrol agents of agricultural pests (Ferreira et al. 2020). Bees visit flowers to collect nectar for the production of honey and in the process carry pollen. They are cosmopolitan, eusocial insects that play a vital role in preserving biodiversity by pollinating a vast variety of plants. Bees that produce honey are essential to humankind for both biological and commercial reasons.

For the survival of many plant species and overall maintenance of the biodiversity in ecosystems, plant-pollinator networks are essential. Social wasps and bees are unique in these networks because of their extensive foraging range and exceptional connectedness. These insects visit a wide variety of flowering species, as they are generalist pollinators, in contrast to many other pollinators, which may specialize in certain plants. This inclination is strongly associated with their social structure, in which numerous foraging workers gather nectar from the most abundant plant species within their area from a single nest. With a great deal of overlap between the plants and their pollinators, these wasps and bees build a network of plants and pollinators that is more resilient to disturbances or extinctions on both sides of the mutualistic interaction. In environments that are fragmented or deteriorated, social wasps may become more common than bees, and they are important 'backup' pollinators that help maintain the integrity of ecosystems (Brock et al. 2021).

Despite the ecological importance of wasps and bees, studies on their diversity and distribution pattern in different habitats remain limited in the northeastern region of India. In this context, the present study was conducted with a focus on the following objectives: 1. to document and identify the Vespidae and Apidae species, and 2. to highlight their diversity and distribution patterns across different habitat types.

MATERIALS AND METHODS

Study area

Kamrup Metropolitan District of Assam comprises various habitats that harbor a rich variety of flora and fauna, and the Gauhati University campus encompasses an array of ecosystems, including wetlands, rugged landscapes, green spaces, and human habitats. The region has an abundance of both native and cultivated vegetation. Spreading over an area of 508.8 ac, the Gauhati University campus is situated at 26.154° N and 91.663° E. The campus lies on the southern bank of the river Brahmaputra towards the northern edge of the Shillong Plateau in the southwestern corner of the Kamrup Metropolitan District of Assam, India. The elevation of the area is 45 m. Temperature ranges 10.6–32 °C, and annual average precipitation is 300–400 mm (Hazarika & Kalita 2018). Natural habitats in the University Campus include hills, marshes, grasslands, forests and small to medium-sized ponds (Hazarika & Kalita 2018) along with human-modified habitats like gardens, residential areas. The campus of Gauhati University exhibits a vast diversity of fauna, particularly insects. In the present study, the insects were surveyed and collected from eight study sites located in four

Table 1. Study sites with geographic coordinates within the Gauhati University campus.

Study site	Habitat type	Geographic coordinates
Site 1	Garden	26.152° N, 91.661° E
Site 2	Garden	26.154° N, 91.660° E
Site 3	Garden	26.151° N, 91.669° E
Site 4	Grassland	26.154° N, 91.659° E
Site 5	Grassland	26.153° N, 91.664° E
Site 6	Grassland	26.154° N, 91.668° E
Site 7	Residential Area	26.153° N, 91.671° E
Site 8	Areas adjacent to wetlands	26.155° N, 91.669° E

distinct habitats: 1) gardens, 2) residential areas, 3) grasslands, and 4) areas adjacent to wetlands within the university campus (Table 1).

Insect collection and identification

Four plots of 100 x 100 m for each of the eight study sites were selected randomly, from which the surveys were conducted from March 2022 to February 2023 at 0800–1700 h and were repeated two to three times a week. The microhabitats from which the insects were observed and collected were recorded. The insects were collected by sweeping using insect collecting nets and were sacrificed in killing jars using benzene/ethyl acetate (Kumar et al. 2015). The sacrificed insects were kept in insect envelopes with proper labelling mentioning the date, time and site of collection, geographic coordinates, and the name of the collector. These were then preserved dry using naphthalene and carbolic acid in appropriate boxes (Kumar et al. 2015). In the laboratory, the specimens were pinned and mounted to display appropriately and observed under a Leica stereo zoom microscope for identification. The specimens were identified using taxonomic keys and diagnostic features available (Bingham 1897; Carpenter & Cumming 1985; Das & Gupta 1989; Carpenter & Nguyen 2003; Kumar & Sharma 2015; Kumar et al. 2015; Pannure et al. 2016).

Data analysis

An independent-samples Kruskal-Wallis test was used to test whether the relative abundance across the four habitat types differs significantly. Post hoc pairwise comparisons were conducted using Dunn's test to identify which habitat types differ significantly. The significance level was set at 0.05. Statistical analysis was performed using IBM SPSS Statistics 20 software. Shannon-Weiner index (H´), Pielou's index (J´), Margalef's index (R), Simpson's index (1-D) and Brillouin index (HB) were calculated using the PAST4.17 programme.

RESULTS AND DISCUSSION

In this study, a total of 71 individuals were documented, representing 17 species, 10 genera, and three subfamilies within the family Vespidae, as well as six species, three genera, and two subfamilies under the family Apidae from the four habitats of Gauhati University campus (Table 2). These findings are comparable to earlier reports (Kumar & Sharma 2014, 2015; Kumar et al. 2015; Siddiqui et al. 2015; Gawas et al. 2020; Mazumdar et al. 2021) from this region and other parts of Indian subcontinent. The findings of this study indicate that the subfamily Polistinae within the family Vespidae with nine species (Table 2; Figure 1) is the most dominant group in the study area. Mazumdar et al. (2021) also reported 40 species of Polistinae from six northeastern states of India including Assam. This dominance can be attributed to their social structure, which enables them to utilize resources and maintain colonies efficiently and their adaptability to various habitats.

The high abundance and diversity of wasp and bee species in the human-modified habitats (gardens and residential areas) (Table 3; Figure 2 & 3), suggest their preference for these habitats. This is congruent with the role of these species as essential pollinators in both natural and human-modified ecosystems (Khan et al. 2020). The relative abundance of the species across the four habitats were found to differ significantly (Independent-Samples Kruskal-Wallis test: $p = 0.001$). Post-hoc pairwise comparisons (Dunn's test) (Table 4) revealed that significant difference in relative abundance of the species occurred between four pairs of habitats (garden & grassland, garden & area adjacent to wetland, grassland & residential area, residential area & area adjacent to wetland) ($p < 0.05$). These findings suggest that habitat heterogeneity significantly influences species distribution, with distinct assemblages associated with specific habitat types.

The species diversity, richness, and evenness across various habitats differ to some extent (Gawas & Gupta 2022). In the present study, residential areas were found to have the highest species diversity and richness with a Shannon-Wiener Index of 3.394 and Margalef's Index of 6.188, respectively (Table 5). These areas are also relatively evenly diverse with Pielou's Evenness Index of 1.295 (Table 5). Gardens are not far behind the

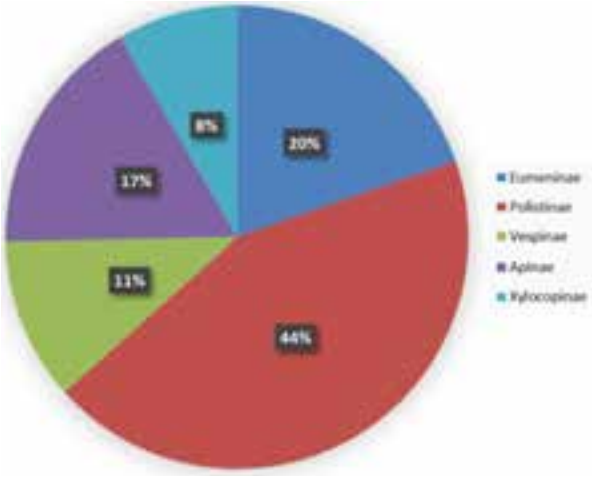

Figure 1. Subfamily-wise percentage occurrence of wasp and bee species found in the Gauhati University campus.

residential areas in terms of species diversity, with a Shannon-Wiener Index of 3.246 and a Margalef's Index of 5.592 (Table 5). This is likely due to the availability of diverse foraging and suitable nesting resources such as ornamental plants, buildings, and other man-made structures. This also infers the ecological success of these species in adapting to urban environments. The natural habitats (grasslands and areas near wetlands) have lower species richness and diversity, with a much lower Shannon-Wiener and Margalef's indices (2.208

Table 2. List of wasp and bee species recorded in the four habitats of Gauhati University campus.

Family	Subfamily	Species
Vespidae	Eumeninae	*Allorhynchium argentatum*
		Antodynerus flavescens
		Antodynerus limbatus
		Labus pusillus
		Phimenes flavopictus
		Rhynchium brunneum
	Polistinae	*Parapolybia varia*
		Polistes olivaceus
		Polistes sagittarius sagittarius
		Polistes wattii
		Ropalidia cyathiformis
		Ropalidia fasciata
		Ropalidia jacobsoni
		Ropalidia ornaticeps
		Ropalidia stigma
	Vespinae	*Provespa barthelemyi*
		Vespa tropica leefmansi
Apidae	Apinae	*Apis cerana*
		Apis dorsata
		Tetragonula iridipennis
	Xylocopinae	*Xylocopa latipes*
		Xylocopa aestuans
		Xylocopa fenestrata

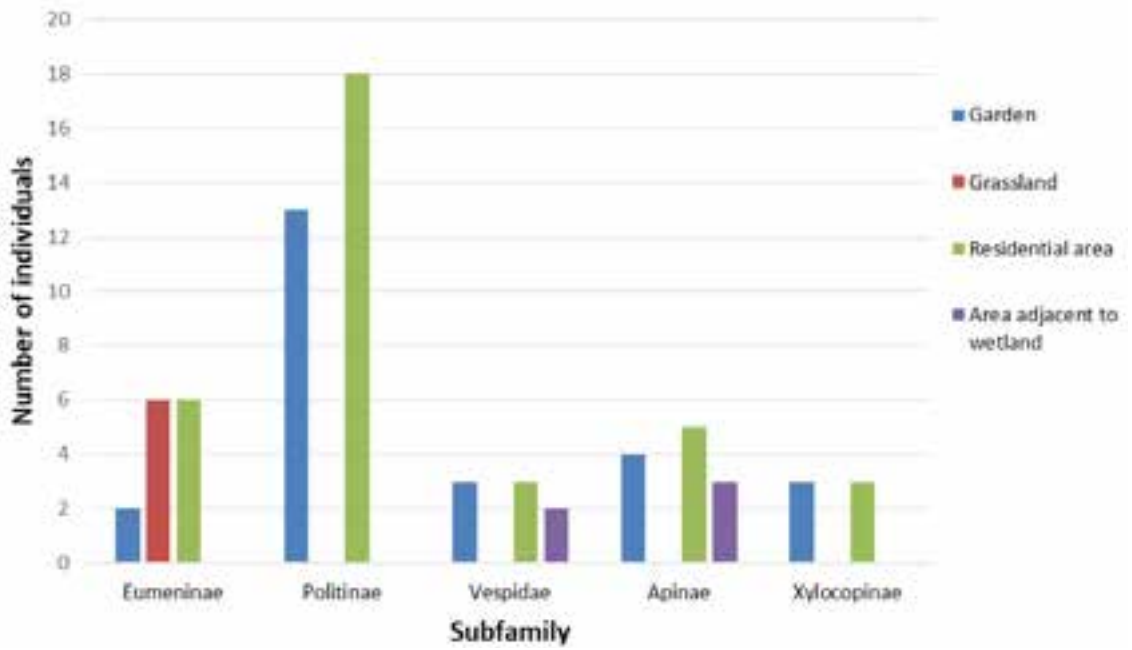

Figure 2. Abundance of each of the subfamilies in the four habitats of Gauhati University campus.

Table 3. Habitat-wise distribution of wasp and bee species found in the Gauhati University campus.

Species	Habitat							
	Garden		Grassland		Residential area		Area adjacent to wetland	
	Abundance	Relative abundance (%)	Abundance	Relative abundance (%)	Abundance	Relative abundance (%)	Abundance	Relative abundance (%)
Allorhynchium argentatum	0	0	1	16.66	1	2.86	0	0
Antodynerus flavescens	0	0	1	16.66	1	2.86	0	0
Antodynerus limbatus	0	0	1	16.66	1	2.86	0	0
Labus pusillus	0	0	1	16.66	1	2.86	0	0
Phimenes flavopictus	1	4	1	16.66	1	2.86	0	0
Rhynchium brunneum	1	4	1	16.66	1	2.86	0	0
Parapolybia varia	2	8	0	0	2	5.71	0	0
Polistes olivaceus	2	8	0	0	2	5.71	0	0
Polistes sagittarius sagittarius	2	8	0	0	2	5.71	0	0
Polistes watti	2	8	0	0	2	5.71	0	0
Ropalidia cyathiformis	1	4	0	0	2	5.71	0	0
Ropalidia fasciata	1	4	0	0	2	5.71	0	0
Ropalidia jacobsoni	1	4	0	0	2	5.71	0	0
Ropalidia ornaticeps	1	4	0	0	2	5.71	0	0
Ropalidia stigma	1	4	0	0	2	5.71	0	0
Provespa barthelemyi	1	4	0	0	2	5.71	1	20
Vespa tropica leefmansi	2	8	0	0	1	2.86	1	20
Apis cerana	1	4	0	0	2	5.71	1	20
Apis dorsata	1	4	0	0	2	5.71	1	20
Tetragonula iridipennis	2	8	0	0	1	2.86	1	20
Xylocopa latipes	1	4	0	0	1	2.86	0	0
Xylocopa aestuans	1	4	0	0	1	2.86	0	0
Xylocopa fenestrata	1	4	0	0	1	2.86	0	0

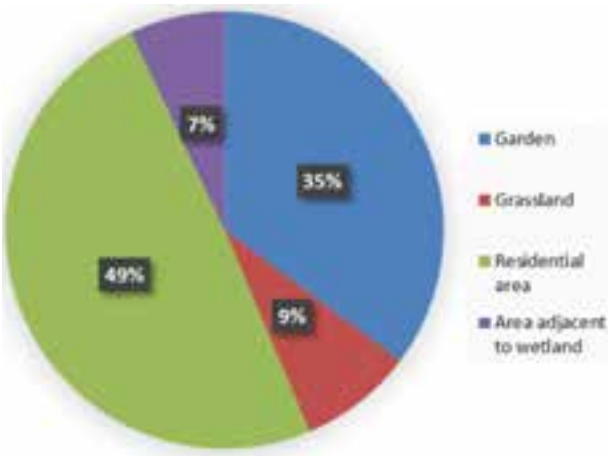

Figure 3. Percentage composition of wasps and bees across the four habitats of Gauhati University campus.

and 2.009, respectively) (Table 5). Pielou's Evenness Index of these two habitats (1.517 and 1.492) (Table 5) reflects the lowest species richness and diversity. This may indicate lesser preference, limited resources or more competition in these regions.

Simpson's and Brillouin indices (Table 5) also supports this data, where the diversity of these species is high in residential areas and gardens and low in grasslands and wetland adjacent areas. This indicates that ecological niches that are man-made, including gardens and residential areas, are capable of supporting many wasp and bee species, and these species can be distributed rather evenly, while ecological niches that are more natural, such as grasslands and wetlands, can support only a few dominant species. This is congruent

Table 4. Pairwise Kruskal-Wallis p-values between habitat types.

Habitat	p-value	Significance
Garden vs. Grassland	0.010	+
Garden vs. Area adjacent to Wetland	0.005	+
Grassland vs. Residential area	0.005	+
Residential area vs. Area adjacent to wetland	0.003	+
Garden vs. Residential area	0.831	
Grassland vs. Area adjacent to Wetland	0.831	

Table 5. Diversity indices of wasp and bee species found in the Gauhati University campus.

Diversity indices	Garden	Grassland	Residential area	Area adjacent to the wetland
Shannon-Weiner index	3.246	2.208	3.394	2.009
Pielou's index	1.352	1.517	1.295	1.492
Margalef's index	5.592	2.791	6.188	2.485
Simpson's index	0.98	1.000	0.9798	1.000
Brillouin index	2.154	1.097	2.395	0.957

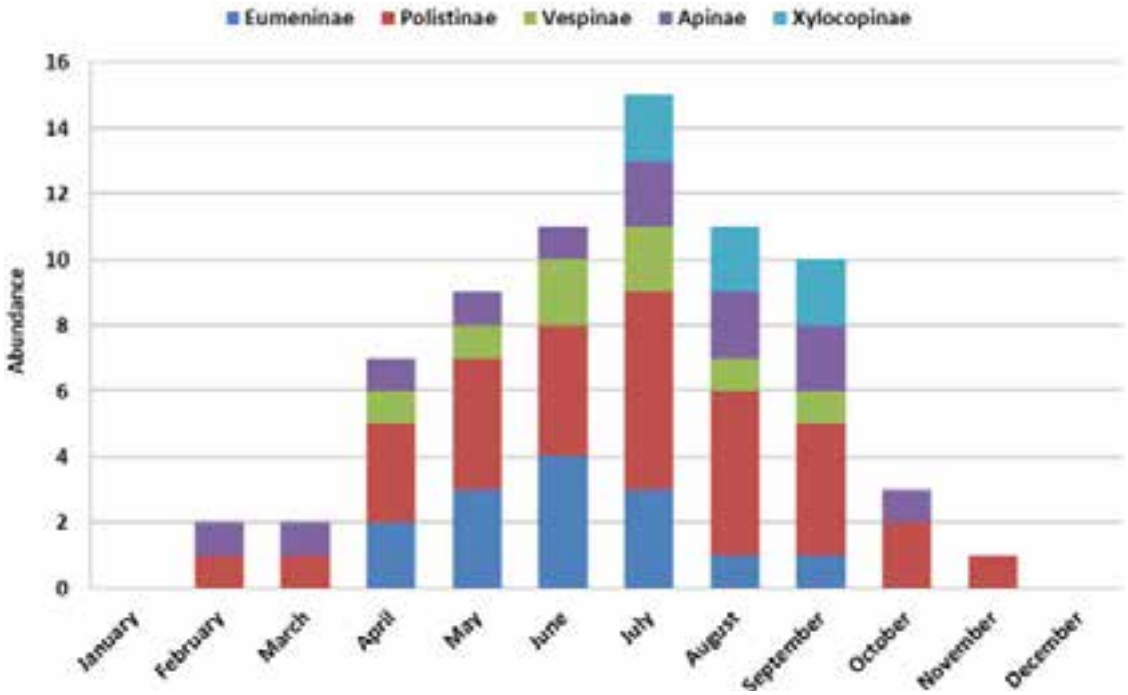

Figure 4. Month-wise abundance of wasp and bee subfamilies across the four habitats of Gauhati University campus.

with earlier studies (Jacques et al. 2017), where they reported high diversity of wasps in anthropized habitats like agricultural fields.

The high abundance of wasps and bees in the months of April–September and very low in the months of October–March (Figure 4) indicates that these insects mostly prefer warm and humid conditions for foraging, nesting, and reproduction. In this study, it was found that social wasp species initiate colonies in spring, colony growth and foraging activity peak in mid to late summer and starts declining in autumn, which was also reported by Spradbery (1973).

The findings of this study add valuable data to the wasp and bee diversity of the Gauhati University campus, which will help in continuous monitoring and conservation efforts for these ecologically important species in this region. Habitats such as residential areas and gardens, which support a wide array of these species, should be protected and managed sustainably.

This study is the first report on the diversity and distribution of wasps and bees, their habitat-wise diversity comparisons from the Gauhati University campus and is also one of the few such studies conducted from Assam, filling a critical gap in the existing literature from this region. The findings of this study provide a baseline for future research on the distribution and diversity of wasp and bee species from this region and contribute to a deeper understanding of the ecological roles of these species. The results of this study are based on a single year of data collection and a restricted geographic scope. So, further studies with increased duration of data collection, a broader geographic region

and exploring the underlying factors contributing to the higher abundance and diversity of these species in human-modified habitats is encouraged.

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COMMUNICATION

Unveiling genital specializations in *Megascolex travancorensis* (Oligochaeta: Megascolecidae) through scanning electron microscopy

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Abstract: When an earthworm reaches reproductive age, its clitellum, also referred to as the genital collar, observably enlarges and becomes more glandular. Genital features in Megascolecidae, including male and female pores, papillae, grooves, and glandular thickenings, show species-specific patterns linked to reproduction, thereby serving as important characters in taxonomy and systematics. This work uses comprehensive scanning electron microscopy (SEM) images to investigate the male reproductive anatomy of *Megascolex travancorensis* Michaelsen, 1910. A slit-shaped male pore located on a raised genital papilla, paired prostatic ducts, a seminal groove, retracted penial setae, and eye-like genital marks on segment 18 are among the distinctive morphological features highlighted in the investigation. Fine-scale structural adaptations have been shown by SEM, which has also helped to classify accurately the genus *Megascolex* taxonomically and provide important information about reproductive morphology.

Keywords: Clitellum, earthworms, genital papilla, penial setae, prostatic ducts, reproduction, seminal groove, taxonomy, tubercula pubertatis.

സംഗ്രഹം: ഒരു മണ്ണിര പ്രത്യുൽപാദന പ്രായത്തിലെത്തുമ്പോൾ, ജനനേന്ദ്രിയ കോളർ (clitellum) ശ്രദ്ധേയമായി വലുതാകുകയും കൂടുതൽ ഗ്രന്ഥികളുള്ളതായി മാറുകയും ചെയ്യുന്നു. മെഗാസ്കോലെസിഡേയിലെ ജനനേന്ദ്രിയ സവിശേഷതകൾ, ആൺ-പെൺ സുഷിരങ്ങൾ, പാപ്പില്ലകൾ, നാളങ്ങൾ, എന്നിവ പ്രത്യുൽപാദനവുമായി ബന്ധപ്പെട്ട സ്പീഷീസ്-നിർദ്ദിഷ്ട പാറ്റേണുകൾ കാണിക്കുന്നു, അത് ടാക്സോണമിയിലും സിസ്റ്റമാറ്റിക്സിലും പ്രധാന സവിശേഷതകളായി പ്രവർത്തിക്കുന്നുണ്ട്. *Megascolex travancorensis* Michaelsen 1910 ന്റെ പുരുഷ പ്രത്യുത്പാദന ശരീരഘടനയെക്കുറിച്ച് അന്വേഷിക്കാൻ ഈ ലേഖനം സമഗ്രമായ സ്കാനിംഗ് ഇലക്ട്രോൺ മൈക്രോസ്കോപ്പി (SEM) ചിത്രങ്ങൾ ആണ് ഉപയോഗിച്ചിരിക്കുന്നത്. ജനനേന്ദ്രിയ പാപ്പില്ലയിൽ സ്ഥിതി ചെയ്യുന്ന ഒരു സ്ലിറ്റ് ആകൃതിയിലുള്ള പുരുഷ സുഷിരം,രണ്ട് പ്രോസ്റ്റേറ്റ് നാളങ്ങൾ, ഒരു സെമിനൽ നാളി, പിന്നോട്ട് ഉൾവലിഞ്ഞ് സ്ഥിതി ചെയ്യുന്ന penial seta, segment 18 ലെ കണ്ണ് പോലുള്ള ജനനേന്ദ്രിയ അടയാളങ്ങൾ എന്നിവ അന്വേഷണത്തിൽ എടുത്തുകാണിച്ചിരിക്കുന്ന വ്യതിരിക്തമായ രൂപഘടന സവിശേഷതകളാണ്. Megascolex genus നെ വർഗ്ഗീകരണപരമായി കൃത്യമായി തരംതിരിക്കാനും പ്രത്യുൽപാദന രൂപഘടനയെക്കുറിച്ചുള്ള പ്രധാന വിവരങ്ങൾ നൽകാനും SEM മുഖേന സഹായിച്ചിട്ടുണ്ട്.

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Author contribution: Jaya Manazhy and Aja Manazhy conceptualized the study and contributed to the review and editing of the manuscript. Sona Sajeev conducted the field study, performed SEM analysis, curated the data, prepared visualizations, and wrote the original draft. John Warren Reynolds provided resources and contributed to the review and editing. Santhosh Punnakattu Parambil contributed to data analysis and manuscript editing

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INTRODUCTION

Hermaphroditism and the presence of a clitellum, a specialized reproductive structure, are the main characteristics that set oligochaetes apart from polychaetes (Reynolds 1974). With more than 5,000 species of terrestrial earthworms, the oligochaetes make up about one-third of the phylum and are the second largest group within Annelida (Reynolds & Wetzel 2025). Their wide range of terrestrial environments highlights their astounding adaptability and ecological significance. The clitellum, a noticeable glandular growth near the front end of their reproductive system, is a crucial component that emerges at sexual maturity. Earthworms produce eggs for a large portion of the year and are regarded as either continuous or semi-continuous breeders (Olive & Clark 1978). Their reproductive activity is greatly influenced by environmental conditions, especially soil temperature and moisture content (Reynolds 2022).

The ventral or ventrolateral surface contains pairs of genital markings, which are external apertures for reproductive exchange, indicating their hermaphrodite characteristics. These apertures and related features display morphological characteristics unique to each species, which are useful in systematics and taxonomy. Genital features that are frequently connected to glands, such as discs, pits, grooves, or pads, are useful for identifying species (Blakemore 2006). Male genital area configuration and sperm transfer requirements are frequently correlated with the shape and location of these characteristics. Male pore arrangements vary; the megascolecine type has both male and prostatic pores on segment 18, but the acanthodriline, microscolecine, and balantine forms have them separated or relocated to segments 17 or 19, occasionally connected by seminal grooves or changed by segmental displacement. In Megascolecidae, the male pores may be associated with prostatic pores, both of them may appear on raised papillae or ridges, and posing tubular or racemose prostates which in turn associated with the posterior ends of vasa defentia. The megascolecids often possess various markings at sexual maturity in the form of tubercles which are the glandular thickenings on the ventral surface and situated both sides or on the clitellum (Figure 1).

There are studies available to identify oligochaetes morphologically across various regions of the world (Gates & Reynolds 2017; Khan et al. 2022; Kamal et al. 2023; Rathour & Julka 2024; Narayanan et al. 2025). There is still a dearth of ultrastructural research on earthworm reproductive architecture in the body of literature, which indicates a lack of thorough microscopic morphological characterization. In-depth ultrastructural examination of genital characteristics, especially with scanning electron microscopy (SEM), allows for accurate characterization of minute surface details such glandular areas, pore shape, and related textures, these are the aspects that conventional light microscopy frequently fails to discern. Proper sample preparation is essential to ensure accurate SEM imaging, minimizing artifacts and enhancing structural clarity. SEM is, therefore, an essential tool for researching the reproductive morphology of earthworms and enhancing species-level identification. The present study aims to characterize the ultrastructural morphology of the selected species, thereby providing insights into their taxonomic and functional significance.

Image 1. An aclitellate adult of *Megascolex travancorensis* on a *Macaranga tanarius* (L.) Müll. Arg. leaf. © Sona.

MATERIALS AND METHODS

Earthworms with well-developed clitellum were obtained from the soil by digging and hand sorting methods (Reynolds 1977, 2022), and also searching in organic micro habitats like leaf litter. Out of the 30 samples collected, ten well-developed clitellate adult specimens were preserved in 10% formaldehyde for further identification using a light microscope and each sample was assigned a code . The type specimens were deposited in Zoology Museum, Sree Kerala Varma College, Thrissur, Kerala with deposition number

THS_{20}1. For SEM analysis, two specimens were fixed in 5% glutaraldehyde ($C_5H_8O_2$) for 30 minutes to preserve ultrastructural details. Following fixation, the dissected clitellum was washed thoroughly and dehydrated using an ascending ethanol series. Specimens are mounted on to SEM stubs using conductive adhesive like carbon taps and coated with a thin layer of conductive material (gold/palladium) using a sputter coater to enhance image quality and reduce charging effects. Prepared samples are placed in the SEM chamber, where they are scanned by the electron beam to generate high-resolution images. The secondary soil data from various localities were obtained from the data provided by the Soil Survey Organisation Agriculture Department (Premachandran 2007). Observations were carried using Carl Zeiss EVO 18 Research SEM (Central laboratory for Instrumentation and facilitation, University of Kerala) and magnified the sample from 10X to 5K X.

RESULTS

Morphological identification by Light microscopy

Family Megascolecidae Rosa, 1891

(Diagnostic features from: descriptions of Stephenson 1923; Gates 1972; Blakemore 2006; Reynolds 2022 and also present observation)

Diagnostic Features

Dorsal pores: present

Male pores: male pores may be united with prostatic pores, paired or unpaired, commonly on 18, rarely on 19 or 20, behind female pores.

Setae: lumbricine or perichaetine.

Clitellum: annular, multilayered.

Nephridia: holoic or meroic.

Intestinal origin: behind ovarian segment.

Gizzard: Oesophageal gizzard(s) present; intestinal gizzard(s): present, or absent.

Last hearts: behind segment 11.

Calciferous glands: present or absent.

Ovaries: in 13, mostly fan shaped and with numerous egg strings.

Spermathecae: single, paired, or multiple; diverticulate (or rarely with intramural sperm chambers),

Prostates: present, tubular to racemose.

Remarks: The position of male pore and nature of prostate are the diagnostic features.

Genus *Megascolex* Templeton, 1844

(Diagnostic Features from: descriptions of Stephenson 1923; Aiyer 1929 and also present observation)

1844. *Megascolex* –Templeton, Proc. Zool. Soc. London, 12(1844): 89.

1895. *Megascolex* – Beddard, Monogr. Oligochaeta, p. 370.

1900. *Megascolex* – Michaelsen, Oligochaeta, Das Tierrich, p. 212.

1907. *Megascolex* – Michaelsen, Fauna S W Australia 1: 168.

1909. *Megascolex + Lampito* – Michaelsen, Mem. Indian Mus. 1: 178.

1916. *Megascolex* – Michaelsen, Mjobeg s Australia Exp. 52: 57.

2009. *Megascolex* – Ramasamy, Doctor of Philosophy in Zoology, Tamilnadu, India, p. 99.

Diagnostic features

Setae: perichaetine.

Spermathecal pores: 1–5 pairs between segments 4–9.

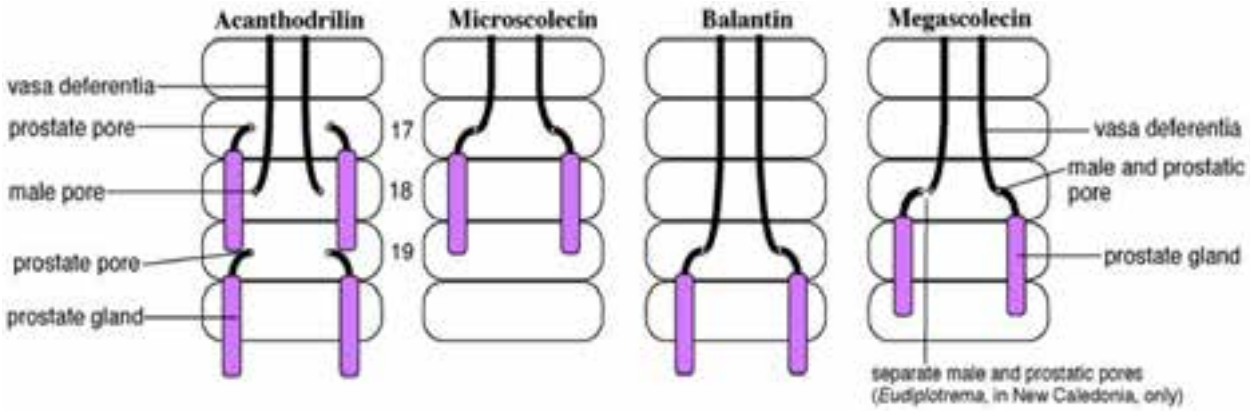

Figure 1. The chief arrangements of prostatic and male pores in the Megascolecidae, Megascolecinae, and Acanthodrilinae (Jamieson 2001).

Gizzard: one in 5, 6 or 7.

Nephridia: meroic.

Prostate: racemose to tubulo-racemose.

Previous records: India (Southern India, Bombay, eastern Himalaya), Australia, Ceylon, Tasmania, northern Island of New Zealand, southwestern Asia, and the Malay Archipelago.

Megascolex travancorensis Michaelsen, 1910

Redescription

1910. *Megascolex travancorensis* f. *typica* Michaelsen, Abh. Ver. Hamburg 19 (5): 72.

1913. *Megascolex travancorensis* var. *typicus*- Michaelsen, Mt. Mus. Hamburg 30(2): 85.

Collectors' name: Sona Sajeev.

Date of collection: 29.iv.2024.

General habitat: coconut plantation (*Cocos* sp.), cultivated area.

Soil texture: gravelly sandy clay, sandy clay loam, clay loam, gravelly clay and sand.

Physiography: low land, mid upland, mid land, mountainous region (classification based on Soil Survey Organisation Agricultural Department, Premachandran 2007).

(Diagnostic Features from: descriptions of Stephenson 1923 and also present observation)

External Features

Size: 80–140 mm; preclitellar region: 2 mm; clitellar region: 3 mm; post clitellar region: (1–2 mm).

Number of segments: 120–280, segment 2–5 biannular; 5–13 triannular.

Pigmentation: dark grey before preservation, unpigmented (Image 1).

Prostomium: epi-tanylobous.

Setae: perichaetine, 16 setae per segment in the middle of the body, However, anterior segments (= up to the segment 25) the setae in lumbricine arrangement (Figure 2).

First dorsal pore: 4/5 (3/4 in one specimen).

Clitellum: well, developed in segments 13–18 (= 6); in some specimens overlapping the male genital markings.

Male pores: in 18 on slightly elevated cushions extended to segment 19, in *ab*, *bc* and extends to ¾ of *cd* on each side which are ellipsoidal, their inner borders approximated and parallel, both cushions together almost fill up a somewhat depressed median area, which is bounded laterally and in front by a slight wall.

Female pores: paired.

Spermathecal pores: two pairs, between a and b, in 7/8 and 8/9, about ½ of the circumference apart.

Genital marking: pair of elevated markings in segments 17, 18 and 19 at more or less at cd in which it is highly ornamented with folding and wrinkles forming the shape of an eye at the base (= 19).

Internal Anatomy

Septa: 6/7 – 12/13 highly thickened, 13/14 and 14/15 moderately thickened.

Gizzard: large in 6.

Calciferous glands: absent.

Testis and funnels: free in 10 and 11.

Seminal vesicle: compactly racemose in 11 and 12.

Spermathecae: spermathecal ampulla large, pear-shaped and usually much bent at its ectal end; duct still thinner, very short, mostly concealed in the body-wall; diverticulum enters the ectal end of ampulla; is narrowly club-shaped and somewhat bent at its ectal end; a mass at the ectal end of ampulla seems to represent an incompletely formed spermatophore.

Prostates: racemose in the 17 and part of the following segments with three to five incisions to form lobes.

Ovary: two pairs in 13 and 14.

Penial setae: absent.

Remarks: The spermathecae similar to *Megascolex konkanensis.* The form of tubercula pubertatis is also a notable feature of the type species *M. travancorensis*. In some specimens, we noticed a digitiform projection in the segments 15/16/17/18. The actual function of these structures is not known and may be a genital marking or an artifact.

Previous records: Southern India.

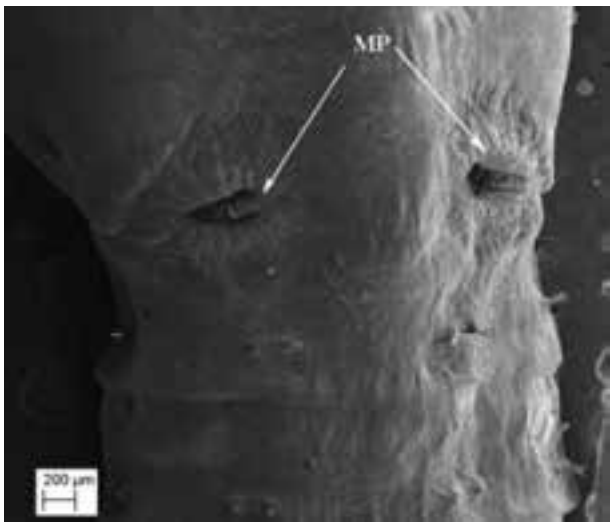

Image 2. Male pore of *Megascolex travancorensis*; MP—Male pore. © Sona.

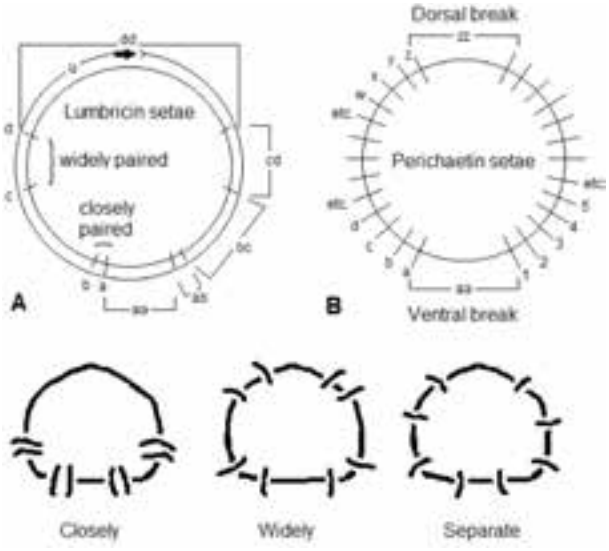

Figure 2. Arrangement of setae: Setae may be closely paired, widely paired, or separate (A, left). Perichaetine arrangement (B, right). The pheretimoid earthworms have numerous setae (as many as 150) per segment. Perichaetin setae are arranged in a ring, circumventing all segments of the specimen (with the exception of the first and last segments). The numbers of setae vary slightly from one segment to another and from one specimen to another. Within specimen variations are usually largest in the pre-clitellar region. The closest seta to the mV is a and they increase to the mL; the seta closest to the mD is z and they decrease to the mL. Sournce: Reynolds, 2022.

Present collection: Thiruvananthapuram, Kollam, Pathanamthitta (south), Thrissur, Palakad (central), Kerala, southern India.

Ultramorphological analysis of genital pore using SEM

Male genital area is highly ornamented with folding, wrinkles, and grooves associated with more pronounced genital marking (Image 2). Although the eye shaped marking is visible by light microscopic analysis, the associated pores and furrows are inconspicuous. The exact segmental location, shape, pattern, and associated structures furnish useful taxonomic characteristics. The extension of clitellar glandular tissue in segments 13–18 overlapping the male genital markings on segment 18 suggests a close structural association between the clitellum and reproductive pores reflecting the genital specialization especially in the genus *Megascolex*. By ultrastructural analysis, the male pore is clearly visible on segment 18 as a small slit with a magnification of 60 X and slightly raised on a male genital papilla that slightly extended to segment 19 (Image 3A,B). Here, tubercula pubertatis appears as a pair of glandular thickened ridges arises on the segments 17–19. Seminal groove seen as a shallow channel that starts from the male pore and runs anteriorly towards the clitellum (Image 3B, 370 X)

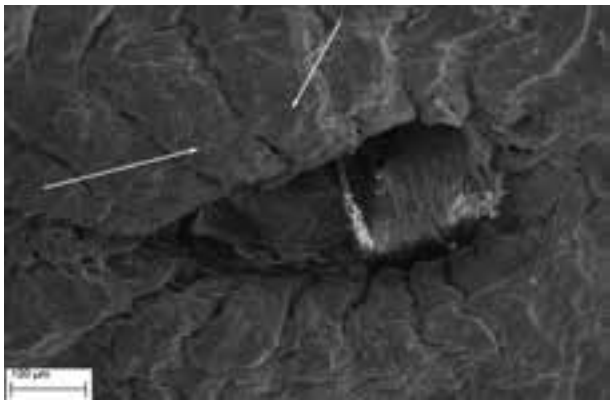

Image 3A. Genital papilla of *Megascolex travancorensis*. © Sona.

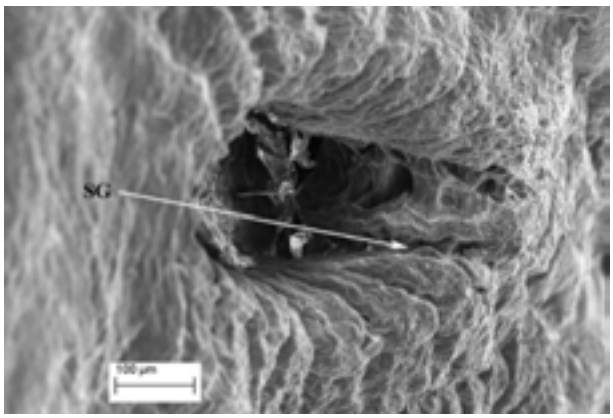

Image 3B. Seminal groove on segment 18 of *Megascolex travancorensis*; SG—Seminal groove. © Sona.

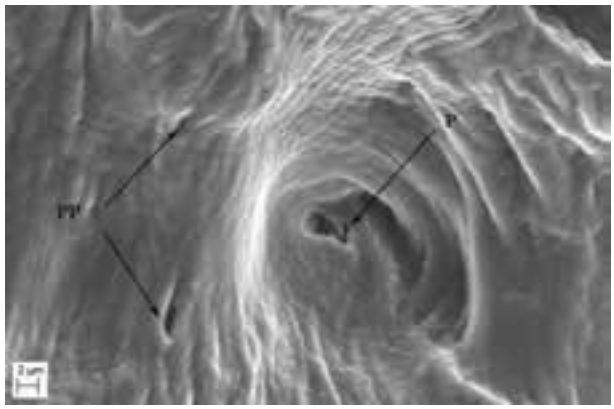

Image 4. Prostatic pore and Penial pore of *Megascolex travancorensis*; PP—Prostatic pore | P—Penial groove. © Sona.

and that helps in transferring sperm during copulation. Prostatic ducts appear as two lateral grooves one above the other from the paired prostatic lobes (Image 4). A deep pore is seen near to the prostatic pore may be the

Image 5A. Female pore on segment 13 of Megascolex travancorensis; FP—Female pore. © Sona.

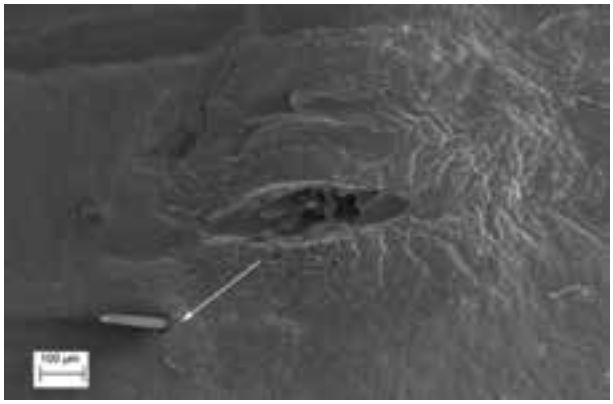

Image 5B. Female pore on segment 13 of *Megascolex travancorensis* at 'ab.' © Sona.

indication of the retracted penial setae (Image 4, 5KX).

DISCUSSION

Similar possibility discussed by Gates (1972) in 'Burmese earthworms' that male chambers may be eversible into characteristic porophores and may contain protrusible penes. Erséus (1981) discussed that *Bathydrilus rohdei* is provided with an X-shaped mid-ventral slit that, corresponds to the location of the tips of the penial setae of the mate. There are previous reports available for specialized genital setae and related glands that make up the sexual papillae may be used to inject sperms into the mate (Cosín et al. 2011). Ambreen et al. (2004) reported that the variations in genital papilla in the genus *Pheretima* (sensu lato) may contribute to species identification. Similar to our study, Yáñez et al. (2006) and Caramelo & Martínez-Ansemil (2012) used scanning electron microscopy to study particular mating structures and sperm transmission processes in aquatic microdriles, exposing copulation-related ultrastructural adaptations and specialized attachment features.

It should be noted that the families Ocnerodrilidae, Acanthodilidae, Octochaetidae, and Megascolecidae, the male pores are associated with the prostatic pores (Julka 1988). In megascolecids with the 'megascolecine' arrangement showed each type of gland connects to the male pores by a muscular prostatic duct that receives sperm from the testis via the vasa deferentia that often joins the duct near the junction with the gland and one pair of male and prostatic pores combined on segment 18 (Blakemore 2006). Here we can observe that, although *M. travancorensis*, there are separate pores of prostatic ducts and later joins with vasa deferentia to the exterior as male pore (see Image 2 and Image 4). Lone et al. (2022) reported high intra specific divergence for *M. travancorensis*. Female pores also clearly demarcated on 13 (Image 5A), however, not much ornamented and associated setae at ab (Image 5B). Because of its less physical diversity across species and relatively conserved position, the female pore is often regarded as having minimal taxonomic relevance. This work provides important taxonomic and systematic insights into *M. travancorensis*'s distinctive reproductive morphology by highlighting the genital markings and related structures in and around the clitellum.

CONCLUSION

Highly specialized and decorated genital characteristics that are important for species identification and reproductive function are revealed by the ultrastructural investigation of *M. travancorensis*. The male genital region is complex, as indicated by the existence of paired prostatic ducts, a seminal groove, and eye-shaped genital marks. Small structural adaptations such as retracted penial setae, lateral prostatic pores, seminal grooves, and glandular papillae can be found with SEM imaging. These discoveries provide useful taxonomic markers within the genus *Megascolex* and advance our knowledge of earthworm reproductive characteristics. Moreover, the distinct genital specializations observed may represent adaptations for efficient sperm transfer, mate recognition, and reproductive isolation, thereby offering insights into phylogenetic relationships.

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REVIEW

Diversity and distribution of climbers of Uttar Pradesh: a preliminary review

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Abstract: Uttar Pradesh (UP) is one of the largest states in India. Based on vegetation types, the state is divided into four main regions: the Terai Region, Gangetic Plains, Vindhyan, and Semi-arid Regions. These regions harbour a rich diversity of unique and interesting plant species. Climbing plants, owing to their distinctive features, have long fascinated ecologists and evolutionary biologists. Interest in these unique plants has surged notably over the past two decades, leading to a significant increase in research on these climbing species in the country. The current state of knowledge on climbers in Uttar Pradesh remains fragmented, with most available studies providing only isolated and sporadic information. In the present study, an attempt has been made to provide insights into the diversity and distribution of climbers across the four regions of Uttar Pradesh based on a literature survey. The study revealed a total of 344 climbing species (including 12 infraspecific taxa) belonging to 169 genera under 42 families and 23 orders across four regions of the state. Fabaceae was the most diverse family with 39 genera, followed by Apocynaceae with 24 genera. *Ipomoea* was the most speciose genus with 23 species. Climbers are an important group of plants with varied climbing mechanisms. They range from ornamental vines to medicinally important plants having significant cultural and economic value. The information gathered from the study would provide baseline data for future climber-based research in India.

Keywords: Annual and perennial plants, biodiversity, floristic composition, medicinal, ornamental, plant biodiversity, species diversity, vegetation zones.

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Author contribution: Rameshwar Prasad conceptualizing the data, collecting the secondary data, drafting and prepared original manuscript; Muzeev Ahmad supervised the study, editing the draft and original manuscript; Sushma Verma collecting the secondary data, drafting and editing the original manuscript; KM Prabhukumar editing the draft and original manuscript; TS Rana conceptualizing the data, supervised the study, editing the original manuscript.

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INTRODUCTION

Climbers, whether annual or perennial, lack self-supporting stems and depend on external structures for vertical growth with diverse climbing mechanisms—branch twiners, stem twiners, tendril climbers, root adhesive climbers, hook climbers, and scramblers (Bongers et al. 2005; Jongkind & Hawthorne 2005). Some genera also bear thorns or rootlets that do not aid in climbing. Overall, climbers exhibit a wide variety of growth strategies (Roy 2019).

This group of plants has independently evolved a climbing habit in several plant families, utilizing various methods to compensate for their weak stems. Climbers are an important group of plants whose structural support does not rely solely on their own tissue. They originate from a rooting position in the soil or a surface near the soil, and their climbing efforts allow them to reach the canopies of trees, carrying their foliage and reproductive organs (Burnham 2009).

Ornamental climbers are both annual and perennial types and possess special structures such as tendrils, thorns, and flowers that enable them to climb on a support. These plants enhance the beauty of gardens with their attractive flowers and foliage, evoking a sense of elegant old-world charm in any landscape. A well-maintained and healthy climber can be a delightful addition to the scenery, while it is advisable to avoid poorly adapted, diseased, or withered specimens. There is a wide variety of ornamental climbers available, catering to evolving tastes, fashion trends, and landscape design concepts. Regardless of their attractiveness and interest, climbers must be properly placed in relation to the land's conformation, ridges, and buildings (Bhattacharjee 2004). Moreover, these plants also hold historical significance, as they contribute to the allure of ancient buildings by concealing architectural or structural flaws, creating a veil of green that enhances their visual appeal (Dutta 1989).

Climbers enhance horticultural beauty with their diverse growth forms and have evolved into woody types in families like Apocynaceae, Bignoniaceae, and Menispermaceae, while in other families like Acanthaceae, Convolvulaceae, Cucurbitaceae, and Passifloraceae, they are herbaceous in nature (Roy 2019). Some woody climbers resemble shrubs, thriving in open sites but producing elongated, leafy branches under shade to climb, forming scandent shrubs. Yet, unchecked growth may block drainage systems or damage host trees, reflecting both their ecological value and management challenges (Roy 2019).

A climber starts its life on the forest floor and spends almost one-fourth of its life on the forest floor. After this initial phase, it begins to adhere, anchor, and lean on other plants in order to achieve great stature (Jongkind & Hawthorne 2005). The families such as Cucurbitaceae, Convolvulaceae, and Dioscoreaceae are known for their abundance of climbers. Among these families, Apocynaceae, Rubiaceae, Celastraceae, and Leguminosae have more than 50 species each (Gentry 1991; Schnitzer & Bongers 2002). Climbers are predominantly found in woody plant ecosystems, although diversity can also be observed in subtropical and tropical forests (Richards 1952; Bongers et al. 2005). Tropical rainforests exhibit a high diversity of climbers, accounting for up to 30% of the vegetation (Schnitzer & Bongers 2002). Climbers are more commonly associated with tropical forests rather than temperate forests (Putz 1984).

Climbers are present in nearly half (46%) of the flowering plant families (Pandi 2023). Most of the lianas or vines are present in the families Hippocrateaceae, Vitaceae, and Smilacaceae (Gentry 1991). In tropical forests, climbers play a significant role in both floristic composition and forest physiognomy (Gentry 1991). They are crucial components of forest ecosystems as they provide habitat and food for animals (Hladik 1978; Emmons & Gentry 1983; Gentry 1991; Galetti & Pedroni 1994).

In Uttar Pradesh, the diversity of climbing plants (both lianas and vines) varies across regions. In northeastern UP, 111 climber species comprising 63 lianas and 48 vines are distributed across 35 families, with Convolvulaceae alone accounting for 19 species (Dvivedi et al. 2016). A total of 46 climbers, notably belonging to Cucurbitaceae, Convolvulaceae, and Fabaceae, have been primarily used to treat urogenital disorders, diabetes, respiratory & gastrointestinal ailments, as well as skin conditions, and jaundice (Tandon et al. 2025). The knowledge of climbers in UP is still fragmented, with most studies offering only scattered or localized accounts. The present study seeks to consolidate this information by reviewing available literature to assess the diversity and distribution of climbers across the four regions of the state.

MATERIALS AND METHODS

Study area

In the present study, the state of UP was chosen as the study area, which is situated at northcentral region of India between 23.867^0 N– 31.467^o E and 77.500^o N–

84.650° E, occupying an area of about 2,40,928 km², of which 17,722.4 km² consists of forests, which is 7.54% of its total area (ISFR 2023). The forest cover of Uttar Pradesh (Table 1 & Figure 2) is 15,045.80 km², excluding the scrub, which is 639.5 km² (ISFR 2023).

Uttar Pradesh shares its boundaries with Haryana, Delhi, and Rajasthan in the west; Madhya Pradesh and Chhattisgarh in the south; Jharkhand and Bihar in the east; and Uttarakhand and the international boundary with Nepal in the north. With reference to natural boundaries, the area is bordered by the Shivalik mountain range in the north, the Yamuna River and the Vindhyan mountain range along the western and southern borders, and the Gandak River in the east. The middle fertile zone formed by the Ganga River is heavily utilised for agriculture. The climate is subtropical and chiefly contains three seasons, namely: summer, rainy, and winter. In the summer (April–June), the temperature rises up to 45 °C and a small amount of rain (10–25 cm) is recorded. The rainy season runs from late June to early October, during which temperatures range 25–35 °C and rainfall averages 80–115 cm. The winter season starts from the last week of October and lasts up to mid-March. In this period, the temperature varies 10–25 °C, and a small amount of rainfall (5–7 cm) is reported in the area. Although the forest cover is very minimal, it harbours a good number of flowering plants due to its varied climatic conditions. Based on forest and vegetation types, the province is broadly categorized into the following four major zones (Figure 1).

1. Terai Region: It includes the northern part adjacent to Nepal, which is a tropical moist deciduous type. It comprises Pilibhit, Lakhimpur Kheri, Bahraich, Shravasti, Balrampur, Gonda, Basti, Siddharthnagar, Gorakhpur, Maharajganj, Deoria, and Kushinagar districts. It has a great biodiversity due to dense forest cover. The dominant forest is Sal and Teak, and also has some patches of *Aegle* forest in Lakhimpur and Bahraich.

2. Gangetic Plain: It forms the central area, which is agriculturally most fertile and has a tropical dry deciduous type of vegetation. The area is chiefly drained by the Ganga, Yamuna, Ghaghra, and Gomti rivers. Their tributaries also form a good network of small rivers, and it forms a highly fertile region for cultivation. Due

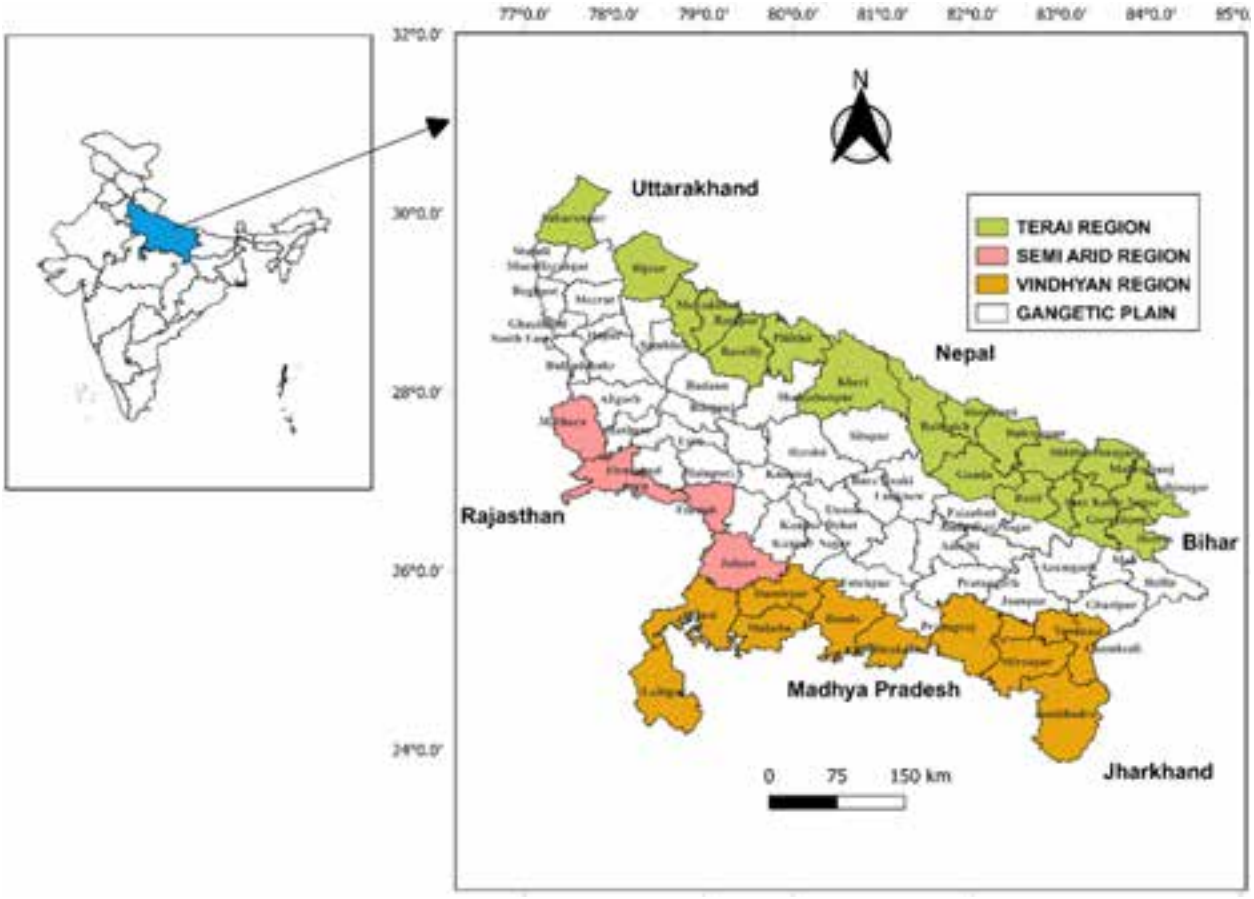

Figure 1. Different geographical zones of Uttar Pradesh.

Table 1. Forest cover of Uttar Pradesh (ISFR 2023).

Class	Area (km²)	Percentage
Very dense forest area	2,688.73	1.12
Moderately dense forest area	4,001.41	1.66
Open forest area	8355.66	3.46
Total forest cover	**15,045.80**	**6.24**
Scrub	639.51	0.27

Table 2. Status of climbers in India (Pandi et al. 2022).

No. of species	Genera	Family
2,624	585	104

to heavy anthropogenic activities, it has very poor biodiversity, except for some small, fragmented patches.

3. Vindhyan Region: It is situated between the Gangetic plains and the Deccan Peninsula with a tropical dry deciduous type of vegetation. It comprises Lalitpur, Jhansi, Jalaun, Hamirpur, Mahoba, Banda, Chitrakoot, Mirzapur, Sonbhadra, Sant Ravidas Nagar, Chandauli, Varanasi, Kaushambi, and some regions of the Allahabad District. It is constituted by a small part of the Vindhyan Hill. Due to the presence of sandy soil, it has very poor fertility. The major cultivated plant is wheat, which is cultivated along the riverbank. Due to mining and other heavy anthropogenic activities, it also has very poor biodiversity. The forest of the area is tropical dry deciduous.

4. Semiarid Region: Only a few areas—Agra, Mathura, Etawah, Auraya, and Jalaun—with tropical dry deciduous type of vegetation form a semiarid region. The forest of the area is an open scrub type. The banks of the Chambal, Betwa, and Yamuna rivers form the vegetation of the area.

Literature survey

The present review is based on an extensive review of available literature, including more than 16 authentic research papers, three books or book chapters and four regional floras. A comprehensive list of climbing species recorded from UP has been compiled through this review. Furthermore, identified taxa up to the level of species and infraspecific ranks (variety/subspecies) have been included. The taxonomic identities of all taxa were verified using the Plants of the World Online (POWO) database to ensure nomenclature accuracy and current accepted names. The taxa are arranged alphabetically (Table 3). This systematic approach ensured comprehensive coverage of available data on climber diversity and distribution in Uttar Pradesh. Map of Uttar Pradesh representing four zones of Uttar Pradesh have been provided in Figure 1.

RESULTS AND DISCUSSION

Status of climbers in India

In India, climbers, including both lianas and herbaceous vines, constitute approximately 12% of the country's total angiosperm flora (Pujari et al. 2025). Regional studies have highlighted their diversity and ethnobotanical importance across several states.

In northern and western India, several species of climbers were documented from Jammu & Kashmir (Bor & Raizada 1954), Gujarat (Jangid & Sharma 2011). Further surveys in eastern India revealed rich distributions, such as 94 species in Koch Bihar, West Bengal (Bandyopadhyay & Mukherjee 2010), 45 in Jharkhand (Kumar et al. 2013), and 120 in Odisha's Similipal Biosphere Reserve (Rout et al. 2022). Northeastern India displays exceptional diversity, with 187 species in Arunachal Pradesh (Soyala et al. 2021), and 26 species recorded from East Sikkim sacred groves (Rai et al. 2016).

Southern India and the Andaman Islands also contribute to this diversity. In Kerala, 59 climbers were recorded by Jayakumar & Nair (2013), while in Karnataka, 170 species of climbers were reported (Prashanth & Siddamallayya 2022). Tamil Nadu encompasses 40–175 taxa across different districts and hill ranges (Muthuperumal & Parthasarathy 2009; Sarvalingam & Rajendran 2014). The Andaman Islands harbour high richness with over 220 species, including herbaceous climbers and lianas (Mahajan 2006).

Consolidating these scattered accounts on climbers, Pandi et al. (2022) & Pujari et al. (2025) provided comprehensive data on Indian climbers, reporting 2,566–2,624 species (Table 2), underscoring the ecological, medicinal, and cultural significance of climbers in India.

Status of climbers in Uttar Pradesh

The state of UP harbours rich climbers' diversity. In their attempt to study the floristic accounts of the state Duthie (1903–1915), Kanjilal (1982), Misra & Verma (1992), Sharma & Dhakre (1995), Narayan & Ranjan (2007), Datt et al. (2015), Kushwaha et al. (2018), and Sinha & Shukla (2021) have mentioned climbing species in their studies. Detailed comprehensive studies on climbing species are lacking from the state. A few available studies concerning the climbing species across

Table 3. List of climbing species recorded from Uttar Pradesh. The names in the parentheses are originally annotated names which are now synonyms.

	Currently accepted names	Family	Order	Habit
1	*Abrus melanospermus* Hassk.	Fabaceae	Fabales	Twining herb
2	*Abrus melanospermus* subsp. *melanospermus* (=*Abrus pulchellus* Wall.ex Voigt.)	Fabaceae	Fabales	Climbing woody shrub
3	*Abrus precatorius* L.	Fabaceae	Fabales	Woody twiner
4	*Acacia gageana* (Craib) Maslin, Seigler & Ebinger	Fabaceae	Fabales	Climbing shrub
5	*Actinostemma tenerum* Griff.	Cucurbitaceae	Cucurbitales	Climbing herb
6	*Aganosma heynei* (Spreng.) I.M. Turner (=*Aganosma caryophyllata* G. Don; *Aganosma dichotoma* K.Schum.)	Apocynaceae	Gentianales	Woody climber
7	*Allamanda cathartica* L.	Apocynaceae	Gentianales	Woody twiner
8	*Allamanda blanchetii* A.DC. (=*Allamanda violacea* Gardner)	Apocynaceae	Gentianales	Woody climber
9	*Allamanda schottii* Pohl (=*Allamanda neriifolia* Hook.)	Apocynaceae	Gentianales	Climbing shrub
10	*Ampelocissus divaricata* (Wall. ex M.A.Lawson) Planch. (=*Vitis divaricata* Wall. ex M.A.Lawson)	Vitaceae	Vitales	Climbing tendril shrub
11	*Ampelocissus indica* (L.) Planch.	Vitaceae	Vitales	Climbing tendril shrub
12	*Ampelocissus latifolia* (Roxb.) Planch.	Vitaceae	Vitales	Woody tendril herb
13	*Ampelocissus rugosa* (Wall.) Planch.	Vitaceae	Vitales	Climbiing shrub
14	*Ampelocissus tomentosa* (Roth.) Planch.	Vitaceae	Vitales	Climbing shrub
15	*Ampelopsis glandulosa* (Wall.) Momiy.	Vitaceae	Vitales	Climbing herb
16	*Anamirta cocculus* (L.) Wight & Arn. (=*Anamirta paniculata* Colebr.)	Menispermaceae	Ranunculales	Woody climber
17	*Aniseia martinicensis* (Jacq.) Choisy	Convolvulaceae	Solanales	Twiner
18	*Antigonon leptopus* Hook. & Arn.	Polygonaceae	Caryophyllales	Climbing tendril herb
19	*Argyreia barbigera* Choisy (=*Lettsomia thomsonii* C.B.Clarke; *Argyreia nasirii* D.F.Austin)	Convolvulaceae	Solanales	Climber
20	*Argyreia kleiniana* (Schult.) Raizada (=*Argyreia populifolia* Choisy)	Convolvulaceae	Solanales	Woody climber
21	*Argyreia nervosa* (Burm.f.) Bojer (=*Argyreia speciosa* (L.f.) Sweet)	Convolvulaceae	Solanales	Twining herb
22	*Argyreia sericea* Dalzell & A.Gibson	Convolvulaceae	Solanales	Twining herb
23	*Argyreia setosa* (Roxb.) Sweet (=*Lettsomia setosa* Roxb.)	Convolvulaceae	Solanales	Large climber
24	*Aristolochia indica* L.	Aristolochiaceae	Piperales	Glabrous climber
25	*Aristolochia littoralis* Parodi	Aristolochiaceae	Piperales	Climbing tendril herb
26	*Artabotrys hexapetalus* (L.f.) Bhandari (=*Artabotrys odoratissimus* R.Br.)Annonaceae	Annonaceae	Magnoliales	Woody climber
27	*Asparagus racemosus* Willd.	Asparagaceae	Asparagales	Woody twining herb
28	*Asparagus setaceus* (Kunth) Jessop	Asparagaceae	Asparagales	Twining herb
29	*Aspidopterys cordata* (B.Heyne ex Wall.) A. Juss.	Malpighiaceae	Malpighiales	Slender climber
30	*Aspidopterys wallichii* Hook.f.	Malpighiaceae	Malpighiales	Woody climber
31	*Basella alba* L. (=*Basella rubra* L.)	Basellaceae	Caryophyllales	Twining herb
32	*Benincasa hispida* (Thunb.) Cogn.	Cucurbitaceae	Cucurbitales	Climber
33	*Biancaea decapetala* (Roth)) O.Deg (=*Caesalpinia decapetala* (Roth) Alston; *Caesalpinia sepiaria* Roxb.)	Fabaceae	Fabales	Climbing shrub
34	*Bignonia corymbosa* Vent.	Bignoniaceaee	Lamiales	Climbing vine
35	*Blastania cerasiformis* (Stocks) A. Meeuse (=*Blastania fimbristipula* Kotschy & Peyr.)	Cucurbitaceae	Cucurbitales	Tendril climber
36	*Blastania garcinii* (Burm.f.) Cogn.	Cucurbitaceae	Cucurbitales	Climbing tendril herb
37	*Boerhavia diffusa* L.	Nyctaginaceae	Caryophyllales	Climbing shrub
38	*Bougainvillea glabra* Choisy	Nyctaginaceae	Caryophyllales	Climbing shrub
39	*Bougainvillea spectabilis* Willd	Nyctaginaceae	Caryophyllales	Woody hook climber
40	*Brachypteris scandens* (Roxb.) Wight & Arn. ex Miq. (=*Derris scandens* (Roxb.) Benth.)	Fabaceae	Fabales	Woody twining climber

	Currently accepted names	Family	Order	Habit
41	*Bridelia stipularis* (L.) Blume	Phyllanthaceae	Malpighiales	Woody climber
42	*Butea superba* Roxb.ex Willd.	Fabaceae	Fabales	Woody climber
43	*Cajanus albicans* (Wight & Arn.) Maesen (=*Atylosia albicans* (Wight & Arn.) Benth.)	Fabaceae	Fabales	Twining shrub
44	*Cajanus crassus* (Prain ex King) Maesen (=*Atylosia crassa* Prain)	Fabaceae	Fabales	Twining shrub
45	*Cajanus mollis* (Benth.) Maesen (=*Atylosia mollis* Benth.)	Fabaceae	Fabales	Woody twining herb
46	*Cajanus platycarpus* (Benth.) Maesen (=*Atylosia platycarpa* Benth.)	Fabaceae	Fabales	Twining herb
47	*Cajanus scarabaeoides* (L.) Thouars (=*Atylosia scarabaeoides* (L.) Benth.)	Fabaceae	Fabales	Twining herb
48	*Calamus tenuis* Roxb.	Arecaceae	Arecales	Twining shrub
49	*Camonea umbellata* (L.) A.R.Simões & Staples (=*Merremia umbellata* (L.) Hallier f.)	Convolvulaceae	Solanales	Woody twining vine
50	*Campsis grandiflora* (Thunb.) K.Schum.	Bignoniaceaee	Lamiales	Woody climber
51	*Campsis radicans* (L.) Bureau	Bignoniaceaee	Lamiales	Woody twining climber
52	*Canavalia africana* Dunn	Fabaceae	Fabales	Woody climbing herb
53	*Canavalia ensiformis* (L.) DC.	Fabaceae	Fabales	Climbing shrub
54	*Canavalia gladiata* (Jacq.) DC.	Fabaceae	Fabales	Climbing shrub
55	*Cansjera rheedei* J.F. Gmel.	Opiliaceae	Santalales	Climbing shrub
56	*Capparis sepiaria* L.	Capparaceae	Brassicales	Woody climbing shrubs
57	*Capparis spinosa* L.	Capparaceae	Brassicales	Climbing shrubs
58	*Capparis zeylanica* L.	Capparaceae	Brassicales	Climbing shrubs
59	*Cardiospermum halicacabum* L.	Sapindaceae	Sapindales	Wiry tendril climber
60	*Cassytha filiformis* L.	Lauraceae	Laurales	Twining herb
61	*Causonis trifolia* (L.) Mabb. & J. Wen	Vitaceae	Vitales	Tendril climber
62	*Cayaponia laciniosa* (L.) C. Jefferey (=*Bryonopsis laciniosa* (L.) Naudin)	Cucurbitaceae	Cucurbitales	Climber
63	*Celastrus paniculatus* Willd.	Celastraceae	Celastrales	Woody twiner
64	*Ceropegia bulbosa* Roxb.	Apocynaceae	Gentianales	Twining herb
65	*Ceropegia hirsuta* Wight & Arn.	Apocynaceae	Gentianales	Twining herb
66	*Ceropegia longifolia* Wall.	Apocynaceae	Gentianales	Twining herb
67	*Ceropegia macrantha* Wight	Apocynaceae	Gentianales	Woody twining herb
68	*Chonemorpha verrucosa* (Blume) D.J.Middleton (=*Rhynchodia wallichii* Benth.)	Apocynaceae	Gentianales	Woody climber
69	*Cissampelos pareira* L. (=*Cissampelos cordifolia* Bojer; *Cissampelos pareira var. hirsuta* (Buch.-Ham.ex DC.) Forman)	Menispermaceae	Ranunculales	Twining herb
70	*Cissus adnata* Roxb. (=*Vitis adnata* (Roxb.) Wall.)	Vitaceae	Vitales	Woody climbing tendril shrub
71	*Cissus quadrangularis* L. (=*Vitis quadrangularis* (L.) Wall. ex Wight)	Vitaceae	Vitales	Tendril vine
72	*Cissus repanda* (Wight & Arn.) Vahl (=*Vitis repanda* Wight & Arn.)	Vitaceae	Vitales	Soft woody tendril shrub
73	*Citrullus lanatus* (Thunb.) Matsum, & Nakai (=*Citrullus vulgaris* Schrad.)	Cucurbitaceae	Cucurbitales	Twining herb
74	*Clematis cadmia* Buch.-Ham. Ex Hook.f. & Thomson	Ranunculaceae	Ranunculales	Slender climber
75	*Clematis gouriana* Roxb. ex DC.	Ranunculaceae	Ranunculales	Woody climber
76	*Clematis integrifolia* L. (=*Clematis nutans* Crantz)	Ranunculaceae	Ranunculales	Woody climber
77	*Clematis zeylanica* (L.) Poir. (=*Naravelia zeylanica* (L.) DC.)	Ranunculaceae	Ranunculales	Woody climber
78	*Clerodendrum splendens* G.Don	Lamiaceae	Lamiales	Woody twiner
79	*Clerodendrum thomsoniae* Balf.	Lamiaceae	Lamiales	Woody twiner
80	*Clitoria ternatea* L.	Fabaceae	Fabales	Wiry twining herb
81	*Coccinia grandis* (L.) Voigt	Cucurbitaceae	Cucurbitales	Climbing tendril herb
82	*Cocculus hirsutus* (L.) W.Theob. (=*Cocculus villosus* DC.)	Menispermaceae	Ranunculales	Twining shrub

	Currently accepted names	Family	Order	Habit
83	*Cocculus pendulus* (J.R.Forst. & G.Forst) Diels	Menispermaceae	Ranunculales	Twining shrub
84	*Combretum albidium* G.Don (=*Combretum ovalifolium* Roxb.)	Combretaceae	Myrtales	Woody climbing shrub
85	*Combretum indicum* (L.) DrFilipps (=*Quisqualis indica* L.)	Combretaceae	Myrtales	Woody twininng shrub
86	*Combretum roxburghii* Spreng. (=*Combretum decandrum* Roxb.)	Combretaceae	Myrtales	Climbing shrub
87	*Convolvulus arvensis* L.	Convolvulaceae	Solanales	Twining herb
88	*Convolvulus wallichianus* Spreng. (=*Calystegia hederacea* Wall.)	Convolvulaceae	Solanales	Climbing herb
89	*Cryptolepis buchananii* R.Br. ex Roem. & Schult. (=*Cryptolepis dubia* (Burm.f.) M.R. Almeida)	Apocynaceae	Gentianales	Twining shrub
90	*Cryptolepis grandiflora* Wight	Apocynaceae	Gentianales	Woody twining shrub
91	*Cryptolepis sinensis* (Lour.) Merr. (=*Cryptolepis elegans* Wall. ex G.Don)	Apocynaceae	Gentianales	Climbing shrub
92	*Cryptostegia grandiflora* Roxb. ex R.Br.	Apocynaceae	Gentianales	Woody climber
93	*Cucumis maderaspatana* (L.) Cogn. (=*Melothria maderaspatana* (L.) Cogn.; *Mukia maderaspatana* (L.) M.Roem.)	Cucurbitaceae	Cucurbitales	Tendril climbing herb
94	*Cucumis melo* L. (=*Luffa cylindrica* (L.) M.Roem)	Cucurbitaceae	Cucurbitales	Tendril climbing herb
95	*Cucumis melo* var. *agrestis*	Cucurbitaceae	Cucurbitales	Wiry climber
96	*Cucumis melo* var. *momordica*	Cucurbitaceae	Cucurbitales	Tendril climber
97	*Cucumis sativus* L.	Cucurbitaceae	Cucurbitales	Tendril climber
98	*Cucumis trigonus* Roxb.	Cucurbitaceae	Cucurbitales	Climbinh herb
99	*Cucurbita maxima* Duchesne	Cucurbitaceae	Cucurbitales	Tendril climbing herb
100	*Cucurbita moschata* Duchesne	Cucurbitaceae	Cucurbitales	Climbing herb
101	*Cucurbita pepo* L.	Cucurbitaceae	Cucurbitales	Climbing herb
102	*Cuscuta australis* R. Br.	Convolvulaceae	Solanales	Twining climber
103	*Cuscuta campestris* Yunck.	Convolvulaceae	Solanales	Parasite climber/Twiner
104	*Cuscuta capitata* Roxb.	Convolvulaceae	Solanales	Twining climber
105	*Cuscuta chinensis* Lam.	Convolvulaceae	Solanales	Twining climber
106	*Cuscuta reflexa* Roxb.	Convolvulaceae	Solanales	Parasite twiner
107	*Cuscuta santapaui* Banerji & S. Das	Convolvulaceae	Solanales	Twining climber
108	*Cynanchum annularium* (Roxb.) Liede & Khanum (=*Holostemma rheedii* Wall.; *Holostemma ada-kodien* Schult.)	Apocynaceae	Gentianales	Twining shrub
109	*Cyphostemma auriculatum* (Roxb.) P. Singh & B.V.Shetty (=*Vitis auriculata* (Roxb.) Wall.)	Vitaceae	Vitales	Woody climber
110	*Dalbergia volubilis* Roxb.	Fabaceae	Fabales	Woody climber
111	*Deeringia amaranthoides* (Lam.) Merr. (=*Deeringia celosioides* R. Br.)	Amaranthaceae	Caryophyllales	Woody climbing shrub
112	*Derris cuneifolia* Benth.	Fabaceae	Fabales	Climbing herb
113	*Derris macrocarpa* Thoth.	Fabaceae	Fabales	Climbing shrub
114	*Dinetus racemosus* (Roxb.) Sweet (=*Porana racemosa* Roxb.)	Convolvulaceae	Solanales	Climbing shrub
115	*Dioscorea alata* L.	Dioscoreaceae	Dioscoreales	Twining herb
116	*Dioscorea belophylla* (Prain) Voigt ex Haines	Dioscoreaceae	Dioscoreales	Twining climber
117	*Dioscorea bulbifera* L.	Dioscoreaceae	Dioscoreales	Twining climber
118	*Dioscorea cumingii* Prain & Burkill (=*Dioscorea echinata* R.Knuth)	Dioscoreaceae	Dioscoreales	Twining climber
119	*Dioscorea deltoidea* Wall. ex. Griseb.	Dioscoreaceae	Dioscoreales	Twining herb
120	*Dioscorea esculenta* (Lour.) Burkill	Dioscoreaceae	Dioscoreales	Twining climber
121	*Dioscorea glabra* Roxb.	Dioscoreaceae	Dioscoreales	Twining climber
122	*Dioscorea hispida* Dennst (=*Dioscorea daemona* Roxb.)	Dioscoreaceae	Dioscoreales	Twining climber
123	*Dioscorea japonica* Thunb.	Dioscoreaceae	Dioscoreales	Twining climber
124	*Dioscorea oppositifolia* L.	Dioscoreaceae	Dioscoreales	Twining climber
125	*Dioscorea pentaphylla* L.	Dioscoreaceae	Dioscoreales	Twining climber

	Currently accepted names	Family	Order	Habit
126	*Dioscorea pubera* Blume (=*Dioscorea anguina* Roxb.)	Dioscoreaceae	Dioscoreales	Climbing herb
127	*Dioscorea wallichii* Hook.f.	Dioscoreaceae	Dioscoreales	Climber herb
128	*Dioscorea wightii* Hook.f.	Dioscoreaceae	Dioscoreales	Climbing herb
129	*Diplocyclos palmatus* (L.) C.Jeffrey	Cucurbitaceae	Cucurbitales	Tendril climber
130	*Distimake aegypticus* (L.) A.R.Simões & Staples (=*Merremia aegyptia* (L.) Urb.)	Convolvulaceae	Solanales	Twining climber
131	*Distimake dissectus* (Jacq.) (L.) A.R.Simões & Staples (=*Merremia dissecta* (Jacq.) Hallier f.)	Convolvulaceae	Solanales	Woody twining climber
132	*Distimake tuberosus* (L.) A.R.Simões & Staples (=*Merremia tuberosa* (L.) Rendle)	Convolvulaceae	Solanales	Twining climber
133	*Distimake vitifolius* (Burm. f.) Pisuttimarn & Petrongari (=*Merremia vitifolia* (Burm.f.) Hallier f.)	Convolvulaceae	Solanales	Twining climber
134	*Dolichandra unguis-cati* (L.) L.G.Lohmann	Bignoniaceaee	Lamiales	Woody tendril climber
135	*Dumasia villosa* DC.	Fabaceae	Fabales	Twining climber
136	*Dunbaria glandulosa* Dalzell & A. Gibson) Prain	Fabaceae	Fabales	Woody climber
137	*Embelia ribes* Burm.f.	Primulaceae	Ericales	Climbing shrub
138	*Embelia tsjeriam-cottam* (Roem. & Schult.) A.DC.	Primulaceae	Ericales	Woody climbing shrub
139	*Endosamara racemosa* (Roxb.) R. Geesink	Fabaceae	Fabales	Woody climbing shrub
140	*Epipremnum pinnatum* (L.) Engl.	Araceae	Alismatales	Woody climbing herb
141	*Erycibe paniculata* Roxb. (=*Erycibe wightiana* J.Graham)	Convolvulaceae	Solanales	Woody climber
142	*Ficus pumila* L.	Moraceae	Rosales	Woody climber
143	*Finlaysonia wallichii* (Wight) Ventre	Apocynaceae	Gentianales	Twining shrub
144	*Galactia mollis* Michx. (=*Galactia villosa* Eaton & Wright)	Fabaceae	Fabales	Twining herb
145	*Galium aparine* L.	Rubiaceae	Gentianales	Climbing herb
146	*Gongronema nepalense* (Wall.) Decne.	Apocynaceae	Gentianales	Large twining shrub
147	*Gongronemopsis tenacissima* (Roxb.) S.Reuss, Liede & Meve (=*Marsdenia tenacissima* (Roxb.) Moon)	Apocynaceae	Gentianales	Twining shrub
148	*Gouania leptostachya* DC.	Rhamnaceae	Rosales	Tendril climber
149	*Guilandina bonduc* L. (=*Caesalpinia bonduc* (L.) Roxb.)	Fabaceae	Fabales	Hook climber
150	*Gymnema decaisneanum* Wight (=*Gymnema hirsutum* Wight & Arn.)	Apocynaceae	Gentianales	Woody climbing undershrub
151	*Gymnema indorum* (Lour.) Decne. (=*Gymnema tingens* (Roxb.) Spreng.)	Apocynaceae	Gentianales	Twinng shrub
152	*Gymnema montanum* (Roxb.) Hook.f.	Apocynaceae	Gentianales	Twining shrub
153	*Gymnema rivulare* Schltr.	Apocynaceae	Gentianales	Woody climbing vine
154	*Gymnema sylvestre* (Retz.) R.Br. ex Sm.	Apocynaceae	Gentianales	Twining shrub
155	*Helinus lanceolatus* Brandis	Rhamnaceae	Rosales	Tendril climber
156	*Hemidesmus indicus* (L.) R.Br.	Apocynaceae	Gentianales	Slender climber
157	*Hiptage benghalensis* var.*benghalensis* (=*Hiptage madablota* Gaertn.)	Malpighiaceae	Malpighiales	Climbing shrub
158	*Hiptage benghalensis* (L.) Kurz.	Malpighiaceae	Malpighiales	Woody twining climber
159	*Holmskioldia sanguinea* Retz.	Lamiaceae	Lamiales	Climbing shrub
160	*Iberis amara* L.	Brassicaceae	Brassicales	Woody twining climber
161	*Ichnocarpus frutescens* (L.) W.T.Aiton	Apocynaceae	Gentianales	Climbing shrub
162	*Ipomoea alba* L.	Convolvulaceae	Solanales	Twining climber
163	*Ipomoea aquatica* Forssk.	Convolvulaceae	Solanales	Twining herb
164	*Ipomoea barlerioides* (Choisy) Benth ex C.B.Clarke	Convolvulaceae	Solanales	Twining herb
165	*Ipomoea batatas* (L.) Lam.	Convolvulaceae	Solanales	Twining herb
166	*Ipomoea biflora* (L.) Pers (=*Ipomoea sinensis* (Desr.Choisy)	Convolvulaceae	Solanales	Twining climber
167	*Ipomoea cairica* (L.) Sweet (=*Ipomoea palmata* Forssk.)	Convolvulaceae	Solanales	Twining climber

	Currently accepted names	Family	Order	Habit
168	*Ipomoea carnea* subsp. *carnea*	Convolvulaceae	Solanales	Woody shrub
169	*Ipomoea cheirophylla* O'Donell	Convolvulaceae	Solanales	Twining herb
170	*Ipomoea coccinea* L. (=*Quamoclit coccinea* (L.) Moench)	Convolvulaceae	Solanales	Climber herb
171	*Ipomoea coptica* (L.) Roth	Convolvulaceae	Solanales	Twining herb
172	*Ipomoea dichroa* (Roemer & Schultes) Choisy	Convolvulaceae	Solanales	Twining herb
173	*Ipomoea eriocarpa* R.Br (=*Ipomoea sindica* Stapf.)	Convolvulaceae	Solanales	Twining herb
174	*Ipomoea hederacea* Jacq. (=*Ipomoea triloba* Thunb.)	Convolvulaceae	Solanales	Twining herb
175	*Ipomoea hederifolia* L.	Convolvulaceae	Solanales	Twining herb
176	*Ipomoea indica* (Burm.) Merr.(=*Ipomoea learii* Paxton)	Convolvulaceae	Solanales	Climber
177	*Ipomoea muricata* (L.) Jacq. (=*Calonyction muricatum* (L.) G.Don; *Ipomoea turbinata* Lag)	Convolvulaceae	Solanales	Twining herb
178	*Ipomoea nil* (L.) Roth	Convolvulaceae	Solanales	Twining herb
179	*Ipomoea obscura* (L.) Ker Gawl.	Convolvulaceae	Solanales	Twining herb
180	*Ipomoea pes-caprae* (L.) R.Br.	Convolvulaceae	Solanales	Twining herb
181	*Ipomoea pes-tigridis* L.	Convolvulaceae	Solanales	Twining climber
182	*Ipomoea purpurea* (L.) Roth	Convolvulaceae	Solanales	Twining herb
183	*Ipomoea quamoclit* L. (=*Quamoclit vulgaris* Choisy)	Convolvulaceae	Solanales	Slender climber
184	*Ipomoea sagittifolia* Burm.f. (=*Ipomoea marginata* (Desr.) Manitz)	Convolvulaceae	Solanales	Twining climber
185	*Jasminum auriculatum* Vahl	Oleaceae	Lamiales	Climbing shrub
186	*Jasminum dispermum* Wall.	Oleaceae	Lamiales	Climbing shrub
187	*Jasminum laurifolium* Roxb. ex Hornem.	Oleaceae	Lamiales	Woody twining climber
188	*Jasminum multiflorum* (Burm.f.) Andrews	Oleaceae	Lamiales	Woody twining climber
189	*Jacquemontia paniculata* (Burm.f.) Hallier f.	Convolvulaceae	Solanales	Twining climber
190	*Lablab purpureus* (L.) Sweet	Fabaceae	Fabales	Twining herb
191	*Lablab purpureus* subsp. *purpureus* (=*Dolichos lablab* L.)	Fabaceae	Fabales	Climbing shrub
192	*Lagenaria siceraria* Ser. (=*Lagenaria vulgaris* Ser.)	Cucurbitaceae	Cucurbitales	Twining herb
193	*Lathyrus odoratus* L.	Fabaceae	Fabales	Climbing herb
194	*Lathyrus oleraceus* Lam. (=*Pisum arvense* L.)	Fabaceae	Fabales	Climbing herb
195	*Leptadenia reticulata* (Retz.) Wight & Arn.	Apocynaceae	Gentianales	Woody twining shrub
196	*Leptospron adenanthum* (G.Mey.) A.Delgado (=*Vigna adenantha* (G.Mey.)Maréchal, Mascherpa & Stainer)	Fabaceae	Fabales	Twining climber
197	*Luffa aegyptiaca* Mill	Cucurbitaceae	Cucurbitales	Climbing herb
198	*Luffa acutangula* (L.) Roxb. (=*Luffa hermaphrodita* N.B Singh & U.C. Bhattach.)	Cucurbitaceae	Cucurbitales	Tendril climber
199	*Luffa echinata* Roxb.	Cucurbitaceae	Cucurbitales	Climber
200	*Luffa graveolens* Roxb.	Cucurbitaceae	Cucurbitales	tendril climber
201	*Macrotyloma biflorum* var. biflorum (=*Dolichos biflorus* L.)	Fabaceae	Fabales	Climber
202	*Maerua arenaria* Hook.f. & Thomson	Capparaceae	Brassicales	Woody climber
203	*Maerua oblongifolia* (Forssk.) A.Rich. (=*Maerua ovalifolia* Cambess.)	Capparaceae	Brassicales	Woody climber
204	*Mallotus repandus* (Rottler) Müll.Arg.	Euphorbiaceae	Malpighiales	Climbing shrub
205	*Mansoa alliacea* (Lam.) A.H.Gentry	Bignoniaceaee	Lamiales	Woody twining climber
206	*Marsdenia hamiltonii* Wight (=*Pergularia hamiltonii* (Wight) D.Dietr.)	Apocynaceae	Gentianales	Twining climber
207	*Marsdenia lucida* Edgew. ex Madden	Apocynaceae	Gentianales	Climber
208	*Marsdenia roylei* Wight	Apocynaceae	Gentianales	Twining shrub
209	*Marsdenia sylvestris* (Retz.) R.Br. ex Sm.	Apocynaceae	Gentianales	Twining undershrub
210	*Merremia calycina* (Maisn.) Hallier f. (=*Ipomoea calycina* Meisn.)	Convolvulaceae	Solanales	Twining herb
211	*Merremia crispatula* Prain=*Operculina petaloides* (Choisy) Ooststr. (=*Merremia crispatula* Prain)	Convolvulaceae	Solanales	Climber

	Currently accepted names	Family	Order	Habit
212	*Merremia hederacea* (Burm.f.) Hallier f.	Convolvulaceae	Solanales	Twining herb
213	*Mezoneuron cucullatum* (Roxb.) Wight & Arn. (=*Caesalpinia cucullata* Roxb.)	Fabaceae	Fabales	Climber
214	*Mikania micrantha* Kunth	Asteraceae	Asterales	Twiner
215	*Mimosa himalayana* Gamble	Fabaceae	Fabales	Woody climbing shrub
216	*Mimosa pudica* L.	Fabaceae	Fabales	Twining climber
217	*Mimosa rubicaulis* var. *rubicaulis* (=*Acacia intsia* (L.) Willd.)	Fabaceae	Fabales	Climber
218	*Momordica balsamina* L.	Cucurbitaceae	Cucurbitales	Tendril climber
219	*Momordica charantia* L.	Cucurbitaceae	Cucurbitales	Tendril climber
220	*Momordica cochinchinensis* (Lour.) Spreng.	Cucurbitaceae	Cucurbitales	Tendril climber
221	*Momordica dioica* Roxb.ex Willd.	Cucurbitaceae	Cucurbitales	Tendril climber
222	*Monstera deliciosa* Leibm.	Araceae	Alismatales	Twining climber
223	*Moullava spicata* (Dalzell ex Wight) Nicolson (=*Wagatea spicata* Dalzell ex Wight)	Fabaceae	Fabales	Woody climber
224	*Mucuna hainanensis* Hayata	Fabaceae	Fabales	Woody twining climber
225	*Mucuna imbricata* (Roxb. ex Lindl.) DC. ex Loudon	Fabaceae	Fabales	Woody twining climber
226	*Mucuna monosperma* DC. ex Wight	Fabaceae	Fabales	Woody twining climber
227	*Mucuna pruriens* (L.) DC. (=*Mucuna prurita* Wight)	Fabaceae	Fabales	Woody twining climber
228	*Nephrosia diversifolia* (DC.) L.Lian & Wei Wang (=*Cocculus diversifolius* DC.)	Menispermaceae	Ranunculales	Climbing vine
229	*Nephrosia orbiculata* (L.) L.Lian & Wei Wang (=*Cocculus trilobus* (Thunb.) DC.)	Menispermaceae	Ranunculales	Woody climbing vine
230	*Nogra grahamii* (Wall. ex Benth.) Merr.	Fabaceae	Fabales	Twining climber
231	*Olax imbricata* Roxb.	Olacaceae	Santalales	Climbing shrub
232	*Olax scandens* Roxb.	Olacaceae	Santalales	Climbing shrub
233	*Operculina petaloidea* (Choisy) Ooststr. (=*Ipomoea petaloidea* Choisy)	Convolvulaceae	Solanales	Climber
234	*Operculina turpethum* (L.) Silva Manso (=*Ipomoea turpethum* (L.) R.Br.)	Convolvulaceae	Solanales	Twining climber
235	*Otosema extensa* Benth. (=*Millettia auriculata* Baker; *Millettia extensa* (Benth.) Benth. ex Baker)	Fabaceae	Fabales	Woody twining climber
236	*Oxystelma esculentum* (L.f.) Sm.	Apocynaceae	Gentianales	Twining climber
237	*Pachyrhizus erosus* (L.) Urb. (=*Dolichos trilobus* Lour.)	Fabaceae	Fabales	Twining climber
238	*Paederia foetida* L.	Rubiaceae	Gentianales	Twining climber
239	*Paracalyx scariosus* (Roxb.) Ali (=*Cylista scariosa* Roxb.)	Fabaceae	Fabales	Woody climber
240	*Passiflora edulis* Sims	Passifloraceae	Malpighiales	Climbing herb
241	*Passiflora foetida* L.	Passifloraceae	Malpighiales	Tendril climber
242	*Passiflora suberosa* L.	Passifloraceae	Malpighiales	Tendril climber
243	*Pentalinon luteum* (L.) B.F. Hansen & Wunderlin	Apocynaceae	Gentianales	Climbing shrub
244	*Pentatropis capensis* (L.f.) Bullock (=*Pentatropis microphylla* (Roth) Wight & Arn.)	Apocynaceae	Gentianales	Twining shrub
245	*Pentatropis nivalis* (J.F.Gmel.) D.V.Field & J.R.I.Wood (=*Pentatropis cynanchoides* R.Br. ex N.E.Br.)	Apocynaceae	Gentianales	Twining shrub
246	*Pergularia daemia* (Forssk.) Chiov. (=*Daemia extensa* R.Br.)	Apocynaceae	Gentianales	Twining shrub
247	*Pericampylus glaucus* (Lam.) Merr. (=*Pericampylus incanus* Miers.)	Menispermaceae	Ranunculales	Climbing shrub
248	*Petrea volubilis* L.	Verbenaceae	Lamiales	Woody twining climber
249	*Phanera vahlii* (Wight & Arn.) Benth. (=*Bauhinia vahlii* Wight & Arn.)	Fabaceae	Fabales	Woody twining climber
250	*Phaseolus coccineus* L.	Fabaceae	Fabales	Twining herb
251	*Phaseolus lunatus* L.	Fabaceae	Fabales	Climbing herb
252	*Phaseolus vulgaris* L.	Fabaceae	Fabales	Climbing herb
253	*Piper longum* L.	Piperaceae	Piperales	Climbing vine

	Currently accepted names	Family	Order	Habit
254	*Poranopsis paniculata* (Roxb.) Roberty (=*Porana paniculata* Roxb.)	Convolvulaceae	Solanales	Woody twining climber
255	*Premna scandens* Roxb.	Lamiaceae	Lamiales	Woody climber
256	*Pueraria tuberosa* (Roxb. ex Willd.) DC.	Fabaceae	Fabales	Woody twining climber
257	*Pueraria phaseoloides* (Roxb. ex Willd.) DC.	Fabaceae	Fabales	Twining climber
258	*Pyrostegia venusta* (Ker Gawl.) Miers	Bignoniaceaee	Lamiales	Tendril climber
259	*Reissantia arborea* (Roxb.) H.Hara (=*Hippocratea arborea* Roxb.)	Celastraceae	Celastrales	Woody climbing shrub
260	*Rhaphidophora glauca* (Wall.) Schott	Araceae	Alismatales	Large climber
261	*Rhynchosia bracteata* Benth. ex Baker	Fabaceae	Fabales	Woody climber
262	*Rhynchosia capitata* (B.Heyne ex Roth) DC.	Fabaceae	Fabales	Climbing herb
263	*Rhynchosia minima* (L.) DC.	Fabaceae	Fabales	Twining herb
264	*Rhynchosia minima* var. *minima*	Fabaceae	Fabales	Twining climber
265	*Rhynchosia rothii* Benth. ex Aitch.	Fabaceae	Fabales	Twining climber
266	*Rivea hypocrateriformis* (Desr.) Choisy	Convolvulaceae	Solanales	Climbing shrub
267	*Rivea ornata* (Roxb.) Choisy	Convolvulaceae	Solanales	Climbing shrub
268	*Rubia cordifolia* L.	Rubiaceae	Gentianales	Climbing herb
269	*Sabia paniculata* Edgew. ex Hook.f. & Thomson	Sabiaceae	Proteales	Woody climbing shrub
270	*Salacia chinensis* L. (=*Salacia prinoides* (Willd.) DC.)	Celastraceae	Celastrales	Woody climbing shrub
271	*Schisandra grandiflora* (Wall.) Hook.f. & Thomson	Schisandraceae	Austrobaileyales	Woody climber
272	*Scindapsus officinalis* (Roxb.) Schott	Araceae	Alismatales	Climber
273	*Secamone alpini* Schult. (=*Oxystelma secamone* (L.) H.Karst.; *Sarcostemma secamone* (L.) Bennet)	Apocynaceae	Gentianales	Wiry twining herb
274	*Senegalia gageana* (Craib) Maslin, Seigler & Ebinger	Fabaceae	Fabales	Climbing shrub
275	*Senegalia pennata* (L.) Maslin (=Acacia concinna Phil.; *Acacia pennata* (L.) Willd.)	Fabaceae	Fabales	Woody prickly climbers
276	*Senegalia torta* (Roxb.) Maslin, Seigler (=*Acacia torta* (Roxb.) Craib)	Fabaceae	Fabales	Climbing shrub
277	*Senra incana* Cav.	Malvaceae	Malvales	Climbing shrub
278	*Shuteria involucrata* (Wall.) Wight & Arn. ex Walp.	Fabaceae	Fabales	Twining herb
279	*Smilax ovalifolia* Roxb. ex D.Don	Smilacaceae	Liliales	Climber
280	*Smilax perfoliata* Lour.	Smilacaceae	Liliales	Woody climbing shrub
281	*Smilax wightii* A.DC.	Smilacaceae	Liliales	Soft woody climber
282	*Smilax zeylanica* L.	Smilacaceae	Liliales	Woody climber
283	*Solena amplexicaulis* (Lam.) Gandhi	Cucurbitaceae	Cucurbitales	Climbing herb
284	*Solena heterophylla* Lour.	Cucurbitaceae	Cucurbitales	Climbing herb
285	*Spatholobus parviflorus* (Roxb. ex DC.) Kuntze (=*Spatholobus roxburghii* Benth.)	Fabaceae	Fabales	Climbing shrub
286	*Stephania japonica* (Thunb.) Miers	Menispermaceae	Ranunculales	Twining herb
287	*Stephania rotunda* Lour (=*Stephania glabra* (Roxb.) Miers)	Menispermaceae	Ranunculales	Twining herb
288	*Stephanotis floribunda* Jacques	Apocynaceae	Gentianales	Woody twining climber
289	*Stephanotis volubilis* (L.f.) S.Eeuss, Liede & Meve (=*Dregea volubilis* (L.f.) Benth. ex Hook.f.;Wattakaka volubilis (L.f.) Stapf)	Apocynaceae	Gentianales	Woody twining climber
290	*Stigmaphyllon emarginatum* (Cav.) A.Juss. (=*Stigmaphyllon periplocifolium* Desf. ex DC.) A.Juss.)	Malpighiaceae	Malpighiales	Twining shrub
291	*Syngonium podophyllum* Schott.	Araceae	Alismatales	Twining herb
292	*Tacomaria capensis* (Thunb.) Spach (=*Tecoma capensis* (Thunb.) Lindl.)	Bignoniaceae	Lamiales	Woody climber
293	*Tarlmounia elliptica* (DC.)H.Rob.,S.C.Keeley,Skvarla & R.Chan	Asteraceae	Asterales	Twining herb
294	*Telosma cordata* (Burm.f.) Merr.	Apocynaceae	Gentianales	Twining undershrub
295	*Telosma pallida* (Roxb.) Craib (=*Pergularia pallida* (Roxb.) Wight & Arn.)	Apocynaceae	Gentianales	Woody twining herb
296	*Teramnus labialis* (L.f.) Spreng.	Fabaceae	Fabales	Tendril climber

	Currently accepted names	Family	Order	Habit
297	*Tetrastigma campylocarpum* (Kurz) Planch.	Vitaceae	Vitales	Tendril climber
298	*Tetrastigma leucostaphyllum* (Dennst.) Alston (=*Vitis lanceolaria* Wall)	Vitaceae	Vitales	Woody climbing shrub
299	*Tetrastigma serrulatum* (Roxb.) Planch. (=Vitis capreolata D.Don)	Vitaceae	Vitales	Slender climber
300	*Thladiantha cordifolia* (Blume) Cogn. (=*Thladiantha calcarata* C.B.Clarke ex Cogn.)	Cucurbitaceae	Cucurbitales	Climbing herb
301	*Thunbergia coccinea* Wall. ex D.Don	Acanthaceae	Lamiales	Twining herb
302	*Thunbergia fragrans* Roxb.	Acanthaceae	Lamiales	Climber
303	*Thunbergia grandiflora* Roxb.	Acanthaceae	Lamiales	Woody climber
304	*Ticanto crista* (L.) Clarke & Gagnon (=*Caesalpinia crista* L.)	Fabaceae	Fabales	Woody climber
305	*Tiliacora acuminata* (Lam.) Miers (=Menispermum acuminatum Lam.; *Tiliacora racemosa* Colebr.)	Menispermaceae	Ranunculales	Woody climbing shrub
306	*Tinospora cordifolia* (Willd.) Hook.f. & Thomson	Menispermaceae	Ranunculales	Woody twing shrub
307	*Tinospora sinensis* (Lour.) Merr. (=*Tinospora malabarica* (Lam.) Hook.f. & Thomson)	Menispermaceae	Ranunculales	Climbing shrub
308	*Trachelospermum jasminoides* (Lindl.) Lem.	Apocynaceae	Gentianales	Twining herb
309	*Tragia gallabatensis* Prain (=*Tragia plukenetii* Radcl.-Sm.)	Euphorbiaceae	Malpighiales	Twiner
310	*Tragia involucrata* L.	Euphorbiaceae	Malpighiales	Twiner
311	*Trichosanthes bracteata* (Lam.) Voigt (=*Trichosanthes palmata* Roxb.)	Cucurbitaceae	Cucurbitales	Climber
312	*Trichosanthes cordata* Roxb.	Cucurbitaceae	Cucurbitales	Tendril climber
313	*Trichosanthes costata* Blume (=*Gymnopetalum chinense* (Lour.) Merr.)	Cucurbitaceae	Cucurbitales	Tendril climber
314	*Trichosanthes cucumerina* L.	Cucurbitaceae	Cucurbitales	Tendril climber
315	*Trichosanthes cucumerina* subsp. *cucumerina* (=*Trichosanthes anguina* L.;*Trichosanthes cucumerina* var. *anguina* (L.) Haines)	Cucurbitaceae	Cucurbitales	Tendril climber
316	*Trichosanthes dioica* Roxb.	Cucurbitaceae	Cucurbitales	Tendril climber
317	*Trichosanthes nervifolia* L.	Cucurbitaceae	Cucurbitales	Tendril climber
318	*Trichosanthes ovigera* Blume (=*Trichosanthes himalensis* C.B.Clarke)	Cucurbitaceae	Cucurbitales	Climber
319	*Trichosanthes tricuspidata* Lour.	Cucurbitaceae	Cucurbitales	Climber
320	*Tropaeolum majus* L.	Tropaeolaceae	Brassicales	Climbing herb
321	*Vallaris solanaceae* (Roth ex Roem. & Schult.) Kuntze (=*Vallaris heynei* Spreng.)	Apocynaceae	Gentianales	Woody twining shrub
322	*Ventilago denticulata* Willd. (=Ventilago calyculata Tul.)	Rhamnaceae	Rosales	Woody climbing shrub
323	*Ventilago madraspatana* Gaertn.	Rhamnaceae	Rosales	Climbing shrub
324	*Vicia hirsuta* (L.) Gray	Fabaceae	Fabales	Twining climber
325	*Vicia sativa* L.	Fabaceae	Fabales	Climbing shrub
326	*Vigna aconitifolia* (Jacq.) Maréchal	Fabaceae	Fabales	Climbing herb
327	*Vigna angularis* (Willd.) Ohwi & H. Ohashi	Fabaceae	Fabales	Climbing herb/twiner
328	*Vigna mungo* (L.) Hepper	Fabaceae	Fabales	Twining herb
329	*Vigna radiata* (L.) R.Wilczek	Fabaceae	Fabales	Climbing herb
330	*Vigna subramaniana* (Babu ex Raizada) Raizada	Fabaceae	Fabales	Twining herb
331	*Vigna trilobata* (L.) Verdc.	Fabaceae	Fabales	Herb twining
332	*Vigna unguiculata* (L.) Walp.	Fabaceae	Fabales	Twining herb
333	*Vincetoxicum indicum* (Burm.f.) Mabb. (=*Tylophora indica* (Burm.f.) Merr.)	Apocynaceae	Gentianales	Twining herb
334	*Vincetoxicum rotundifolia* (Buch.-Ham.ex Wight) Kuntze (=*Tylophora rotundifolia* (Buch.-Ham. ex Wight) Kuntze)	Apocynaceae	Gentianales	Twining shrub
335	*Vincetoxicum spirale* (Forssk.) D.Z.Li (=*Pentatropis spiralis* (Forssk.) Decne.)	Apocynaceae	Gentianales	Twining shrub
336	*Vitis heyneana* Schult.	Vitaceae	Vitales	Climbing shrub
337	*Vitis heyneana* var. *heyneana* (=*Vitis jacquemontii* R.Parker)	Vitaceae	Vitales	Climbing shrub
338	*Vitis labrusca* L. (=*Vitis latifolia* Raf.; *Vitis rugosa* Raf.)	Vitaceae	Vitales	Climber

	Currently accepted names	Family	Order	Habit
339	*Vitis parkeri* Gagnep. ex Osmaston (Kurz) Planch.	Vitaceae	Vitales	Soft woody climber
340	*Vitis vinifera* L.	Vitaceae	Vitales	Wooding twining climber
341	*Wisteria sinensis* (Sims) DC.	Fabaceae	Fabales	Wooding twining climber
342	*Zehneria scabra* (L.f.) Sond.	Cucurbitaceae	Cucurbitales	Climber
343	*Zehneria scabra* subsp. *scabra* (=*Melothria perpusilla* (Blume) Cogn.)	Cucurbitaceae	Cucurbitales	Tendril climber
344	*Ziziphus oenopolia* (L.) Mill.	Rhamnaceae	Rosales	Woody hook climber

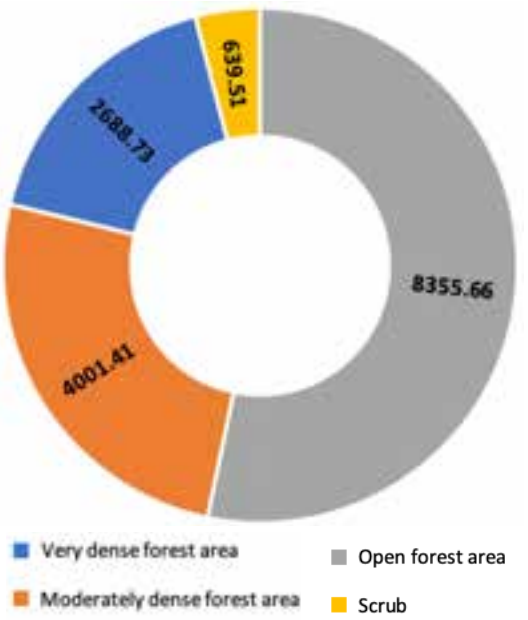

Figure 2. Representation of forest cover of Uttar Pradesh (ISFR 2023).

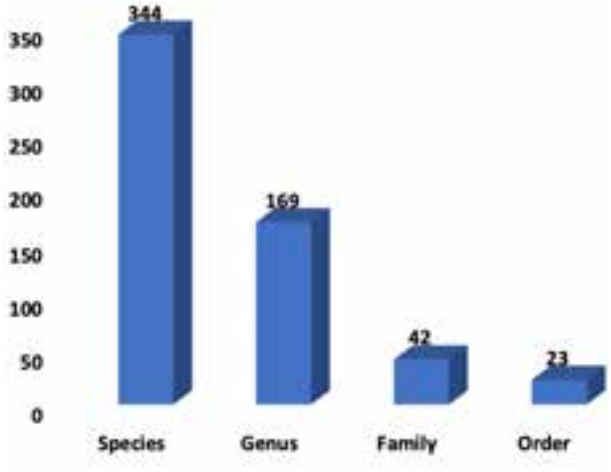

Figure 3. Details of taxa of climbing species recorded from Uttar Pradesh.

four regions of the state are reviewed as follows.

Terai Region: There are a few studies carried out by different workers on climbers of this region. Srivastava (2014) conducted a survey on wild flora of Gonda District and reported 18 plant species. Out of these 18 plant species, two were observed as climbers used by local people and ayurvedic experts in herbal and folk medicine in the area. Similarly, Khanna (2015) also reported two species of climbers from the family Apocynaceae and Basellaceae out of 212 angiosperms documented from Parvati Arga Bird Sanctuary in Gonda District. Kumar et al. (2015) in their study on flowering plants of Katerniaghat Wildlife Sanctuary in Bahraich District of Terai region, presented 778 species of Angiosperms, out of which 103 were climbers of much significance under 77 genera belonging to 31 families. Dvivedi et al. (2016) reported a total of 111 climbing species, including 63 lianas and 48 vine species of wild occurrence from the terai belt of the foothills of the Himalaya, representing 81 genera under 35 families. Khanna (2018), in his study on angiosperm plants of Terai region, documented 10 species of climbers of significant importance out of 1,753 species investigated from the entire Terai belt. Saini et al. (2021) reported 116 species of climbers, of which 66 were herbaceous climbers, 33 woody climbers or lianas and 15 climbing shrubs, along with two parasite climbers. The species also exhibited remarkable diversity in the nature of climbing. Of 116 species, 70 were twiners, 24 were tendril climbers, 15 were climbing shrubs, and four and three species were root and hook climbers, respectively. These climbers belonged to 27 different families, with Fabaceae, Convolvulaceae, Cucurbitaceae, and Apocynaceae being dominant families in the region. The study recorded the occurrence of 14 threatened climbers as well.

Gangetic Plain: Due to heavy anthropogenic activities, it has very poor biodiversity, except for some small, fragmented patches. Satya & Kanaujia (2007) in their study on the angiospermic plants of Pratapgarh reported 75 species under 64 genera and 46 families, out of which three species were recorded as climbers under

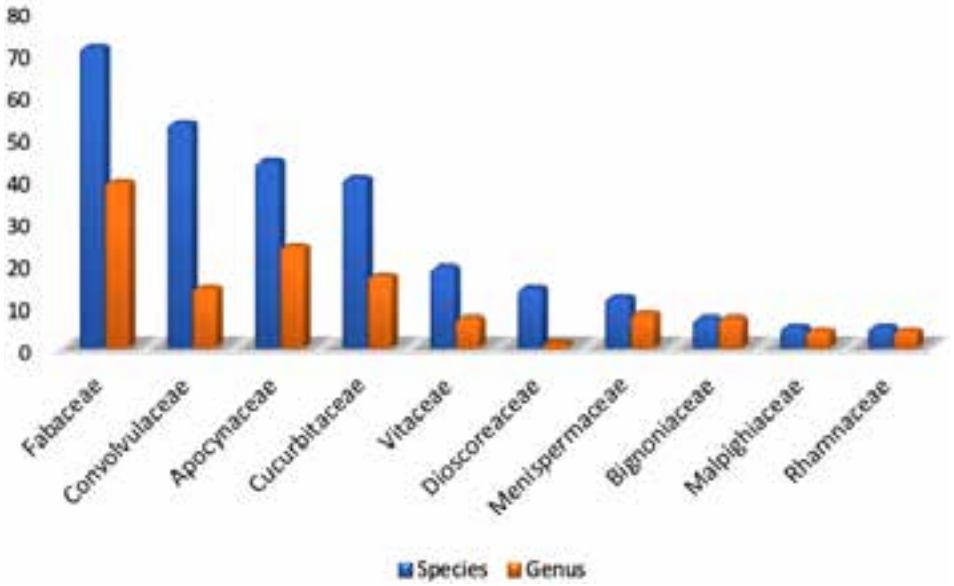

Figure 4. Dominant families of climbing species recorded from Uttar Pradesh.

three genera and two families. Maurya et al. (2015) studied the ethnobotanical uses of plants in Chandra Prabha Wildlife Sanctuary. Among 100 plants, 16 species were found to be climbers of medicinal importance

Vindhyan Region: It is constituted by a small range of the Vindhyan Hill. Due to the presence of sandy soil, it has very poor fertility. The major cultivated plant is wheat, which is cultivated along the riverbank. Due to mining and other heavy anthropogenic activities, it also has very poor biodiversity. The forest of the area is tropical dry deciduous. Singh & Dubey (2012) studied the ethnomedicinal importance of plants of Sonebhadra District, wherein they reported that the tribal people of Sonebhadra District use 143 species as traditional medicinal plants in treating various ailments. Out of 143 climbers, 17 were of climbing habit, exhibiting the ethnomedicinal potential of immense value. Singh (2015) in their study on flora of Varanasi observed 22 species under 19 genera belonging to 12 families as woody climbers out of 1,015 plant species. Family Apocynaceae was found to be the dominant family with six species under four genera, followed by Bignoniaceae with four species under three genera. Kushwaha et al. (2018) in their study on taxonomic account of angiosperms of Sonbhadra District recorded a total of 443 species, out of which 29 species were climbers with Convolvulaceae being the dominant family. Singh (2020) in his study documented 198 exotic species distributed among 157 genera belonging to 68 families from Varanasi District. Out of these 198 species, 11 species were of climbing habit represented as ornamental, crops and fruit-yielding species being utilized as herbal medicine by the rural folks of the area.

Semiarid region: Narain (2005) studied the flora of the Hamirpur District of Bundelkhand region. Out of 36 species seven species were reported to be climbers. Narain (2010) reported 27 species of climbing habit out of 602 species enumerated in the Hamirpur and Mahoba districts of the Bundelkhand region.

The critical analysis of literature in the present study indicates the presence of 344 species (including 12 intraspecific taxa), belonging to 169 genera under 42 families and 23 orders, (Table 3; Figure 3). Among the families, Fabaceae under the order Fabales emerged as the most dominant family contributing the highest number of species (71), followed by family Convolvulaceae under the order Solanales contributing to 53 species (Figure 4). Other well represented families include Apocynaceae (44) and Cucurbitaceae (40). Furthermore, *Ipomoea* was observed to be the most speciose genus, in the present study. At the order level Fabales, Solanales, Cucurbitales, and Gentianales showed maximum species richness. (Table 3). The dominance of these families and orders reflects the ecological adaptability and evolutionary success of climbers within these groups particularly in the Terai regions of the state. Furthermore, the highest diversity of climbers in this region may be attributed due to high rainfall and a humid monsoon climate, diverse vegetation structure, and, importantly, the region's overlap with the Himalayan and Gangetic floras, forming an ecotone (Dvivedi et al. 2016).

CONCLUSION

Climbers in UP have been the subject of several studies conducted by various researchers. These studies have shed light on different aspects of climbers, providing valuable insights into their diversity, distribution, ecology, and other relevant characteristics.

The climbing flora of UP makes a significant contribution to the overall plant diversity of India, both ecologically and economically. Uttar Pradesh harbours a considerable number of climber species, many of which are medicinally and economically valuable. Climbers represent an important component of the vegetation, adding structural complexity to forests, groves, and hedgerows, while also enhancing biodiversity. Although the climbing flora of UP represents only a fraction of India's total diversity, it reflects the state's unique biogeographic position and ecological heterogeneity. Their presence emphasises the state's role as a repository of useful plant resources. Conserving this diversity is thus essential, not only for maintaining ecological balance but also for sustaining cultural and economic traditions linked to the use of climbers.

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SHORT COMMUNICATION

First record of leucism in Rock Hyrax *Procavia capensis* from Ibex Reserve Protected Area, Saudi Arabia

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Abstract: Pigment anomalies such as leucism and albinism are rare in wild mammals, often linked to genetic or developmental factors and sometimes carry ecological consequences. Here, we report the first record of leucism in the Rock Hyrax *Procavia capensis* from Saudi Arabia. The observation was made during routine monitoring in the Ibex Reserve Protected Area on 17 May 2025. The individual, an adult with pale pelage and normal dark eyes, was classified as leucistic. Given the healthy and non-fragmented hyrax population in the reserve, this case is likely an isolated anomaly rather than evidence of inbreeding or population-level genetic issues. This record extends the taxonomic and geographic range of leucism to *P. capensis* in central Saudi Arabia and underscores the importance of continued monitoring and systematic documentation of aberrant colour morphs in wildlife.

Keywords: Genetic variation, Hyracoidea, Mammalia, phenotypic anomaly, pigmentation anomaly, Procaviidae, wildlife monitoring.

Pigmentation anomalies such as leucism and albinism are rare but have been recorded in many vertebrate groups. These conditions, often collectively referred to as hypopigmentation, arise from a reduction in pigment production and can manifest as albinism, leucism, or piebaldism in birds and mammals (Abreu et al. 2013; Van Grouw 2013). Leucism is characterised by partial or complete loss of integumentary pigment while typically retaining normal eye colour, in contrast to albinism, which also involves a loss or reduction of ocular pigmentation (Van Grouw 2013). Recording such observations improves understanding of their frequency, causes and possible conservation implications. The extreme rarity of leucistic morph in the animal kingdom could be linked with their odds of getting selected in nature, as these individuals may suffer from reduced foraging opportunities and communication, increased threats, affected organ development as well as physiological disadvantages, which are often poorly understood (Caro 2005; Fan et al. 2023). Hence, it is imperative to document the presence of such colour anomalies in different taxa and determine the causal factors, in addition to their distribution and survival probability.

In most animals, colouration plays a crucial role in camouflage, predator avoidance, and enhancing foraging efficiency (Ruxton et al. 2004; Stevens & Cuthill 2006). However, individuals exhibiting leucism or albinism may face survival disadvantages, as their conspicuous appearance makes them more easily

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detected by both predators and prey (Camargo et al. 2014). This heightened visibility can reduce survival prospects and, in some cases, disrupt normal social interactions (Barreto et al. 2023). Despite being relatively rare, pigment anomalies have been documented across a wide range of mammalian orders, including Carnivora (Talamoni et al. 2017; Descalzo et al. 2021; Chaudhuri et al. 2024), Chiroptera (Rocha et al. 2013; Romano et al. 2015), Primates (Aximoff et al. 2020; Barros-Diaz et al. 2022), and Rodentia (Camargo et al. 2014; Samson et al. 2017; Beninato et al. 2020). Comparable cases have also been observed in avifauna, with Islam et al. (2015) reporting leucism in the Houbara Bustard *Chlamydotis macqueenii* from Saudi Arabia. Notably, leucism has not previously been recorded in any member of the order Hyracoidea.

Study area

The Ibex Reserve Protected Area, located within the Tuwaiq Escarpment landscape in Riyadh, Saudi Arabia, covers an area of 1,842 km² (Cunningham & Wronski 2009) (Image 1). The reserve is characterized by undulating limestone plateaus interspersed with canyon wadis (Wronski et al. 2012). Vegetation is sparse and during summer (May to October), temperatures average around 40 °C (Wronski et al. 2012). Rainfall is sporadic, peaking in winter with an annual average of around 60 mm (Wronski et al. 2012). In terms of its mammal diversity, the protected area has been the focus of a key conservation and reintroduction program of the vulnerable Nubian Ibex *Capra nubiana*.

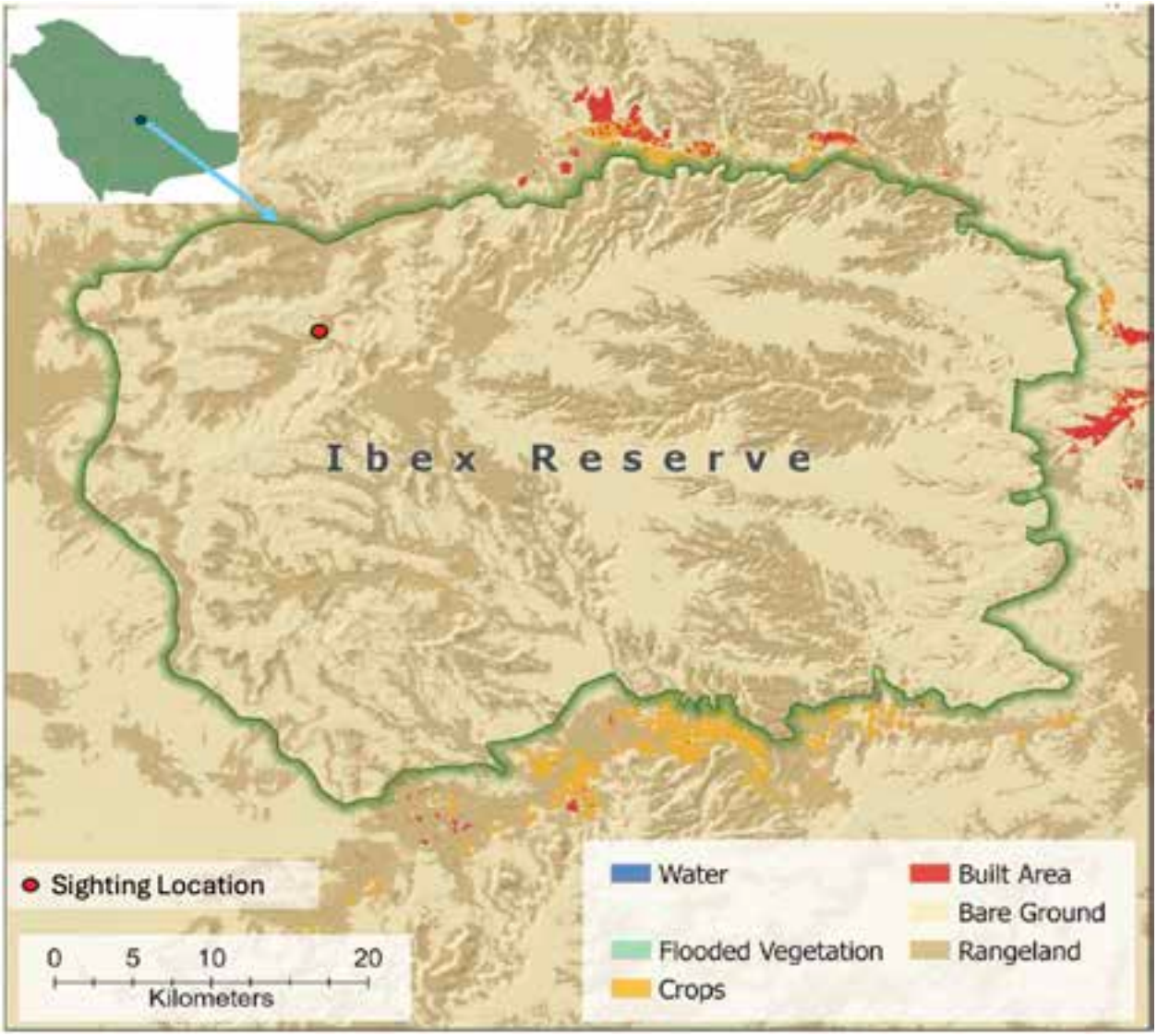

Image 1. Ibex Reserve Protected Area (showing the location of leucistic Rock Hyrax observation).

The area is also inhabited by important populations of the Arabian Wolf *Canis lupus*, and Arabian Gazelle *Gazella arabica* in addition to other mammal species. The protected area also supports a healthy population of Rock Hyrax *Procavia capensis*.

Observation and Discussion

In Saudi Arabia order Hyracoidea is only represented by Rock Hyrax which is distributed along the western mountains extending from the Gulf of Aqaba down southward reaching the Yemen border. It is also associated with the rocky terrain of Tuwaiq mountains in central Saudi Arabia. The distribution of the Rock Hyrax is limited by the presence of rocky terrain with steep mountains. The Rock Hyrax is a robust, rabbit-like mammal with short ears and a short tail, weighing around 4 kg. Typically, it has thick, grey-brown fur that varies in shade depending on the environment. The species is assessed as 'Least Concern' by the IUCN Red List (Butynski et al. 2015), but it is listed as Near Threatened in the National Red List of Saudi Arabia.

Here, we present the first record of a leucistic Rock Hyrax, from a central Saudi Arabian protected area. During routine trail monitoring on 17 May 2025 at Ibex Reserve Protected Area (approximate coordinates: 23.492° N, 46.348° E), we detected an unusually pale Rock Hyrax individual. The animal, an adult *Procavia capensis*, was observed on a rocky outcrop at 1700 h. It was readily identified as leucistic by its partially white pelage and normal dark eyes (Image 2). The individual's unique pattern of pale fur provided a natural visual marker, allowing us to reliably distinguish this hyrax from conspecifics during subsequent monitoring and to avoid duplicate observations. The Ibex Reserve is known for its rugged Tuwaiq escarpment habitat, which is ideal for the Rock Hyrax. The hyrax population in this reserve is good, reflecting effective protection.

The retained dark eye colour in the observed rock hyrax, combined with its pale/white pelage, supports classification as leucism rather than albinism. Leucism in wild mammals is uncommon and has been linked to a range of causes, including genetic factors such as recessive alleles, genetic drift in small or isolated populations, and occasional developmental anomalies (Caro & Mallarino 2020). Ecological effects, such as increased detectability to predators, have been noted for some species. However, leucistic individuals are capable of reaching adulthood and reproducing successfully, and isolated observations do not necessarily indicate underlying population-level genetic issues.

In the present case, the Ibex Reserve supports a

Image 2. Leucistic Rock Hyrax *Procavia capensis* observed on 17 May 2025 in Ibex Reserve, Saudi Arabia. © Naif Alajami.

healthy and non-fragmented Rock Hyrax population, making it unlikely that this single observation reflects inbreeding or other genetic bottlenecks. Instead, it is best regarded as a rare, individual anomaly. Continued monitoring and the systematic archiving of photographic vouchers will be valuable for documenting any future occurrences and understanding possible patterns.

Comparable records of leucism and other pigment anomalies in wildlife have been reported from diverse regions and taxa. For example, Barreto et al. (2023) described the first known case of leucism in a Brazilian rodent *Kerodon rupestris*, Chaudhuri et al. (2024) reported a leucistic Sloth Bear *Melursus ursinus* in India, and Al-Sheikhly et al. (2018) documented aberrant white plumage in the endangered Basra Reed Warbler *Acrocephalus griseldis*. Each of these studies stresses that although pigment anomalies are rare, their documentation is important for understanding both proximate causes and broader ecological implications. Similarly, Abreu et al. (2013) and Barreto et al. (2023) highlight that recording such events contributes to knowledge of environmental contexts in which they arise. Our report extends the taxonomic and geographic record of leucism to *P. capensis* in Saudi Arabia.

While some studies note higher leucism frequency in small or isolated populations due to reduced genetic diversity, the current observation confirms that such individuals can survive to adulthood without obvious growth limitations. The hyrax in question appeared fully mature and in good condition, indicating no apparent developmental disadvantage in this case. Interestingly, Ortiz-Hoyos et al. (2020) suggest that in diurnal species, leucistic and albino individuals may experience reduced predation risk compared to nocturnal species, as the latter are more visible in low-light environments. This may help explain how visibly distinctive individuals like this hyrax can persist in the wild.

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SHORT COMMUNICATION

First national record of Yellow Owl Butterfly *Neorina hilda* Westwood, 1851 (Lepidoptera: Nymphalidae: Satyrinae) for Nepal

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Abstract: The present finding reports the first national record of *Neorina hilda* Westwood, 1851 (Nymphalidae: Satyrinae), commonly known as the Yellow Owl Butterfly from Nepal. A single adult individual was observed and photographed at Taplejung District (27.363° N, 87.724° E), eastern Nepal, on 29 July 2025. This species was recorded in an upper temperate mixed broad-leaved evergreen forest at an elevation of 2,625 m. Previously known from northeastern India and extending through Myanmar to southeastern Asia, this finding expands the current known geographical range of the species to the west. This record has important implications for butterfly conservation planning and habitat connectivity assessments in the eastern Himalaya where a detailed assessment is recommended.

Keywords: Butterfly diversity, community forest, eastern Himalaya, ecological connectivity, forest habitat, Habre center, habitat protection, Kangchenjunga landscape, range extension, threats.

नेपाली सार: यस खोजबाट निम्फालिडे परिवारमा पर्ने निओरिना हिल्डा वेस्टवुड, १८५१ नामक पुतली नेपालमा पहिलो पटक राष्ट्रिय रुपमा अभिलेख गरिएको छ। २९ जुलाई २०२५ मा पूर्वी नेपालको ताप्लेजुङ जिल्लाको देउराली भित्रि सामुदायिक वनमा अवस्थित हिमालयन हाब्रे केन्द्र परिसरबाट यस प्रजाति पहिलो पटक अभिलेख गरिएको थियो। माथिल्लो समशीतोष्ण मिश्रित चौडा-पात सदाबाहार वन पारिस्थितिक प्रणालीमा पर्ने अभिलेखित स्थान समुद्री सतहबाट २,६२५ मिटरको उचाईमा रहेको छ। यस खोजले अभिलेखित पुतली पूर्व उल्लेखित वितरण दायरा उत्तरपूर्वी भारत तथा म्यानमार हुँदै दक्षिणपूर्व एशिया सहित नेपालको पूर्वी क्षेत्र सम्म रहेको प्रमाणित गर्दछ। साथै यस खोजले नेपालको पूर्वी हिमाली भेग पुतली विविधता र वितरणको लागि महत्वपूर्ण क्षेत्र रहेको र थप पुतली केन्द्रित अध्ययन र अनुसन्धानको खाचो रहेको प्रस्ट पर्दछ।

The Yellow Owl *Neorina hilda* Westwood, 1851 is a rare Satyrinae butterfly belonging to the Nymphalidae family, distributed across the eastern Himalaya and southeastern Asia. This elusive species is currently protected under Schedule II of India's Wildlife (Protection) Amendment Act, 2022, reflecting its conservation significance. The *N. hilda* is a distinctive butterfly species of eastern Himalayan broadleaf and cool temperate sub-alpine forests (Chettri 2015), often observed flying along forest paths and resting on the ground, tree trunks, and bare hillsides.

The genus *Neorina*, commonly known as "owl" butterflies, was proposed by Westwood in 1850 and comprises five distinct species: *crishna* (Westwood, 1851), *lowii* (Doubleday, 1849), *patria* (Leech, 1891),

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neosinica (Lee, 1985), and *hilda* (Westwood, 1851). The species exhibits a robust body structure with distinct morphological features that facilitate identification. *Neorina hilda* can be distinguished from others by its characteristic broad yellow discal bands and specific ocellar patterns (Evans 1932; Wynter-Blyth 1957; Mani 1986).

N. hilda is patchily distributed across an altitudinal range of 2,100–2,700 m (7,000–9,000 ft) corresponding to the temperate broadleaf forest ecoregion of the eastern Himalaya (Kunte et al. 2024). This ecoregion supports rich butterfly diversity, with species richness peaking at mid-elevations due to favourable climate and vegetation (Dewan et al. 2024). The forests occurring at elevations of 2,600–3,000 m in the eastern Himalayan region are classified as broadleaf-evergreen forests (Negi et al. 2024) and are dominated by *Quercus lamellosa* (oak), *Castanea* species (chestnut), *Rhododendron* spp., *Magnolia* spp., and various laurel species, providing better canopy cover and vegetation structure for *N. hilda*.

This note aims to report the first national record of *Neorina hilda* in Nepal, expanding its known geographical range and highlighting its conservation implications for the eastern Himalayan region.

Materials and Methods

The Himalayan Habre Center (Habre Center) is located on a hilltop (27.363° N, 87.724° E) along the Pathibhara trail in Deurali-Bhitri Community Forest in Taplejung District, Nepal (Image 1). It borders the forest-edge areas of the adjacent Yamabung and Sayapatri-Pokhari community forests. These forests are dominated by *Rhododendron* spp., *Magnolia* spp., and various broad-leaved trees collectively forming an upper temperate mixed broad-leaved forest zone.

This finding is based on opportunistic observation while walking around the Habre Center on a sunny day, 29 July 2025, at 1144 h (NPT time zone). Photographs and video were captured using a Sony camera (model ZV-1F) equipped with a 2.0/7.6 mm lens, and identified based on its distinct morphological and taxonomic characteristics by comparing against the illustrated checklist of Nepal butterflies (Smith 2006; van der

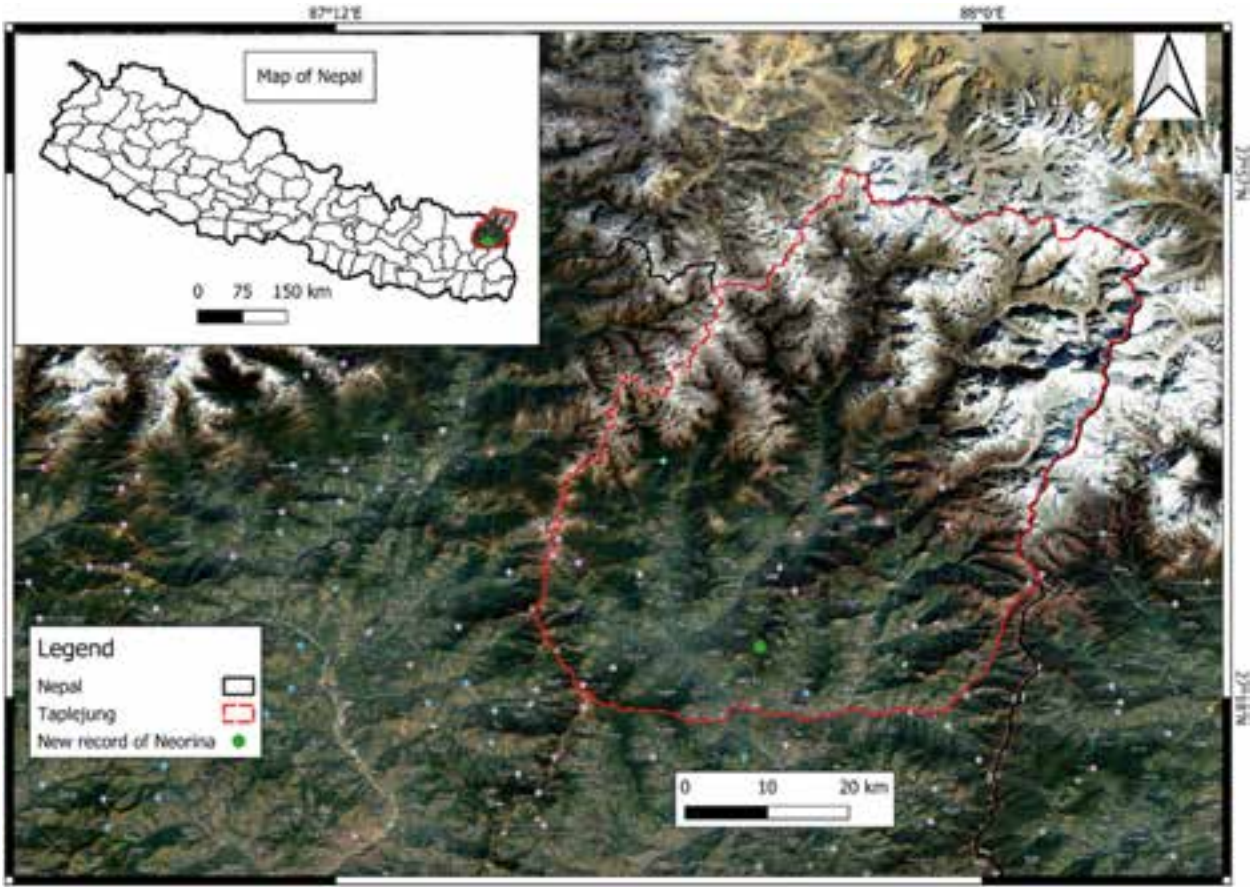

Image 1. Map showing new distribution record of *Neorina hilda* from Taplejung, Nepal.

Poel & Smetacek 2022). Expert consultation was also conducted to validate the identification (M.S. Limbu & S.P. Suwal, pers. comm. July 2025).

Results

A single individual of *Neorina hilda*, having a partially damaged hindwing, was observed gliding along the forest margin near the Habre Center before landing on a stone (Images 4 & 5).

The size of an adult *N. hilda* ranges 96–104 mm (Bingham 1905). Morphologically, N. *hilda* shares similar characteristics with *N. patria* (White Owl), particularly in having a well-defined subapical ocellus equal in size to that of *N. patria*. *N. hilda* differs significantly by lacking a tail at v3 and possessing a broad yellow discal band at the upper side of the forewing (Image 5), which is white in *N. patria* (Leech 1893). *Neorina hilda* can be distinguished from its other species with the same genus by its distinct pale-yellow bands and by the presence of a large, black, white-centered ocellus with a proximal yellow outline, accompanied by two smaller, blue-spotted subanal ocelli (Images 4 & 5). While Lethe *Europa* superficially resembles *N. hilda*, it can be readily distinguished by its white (rather than yellow) forewing discal band, which is also narrower. Other *Lethe* species, including *L. confusa*, *L. verma*, and *L. rohria,* possess distinctive white forewing discal bands but are considerably smaller in size compared to *N. hilda. Thaumantis diores* (Amathusini) closely resembles *N. hilda* in general appearance and size; however, it lacks the characteristic broad discal band entirely, making differentiation straightforward Wynter-Blyth 1957; (Leech 1893; Evans 1932; Mani 1986). Hence, this recording of *N. hilda* cannot be confused with any other species.

After clear identification, the species was confirmed as a new record for Nepal by examining existing literature, including the annotated checklist of Nepal's butterflies, which previously listed 695 species (Smith 2006; van der Poel & Smetacek 2022; van der Poel 2024). This new record brings the total to 696 species.

Discussion

One individual of *N. hilda* recorded in Taplejung, eastern Nepal, indicates a low population density of the species in the area. Its hindwing was partially damaged, suggesting a possible predatory encounter, most likely

Image 2. Surrounding forest habitats of Sayapatri-Pokhari and Yamabung community forests around the recorded area. © Nishan Limbu.

Image 3. *Neorina hilda* from the observation, whose hindwing can be seen partially damaged (possibly from a predator attack). © Nishan Limbu.

Image 5. Forewing of *Neorina hilda* have two ocelli with two white small dots above and below the ocelli. © Nishan Limbu.

Image 4. Forewing and hindwing of *Neorina hilda* have two white-centered white ocelli with a yellow band on the forewing, with clearly showing mud-puddling behavior. © Nishan Limbu.

with birds, which are known predators of butterflies in forest-edge habitats. The observation site was also situated at the forest edge characterized by strong wind currents and frequent bird gliding activity, which may increase predation pressure.

During the observation, *N. hilda* repeatedly visited three times on the recently cemented stone surface, displaying mud-puddling behaviour (Image 4). This is a well-documented phenomenon in Satyrinae, where individuals extract essential nutrients such as sodium from inorganic substrates. This behaviour is consistent with reports of butterflies seeking sodium and other nutrients from moist, earthy surfaces. Such behaviour is ecologically significant as it supplements their diet and supports physiological functions like reproduction and flight (Lamie et al. 2025). After each foraging attempt, it returned to the surface before eventually flying off into the surrounding forest.

Neorina hilda is documented from the Moruo area, southeastern Tibet (Evans 1932), Myanmar (Shizuya et al. 2005), Yunnan Province, China (Lo & Bi 2019), Bhutan (Singh et al. 2015), and from northeastern India (Kunte et al. 2024; Lepcha & Thapa 2025). Whereas the new occurrence record from Nepal further expands its easternmost distribution range of the species (Image 1), and indicates the possibility of this species further west. Besides, the finding highlights the importance of the eastern Himalayan broad-leafed forest as habitat of this species.

The forest in the region is experiencing a high threat due to rapid developmental projects such as roads, dams, and human settlements, resulting in significant loss of forest cover. The recent controversy on cable car construction to Pathibhara Temple at the summit is ongoing, while hundreds of ecologically important trees, such as rhododendron, have already been wiped out. This has undoubtedly disrupted the habitat for many faunal species, including the threatened Red Panda *Ailurus fulgens*, Clouded Leopard *Neofelis nebulosa*, Chinese Pangolin *Manis pentadactyla*, and Himalayan Black Bear *Ursus thibetanus*. Little known is the fact that there have been records of species only recorded in Taplejung District and nowhere else in Nepal, such as

Single Silverstripe *Lethe ramadeva* (de Nicéville, 1887) and the Freak *Calinaga buddha* (Moore, 1857) (Tamang & Panthee 2021; Tamang & Motoki 2022).

Given the site's transitional nature between human-modified and forested zones, further assessment could unveil seasonal occurrence**,** population stability, and habitat specificity of *N. hilda* in this region. This record also underscores the need for systematic monitoring and ecological studies to determine its conservation status, especially in light of potential threats from habitat disturbance and climate variability. Given the protected status of this species in India, its occurrence in eastern Nepal also highlights the need for regional collaboration in butterfly conservation. Additionally, the extension of the known range to eastern Nepal clearly indicates butterfly-rich habitat around the areas requiring an immediate need of detailed ecological studies focusing on the butterfly diversity.

Conclusion

This study reports the first national record of *Neorina hilda* in Nepal, specifically from Taplejung District. The finding expands the known geographical distribution of this rare and protected butterfly species, contributing to Nepal's butterfly discovery, which now stands at 696 species. The confirmation of this species in the Deurali-Bhitri Community Forest suggests the potential ecological connectivity with the adjoining forest habitats in India. As only a single individual was observed, further systematic monitoring and ecological studies are crucial to assess population status, seasonal occurrence, and habitat choices in the Kangchenjunga Landscape in eastern Nepal. This finding also suggests the need for a detailed study on the butterfly distribution and diversity in the region with protection and management of the forested areas as well as mud-puddling sites.

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NOTE

First record of Wall's Krait *Bungarus walli* Wall, 1907 (Reptilia: Squamata: Elapidae) from Assam, and diagnostic keys to the kraits of India

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Kraits of the genus *Bungarus* Daudin, 1803 are highly venomous ophiophagous snakes belonging to the family Elapidae found in southern and south-eastern Asia across Afghanistan, Bangladesh, Bhutan, Brunei, Cambodia, China, India, Indonesia, Iran, Laos, Malaysia, Myanmar, Nepal, Pakistan, Singapore, Sri Lanka, Taiwan, Thailand, and Vietnam (Wallach et al. 2014; Midtgaard 2022; Uetz et al. 2026). The genus currently comprises 18 recognised species, nine of which are known to occur in India: *Bungarus andamanensis* Biswas & Sanyal, 1978; *B. bungaroides* (Cantor, 1839); *B. caeruleus* (Schneider, 1801); *B. fasciatus* (Schneider, 1801); *B. lividus* Cantor, 1839; *B. niger* Wall, 1908; *B. sindanus* Boulenger, 1897; *B. suzhenae* Chen, Shi, Vogel, Ding & Shi, 2021, and *B. walli* Wall, 1907 (Uetz et al. 2026).

Among these, *Bungarus walli*, commonly referred to as Wall's Krait, was originally described from Fyzabad (at present Faizabad), Uttar Pradesh, India (Wall 1907). The species is known from the Indian subcontinent, with confirmed occurrences in India, Bangladesh, Nepal, and Bhutan (Smith 1943; Lenz 2012; Wallach et al. 2014; Ahsan & Rahman 2017; Ghosh et al. 2021). Within India, *B. walli* exhibits a fragmented distribution and has been reported from a limited number of states, including Bihar, Odisha, Uttar Pradesh, and West Bengal (Figure 1) (Whitaker & Captain 2004; Bhattacharjee & Sarkar 2021). Recently, *B. walli* has been reported from Tripura, marking the first-ever record of the species from northeastern India (Deb et al. in press). In addition to distributional records, existing studies have reported aspects of the species' natural history, including habitat preference and venom effects (Sharma et al. 2013), leucism (Devkota et al. 2020), reproductive biology (Ray et al. 2020; Ray et al. 2023), and scavenging behaviour (Banik & Ray 2023).

While a few reports of *Bungarus sindanus walli*

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are present from Maharashtra State in western India (Nande & Deshmukh 2007; Deshmukh et al. 2016), they have now come to be identified as *Bungarus sindanus* complex based on a smaller number and extent of bands, yellowish supralabials among other variations, distinct from *B. walli*, which is more of an eastern Indian species. In northeastern India, six species of *Bungarus* are currently known: *B. bungaroides*, *B. fasciatus*, *B. lividus*, *B. niger*, *B. suzhenae*, and *B. walli,* of which all except *B. suzhenae* and *B. walli* have been reported from Assam (Basfore et al. 2024; Gerard et al. 2024; Deb et al. in press). The present study confirms the occurrence of the fifth species of *Bungarus* recorded from Assam, based on data of a live uncollected subadult encountered in the Raimona National Park.

The Raimona National Park is located on the northern bank of the Brahmaputra River and falls under the Kachugaon Forest Division of the Kokrajhar District in Assam, India. It lies along the Indo–Bhutan international border, with the Sonkosh River forming the western boundary and the Saralbhanga River marking the eastern extent. To the northern side, Raimona shares a contiguous landscape with the Phipsoo Wildlife Sanctuary of Bhutan, while the Buxa Tiger Reserve of West Bengal borders it to the western side. The occurrence of *B. walli* in Assam is likely attributable to its close proximity to West Bengal, a region where the species is already known to occur.

On 17 July 2025, at 2030 h, during a herpetofaunal survey, a juvenile *Bungarus walli* (Image 1), approximately 460 mm in total length, was encountered in the Western Range (26.673° N, 89.972° E; elevation: 117 m) of the Raimona National Park. The specimen was found actively foraging across a moist, semi-shaded habitat along a shallow forest stream surrounded by dense vegetation. The area is characterised by thick undergrowth dominated by climbers, shrubs, ferns, and grasses along the margins of the narrow stream. The adjoining forest is composed of tall evergreen and semi-evergreen trees with a dense canopy, creating a humid and shaded environment.

Upon encounter, the snake was photographed,

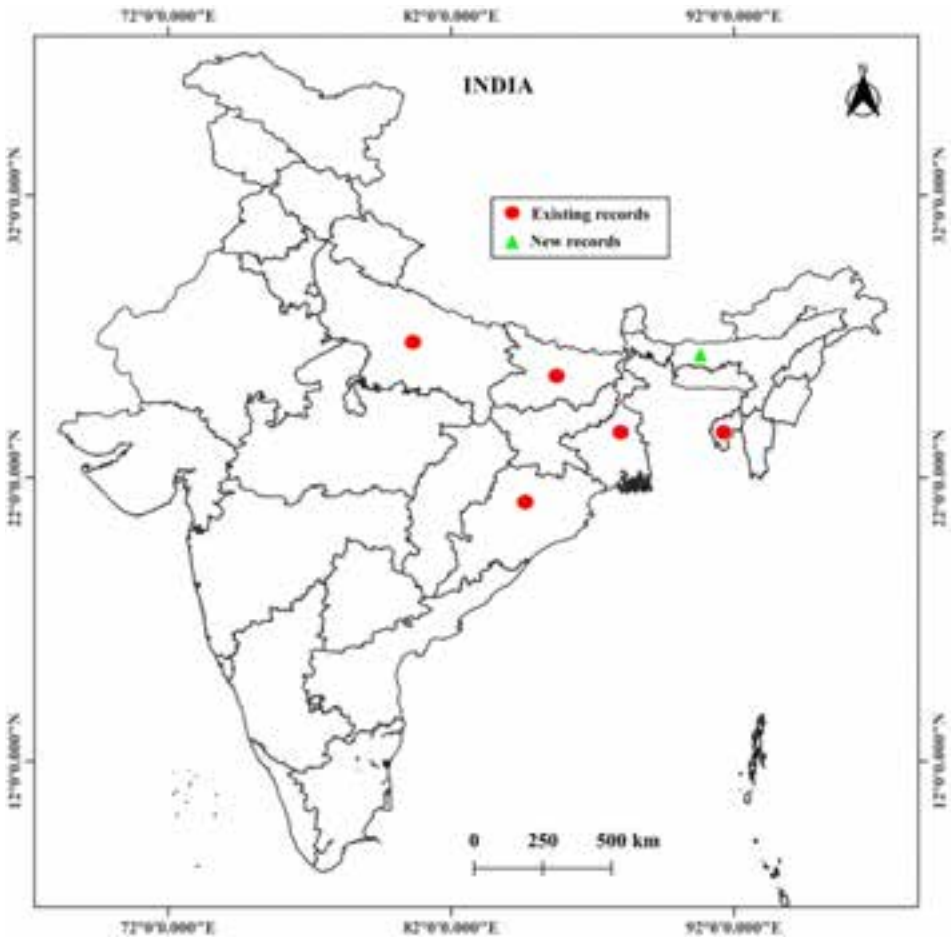

Figure 1. Updated geographical distribution of *Bungarus walli* in India.

and essential meristic and morphometric data were recorded. Identification was carried out based on the following diagnostic characters: (1) Dorsal scale rows: 19:17:17; (2) Ventrals: 207; (3) Supralabials: seven, with the 3rd and 4th touching the eye; (4) 2nd supralabial narrower than the 3rd; (5) Infralabials: four; (6) mid-body vertebral scales distinctly broader than long; (7) body distinctly compressed; and (8) glossy black colouration with 66 white, unpaired transverse bands, all consistent with existing published descriptions (Table 1).

A comparative account of the newly encountered specimen with published literature is provided in Table 1, while Table 2 presents diagnostic keys to the kraits of India. Other herpetofaunal species recorded at the site included Irawaddy Crested Lizard *Calotes* cf. *irawadi*, Eastern Bronzeback *Dendrelaphis proarchos*, Bangladesh Skittering Frog *Euphlyctis adolfi*, Northern House Gecko *Hemidactylus aquilonius*, Common House Gecko *Hemidactylus frenatus*, Flat-tailed House Gecko *Hemidactylus platyurus*, Littoral Bullfrog *Hoplobatrachus litoralis*, Bhamo Frog *Hylarana humeralis*, Cope's Assam Frog *Hylarana leptoglossa*, Theobald's Ranid Frog *Hylarana tytleri*, Nepal Cricket Frog *Minervarya nepalensis*, Pierre's Cricket Frog *Minervarya pierrei*, and Bengal Monitor Lizard *Varanus bengalensis*.

The present record of *Bungarus walli* from Assam represents a significant extension of its known geographic range, approximately 778 km east of the type locality in Uttar Pradesh (Uetz et al. 2026), about 393 km from the recent confirmed record in Tripura

Image 1. *Bungarus walli* from Raimona National Park, Assam: top–entire view; bottom–head close-up view. © Bijay Basfore.

Table 1. Comparison of *Bungarus walli* from Raimona National Park, Assam with published descriptions.

Character	Present specimen	Wall (1907)	Smith (1943)	Whitaker & Captain (2004)	Bhattacharjee & Sarkar (2021)
Total length (in mm)	460	393–1517	1640 (Male) & 1500 (Female)	1518	-
Dorsal scale rows	19:17:17	19:17:17	19 or 21: 17 or 19:17	17 or 19:17 or 19:17	17 or 19:17 or 19:17
Ventrals	207	203	196–208	196–208	192–207
Subcaudals	55	55	50–55	50–55	48–55
Cloaca	Entire	Entire	-	Entire	-
Supralabials	7 (3 & 4 touching eye)	7 (3 & 4 touching eye)	-	7 (3 & 4 touching eye)	-
2nd supralabial narrower than 3rd	Yes	Yes	-	-	-
Infralabial	4	4	-	-	-
Preocular	1	-	-	1	-
Postocular	2	-	-	2	-
Loreal	Absent	-	-	Absent	-
Temporals	1+2	1 (anterior)	-	1+2	-
Preocular spot	Absent	Absent	Absent	-	-
Vertebrals broader than long	Yes	Yes	-	Yes	Yes
Number of bands	66	-	65–80	-	-

Table 2. Diagnostic key to the Kraits of India.

Species	DSR (midbody)	VEN	SC	Dorsal pattern	Body bands	Reference
B. andamanensis	15	193–197	45–47 (undivided)	Narrow white or yellowish-white bands	39–47	Biswas & Sanyal, (1978); Smith (1943)
B. bungaroides	15	220–237	44–51 (divided)	White or pale yellow bands	46–60	Smith (1943); Das (2018)
B. caeruleus	15	200–217 (234)	33–54 (undivided)	Narrow white bands (sometimes paired)	29–65	Biswas & Sanyal (1978); Slowinski (1994); Whitaker & Captain (2004)
***B. fasciatus* sensu stricto**	15	222–228 (male) & 224–231 (female)	35–37 (male) & 32–36 (female) (undivided)	Black and yellow bands	22–27	Biakzuala et al. (2023)
B. lividus	15	209–221	35–43 (undivided)	Black or bluish-black	Absent	Smith (1943)
B. niger	15	216–231	47–57 (undivided)	Glossy black body	Absent	Wall (1908); Smith (1943)
B. sindanus	17 or 19	220–237	49–52 (undivided)	White bands	-	Boulenger (1897)
B. suzhenae	15	220–229	51–54 (undivided)	White bands	26–38	Chen et al. (2021)
B. walli	17 or 19	196–208	50–55 (undivided)	Narrow white unpaired bands	65–80	Wall (1907); Smith (1943)

(Deb et al. in press), and about 62 km from its nearest previously known record from West Bengal (Banik & Ray 2023). Thus, the present study highlights the significance of systematic herpetofaunal surveys in transboundary landscapes, having contiguous forests with countries like Bhutan, as these regions may harbour undocumented taxa. The finding also emphasises the role of Raimona National Park, a recently established protected area, as a valuable site for documenting poorly known or range-extended herpetofaunal species. *Bungarus walli* is often misidentified as *B. caeruleus* or *B. sindanus,* and as a medically important venomous snake, such misidentifications are of concern, as existing polyvalent antivenoms may exhibit variable efficacy across different *Bungarus* species (Chippaux 2017). Therefore, accurate identification and targeted inventory of herpetofauna are essential not only for conserving biodiversity but also for enhancing public health preparedness in

snakebite-prone regions, such as western Assam, where agriculture is the primary livelihood activity and brings people into frequent contact with snakes.

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NOTE

Eastern range extension of the band-winged grasshopper *Pusana rugulosa* (Uvarov, 1921) (Insecta: Orthoptera: Acrididae) in India

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The short-horned grasshopper belongs to the family Acrididae, which is the largest family under the superfamily Acridoidea (Insecta: Orthoptera) with about 6,891 species worldwide (Cigliano et al. 2025) and 361 species in India (Chand et al. 2024). The Indian Acrididae are catalogued under 15 subfamilies of which the members of the subfamily Oedipodinae are commonly called band-winged grasshoppers.

The genus *Pusana* was proposed by Uvarov (1940) as a nomen novum for the generic name *Pusa* Uvarov, 1921, under the subfamily Oedipodiane. This genus is distinguishable by its elongated head; very long and slender hind femur, and a feeble median carina of the pronotum, an indistinct lateral carina of pronotum, and a median carina of the pronotum crossed by three deep transverse sulci. Globally, this genus is represented by three species; of which two species, namely, *P. laevis* and *P. rugulosa*, are known to occur in India (Shishodia et al. 2010; Chand et al. 2024; Cigliano et al. 2025) and *Pusana chayuensis* (Yin, 1984) from China. Among the two species found in India, *P. rugulosa* has an apparent disjunct distribution in Bihar, Punjab, and Uttarakhand (Sharma 2017). Whereas, *P. laevis* has been reported from Bihar, Himachal Pradesh, and Sikkim (Shishodia et al. 2010).

This study marks the first report of *P. rugulosa* from northeastern India as well as the first report of the genus *Pusana* from Assam. A detailed description of the male and female genitalia of the species is provided.

In 2024, two faunistic surveys were conducted in Dibru-Saikhowa Biosphere Reserve (Image 1) located in eastern Assam, where 13 specimens (5 males + 8 females) of *Pusana* were collected. The specimens were handpicked from sandy river bank, euthanised with ethyl acetate vapours and dry preserved. These were studied under stereo zoom microscope in the laboratory. The subfamily level identification is done based on the extant keys and descriptions (Kirby, 1914; Usmani, 2009; Usmani & Kumar, 2011) and the genus was determined based on Uvarov (1921) and Kumar & Usmani (2016). Identification to the species level is based on the morphological description by Uvarov (1921). The photographs of holotype catalogued in the orthopteraspeciesfile.org by Cigliano et al. (2025) were

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also compared which exhibits morphological similarity with our specimens. The specimens were processed for genitalic studies by the methods used by Usmani (2009) and Kumar et al. (2014). The terminology used for describing male and female genitalia follows Dirsh (1965) and Slifer (1939), respectively. The specimens are deposited in the national zoological collection of North Eastern Regional Centre, Zoological Survey of India, Shillong.

Pusana rugulosa (Image 2) is characterized by its notably elongated head, a typical feature of the genus, with frons less strongly reclined and a hexagonal fastigium that is slightly inclined and rounded where it meets the frontal ridge. The eyes are prominently bulging and nearly hemispherical, and the antennae are filiform, slightly thickened in the apical third. The species can be easily distinguished from its congener *P. laevis* as its habitus is more robust; face and body more densely covered with hairs, the face is rugulose with numerous, though not dense, impressed points.

Keys to the Indian species of *Pusana* Uvarov, 1940 (derived from Uvarov, 1921):

1. Face smooth, impunctate; pronotum only feebly constricted anteriorly; metazoan almost flat. Face and body covered with sparse hairs ..... *P. laevis*, Uvarov, 1921.
2. Face rugulose, with numerous, though not dense, impressed points; pronotum more constricted anteriorly, with metazoan convex and distinctly raised above prozona. Face and body more densely hirsute ..... *P. rugulosa*, Uvarov, 1921.

The *P. rugulosa* in Dibru-Saikhowa are adapted to sandy habitats as it provides natural camouflage.

The genus *Pusana* was proposed by Uvarov (1940) as a nomen novum for the generic name *Pusa* Uvarov, 1921, which was identified as a junior homonym of the mammalian genus *Pusa* Scopoli, 1771 , used for earless seals. In his original description of *Pusa rugulosa*, Uvarov (1921) noted that the "typical male" was from an "unknown locality," while the paratypic series was

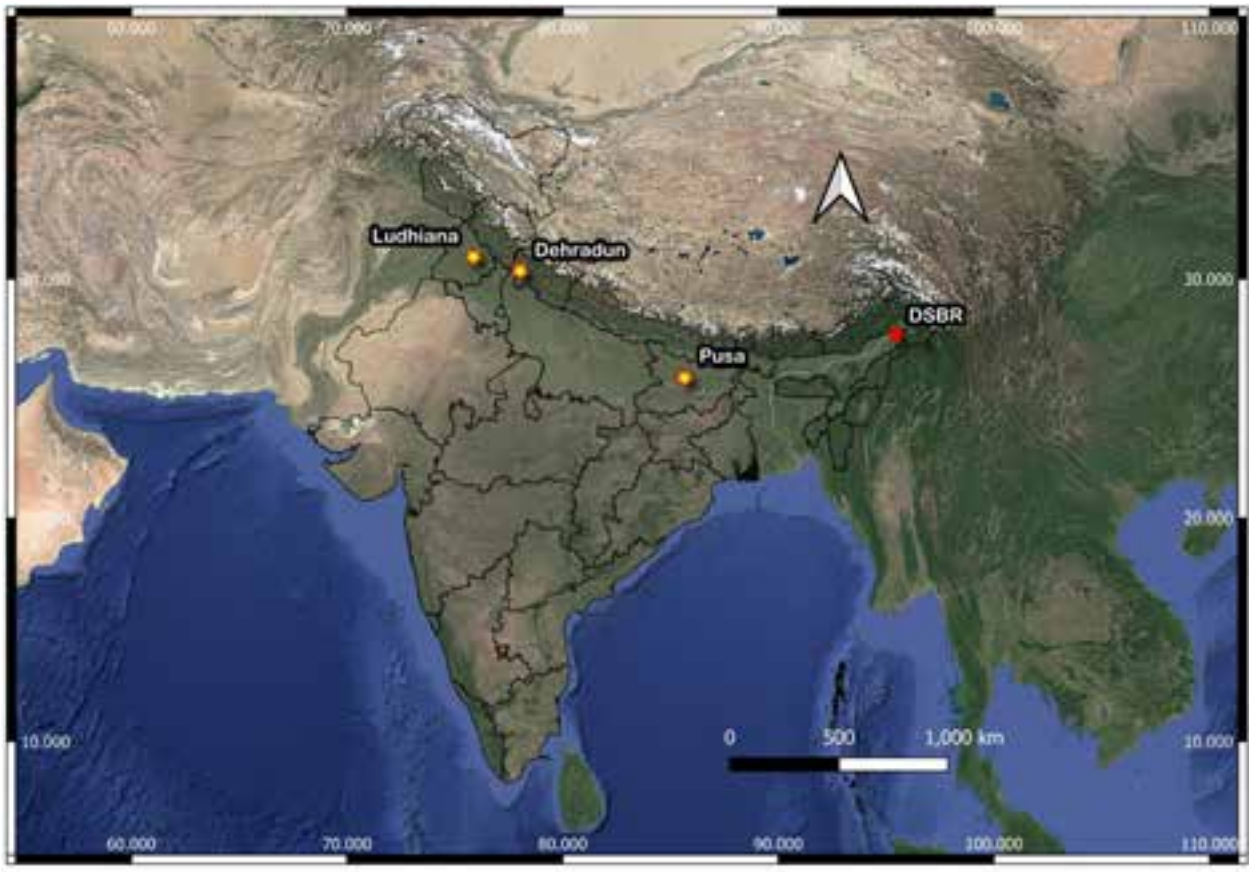

Image 1. Map showing locality records of *Pusana rugulosa* in India (yellow asterisk) with the new locality record in Assam (red asterisk, DSBR—Dibru Saikhowa Biosphere Reserve).

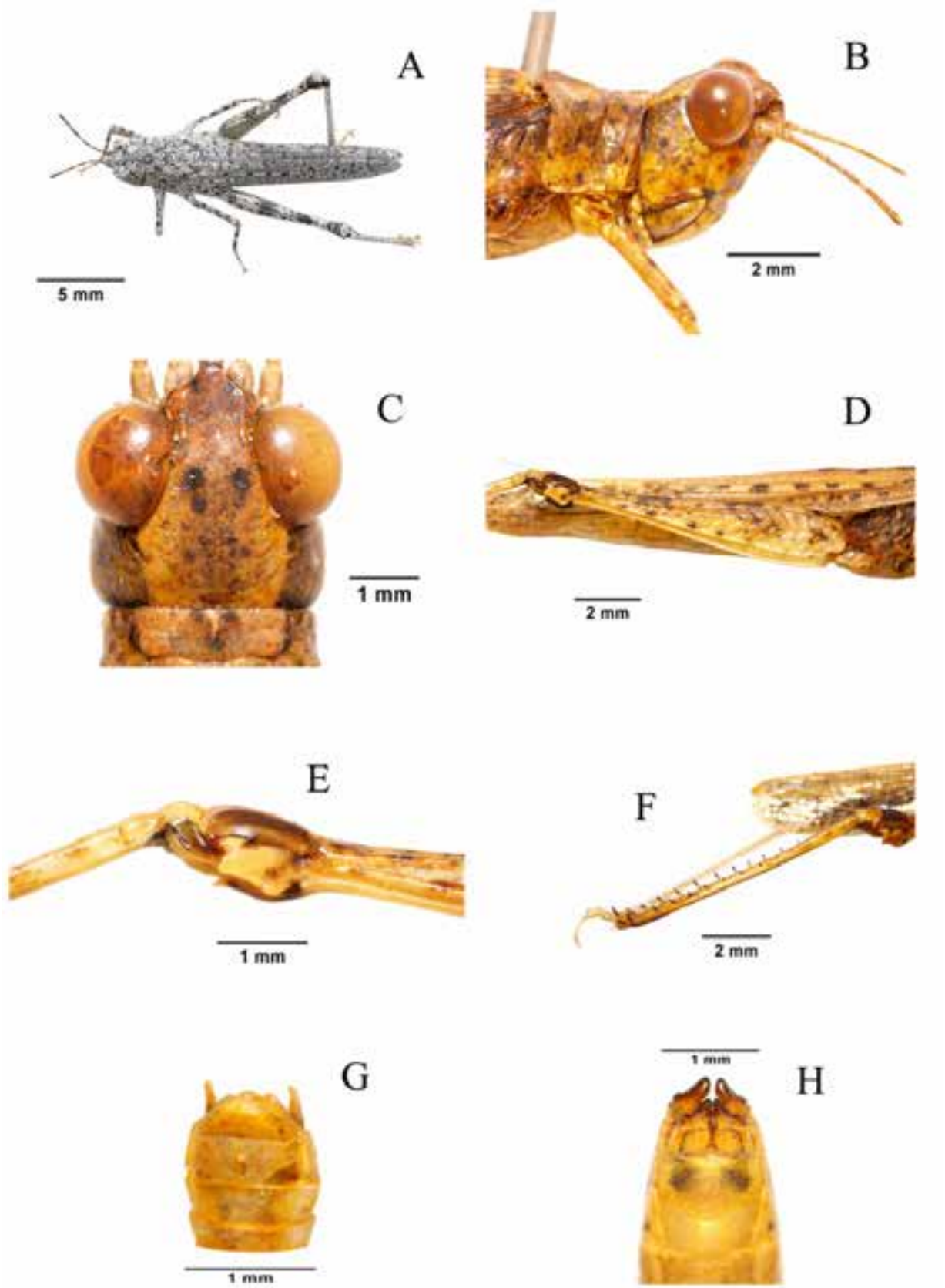

Image 2. ***Pusana rugulosa*** **(male): A—Dorsal view | B—Lateral view of head and pronotum | C—Dorsal view of eye and fastigium of vertex | D—Hind femur | E—Knee lobe | F—Hind tibia | G—Ventral view of apex of abdomen | H—Ventral view of apex of abdomen (female).**

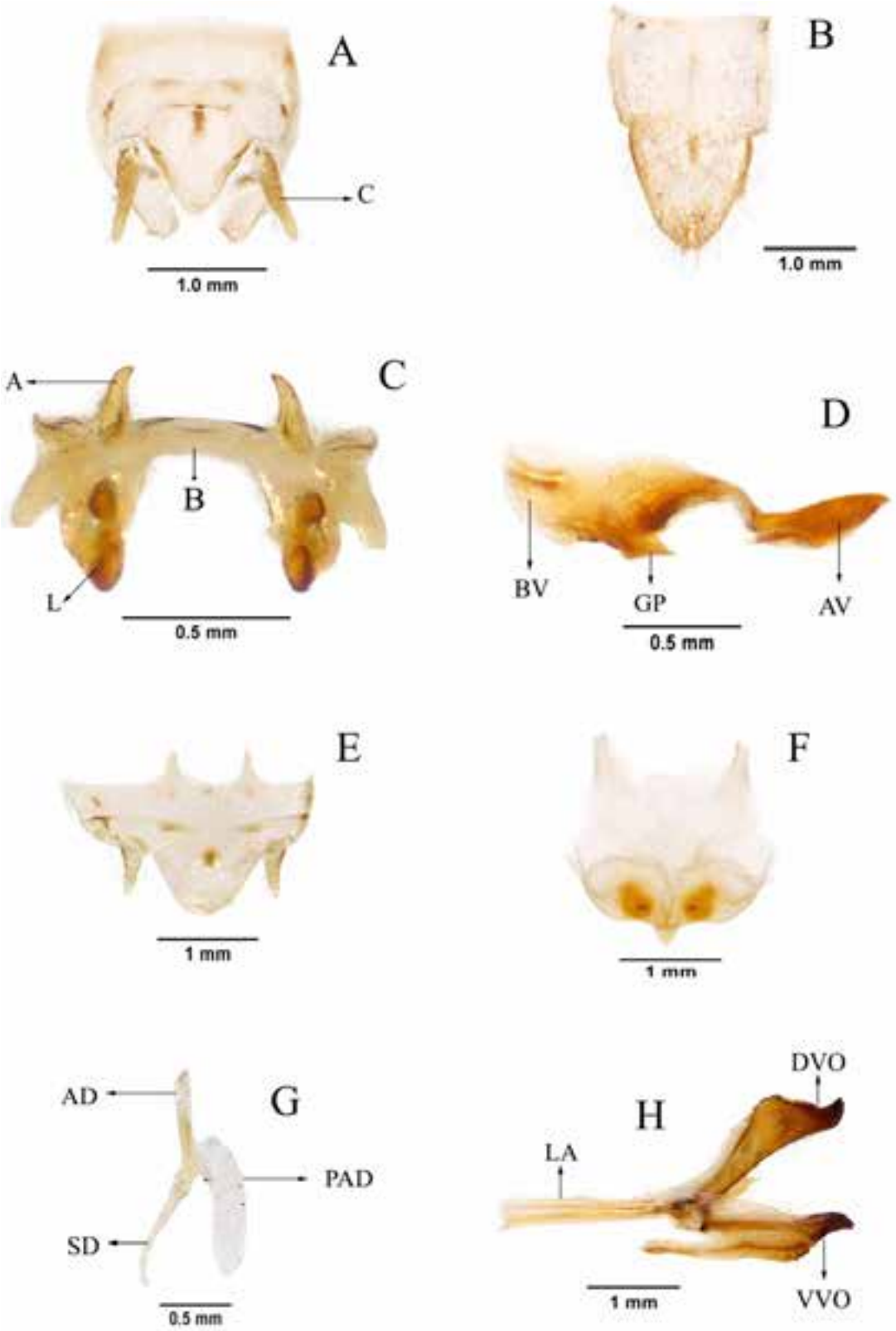

Image 3. Genitalia of *Pusana rugulosa* A–D (male); E–H (female): A—Supraanal plate | B—Subgenital plate | C—Epiphallus | D—Aedeagus | E—Supraanal plate | F—Subgenital plate | G—Spermatheca | H—Ovipositor.
Abbreviations: A—Ancorae | B—Bridge | C—Circus | L—Lophus | BV—Basal valve | AV—Apical valve | GP—Gonopore process | AD—Apical diverticulum | PAD—Preapical diverticulum | SD—Spermathecal duct | LA—Lateral apodeme | DVO—Dorsal valve of ovipositor | VVO—Ventral valve of ovipositor. © Amlanjyoti Gautam.

collected "partly from Pusa, Bihar and partly without precise data". Assessment of the type material deposited at the Natural History Museum, London (NHMUK), as cataloged in the Orthoptera Species File (Cigliano et al. 2025), clarifies that the holotype male actually originated from Punjab, India. The previously reported range of *P. rugulosa* is apparently disjunctive, with established records from Bihar, Punjab, and Uttarakhand in India (Sharma 2017), and an extranational report from Afghanistan (Sharma 2017).

This study confirms the range extension of *P. rugulosa* to Assam, which now represents the easternmost known range for the species and the first record of the genus *Pusana* from the state of Assam. While photographic records (Ray 2020) on citizen science platforms such as iNaturalist have recently suggested the species' presence in the westernmost part of Assam, the photographs alone are not sufficient to confirm the record as conspecific with *P. rugulosa*. This study provides the necessary taxonomic verification of the occurrence of this species in Assam through detailed morphological and genital examination of the collected specimens. Prior to this, the only species of the genus known from northeastern India was *Pusana laevis* (Uvarov, 1921), recorded from Sikkim by Shishodia et al. (2003).

This finding bridges a geographical gap in the species distribution suggesting that *P. rugulosa* may have a broader and more continuous range across northern and eastern India than previously thought. It highlights the potential for undiscovered populations in intervening regions, such as West Bengal or other parts of north-eastern India.

Description of genitalia

Male (Image 3A–D): Supraanal plate elongate angular, apex obtusely rounded, as long as wide; circus small, conical, longer than supra-anal plate; subgenital plate broad, longer than wide, apex obtusely conical, covered with setae. Epiphallus with narrow bridge and undivided medially; ancorae short with pointed apices, incurved; lophi bilobate and lobiform; Aedeagus flexure, apical valve short and broad, moderately curved, apex pointed, narrower and shorter than basal valve, connected with basal valve with flexure; basal valve broad, narrow towards the slightly acute apex, gonopore process short with acute apex.

Female (Image 3E–H): Supraanal plate broad with obtuse apex, circus short and conical, shorter than supraanal plate; three times as long as wide with obtusely conical apex, subgenital plate with posterior margin semicircular, posterior marginal setae present; egg guide broad and conical, apex obtusely rounded; spermatheca with apical diverticulum shorter than the pre-apical diverticulum, tubular; pre-apical diverticulum long, broad, sac like; ovipositor valves short, robust and curved; dorsal valve broad, as long as the lateral apodeme, apical tip short and acute; ventral valve with apical tip short and acute, mesial valve dilated apically.

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