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Cover: A Warty Hammer Orchid *Drakaea livida* gets pollinated by a male thynnine wasp through 'sexual deception' — a colour pencil reproduction of photos by ron_n_beths (flickr.com) and Rod Peakall; Water colour reproduction of Flame Lily *Gloriosa superba* -- photo by Passakoran_14; and a bag worm and its architectural genius (source unknown). Art work by Pannagasri G.

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ARTICLE

Fruit bat (Pteropodidae) composition and diversity in the montane forests of Mt. Kampalili, Davao De Oro, Philippines

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Abstract: Fruit bats are important bioindicators of tropical forests because of their species richness, ecological roles, and sensitivity to environmental changes. This study assessed the species composition and diversity of fruit bats on Mt. Kampalili, Davao de Oro, Philippines, through mist-netting conducted in May and July 2023 across lower and upper montane forests. A total of 423 individuals representing nine species from seven genera were recorded. Of these, six species (66.67%) are endemic to the Philippines and two (*Dyacopterus rickarti*, Endangered; *Ptenochirus wetmorei*, Vulnerable) are threatened. Four species, *Cynopterus brachyotis*, *Ptenochirus wetmorei*, *Harpyionycteris whiteheadi*, and *Eonycteris spelaea*, were newly recorded on Mt. Kampalili in Davao de Oro, increasing the known fruit bat richness in the area to nine species. Diversity was low (H’ = 1.71), with no significant differences in species abundance between the two forest types. The presence of endemic and threatened species, combined with indications of disturbance tolerance by generalist species, highlights the ecological importance and vulnerability of Mt. Kampalili. Long-term monitoring and site-based conservation measures are recommended, particularly in lower montane areas where anthropogenic activities are more evident.

Keywords: Conservation, *Dyacopterus rickarti*, Eastern Mindanao Biodiversity Corridor, ecology, Endemism, *Ptenochirus wetmorei*, species richness, threatened species, wildlife.

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INTRODUCTION

Fruit bats (Family: Pteropodidae) are among the most diverse mammals that inhabit a diverse range of habitats and elevations in forest ecosystems. In the Philippines, 26 species of fruit bats have been recorded, 17 of which are endemic (Heaney et al. 2016). They play a vital role as seed dispersers and pollinators in tropical forest ecosystems, contributing significantly to forest regeneration, and plant community dynamics (Aziz et al. 2021). Given their high diversity and crucial ecological functions, bats have become a major focus of biodiversity research in the Philippines, particularly in forest ecosystems.

Between 2000 and 2017, research on Philippine bats averaged nearly eight published studies per year, with the majority focusing on biodiversity exploration (Tanalgo & Hughes 2018). Despite this progress, several areas, particularly in Mindanao, remain poorly studied and underexplored (Dela Cruz et al. 2023; Tanalgo et al. 2023). While bat diversity surveys have been conducted in various mountain ranges across the region, these efforts have largely concentrated on well-known sites such as Mt. Apo and Mt. Kitanglad (Heaney et al. 2006; Relox et al. 2014; Amoroso et al. 2019). As a result, many mid- to high-elevation zones and some isolated mountain systems in Mindanao lack comprehensive bat biodiversity assessments.

Mindanao Island, which forms a major part of the Mindanao Faunal Region, is recognized as a biodiversity hotspot in the Philippines. It faces serious threats such as deforestation, mining, and agricultural expansion. In addition to these challenges, biodiversity conservation in the region is hindered by significant knowledge gaps, with some areas still lacking, and limited biodiversity data (Agduma et al. 2023). One such understudied site is Mt. Kampalili in Eastern Mindanao. Rising to 2,388 m, it hosts a range of forest ecosystems, from lowland dipterocarp to mossy forests (BirdLife International 2022), and supports a high potential for endemic biodiversity, as evidenced by recent discoveries such as *Baletemys kampalili* (Rowsey et al. 2022), and *Nepenthes kampalili* (Lagunday et al. 2024). Despite its status as a Key Biodiversity Area (KBA), Mt. Kampalili remains unprotected under the National Integrated Protected Areas System (NIPAS), and is increasingly threatened by anthropogenic pressures, including logging, and small-scale mining activities. Notably, data on fruit bat diversity in Mt. Kampalili remain limited, with this study representing only the second documented assessment in the area (Ibañez & Baron 2011). The absence of comprehensive baseline information hinders the development of targeted, evidence-based conservation strategies, particularly for endemic, and threatened mammals that are sensitive to habitat disturbance (Tanalgo et al. 2023).

This study assessed the composition and diversity of fruit bat species across select forest habitats in Mt. Kampalili, Davao de Oro. By addressing a critical knowledge gap, the findings aim to contribute to the conservation of regional biodiversity, particularly within the Eastern Mindanao Biodiversity Corridor (EMBC).

MATERIALS AND METHODS

Permits and Clearances

All necessary permits and clearances were obtained in accordance with Philippine regulatory protocols. Coordination was conducted with the Municipal Government of Maragusan, Davao de Oro, and with representatives of the Mandaya-Mansaka Indigenous Cultural Communities / Indigenous Peoples (ICCs/IPs) in the Barangays of Bahi and Langgawisan to secure Prior Informed Consent (PIC). The project was also reviewed by the National Commission on Indigenous Peoples (NCIP) Davao de Oro Provincial Office. Following these processes, the Department of Environment and Natural Resources Region XI (DENR XI) issued a Wildlife Gratuitous Permit (WGP No. XI-2023-08), authorizing biodiversity assessment on Mt. Kampalili.

Study Site and Duration

Bat diversity data were collected from two forest types: the lower montane and upper montane forests of Mt. Kampalili, Davao de Oro. Mt. Kampalili is located along the boundary of Manay, Davao Oriental and the southeastern part of Maragusan, Davao de Oro (Figure 1), with an elevation of 2,388 m. The study was conducted in May and July 2023 at two sites within the montane forests of Mt. Kampalili.

The first site was classified as a lower montane forest ranging from 1,350–1,550 m (Image 1). The forest consists of dense portions of cultivated Abaca *Musa textilis*, banana *Musa* sp., bamboo *Bambusa* sp., as well as several types of fruits and wild trees. The forest canopy was dominated by Oak trees *Lithocarpus caudatifolius*, Igem *Dacrycarpus imbricatus*, Laurels *Litsea philippinensis*, and Nato *Palaquium luzoniense* with heights ranging 12–27 m and DBH ranging 8–60 cm. Furthermore, *Ficus* density was low but the density of other fruiting trees such as *Palaquium luzoniense,*

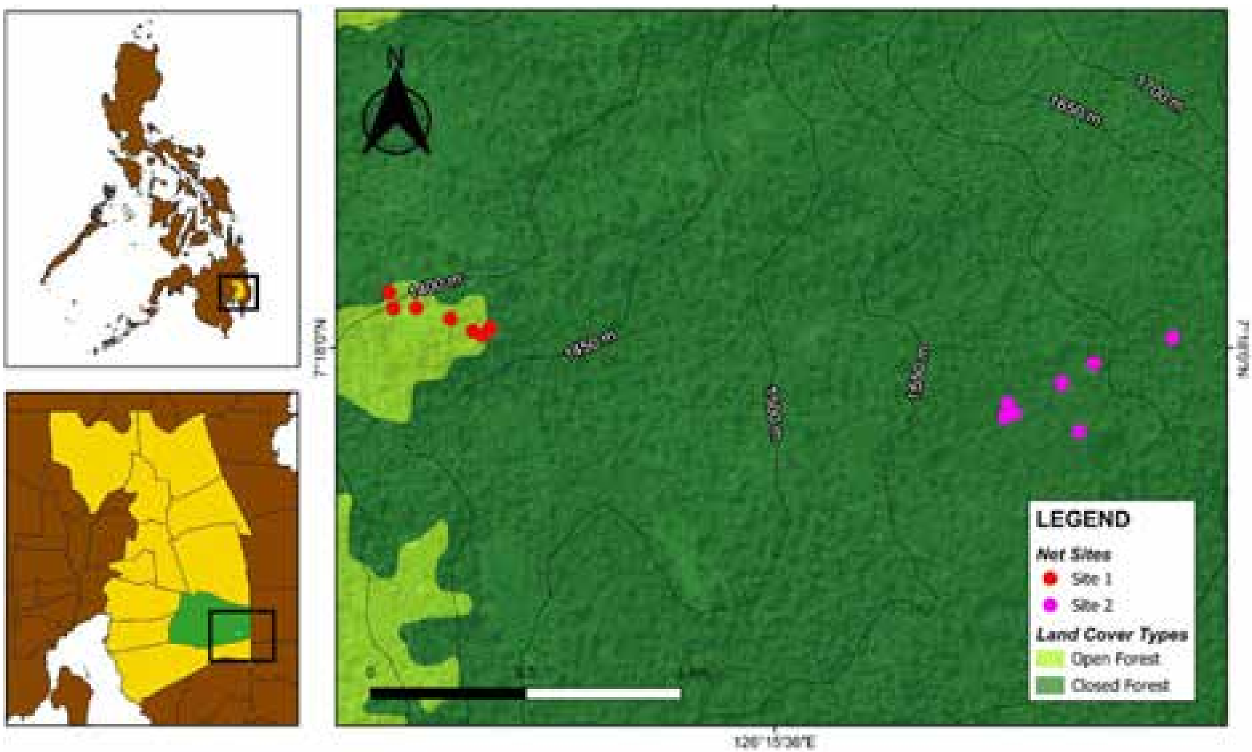

Figure 1. Vegetation map of Mt. Kampalili, Davao de Oro showing locations of mist nets in both lower montane (red) and upper montane (pink) forest. Maps generated using QGIS and Google Satellite Imagery.

Elaeocarpus sp., and *Syzygium* spp. were fairly high. The high presence of these trees corroborates the findings of Fernando et al. (2008) who stated that the tropical lower montane forest is dominated by oak trees, oil fruits, laurels, and *Syzygium* spp. The observed anthropogenic disturbances include the clearance of land for agriculture, cultivation of abaca plantations and other cash crops, and the minimal presence of human settlements.

Meanwhile, the second site is situated approximately 1 km from the first location with an elevation ranging 1,570–1,680 m and the forest type is categorised as upper montane (Image 2). The montane forest canopy was 20–25 m high and the maximum recorded DBH was 65 cm. Canopy trees such as Igem and Laurel *Cinnamomum mercadoi* dominated the forest, comprising a relative dominance of 32.75% and 22.41%, respectively. Other canopy trees observed in the area included *Agathis philippinensis, L. caudatifolius*, *Syzygium polyanthum*, *Elaeocarpus* sp., and *P. luzoniense*, which bear fruits that are essential food sources for bats. Moreover, *Ficus* species were denser at this location compared to Site 1. The increased density of fig trees was particularly significant. A lake, also locally called Lake Danao, was situated at a distance of 200–300 m between Point 2 (1,586 m elevation), and Point 3 (1,590 m elevation) along the established transect line. Additionally, the site had fewer human-caused disruptions with few abaca plantations in the area, but they were not as widespread as those at Site 1.

Bat Collection and Identification

Within the 2,000 m transect line, bat surveys were conducted using standard aerial and ground mist-netting techniques. Mist nets measuring 6 x 3 and 12 x 3 m were placed along the transect lines and the established flight paths of the bats. Nets were deployed strategically in areas with abundant fruit trees and bodies of water, maximizing the likelihood of capturing diverse species. This approach aimed to optimize catch yields by targeting areas rich in natural food sources and water access points. Nets were established in the afternoon until the dawn of the next day (1700–0400 h), and were regularly inspected at 3-hour intervals to prevent mortality. The accessibility of the sampling locations and the quality of the sites for collecting bats played a major role in the site selection process. Hence, high-quality sites, such as bat flyways in the forest understory and gaps between trees, were selected for the deployment of mist nets. Furthermore, during periods of heavy rains, the mist

Image 1. Sampling site 1: Lower montane forest area of Mt. Kampalili, Davao de Oro, featuring *Abaca Musa* textilis interspersed within the landscape. © MD Superio.

nets were removed earlier than usual.

In Site 1, data collection was conducted within three sampling nights, completing a total of 39 net nights of observation. Nets in these sites were meticulously positioned in locations exhibiting a high abundance of fruiting trees, capitalizing dietary preferences and foraging behaviors. Furthermore, a series of nets were strategically deployed proximal to the creek, which has diverse *Musa* species around its vicinity. Complementary tactics involved the strategic placement of nets along documented flight paths and in close proximity to their roosting sites.

Meanwhile, Site 2 accumulated 52 net nights across the four sampling nights (Image 2). The nets in this site were strategically positioned in the documented flight paths of bats. Additionally, while the abundance of fruiting trees was limited in the second area, efforts were concentrated near known food sources such as *Syzygium* sp., *Elaeocarpus* sp., and *Ficus* species. A net series was also established near Lake Danao, recognizing water bodies as areas commonly visited by bats.

Each captured fruit bat sample was then identified using field guides and taxonomic keys in situ (for example Ingle & Heaney 1992; Ingle et al. 1999). The degree of ossification of the carpal joints of the wing, the quality of the pelage, and the development of nipples, and testicles were used to determine the relative age and sex (Anthony 1988). Following identification and examination, bat species were marked on their wing membranes with nail polish before being returned to the forest. The conservation status and endemicity of the species were assessed using the latest database from the International Union for Conservation of Nature Red List version 2025-1 (IUCN 2025).

Data Analysis

The adequacy of the sampling effort for species richness in each forest type was estimated using individual-based rarefaction curves, which were generated by iNEXT (iNterpolation and EXTrapolation) online (Hsieh et al. 2016). The Shannon-Wiener diversity index, Simpson dominance index, and Pielou's index of evenness were used to characterize the fruit bat diversity, dominance, and evenness in different sites with varying degrees of disturbances. These biodiversity indices were calculated using Paleontological Statistics Software (PAST) version 4.03 (Hammer-Muntz et al. 2001). Furthermore, a two sample t-test was used to determine if there is a significant difference in the abundance of each fruit bat species between the two sites.

Image 2. Sampling site 2: Upper Montane forest area of Mt. Kampalili, Davao de Oro, characterized by dense moss cover. © MD Superio.

RESULTS

Fruit Bat Composition and Species Accounts

A total of 423 individuals representing nine species from seven genera were recorded over 91 net-nights (Table 1). The bat assemblage exhibited a 66.67% endemism rate, with six Philippine endemic species: *Dyacopterus rickarti*, *Haplonycteris fischeri*, *Ptenochirus wetmorei, Harpyionycteris whiteheadi*, *Ptenochirus jagorii*, and *Ptenochirus minor*. The remaining three species were native non-endemic (Image 3). Two species are listed as threatened, representing 22.22% of the total species recorded: *D. rickarti* is classified as 'Endangered', and *Ptenochirus wetmorei* as 'Vulnerable'. Despite a slightly lower sampling effort in Site 1, all expected species appear to have been documented (Figure 2). In contrast, Site 2 has higher species richness, and data suggest that additional species may still be recorded with continued sampling (Figure 2).

Cynopterus brachyotis (Müller, 1838)

The Lesser Dog-Faced Fruit bat *Cynopterus brachyotis* is a frugivorous bat widespread across southern to southeastern Asia. In the Philippines, this species occurs from sea level to 1,600 m and is the most common bat in lowland disturbed habitats (Heaney et al. 2016). It was the most abundant species in this study, which is interesting considering that earlier explorations where this bat was not recorded (Ibañez & Baron 2011). During the current survey, several pregnant individuals of *C. brachyotis* were captured, and two were observed to have dependent offspring during the first field visit in May 2023. Notably, one individual, presumably stressed from entanglement attempts in mist nets, appeared to undergo premature parturition. Genomic analyses suggest that the Philippine population of *C. brachyotis*, particularly those on Mindanao Island, may represent a distinct species separate from other populations found outside the country (Gaite et al. 2022). *Cynopterus luzoniensis* is currently used in some literature for both Sulawesi and Philippine populations, but past studies suggest that these lineages show a clear geographical, and evolutionary distinction, and thus both should be raised as a separate species (see Campbell et al. 2004). The species is not classified as threatened under the IUCN Red List.

Dyacopterus rickarti Helgen, Kock, Gomez, Ingle & Sinaga, 2007

The Philippine Large-headed Fruit Bat *Dyacopterus rickarti* is a poorly known Philippine endemic bat, found only in the islands of Luzon and Mindanao (Gomez & Waldien 2020). It is only identified to be present in regenerating secondary or primary montane and mossy forests, at 550–1,680 m (Heaney et al. 2016). This species was only recorded in this study in the lower montane forest. Five individuals were captured using mist nets placed along forest trails and near Abaca plantations at elevations ranging approximately 1350–1409 m, aligning with the known elevational occurrence of the species (Gomez & Waldien 2020). Of the five captured specimens, three were female, and two were male, and all individuals were identified as adults. Currently, the knowledge of the natural history of *D. rickarti* remains limited. Its primary diet is unknown, but our records in the species' capture sites in Mt. Kampalili includes *Elaeocarpus* spp., *Syzygium* spp., *Pandanus*, and fruiting palms, similar to previous observations (see Helgen et al. 2007). The species is classified as 'Endangered' (EN) on the IUCN Red List of Threatened Species, with its population status poorly understood due to lack of sufficient data.

Eonycteris spelaea **(Dobson, 1871)**

The Dawn Bat *Eonycteris spelaea* is a southern and southeastern Asian native bat that is widespread throughout the Philippines. This cave-dwelling species typically occurs in the country from sea level to 1,100 m, being abundant in lowland agricultural areas, and secondary forests (Heaney et al. 2010). The dawn bat typically feeds on nectar, pollen, and soft fruits, hence, an important pollinator and seed disperser in regenerating forests. This study only recorded one adult female individual. Previous reports suggest *E. spelaea* is in lower elevations and avoids old-growth forests (Heaney et al. 2006, 2010, 2016), but the record of the individual in Mt. Kampalili was made on the upper montane forest at 1,589 m, with no observations made in the lower montane site. Additionally, this species was not reported in a previous study by Ibañez & Baron (2011), further suggesting a potentially low population density in the surveyed areas. The species is currently classified as 'Least Concern' on the IUCN Red List of Threatened Species.

Haplonycteris fischeri **Lawrence, 1939**

Endemic only to the country, the Philippine Pygmy Fruit Bat *Haplonycteris fischeri* is among the most common bats in primary forests, uncommon in secondary forests, and absent in agricultural areas (Heaney et al. 2010). Preferring mid-elevation habitats, ranging from 150–2,250 m, a total of 42 individuals were recorded at the lower montane site, and 41 at the upper montane site of Mt. Kampalili. The highest elevation at which an individual was captured in this study was 1,630 m. Of the 83 captured individuals, 52 were female and 64 were identified as adults. The persistence of this species in forest fragments, especially at the lower montane site, suggests a degree of tolerance similar to previous observations (Heaney et al. 2016). The species is currently listed as 'Least Concern' (LC) in 2025 IUCN Red List of Threatened Species.

Harpyionycteris whiteheadi **Thomas, 1896**

The Philippine endemic Harpy Fruit Bat *Harpyionycteris whiteheadi*, primarily inhabits lowland and montane forests ranging from approximately 500–1,800 m (Duya et al. 2021). This bat is distinguished by its pale mottled wing markings and forward-projecting

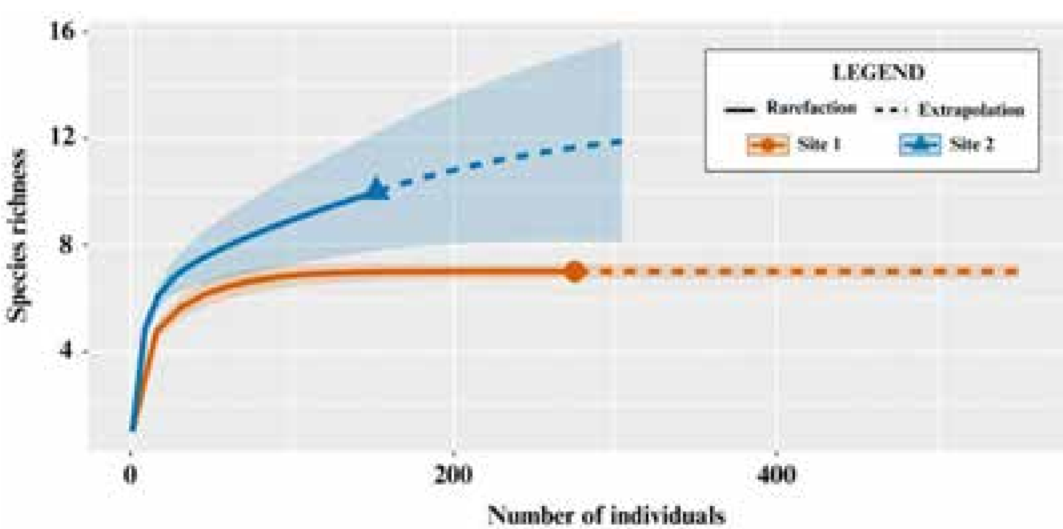

Figure 2. Individual-based rarefaction curve for site 1 (lower montane) and site 2 (upper montane) at Mt. Kampalili, Davao de Oro.

Table 1. Summary and comparison of fruit bat species recorded in Mt. Kampalili, Davao de Oro.

Species	Common name	IUCN Red List (2025)	Distribution status	Lower montane	Upper montane	Total	†p value (<0.05)
Cynopterus brachyotis (Müller, 1838)	Lesser Dog-faced Fruit Bat	LC	R	101	16	117	0.0987
Dyacopterus rickarti Helgen, Kock, Gomez, Ingle & Sinaga, 2007	Philippine Large-headed Fruit Bat	EN	PE	5	0	5	*
Eonycteris spelaea (Dobson, 1871)	Dawn Bat	LC	R	0	1	1	*
Haplonycteris fischeri Lawrence, 1939	Philippine Pygmy Fruit Bat	LC	PE	42	41	83	0.5959
Harpyionycteris whiteheadi Thomas, 1896	Harpy Fruit Bat	LC	PE	0	1	1	*
Macroglossus minimus (É. Geoffroy Saint- Hilaire, 1810)	Dagger-toothed Long-nosed Fruit Bat	LC	R	24	22	46	0.3636
Ptenochirus wetmorei (Taylor, 1934)	Mindanao Fruit Bat	VU	ME	7	27	34	0.8585
Ptenochirus jagorii (Peters, 1861)	Greater Musky Fruit Bat	LC	PE	86	30	116	0.0745
Ptenochirus minor Yoshiyuki, 1979	Lesser Musky Fruit Bat	LC	ME	10	10	20	0.8531
Total abundance				***275***	***148***	***423***	
Richness				***7***	***8***	***9***	
Dominance (Simpson dominance index, *D*)				**0.26**	**0.18**	**0.21**	
Evenness (Pielou's evenness index, J)				**0.70**	**0.75**	**0.61**	
Diversity (Shannon-Wiener index, *H'*)				***1.53***	***1.79***	***1.71***	

EN—Endangered | VU—Vulnerable | LC—Least Concern | OWS—Other Wildlife Species | R—Resident | PE—Philippine Endemic | ME—Mindanao Faunal Region Endemic | *—minimal individuals caught | †—two-sample t-test (PAST ver 4.03).

teeth, including prominent canines (Heaney et al. 2016). An adult female *H. whiteheadi* was captured at the upper montane forest at 1,589 m elevation. As a forest specialist, this species is known to prefer undisturbed or minimally impacted habitats (Heaney et al. 2010; Fidelino et al. 2020), highlighting the species' potential sensitivity to anthropogenic disturbance. The species is currently classified as a 'Least Concern' (LC) species in IUCN Red List of Threatened Species.

Macroglossus minimus (É. Geoffroy Saint- Hilaire, 1810)

The Dagger-toothed Long-nosed Fruit Bat *Macroglossus minimus* has a widespread geographical range that extends from Thailand to Australia. It is widely distributed in the Philippines and inhabits both primary and secondary tropical moist forests, but shows a particular preference for secondary growth, agricultural areas, and other disturbed environments. It has also been reported in woodlands, mangroves, swamp forests, various plantations, and urban habitats, with an elevation range from sea level to approximately 2,250 m (Heaney et al. 1998; Waldien et al. 2021; Dela Torre et al. 2024). It feeds on *Musa* species and other cultivated plants (Relox et al. 2014; Wibowo et al. 2022) which were numerous in the site, particularly in Site 1. This study documented 24 individuals of *Macroglossus minimus* in the lower montane forest and 22 in the upper montane forest. Notably, a substantial proportion of the recorded specimens were adults, comprising 80.43% of the total captures. Of the 46 individuals collected from all sites, 24 were male, and 22 were female. The species is not classified as threatened in the IUCN Red List of Threatened Species.

Ptenochirus wetmorei (Taylor 1934)

The Mindanao Fruit Bat *Ptenochirus wetmorei* is a species endemic to the Mindanao Island. It was previously known to occur in primary and lightly disturbed lowland forests, and absent in montane forests (Heaney et al. 1998). The species was recorded in both lower and montane forests, with the highest elevational record of 1,589 m. This is consistent with previously reported elevation ranges for the species, from as low as 58 m to as high as 1,719 m (Heaney 1986; Achondo et al. 2014; Nuñeza et al. 2015). A notable proportion of the recorded specimens were adults (29 of 34), with a strong female bias (24 of 34). Previously known as *Megaerops wetmorei*, the recent molecular data support a taxonomic transfer of the Mindanao population to the genus *Ptenochirus* (Almeida et al. 2020). The

Image 3. Bat species documented in Mt. Kampalili, Maragusan, Davao de Oro: A—*Ptenochirus minor* | B—*Ptenochirus jagorii* | C—*Cynopterus brachyotis* | D—*Ptenochirus wetmorei* | E—*Haplonycteris fischeri* | F—*Dyacopterus rickarti* | G—*Harpyionycteris whiteheadi* | H—*Eonycteris spelaea* | I—*Macroglossus minimus*. © IJ Yangurin, LD Gamalo, MJM Achondo, & MD Superio.

species is currently classified as 'Vulnerable' (VU) under *Megaerops wetmorei* on the IUCN Red List because of the continued threat of habitat loss from deforestation, particularly in lower dipterocarp forests.

***Ptenochirus jagorii* (Peters, 1861)**

The Greater Musky Fruit Bat *Ptenochirus jagorii* is a Philippine endemic frugivorous bat, found almost all over the archipelago except in Palawan and Batanes regions (Alviola et al. 2021). The species primarily inhabits lowland and is uncommon in montane forests in the Philippines, with an elevation range from sea level up to 1,950 m (Heaney et al. 2010). Along with *C. brachyotis*, this bat was among the most abundant species recorded in the study areas. Individuals were captured from both sampling sites, and the majority were identified as adult females. Notably, approximately 25 individuals were recorded as pregnant, and four were observed with dependent young individuals already attached. According to the IUCN Red List of Threatened Species, *P. jagorii* is currently not classified as a threatened species.

***Ptenochirus minor* Yoshiyuki 1979**

The Lesser Musky Fruit Bat *Ptenochirus minor* is restricted only to the Mindanao Faunal Region, where it inhabits lowland and montane habitats, as well as secondary forests from sea level to 1,600 m (Heaney et al. 2010). This broad elevation range and ecological adaptability show its resilience to varying environmental conditions in forests of different degrees of disturbance (Relox et al. 2014). This species, although occasionally misidentified as *P. jagorii*, can be distinguished by its smaller body size, and distinct adult morphometric characteristics. Of the 20 individuals recorded, 14 were identified as female and all individuals were confirmed to be adults. As expected, the species was recorded within the study sites since previous records indicate its preference towards montane forests (Heaney et al. 2010). The species is currently classified as non-threatened under the IUCN Red List of Threatened Species.

Fruit Bat Diversity

The overall Shannon-Wiener diversity index (H') was 1.71, reflecting a relatively low species diversity due to the low species richness and only a semi-balanced (J = 0.61) distribution of individuals among species. Diversity comparisons between sites showed that Site 2 had slightly higher diversity (H' = 1.79) and evenness (J = 0.75) compared to Site 1 (H' = 1.53; J = 0.70). Site 1 exhibited greater overall fruit bat abundance but showed no statistically significant difference between sites for each fruit bat species (Table 1).

DISCUSSION

This study recorded nine species of fruit bats in Mt. Kampalili, underscoring its status as one of the most species-rich sites within the Eastern Mindanao Biodiversity Corridor (EMBC). This result adds to existing records from other mountains in the EMBC, such as Mt. Hilong-hilong with nine species (Ibañez & Baron 2011) and Mt. Hamiguitan Range with eight species (Amoroso et al. 2019).

The earlier survey of Mt. Kampalili in 2008 reported only five species (Ibañez & Baron 2011). All of these bats were confirmed in the present study, along with four additional species, namely *Cynopterus brachyotis*, *Ptenochirus wetmorei*, *Harpyionycteris whiteheadi*, and *Eoncyteris spelaea*. The increase in species richness may reflect improved sampling effort, as the earlier survey was not able to have extended sampling periods, particularly in the lower elevation sites due to insurgency (Ibañez & Baron 2011). These results highlight the value of repeated biodiversity assessments in underexplored areas and point to the potential presence of additional undocumented taxa in Mt. Kampalili.

When comparing sites, Site 1 showed a greater overall abundance, but not statistically significant different from Site 2 in species abundance. For instance, *Haplonycteris fischeri*, *Macroglossus minimus*, and *Ptenochirus minor* exhibited nearly equal abundances at both sites. These species are typically associated with primary and secondary forests, and are known to tolerate habitat disturbance, especially *M. minimus* (Relox et al. 2014; Fidelino et al. 2020; Waldien et al. 2021). The availability of abundant food resources, such as *Ficus* and *Syzygium* species, which were observed at both sites, may help explain this lack of difference in abundance.

Although some species appeared more frequently in one site than the other (e.g., *Cynopterus brachyotis* and *Ptenochirus jagorii* in Site 1), no statistical differences were found. Their presence in both disturbed and intact habitats reflects their ecological flexibility, since both are known to feed on cultivated fruits and to roost in a variety of habitats, including tree hollows and urban areas (Heaney et al. 2010; Alviola et al. 2021; Dela Torre et al. 2025). In terms of diversity, however, Site 2 (upper montane forest) exhibited slightly higher diversity than Site 1. This pattern may be explained by the greater species richness detected in Site 2, which could still increase with additional sampling effort (see Figure 2). The relatively high dominance of *P. jagorii* and *C. brachyotis* in Site 1 likely contributed to its lower diversity score, despite the general expectation of declining bat diversity with increasing elevation (Heaney 2001; Heaney et al. 2016).

The record of the 'Endangered' *D. rickarti* and the 'Vulnerable' *Ptenochirus wetmorei* adds to the conservation relevance of the mountain ecosystem. Although these species were also detected in degraded areas, these findings likely indicate that remaining forest patches still provide essential resources. However, such observations should not be taken as evidence of long-term species persistence under ongoing disturbance. Forest fragmentation reduces structural complexity and resource availability, directly affecting sensitive bat species (Meyer et al. 2016; Duco et al. 2023). While plantations and agricultural areas may still continue to support bat populations as observed in this study, rare and threatened species, such as *D. rickarti,* might cease to exist (Tanalgo & Hughes 2018). Additional studies are needed to determine whether the presence of these species in degraded habitats reflects short-term foraging or potential adaptability.

These findings emphasize the need for stronger conservation measures in Mt. Kampalili, particularly the protection of the remaining forest patches and the integration of biodiversity safeguards into land-use planning and agricultural expansion (e.g., abaca cultivation, which is more prevalent in Site 1). In 2008, a conservation framework for the EMBC which includes Mt. Kampalili, was developed by Philippine Eagle Foundation, Department of Environment and Natural Resources, and Conservation International-Philippines, suggesting mainly its local legislation as an IP-protected area under ancestral domain certification (Philippine Eagle Foundation, Conservation International-Philippines, Department of Environment and Natural Resources, 2008). Building on the bat conservation framework proposed by Tanalgo & Hughes (2018), conservation priorities in the area should include (1) securing legal protection of the mountain under the National

Integrated Protected Areas Management (NIPAS) Act, (2) restoring degraded habitats and maintaining structurally complex forests, and (3) establishing long-term biodiversity monitoring to track changes in bat assemblages. Moreover, continuous information and educational campaigns (IECs) with stakeholders should be done for the overall biodiversity conservation of the habitat and to highlight the importance of bats in the area. As suggested by PEF-CI and DENR, an IEC core group can be formed and trained for the implementation of these IECs for community-based conservation activities (Philippine Eagle Foundation, Conservation International-Philippines, Department of Environment and Natural Resources, 2008).

Some limitations, however, should be considered when interpreting the results. Net placement and the number of net nights were constrained by logistical challenges, particularly the unpredictable weather in Mt. Kampalili. While richness estimates may help account for this limitation, the findings still indicate that additional sampling would likely document more species, particularly in Site 2 (Figure 2). Even so, the conclusion that Site 2 has higher species richness than Site 1 remains valid. With this result, further studies are recommended to complete the bat inventory of Mt. Kampalili, particularly in other habitat types (e.g., dipterocarp forest), and other locations in the mountain (e.g., Davao Oriental side) which were not part of the current and previous (Ibañez & Baron 2011) studies in Mt. Kampalili. Another limitation is the absence of analyses on the potential drivers of the observed patterns (e.g., higher richness in Site 2). Studies on food source availability and habitat preferences in the site are highly recommended for future studies as it is hypothesized that they might be important factors that affect bat composition. Despite these constraints, the study provides valuable information on the bat assemblages of Mt. Kampalili which warrants additional protection due to the presence of endemic and threatened species, and contributes to the broader understanding of bat diversity in Mindanao, especially on the new geographical records of bat species observed in this study.

CONCLUSIONS

This study provides updated data on the fruit bat assemblage of Mt. Kampalili in Davao de Oro, the Philippines. A total of nine species were recorded, including threatened Philippine (e.g. *Dyacopterus rickarti*) and Mindanao (e.g. *Ptenochirus wetmorei*) endemics. The presence of these species highlights the ecological importance of Mt. Kampalili and the Eastern Mindanao Biodiversity Corridor (EMBC), underscoring its role in sustaining endemic and threatened bat populations. The study also revealed the dominance of disturbance-tolerant generalists such as *Cynopterus brachyotis* and *Ptenochirus jagori*, which were more abundant in the lower montane forest. This dominance may have contributed to the lower diversity observed at that site, in contrast to the higher diversity found in the upper montane area.

This study further emphasizes Mt. Kampalili's ecological significance, and thus needs stronger protection of its forest ecosystem of both lower and higher elevations. Such protection would enable stricter regulation of land use and help prevent further habitat degradation.

REFERENCES

Achondo, M.J.M.M., L.F. Casim, K.C. Tanalgo, A.R. Agduma, B.L.P. Bretaña, J.P. Supremo, L.S. Mancao, J.G.S. Salem & V.P. Bello (2014). Occurrence and abundance of fruit bats in selected conservation areas of North Cotabato, Philippines. *Asian Journal of Conservation Biology* 3(1): 3–7.

Agduma, A.R., F.G. Garcia, M.T. Cabasan, J. Pimentel, R.J. Ele, M. Rubio, S. Murray, B.A. Hilario-Husain, K.C.D. Cruz, S. Abdullah & S.M. Balase (2023). Overview of priorities, threats, and challenges to biodiversity conservation in the southern Philippines. *Regional Sustainability* 4(2): 203–213. https://doi.org/10.1016/j.regsus.2023.05.003

Almeida, F.C. N.B. Simmons & N.P. Giannini (2020). A species-level phylogeny of Old World fruit bats with a new higher-level classification of the family Pteropodidae. *American Museum Novitates* 2020(3950): 1–24. https://doi.org/10.1206/3950.1

Alviola, P.A., M.R. Duya, P. Ong, R.G.B. Rosell-Ambal, B. Tabaranza, L.R. Heaney, M. Pedregosa, L.M. Paguntalan, A. Carino, S.P. Ramayla, P. Duya, D. Warguez, E. Alcala, H.J.D. Garcia, R. Pamaong, J.C. Gonzalez & R.P. Lorica (2021). *Ptenochirus jagori*. The IUCN Red List of Threatened Species 2021: e.T18653A22071217. Accessed on 13.vii.2025. https://doi.org/10.2305/IUCN.UK.2021-1.RLTS.T18653A22071217.en

Amoroso, V.B., A.B. Mohagan, F.P. Coritico, S.H. Laraga, N.E. Lagunday, K.L. Domingo, R. Colong & R. Ponce (2019). Status of mammals in the expansion sites of the Mt. Hamiguitan Range Wildlife Sanctuary, Mindanao, Philippines. *Journal of Environmental Science and Management* 22(2): 6–12. https://doi.org/10.47125/jesam/2019_2/02

Anthony, E. (1998). Age determination in bat, pp. 47–58. In: Kunz, T.H. (ed.). *Ecological and Behavioral Methods for the Study of Bats*. Smithsonian Institution Press, Washington, DC, xxii + 553 pp.

Aziz, S.A., K.R. McConkey, K. Tanalgo, T. Sritongchuay, M.R. Low, J.Y. Yong, T.L. Mildenstein, C.E. Nuevo-Diego, V.C. Lim & P.A. Racey (2021). The critical importance of Old World fruit bats for healthy ecosystems and economies. *Frontiers in Ecology and Evolution* 9: p641411. https://doi.org/10.3389/fevo.2021.641411

BirdLife International (2022). Important Bird Areas factsheet: Mount Kampalili-Puting Bato. http://datazone.birdlife.org/site/factsheet/mount-kampalili-puting-bato-iba-philippines. Accessed on 28.vi.2025.

Campbell, P., C.J. Schneider, A.M. Adnan, A. Zubaid & T.H. Kunz

(2004). Phylogeny and phylogeography of Old World fruit bats in the *Cynopterus brachyotis* complex. *Molecular Phylogenetics and Evolution* 33(3): 764–781. https://doi.org/10.1016/j.ympev.2004.06.019

Dela Cruz, K.C., S.S. Abdullah, A.R. Agduma, & K.C. Tanalgo (2023). Early twenty-first century biodiversity data pinpoint key targets for bird and mammal conservation in Mindanao, Southern Philippines. *Biodiversity* 24(3): 146–163. https://doi.org/10.1080/14888386.2023.2210119

Dela Torre, V.C.P., B.L. Pototan, R.R. Choa., G.D.T. Petros, I.G.M. Panogalinog, M.G. Bacus, A.F. Raganas, L.E.D. Gamalo & M.N.R.M. Quibod (2024). Habitat associations of bats in the green spaces of Davao City, Mindanao, Southern Philippines. *Mammal Research* 70(1): 115–126. https://doi.org/10.1007/s13364-024-00767-w

Duco, R.A.J., J.S. Fidelino, M.V. Duya & M. Ledesma. (2023). Patterns of fruit bat diversity in forest fragments and exotic tree–based reforestation areas within highly modified karst areas in the Philippines. *Asian Journal of Conservation Biology* 12(2): 304–313.

Duya, M.R., P. Ong, R.G.B. Rosell-Ambal, B. Tabaranza, L.R. Heaney, J.C.T. Gonzalez, D.S. Balete, L.M. Paguntalan & S.P. Ramayla (2021). *Harpyionycteris whiteheadi*. The IUCN Red List of Threatened Species 2021: e.T9740A22045044. https://doi.org/10.2305/IUCN.UK.2021-1.RLTS.T9740A22045044.en

Fernando, E.S., M.H. Suh, J. Lee & D.K. Lee (2008). *Forest Formations of the Philippines*. ASEAN-Korea Environmental Cooperation Unit.

Fidelino, J.S., M.R.M. Duya, M.V. Duya & P.S. Ong (2020). Fruit bat diversity patterns for assessing restoration success in reforestation areas in the Philippines. *Acta Oecologica* 108: 103637. https://doi.org/10.1016/j.actao.2020.103637

Gaite, P.L.A., W. Aala, M.G. Bacus, C.C. Labrador, A.M.M. Numeron, L.L. Gamalo & L.A. Murao (2022). The first complete mitochondrial genome sequence of *Cynopterus brachyotis* (Chiroptera, Pteropodidae) from the Philippines. *Biodiversity Data Journal* 10: e72768. https://doi.org/10.3897/bdj.10.e72768

Gomez, R. & D.L. Waldien (2020). *Dyacopterus rickarti*. The IUCN Red List of Threatened Species 2020: e.T84457541A95642280. Accessed on 13.vii.2025. https://doi.org/10.2305/IUCN.UK.2020-2.RLTS.T84457541A95642280.en

Hammer-Muntz, O., D. Harper & P. Ryan (2001). PAST: paleontological statistics software package for education and data analysis version 2.09. *Palaeontologia Electronica* 4(1): 1–9. http://scienceopen.com/document?vid=f7c81409-9131-4ded-a3d6-e1509342d3df

Heaney, L.R. (1986). Biogeography of mammals in SE Asia: estimates of rates of colonization, extinction and speciation. *Biological Journal of the Linnean Society/Biological Journal of the Linnean Society* 28(1–2): 127–165. https://doi.org/10.1111/j.1095-8312.1986.tb01752

Heaney, L.R., D.S. Balete, M.L. Dollar, A.C. Alcala, A.T.L. Dans, P.C. Gonzales, N.R. Ingle, M.V Lepiten, W.L.R. Oliver, P.S. Ong, E.A. Rickart, B.R. Tabaranza Jr. & R.C.B. Utzurrum (1998). A synopsis of the mammalian fauna of the Philippine Islands. *Fieldiana: Zoology (New Series)* 88: 1–61.

Heaney, L.R. (2001). Small mammal diversity along elevational gradients in the Philippines: an assessment of patterns and hypotheses. *Global Ecology and Biogeography* 10(1): 15–39. https://doi.org/10.1046/j.1466-822x.2001.00227.x

Heaney, L.R., B.R. Tabaranza Jr., E.A. Rickart, D.S. Balete & N.R. Ingle (2006). The mammals of Mt. Kitanglad Nature Park, Mindanao, Philippines. *Fieldiana Zoology* 112: 1–63.

Heaney, L.R., M.L. Dolar, D.S. Balete, J.A. Esselstyn, E.A. Rickart & J.L. Sedlock (2010). Synopsis of Philippine Mammals. *Field Museum of Natural History.* http://www. fieldmuseum. org/philippine_mammals/ Internet resource accessed on 12.vii.2025.

Heaney, L.R., D.S. Balete & E.A. Rickart (2016). *The Mammals of Luzon Island: Biogeography and Natural History of a Philippine Fauna*. John Hopkins University Press, Baltimore, 304 pp. https://muse.jhu.edu/book/44856

Helgen, K.M., D. Kock, R.K.S.C. Gomez, N.R. Ingle & M.H. Sinaga (2007). Taxonomy and Natural History of the Southeast Asian Fruit-Bat Genus *Dyacopterus*. *Journal of Mammalogy* 88(2): 302–318. https://doi.org/10.1644/06-MAMM-A-276R.1

Hsieh, T.C., K.H. Ma & A. Chao (2016). iNEXT: an R package for rarefaction and extrapolation of species diversity (Hill numbers). *Methods in Ecology and Evolution* 7(12): 1451–1456. https://doi.org/10.1111/2041-210X.12613

Ibañez J. & E.M. Baron (2011). Eastern Mindanao Biodiversity Corridor Archiving and Assessment Project: Biodiversity Surveys Technical Report. Philippine Eagle Foundation & Department of Environment and Natural Resources.

Ingle, N.R., J.L. Sedlock & L.R. Heaney (1999). *Bats of Mindanao Island, Philippines* (Rapid Color Guide No. 49, Version 1.2). The Field Museum, Environmental & Conservation Programs, Chicago.

Ingle, N.R. & L.R. Heaney (1992). A key to the bats of the Philippine Islands. *Fieldiana: Zoology, New Series* 69: 1–44. https://doi.org/10.5962/bhl.title.3504

IUCN (2025). *The IUCN Red List of Threatened Species* (Version 2025-1). International Union for Conservation of Nature. Retrieved on 29.vi.2025 from https://www.iucnredlist.org

Lagunday, N.E., A. Yurong & V.B. Amoroso (2024). *Nepenthes kampalili* (Nepenthaceae), a new species of pitcher plant from the eastern Mindanao biodiversity corridor, Philippines. *Phytotaxa* 644(2): 163–170. https://doi.org/10.11646/phytotaxa.644.2.8

Meyer, C.F., M.J. Struebig & M.R. Willig (2016). Responses of tropical bats to habitat fragmentation, logging, and deforestation. *Bats in the Anthropocene: conservation of bats in a changing world* 63–103. https://doi.org/10.1007/978-3-319-25220-9_4

Nuñeza, O., M.L. Non, R. Makiputin & E. Oconer (2015). Species diversity of bats in Mt. Matutum protected landscape, Philippines. *Journal of Biological and Environmental Sciences* 6(6): 377.

Philippine Eagle Foundation, Conservation International-Philippines, & Department of Environment and Natural Resources (2008). Eastern Mindanao Biodiversity Corridor Conservation Framework. Davao City, Philippines, 95 pp.

Relox, R.E., L.M. Florece, J.A Baril, & J.O. Coladilla (2014). Assessment of fruit bats and its food preferences in Mt. Apo Natural Park, Kidapawan City, North Cotabato, Philippines. *Journal of Environmental Science and Management* 17(1): 12–20. https://doi.org/10.47125/jesam/2014_1/02

Rowsey, D.M., M.R.M. Duya, J.C. Ibañez, S.A. Jansa, E.A. Rickart & L.R. Heaney (2022). A new genus and species of shrew-like mouse (Rodentia: Muridae) from a new center of endemism in eastern Mindanao, Philippines. *Journal of Mammalogy* 103(6): 1259–1277. https://doi.org/10.1093/jmammal/gyac057

Tanalgo, K.C., K.C.D. Cruz, A.R. Agduma, J.M.V. Respicio, S.S. Abdullah, R.J. Alvaro-Ele, B.A. Hilario-Husain, M. Manampan-Rubio, S.A. Murray, L.F. Casim & A.M.M. Pantog (2023). The MOBIOS+: A FAIR (Findable, Accessible, Interoperable and Reusable) database for Mindanao's terrestrial biodiversity. *Biodiversity Data Journal* 11: e110016. https://doi.org/10.3897/BDJ.11.e110016

Tanalgo, K.C. & A.C. Hughes (2018). Bats of the Philippine Islands—A review of research directions and relevance to national-level priorities and targets. *Mammalian Biology* 91: 46–56. https://doi.org/10.1016/j.mambio.2018.03.005

Waldien, D.L., J. Dancy, G. Wortham & K. Santiago (2021). *Macroglossus minimus*. The IUCN Red List of Threatened Species 2021: e.T12594A22027337. Accessed on 13.vii.2025. https://doi.org/10.2305/IUCN.UK.2021-3.RLTS.T12594A22027337.en

Wibowo, A., A. Basukriadi, E. Nurdin & G. Benhard (2022). Ecology and microhabitat model of long-tongued fruit bat *Macroglossus minimus* (Chiroptera: Pteropididae) in karst ecosystem of Klapanunggal, Bogor, West Java, Indonesia. *International Journal of Tropical Drylands* 6(1): 11–15. https://doi.org/10.13057/tropdrylands/t060102

Appendix Table. Summary of the demography of bats recorded in this study.

Species	Common name	Number of individuals captured	Male to female ratio	Number of adults
Cynopterus brachyotis (Müller, 1838)	Lesser Dog-faced Fruit Bat	117	49:68	91
Dyacopterus rickarti Helgen, Kock, Gomez, Ingle & Sinaga, 2007	Philippine Large-headed Fruit Bat	5	2:3	5
Eonycteris spelaea (Dobson, 1871)	Dawn Bat	1	0:1	1
Haplonycteris fischeri Lawrence, 1939	Philippine Pygmy Fruit Bat	83	31:52	64
Harpyionycteris whiteheadi Thomas, 1896	Harpy Fruit Bat	1	0:1	1
Macroglossus minimus (É. Geoffroy Saint-Hilaire, 1810)	Dagger-toothed Long-nosed Fruit Bat	46	22:24	37
Ptenochirus wetmorei (Taylor, 1934)	Mindanao Fruit Bat	34	10:24	29
Ptenochirus jagorii (Peters, 1861)	Greater Musky Fruit Bat	116	50:66	109
Ptenochirus minor Yoshiyuki, 1979	Lesser Musky Fruit Bat	20	6:14	20

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ARTICLE

The impact of anthropogenic activities on *Manis javanica* Desmarest, 1822 (Mammalia: Pholidota: Manidae) in Sepanggar Hill, Malaysia

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Abstract: The Sunda Pangolin, also known as *Manis javanica* Desmarest, 1822 (Pholidota: Manidae), is the only pangolin species found in Malaysia. This species is 'Critically Endangered' as per the IUCN Red List of Threatened Species and is among the most heavily trafficked mammals globally. Anthropogenic activities such as residential development and frequent human movement near forest edges have increasingly threatened the safety of the Sunda Pangolin. These activities not only lead to habitat fragmentation but also expose wildlife to elevated noise levels and human disturbances due to the proximity of settlements. Therefore, this study aims to determine the impact of anthropogenic activities that influences the distribution of Sunda Pangolins in Sepanggar Hill using camera trap survey method. Ten camera traps were set up in a systematic random design from May 2023–January 2024. The distances of nearest human settlements from the camera traps and anthropogenic noise level were also measured. The data from the camera traps and the anthropogenic noise level were collected every month. Over 2,724 trapping nights, camera traps captured five pangolin events. The Pearson correlation shows very weak correlations (-0.24 - 0.32) on the correlation of Sunda Pangolin presence and the proximity to the human settlements based on 2,741 data points. Despite high noise levels ranging 44.3 – 57.0 dB, Sunda Pangolins were detected more frequently near the first camera trap (N = 348, r = 0.147, p = 0.006**), an area with the highest anthropogenic noise, indicating a degree of noise tolerance. These findings highlight the adaptability of Sunda Pangolins to disturbed habitats as long as they do not feel threatened, but also underscore the necessity for targeted conservation efforts to mitigate more areas. Preserving quieter environments and reducing human impact is critical to ensure the survival of Sunda Pangolins in Sepanggar Hill. This research provides valuable insights for developing effective conservation strategies to protect this Critically Endangered species.

Keywords: Activity pattern, adaptability, camera trap, Critically Endangered, human impact, human presence, human proximity, noise level, Sunda Pangolin.

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Author contributions: NAS: Led field data collection and prepared the initial draft of the manuscript. JK: co-supervised and contributed to critical manuscript revision and refinement of the text. NbAB: Provided administrative coordination and strategic oversight throughout the project. JS: Conceptualized the study design and supervised academics as well as all fieldwork activities.

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UMS UNIVERSITI MALAYSIA SABAH

INTRODUCTION

Sabah, on the island of Borneo, supports high biodiversity, and is home to key wildlife species essential for ecosystem function, including the Clouded Leopard *Neofelis diardi*, Bornean Tembadau *Bos javanicus lowi*, Bornean Pygmy Elephant *Elephas maximus borneensis*, and Sunda Pangolin *Manis javanica* (Hearn et al. 2019; Sompud et al. 2022, 2023; Hiew et al. 2023). These species contribute significantly to habitat stability and ecological processes. Their persistence is increasingly threatened by habitat loss, poaching, and illegal trade, which collectively undermine regional biodiversity (Sompud et al. 2019; Giordano et al. 2023).

The Sunda Pangolin *Manis javanica* (Desmarest, 1822, Pholidota: Manidae) (Image 1), also known as the Malayan or Javan Pangolin, is a species of pangolin native to southeastern Asia. These solitary and nocturnal mammals are primarily found in various habitats, including tropical forests, subtropical forests, grasslands, and agricultural areas. Sunda Pangolins are adept climbers, often dwelling in trees, and utilizing their strong, curved claws to forage for ants, and termites (Chong et al. 2020). They play a crucial role in the ecosystems by controlling insect populations (Lim & Ng 2008; Sompud et al. 2019).

Despite their ecological importance, Sunda Pangolins are Critically Endangered due to severe threats from illegal wildlife trade and habitat destruction (Challender et al. 2019). They are among the most heavily trafficked mammals globally, driven by high demand for their scales, and meat (Challender et al. 2015; Aisher 2016; Nash et al. 2018). In Peninsular Malaysia, the Sunda Pangolin is protected under the Wildlife Protection Act No. 72 of 1972 (Sing & Pantel 2009). Meanwhile, in Sabah, the Sunda Pangolin is listed as a protected animal species, in Part I of Schedule 2 of the State's Wildlife Conservation Enactment 1997 (Pantel & Anak 2010). Internationally, it is listed in Appendix I of the Convention on International Trade in Endangered Species (CITES). Despite these legal protections, Sunda Pangolins continue to be captured, and illegally traded across southeastern Asia, including in Malaysia (Ariffin & Nan 2018). The scales are highly valued in traditional medicine, particularly in China, and Vietnam, for their alleged health benefits (Cheng et al. 2017). Additionally, pangolin meat is considered a delicacy in some cultures (Duckworth et al. 2008). The relentless poaching and habitat loss have pushed the Sunda Pangolin to the brink of extinction, necessitating urgent global conservation, and law enforcement efforts to combat the illicit trade, and protect the species.

The relationship between Sunda Pangolins and humans is fraught with challenges. Conservation of the Sunda Pangolin is hindered by differing levels of awareness and participation across community groups (Nash et al. 2020; Jomes et al. 2023). Human encroachment on their habitats through deforestation and agricultural expansion displaces pangolins, leading to increased contact with human settlements. This often results in pangolins being accidentally caught in traps set for other animals, which subsequently increases poaching rates. Although previous studies suggest that Sunda Pangolins can tolerate some level of human presence (Chong et al 2020; Withaningsih et al. 2021; Nursamsi et al. 2023), their ability to survive in areas affected by people largely depends on the type and intensity of the activities, less harmful actions like research or hiking may not disturb them, while more damaging activities like logging, and land clearing can seriously impact their chances of living in those areas. Human encroachment, especially when involving habitat modification such as felling trees or agricultural expansion, can disrupt pangolin behavior, diminish food source, and reduce habitat quality (Panjang 2015; Chao et al. 2020). Furthermore, Subba et al. (2024) stated that urban expansion results in habitat fragmentation, negatively affecting pangolin occupancy rates due to increased human disturbance.

Hence, studying the impact of human activities on the Sunda Pangolin is crucial for several reasons. Firstly, it helps in understanding how human activities influence pangolin behaviour and resource access, which can inform effective conservation strategies (Bhandari et al. 2025; Chen et al. 2025). Secondly, such research can identify critical habitats needing protection to ensure the

Image 1. Sunda Pangolin *Manis javanica*. © Sompud, J., 2025.

survival of this endangered species by pinpointing areas most affected by human activities (Camaclang et al. 2015; Peters et al. 2023). Thirdly, investigating these dynamics offer insights into human-wildlife negative interactions, guiding strategies to benefit both local communities, and wildlife (Sompud et al. 2023). Addressing the impact of human activities such as logging and forest degradation requires comprehensive, long-term approaches that go beyond ecological research. These include preserving remaining natural habitats, enforcing wildlife protection laws more effectively, and engaging local communities through education to reduce demand for pangolin products, and increase awareness of the species' Critically Endangered status.

The objectives of this study are to assess the impact of anthropogenic activities that influences the distribution of Sunda Pangolin. These anthropogenic activities were measured based on the anthropogenic proximity, anthropogenic activity patterns, and anthropogenic noise in Sepanggar Hill. As such these are the specific objectives; 1) to assess the distribution of Sunda Pangolins in Sepanggar Hill, 2) to determine how human presence influences pangolin distribution in Sepanggar Hill, 3) to determine the correlation between the proximity to human settlements and the presence of the Sunda Pangolin, 4) to determine the correlation between anthropogenic noise levels and the presence of the Sunda Pangolin, and 5) to determine the activity pattern of human and Sunda Pangolins.

This study hypothesizes that Sunda Pangolins exhibit a positive response to certain aspects of human presence, particularly in areas where direct threats such as hunting are absent or minimal. It is proposed that Sunda Pangolins may be more frequently detected near human settlements or infrastructure due to indirect benefits such as reduced presence of natural predators, increased availability of food sources like termites associated with human-modified environments, or the presence of secondary vegetation that provides suitable cover. Furthermore, in areas with consistent and non-threatening human activity, Sunda Pangolins may become habituated and show reduced avoidance behaviour, allowing them to utilize edge habitats, and anthropogenic landscapes more freely. This suggests that under specific conditions, human-modified environments may offer ecological opportunities that Sunda Pangolins can exploit, indicating a level of behavioural flexibility, and potential for coexistence with humans in low-risk environments.

MATERIALS AND METHODS

Study Area

The study area is located in Sepanggar Hill, Universiti Malaysia Sabah (UMS), commonly known as UMS forest (Figure 1). This area includes Sustainable Forest and Research Area at Universiti Malaysia Sabah (SFERA@UMS), a 0.25 km^2 of land that has been set aside as a forest reserve by the UMS management to be utilized for forest research and education development (The Borneo Post 2022). It is located northwest of the campus with coordinates of 6.037° N and 116.115° E. Sepanggar Hill is a 2.2 km^2 secondary forest with its tallest peak at 190 m (Majuakim et al. 2018). The terrain varies from flat to hilly with some steep slopes. The land cover within the study area primarily consists of secondary forested habitats, although certain parts have been cleared, and are currently used as agricultural land. Notably, UMS protected and managed a small area for conservation, and research purposes (SFERA@UMS), while the other half is classified as state land, which lacks formal protection for biodiversity. This site was chosen because Sunda Pangolins were first found here in 2023, with no research done on their ecology (Sompud et al. 2023).

Methodology

The study employs a combination of camera trap surveys, decibel meters, and geographical tools to investigate the impact of anthropogenic activities on Sunda Pangolins. Camera traps are utilized to monitor and record the presence of both humans and Sunda Pangolins at each camera trap stations, providing data on their frequency of occurrence. To assess anthropogenic noise level, a decibel meter was used to measure the level of anthropogenic noise at the camera trap stations. Additionally, Google Maps was employed to calculate the distances between human settlements, and the camera trap locations, offering insights into how proximity to human activity influences pangolin behaviour.

Camera Trap Survey

The camera trap survey was conducted over eight months, from 17 May 2023–28 January 2024. The plot size was 300 x 300 m to maximize coverage by the camera traps. Each plot included a camera trap station with one camera trap. Stations were selected using a systematic random design (Stehman et al. 1992). The selection criteria for camera trap locations were based on ecological features known to attract *Manis javanica*, such as wildlife trails (Image 2), termite mounds (Image 3), and areas with dead trees (Image 4) (Simo et al.

2023). Each station was chosen to represent a range of microhabitats across the study area, ensuring varied terrain coverage. The consistency in habitat type was maintained by positioning camera traps within the secondary forest, avoiding areas with dense undergrowth that might obscure the field of view.

Upon determining the optimal position, each camera trap, equipped with an infrared sensor, was affixed to the base of a tree, positioned approximately 20–40 cm above ground level using a belt (Image 5). Placement adjustments were made based on topographical considerations, ensuring an appropriate camera angle (Ancrenaz et al. 2012). Following setup, batteries, and a memory card were inserted, and a walk test was conducted to confirm the camera's coverage of the selected areas. Camera trap data were collected

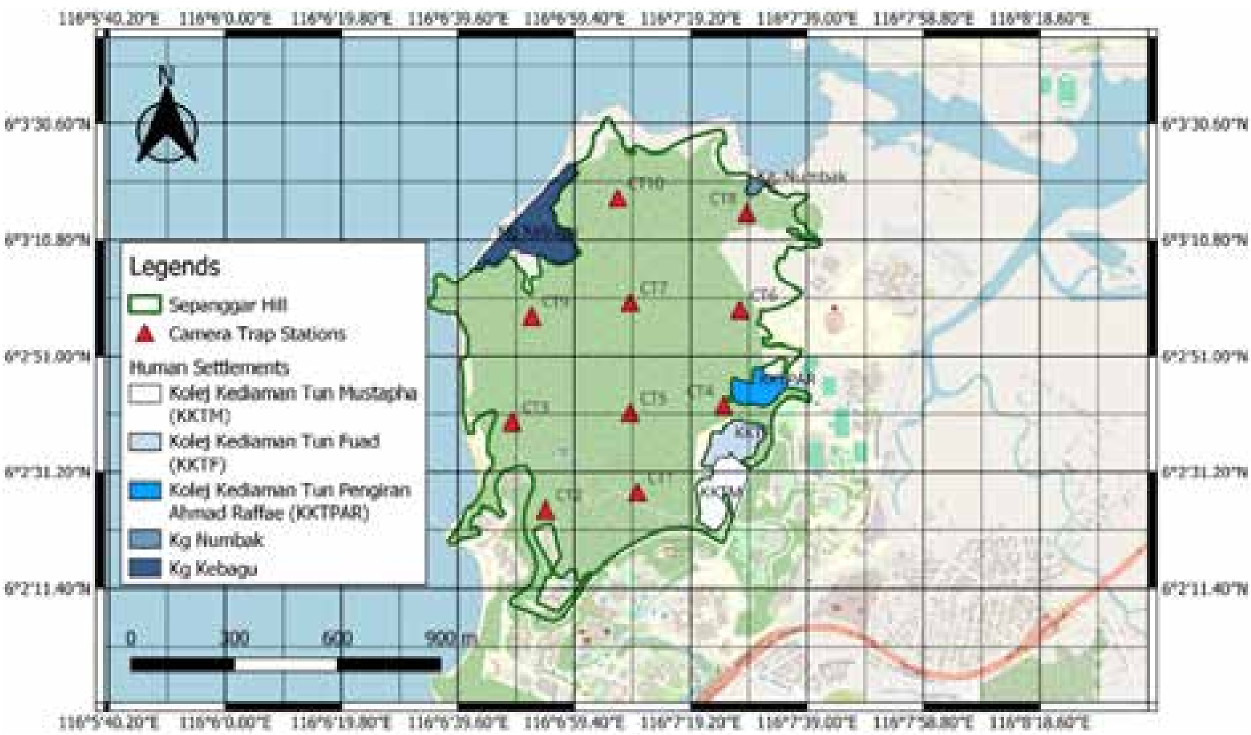

Figure 1. Map of the location of camera traps in Sepanggar Hill.

Image 2. Wildlife trail that was chosen for CT3. © UMS, 2023.

Image 3. Termite mound that was chosen for CT1. © UMS, 2023.

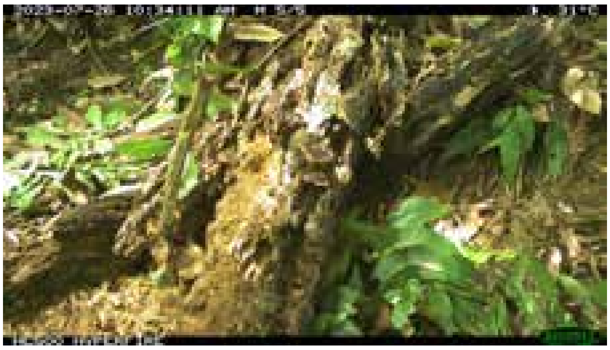

Image 4. Dead trees that was chosen for CT7. © UMS, 2023.

Image 5. Installing camera trap in CT1. © Shairi, N.A., 2023.

on a monthly basis, including battery replacement. The camera traps were set to capture images instead of videos because video files are much larger, which would have filled up the memory quickly, and reduced the amount of data that could be collected. The captured images were analyzed to detect the presence of Sunda Pangolins and humans. Additionally, the images obtained from the camera traps were utilized to assess the activity patterns of both humans and the pangolins by recording the number of human and pangolin events captured by the camera traps hourly.

Measuring distances between camera trap locations and the nearest human settlements

The distances from each camera trap station to the nearest human settlement were measured using Google Maps, based on straight-line (Euclidean) distance from the center point of each settlement to the exact GPS coordinates of each camera trap location (Trianni et al. 2014). For consistency, the nearest house or structure from each settlement to the study area was selected as the reference point. This approach was used to reflect the point of first human presence closest to the forest edge, which is more relevant to the Sunda Pangolin's sensitivity to human disturbance. While this method does not account for the full spatial extent of each settlement, it provides a standardized, and ecologically relevant measure of the nearest point of human activity to the study area. Five closest settlements were chosen: Kolej Kediaman Tun Mustapha (KKTM), Kolej Kediaman Tun Fuad (KKTF), Kolej Kediaman Tun Pengiran Ahmad Raffae (KKTPAR), Kg. Numbak, and Kg. Kebagu (Figure 1). The total number of UMS residents in the KKTM, KKTF, and KKTPAR are 1,600, 1,400, and 3,000 students, respectively (Universiti Malaysia Sabah, 2015). Meanwhile, the total number of humans resides in Kg. Numbak and Kg. Kebagu were estimated to be 600 and 300 people, respectively (Alim pers. comm. 24.xi.2023; Abniti pers. comm. 20.viii.2024).

Measuring anthropogenic oise levels

Anthropogenic noise levels were measured manually using a calibrated decibel meter model of SL-5868P from May 2023–April 2024 (Akpan & Obisung 2022). The decibel meter was calibrated before each field deployment to ensure accurate sound level readings. Calibration was conducted using a standard sound level calibrator set at 94 dB at 1 kHz. This process allowed for consistent baseline measurements across different collection periods.

Sound readings were taken during times of minimal wind activity to limit external interference. Furthermore, the noise level was only taken during the day because the noise levels at night are much lower than during daytime due to less noise pollution at night (Anomohanran & Osemeikhian 2006). For example, the calls for prayers can only be heard once at night, compared to the day, and there are fewer cars, and buses at night. Vegetation density was accounted for by positioning the decibel meter in open clearings near the camera trap stations to prevent absorption or reflection effects from dense foliage. Readings were conducted at approximately ear height to standardize the measurement environment and mitigate sound propagation issues related to variable terrain and vegetation (Alademomi et al. 2020). This data was meticulously recorded and entered into an Excel spreadsheet for further analysis.

Data analysis

Distribution of the Sunda Pangolin in Sepanggar Hill

For the first objective, the data collected from the camera traps were meticulously organized in an Excel spreadsheet. This spreadsheet included detailed information such as the camera trap stations, dates, times, locations, the number of Sunda Pangolin events, the number of human events, and the image titles. A descriptive analysis was conducted to map the distribution of Sunda Pangolins within Sepanggar Hill. Each plot where Sunda Pangolins were present was marked on a detailed map of the area, providing a visual representation of their distribution across the study site. The occupancy rate was also calculated by using the following equation:

$$\textit{Occupancy rate } (\psi) = \frac{\textit{Number of sites occupied}}{\textit{Total number of sites surveyed}}$$

Impact of Human Presence and Settlements on Pangolins

To achieve the second and third objective, a two-tailed Pearson correlation coefficient analysis was conducted using the Statistical Package for the Social Sciences (SPSS). The Pearson correlation is a parametric statistical test used to measure the strength and direction of the linear relationship between two variables, with values ranging from -1 (perfect negative correlation) to +1 (perfect positive correlation) (Berman 2016). In this study, the analysis was based on 2,741 data collected from 10 camera trap stations distributed across Sepanggar Hill, with each station contributing one observation. The dependent variable was the presence of Sunda Pangolins, coded as 1 for presence and 0 for absence. Independent variables included the presence of humans (1 = present, 0 = absent), as well as the distances (in km) from each camera trap station to five human settlements: KKTM, KKTF, KKTPAR, Kg. Numbak, and Kg. Kebagu. This analysis aimed to determine whether there was a significant relationship between Sunda Pangolin presence and human-related factors in the study area.

Activity pattern

For the fourth objective, the activity pattern was

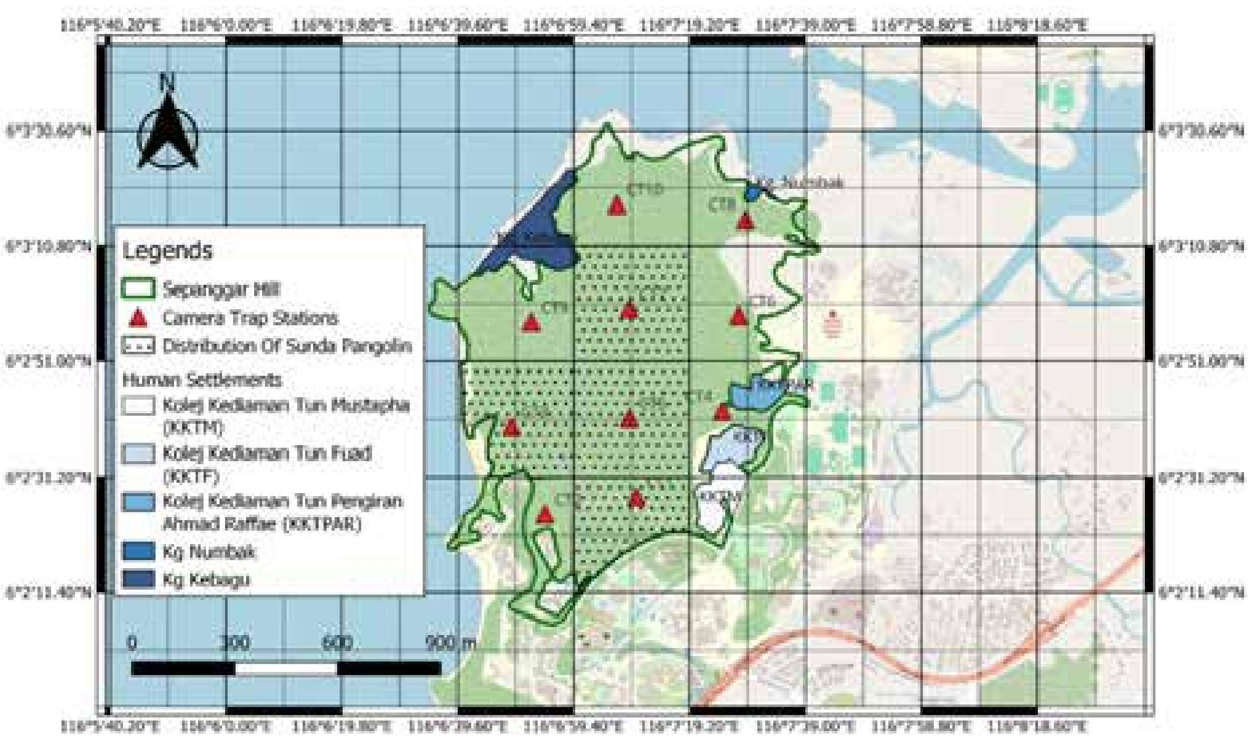

Figure 2. Distribution map of Sunda Pangolins in Sepanggar Hill.

analyzed by calculating the total events of human presence and the presence of Sunda Pangolin in each plot of camera trap during diurnal, and nocturnal times. Diurnal time is defined as the time taken between 0600–1759 h (12 hr) and the nocturnal time is the period between 1800–0559 h (12 hr) (Semiadi et al. 1993). The data was calculated and analyzed using descriptive analysis by observing, and counting the number of events of human presence, and the Sunda Pangolin presence in the camera trap pictures every 60 minutes. Hence, the data was counted as one if multiple pictures were taken within 60 minutes (Gardner & Goossens 2017). The data were then presented in an image to measure humans' and Sunda Pangolins' relative number of active times for each camera trap station.

Anthropogenic noise levels

For the fifth objective, the relationship between the presence of Sunda Pangolins and the average anthropogenic noise levels was also analyzed using Pearson correlation coefficient analysis in SPSS (Fialho et al. 2025). Noise levels were recorded monthly at each camera trap station using decibel meters, and these data were correlated with the frequency of pangolin detections at each station. The correlation analysis was performed individually for each camera trap to assess whether higher noise levels affected pangolin activity and distribution. This analysis provided insights into the impact of noise pollution on the behavior and habitat use of Sunda Pangolins within Sepanggar Hill.

RESULTS AND DISCUSSIONS

In general, 1,17,993 pictures were captured, derived from 2,724 trapping nights. Six camera traps were relocated after three months because those camera traps captured no Sunda Pangolin. During the survey, the camera traps also captured images of various other wildlife species, highlighting the biodiversity within Sepanggar Hill. These species included groups of Long-tailed Macaques *Macaca fascicularis*, Mouse Deer *Tragulidae* sp., Monitor Lizard *Varanus* sp., Birds (*Aves sp.*), Squirrels *Sciurus* sp., Water Buffaloes *Bubalus bubalis*, Masked Palm Civets *Paguma larvata*, and Ground Tortoise *Testudinidae* sp. This diverse array of animals underscores the ecological richness of the area and the importance of preserving this habitat, not only for the Critically Endangered Sunda Pangolin but also for the myriad of other species that coexist within this ecosystem.

Distribution of the Sunda Pangolin

Despite the high volume of data, Sunda Pangolins were recorded in only five events at four camera trap stations (CT1, CT3, CT5, and CT7) with an occupancy rate of 40%. The distribution of Sunda Pangolins appeared to be concentrated towards the center of Sepanggar Hill and more towards the UMS campus, as shown in Figure 2. This spatial distribution could be influenced by several factors, including habitat preferences such as human encroachment, and their preference for undisturbed environments (Liu & Weng 2014; Chong et al. 2020).

In this study, the differences in human activities within UMS campus and outside of the campus may contribute to the visitation factor of the Sunda Pangolin. UMS has designated 0.25 km^2 of land in the Sepanggar Hill forest as a forest reserve, which serves as a research area (The Borneo Post, 2022). This protected status may contribute to the presence of Sunda Pangolins in camera trap stations located closer to UMS, as they do not feel threatened even though there are existing anthropogenic activities that are confined to research and education activities only. On the other hand, the areas that are outside of the UMS campus are accessible to the residents who live near the forested areas. We observed during the course of this study that there were some areas that had become barren due to the felling of trees by the people around the area, totalling 0.099 km^2. This could be the reason why the Sunda Pangolin does not prefer to visit areas outside of the UMS campus, as this species are vulnerable to habitat loss, and poaching (Challender et al. 2012).

Although the study recorded only five independent Sunda Pangolin events within a limited study area, which may constrain the statistical power and generalizability of the findings, this limitation is expected given the species' elusive behaviour, and Critically Endangered status (Panjang et al. 2024). Reliable field data on Sunda Pangolins remain scarce, and even a small number of detections can offer valuable insights into their habitat use and potential responses to anthropogenic disturbances. These preliminary findings provide a foundation for future, larger-scale research, and underscore the importance of long-term monitoring efforts in human-impacted landscapes.

The Presence of Sunda Pangolins and Humans

Pangolins show some resilience to moderate human disturbances depending on various factors (Zanvo et al. 2023). In the current study, it was found that the presence of Sunda Pangolins was detected even in areas with recorded human presence, as evident by camera

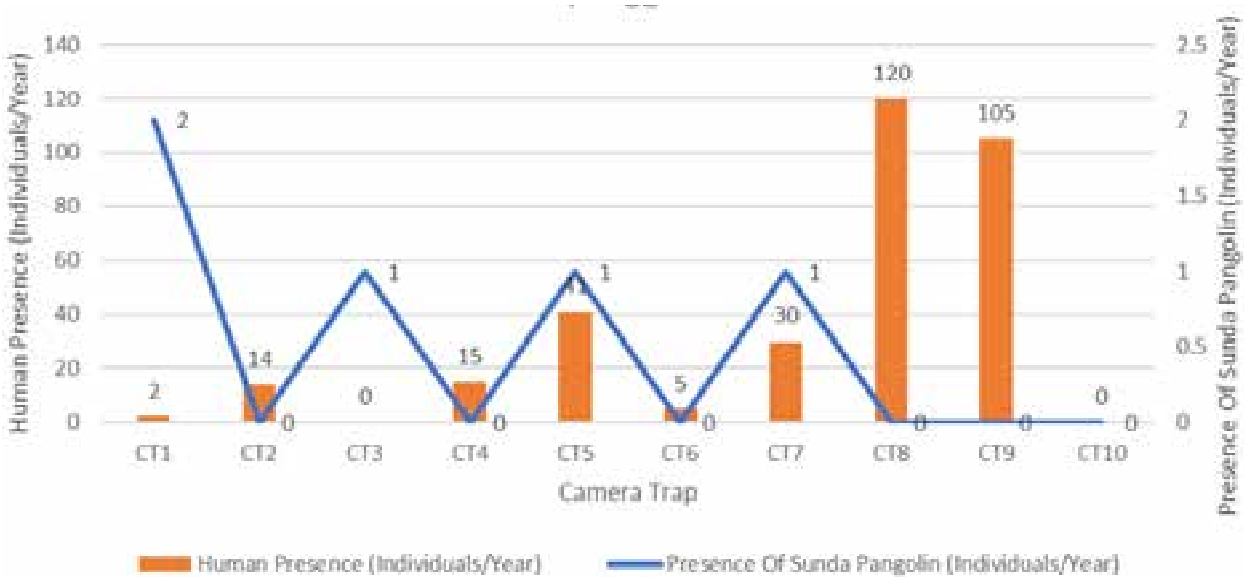

Figure 3. Graph of human presence and the Sunda Pangolins in Sepanggar Hill.

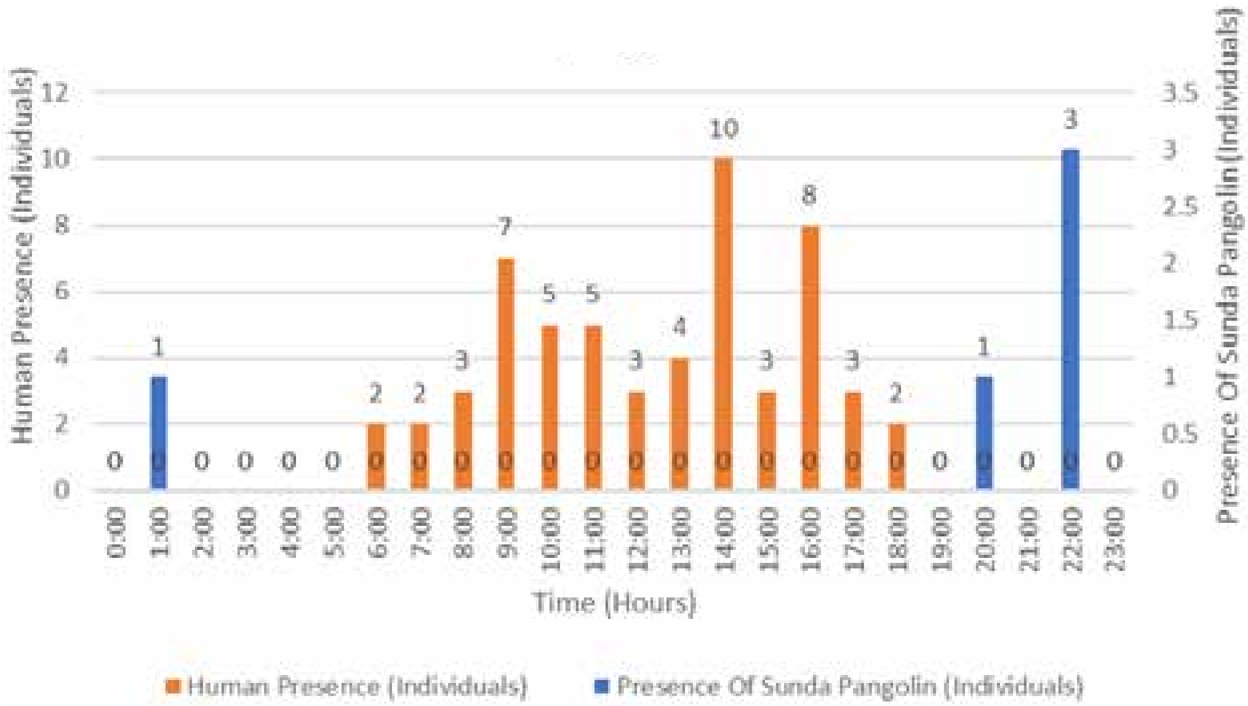

Figure 4. Graph of activity pattern of humans and the Sunda Pangolins in Sepanggar Hill.

trap data (Figure 3). The human presence ranged from 2–120 individuals during data collection, with one to three individuals recorded per event. In this study, the Pearson correlation analysis examined the relationship between Sunda Pangolin presence and distance from five human-related locations: KKTM, KKTF, KKTPAR, Kg. Numbak, and Kg. Kebagu. The correlation values were -0.24, -0.12, 0.00, 0.32, and -0.01, respectively, with a sample size of 2,741 (Table 1). These values show very weak relationships, meaning that the distance from human areas does not strongly affect whether pangolins are present or not.

Interestingly, the analysis showed a weak negative correlation near KKTM and KKTF, which are residential

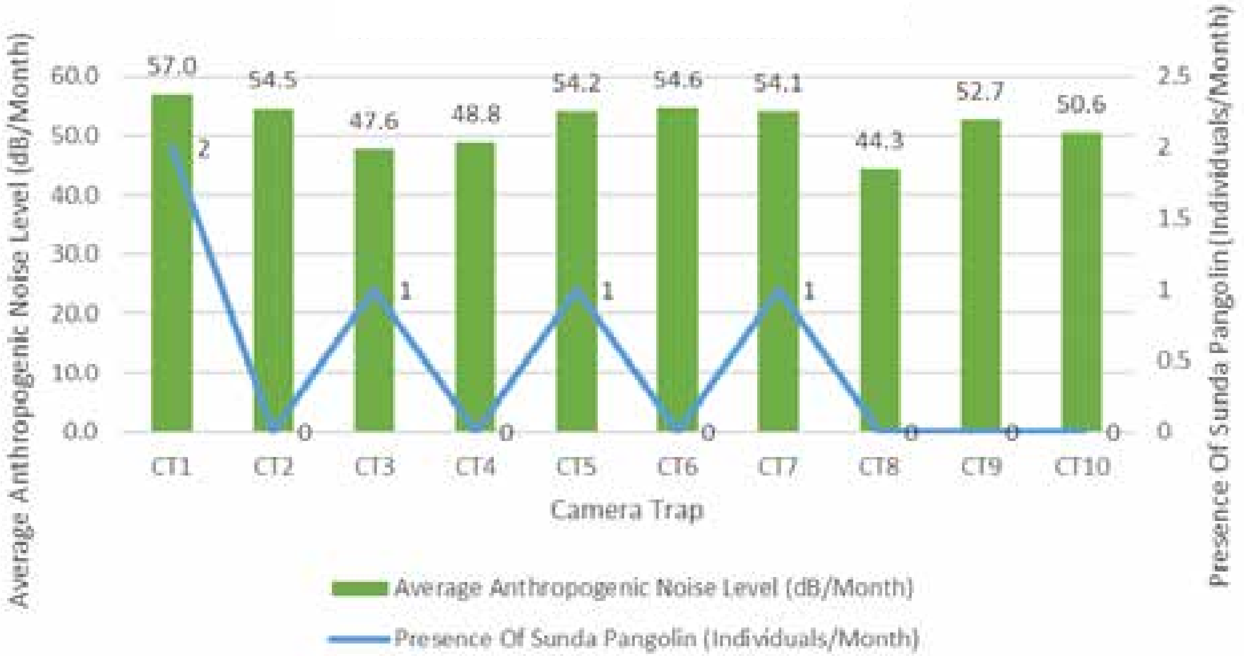

Figure 5. Graph of anthropogenic noise level and the Sunda Pangolins in Sepanggar Hill.

Table 1. Results of Pearson correlation coefficient analysis on the correlation between the presence of Sunda Pangolin and the human settlements.

	Presence of Sunda Pangolin	Proximity to KKTM	Proximity to KKTF	Proximity to KKTPAR	Proximity to Kg Numbak	Proximity to Kg Kebagu
Correlation Coefficient	1	-0.024	-0.012	0.000	0.032	-0.001
Sig. (2-tailed)		0.206	0.521	0.989	0.098	0.957
N	2741	2741	2741	2741	2741	2741

areas for UMS staff and students. People in these areas mostly do research or hiking, not harmful activities. However, because people are regularly present there, the Sunda Pangolins might avoid the area even if there is no direct threat. This may be because disturbances like human noise or lingering scent trails can affect wildlife, especially, since pangolins depend on their sense of smell to find food while foraging (DiPaola et al. 2020).

On the other hand, a weak positive correlation was found near Kg. Numbak and Kg. Kebagu, even though people in these villages do more harmful activities like cutting trees and using fire to clear land. One reason for this might be that these destructive actions usually happen during the day, while pangolins are active at night. Additionally, disturbed areas may offer improved burrows, and foraging conditions for pangolins, such as increased access to termites in decaying wood (Dorji 2017; Chao et al. 2020).

Other studies support the idea that pangolins respond differently depending on the situation. Some studies, like Karawita et al. (2017), say that pangolins tend to avoid humans as they are highly sensitive to human activities (Manshur et al. 2015; Anasari et al. 2021; Sulaksono et al. 2023). But others, like Chong et al. (2020), found that pangolins are sometimes seen in human-modified areas. In one case, a pangolin was even spotted walking inside a shop at KKTPAR without showing fear, suggesting that they may get used to humans in places where they are not hunted (Sompud et al. 2023).

Overall, the results suggest that Sunda Pangolins do not completely avoid areas with people. Instead, they might adjust based on how often people are around, what kind of activities they do, and whether the environment still meets their needs. This shows that pangolins may have some ability to live in areas where human activity is present, especially when the risks are low, and resources are still available (Chong et al. 2020; Nash et al. 2020).

Activity pattern of Sunda Pangolins and humans

Humans are primarily diurnal due to the nature of the human body which operates on the circadian rhythm and other biological factors that help modulate activity levels during daylight hours (Bonny & Firsov 2012; Andreatta & Allen 2021). In this study, the humans were observed to be diurnal, in which they are active during daytime (Figure 4). For instances, the humans were mostly seen active from 0600–1859 h, with the peak activity observed from 1400–1459 h as observed in Figure 4. On the contrary, the Sunda Pangolins were observed to be active at night from 2000–0159 h, with peak activity at range time between 2200–2259 h . This shows that the Sunda Pangolin is a nocturnal mammal species as seen in previous research (Lim & Ng 2008; Challender et al. 2012; Sompud et al. 2019). Based on Figure 4, there were no instances where Sunda Pangolins and humans were present simultaneously at the same location. This temporal separation suggests that there is no direct overlap in the activities of Sunda Pangolins and humans in the Sepanggar Hill forest, which might be a coping mechanism for the pangolins to avoid human encounters. This behavior could be crucial for their survival in disturbed habitats where human presence is significant.

Currently, there is a dearth of studies specifically examining the activity patterns of Sunda Pangolins and humans. The nocturnal behaviour observed in this study aligns with previous research conducted by Lim & Ng (2008), Challender et al. (2012), and Sompud et al. (2019), which consistently reported nocturnal activity in Sunda Pangolins. In contrast, humans are diurnal which means that they are primarily active during the day and resting at night. This nocturnal lifestyle allows them to coexist with humans, however, it also increases their susceptibility to poaching (Khatiwada et al. 2022).

Anthropogenic noise level and presence of the Sunda Pangolin

Sunda Pangolins, like many nocturnal mammals, rely heavily on their acute sense of hearing for foraging and predator avoidance (DiPaola et al. 2020). Increasing levels of anthropogenic noise can interfere with these crucial activities. The analysis shows that there is a positive correlation between noise levels and pangolin presence at Camera Trap Station 1 (N = 348, r = 0.147, p = 0.006**). The anthropogenic noises that were observed come from cars, aeroplanes, people talking, the call to prayer (adhan), and occasional ferry horns. The observations of this study revealed that the noise levels in Sepanggar Hill ranged 44.3–57.0 dB (Figure 5). Based on the Figure 5, the Sunda Pangolin was detected in areas ranging 47.6–57.0 dB. This suggested that the Sunda Pangolin can tolerate the noise levels below 57.0 dB as it is still below the threshold that can causes stress on the species. A study done by Manci (1988) found that noise levels up to 60 dB does not cause negative response to animals that have habituated to noise (Johansson et al. 2016). Therefore, it was suggested that the Sunda Pangolin have adapted the noise level in Sepanggar Hill.

This result is somewhat unexpected, given that previous research, such as Shannon et al. (2016) and Withaningsih et al. (2018), found that many wildlife species, including pangolins, tend to avoid areas which are above 40 dB (Duporge et al. 2021). High noise levels, between 52–68 dB are generally thought to interfere with foraging, communication, and predator avoidance behaviour, leading to increased stress, and decreased reproductive success in many wildlife species (Nursamsi et al. 2023; Shannon et al. 2016). In a study done by Dipaola et al. (2020), the Sunda Pangolin was suggested to react to loud noises, and may adjust their tail position, and their movement to minimize the noise they make in their natural environment. Although pangolins may not rely on sound to find prey, it is likely they use it to detect, and avoid predators. A similar study was done by Sabin et al. (2024) on the impacts of anthropogenic noise on other pangolin species in Chandragiri-Champadevi Hills, Nepal. The study focuses more on the impacts of noise on the foraging and resting burrow count for Chinese Pangolins in the study area. It was found that the presence of these species at foraging burrows is significantly higher in areas with elevated noise levels (0.285 ± 0.073 m), ranging 22.67–58.00 dB. This could be due to their preference for agricultural areas which are the potential habitats for these species (Newton et al. 2008). In contrast, the impact of noise on resting burrow selection by Chinese Pangolins was deemed insignificant. This shows that anthropogenic noise impacts only certain behaviors of the Chinese Pangolins such as foraging.

CONCLUSION

In conclusion, there were impacts of the anthropogenic activities on the Sunda Pangolin in Sepanggar Hill, such as human presence, proximity to human settlements, activity pattern, and anthropogenic noise levels. The analysis results indicate a positive correlation between the Sunda Pangolin and anthropogenic activities, specifically, proximity to human settlements, and anthropogenic noise levels. It was found that the Sunda Pangolin does not avoid humans completely as evident in this study. For instance, the Sunda Pangolins were still detected even in areas near human settlements with minimal activity pattern such as CT1. This shows that the Sunda Pangolins have adapted to human presence in Sepanggar Hill. On the other hand, it was observed that anthropogenic noise levels do not impact the Sunda Pangolins that much despite being significant at CT1. This could be due to the insufficient data over the six-month period, and the noise levels recorded are below 60 dB. Thus, it is concluded that three out of four parameters of the anthropogenic activities had impacted the Sunda Pangolin.

Given these findings, it is clear that while pangolins can coexist with low-impact human activities, the more severe impacts of habitat destruction, and noise from areas outside UMS threaten their survival. Therefore, we recommend for collaborative conservation efforts between the local governments, non-government organisations, and researchers at UMS by enforcing stricter regulations to protect Sunda Pangolins. By combining knowledge and resources, these groups can develop a clear strategy that addresses the species' needs, and their habitat by limiting deforestation, and land-clearing activities in Sepanggar Hill forest, and nearby areas. Thus, it is important to secure enough funding and resources to execute this plan. These funds can be used to put protective measures in place, support research, and ensure that the efforts to conserve pangolins can continue over time. Working as a team will help achieve long-term success in protecting this Critically Endangered species. In addition, buffer zones should be set up around Sepanggar Hill to provide a safe space between humans and wildlife by minimizing the anthropogenic noise, construction, and agricultural development, on the habitats of the Sunda Pangolins. These buffer zones would act as transitional spaces and introducing noise barriers, reducing direct human encroachment, and providing a safe boundary for pangolins to thrive. These steps could provide actionable pathways to mitigate threats to Sunda Pangolins while promoting coexistence with human activities.

REFERENCES

Aisher, A. (2016). Scarcity, Alterity and Value: Decline of the Pangolin, the World's Most Trafficked Mammal. *Conservation and Society* 14(4): 317–329. https://doi.org/10.4103/0972-4923.197610

Akpan, A.O. & E.O. Obisung (2022). Evaluation of acoustic conditions, occupants' satisfaction and comfort in open-plan offices: a case study of select places in Akwa Ibom State, Nigeria. *Researchers Journal of Science and Technology.* Retrieved from https://rejost.com.ng/index.php/home/article/view/23

Alademomi, A., C. Okolie, B. Ojegbile, O. Daramola, J. Onyegbula, R. Adepo & W. Ademeno (2020). Spatial And Statistical Analysis Of Environmental Noise Levels In The Main Campus Of The University Of Lagos. The *Journal of Engineering Research* 17(2): 75–88. https://doi.org/10.24200/tjer.vol17iss2pp75-88

Anasari, S.D., W. Pusparini & N. Andayani (2021). Predicting the Distribution of Sunda Pangolin (*Manis javanica* Desmarest, 1822) in Way Canguk Research Station, Bukit Barisan Selatan National Park, Lampung. *Journal of Tropical Biodiversity and Biotechnology* 6(1): 1–11. https://doi.org/10.22146/jtbb.58612

Ancrenaz, M., A.J. Hearn, J. Ross, R. Sollmann & A. Wilting (2012). Handbook for wildlife monitoring using camera-traps. BBEC Publication, Sabah Parks and Japan International Cooperation Agency, 71pp.

Andreatta, G. & C.N. Allen (2021). How neurons adjust to diurnality. *Elife* 10. https://doi.org/10.7554/ELIFE.74704

Anomohanran, D. & J.E. Osemeikhian (2006). Day and night noise pollution study in some major town in Delta State, Nigeria. *Ghana Journal of Science* 46: 47–54. https://doi.org/10.4314/gjs.v46i1.15916

Ariffin, M. & M.B.C. Nan (2018). Sunda Pangolin protection and trade-related crimes: Assessing local community knowledge in Kedah, Malaysia. *Journal of Sustainability Science and Management* 13(1): 169–180.

Berman, J.J. (2016). Chapter 4 - Understanding Your Data. Data Simplification: Taming Information with Open Source Tools. Science Direct 2016: 135–187. https://doi.org/10.1016/B978-0-12-803781-2.00004-7

Bhandari, B., B. Dhami, N. Kc, P. Mahatara, A. Neupane, S. Gosai, A. Udaya, N. Phuyal & P. Ghimire (2025). Habitat and Anthropogenic Determinants of Chinese Pangolin (Manis pentadactyla) Burrow Occupancy in Udayapur, Eastern Nepal: Implications for Site-Specific Conservation. *Ecology and Evolution* 15(6): e71493. https://doi.org/10.1002/ece3.71493

Bonny, O. & D. Firsov (2012). L'importance des rythmes circadiens en pratique clinique. *Forum Médical Suisse* 12(45): 879–881. https://doi.org/10.4414/SMF.2012.01327

Camaclang, A.E., M. Maron, T.G. Martin & H.P. Possingham (2015). Current practices in the identification of critical habitat for threatened species. *Conservation Biology* 29(2): 482–492. https://doi.org/10.1111/cobi.12428

Challender, D.W., N.V. Thai, M. Jones & L. May (2012). Time-budgets and activity patterns of captive Sunda Pangolins (*Manis javanica*). *Zoo Biology* 31(2): 206–218.

Challender, D.W., S.R. Harrop & D.C. MacMillan (2015). Understanding markets to conserve trade-threatened species in CITES. *Biological Conservation* 187: 249–259. https://doi.org/10.1016/j.biocon.2015.04.015

Challender, D.W.S., D.H.A. Willcox, E. Panjang, N. Lim, H. Nash, S. Heinrich & J. Chong (2019). *Manis javanica*. The IUCN Red List of Threatened Species 2019:e.T12763A123584856. https://doi.org/10.2305/IUCN.UK.2019-3.RLTS.T12763A123584856.en

Chao, J.T. H.F. Li & C.C. Lin (2020). Chapter 3 - The role of pangolins in ecosystems. In *Pangolins : Science, Society and Concervation* 2020: 43–48. https://doi.org/10.1016/B978-0-12-815507-3.00003-4

Chen, H.L., Y.C. Liao, W.J. Lin & H.F. Li (2025). Historic record, current distribution and habitat selection of Chinese pangolin in Yangmingshan National Park, Taiwan. *Global Ecology and Conservation* 59: e03521. https://doi.org/10.1016/j.gecco.2025.e03521

Cheng, W., S. Xing & T.C. Bonebrake (2017). Recent pangolin seizures in China reveal priority areas for intervention. *Conservation Letters* 10(6): 757–764. https://doi.org/10.1111/conl.12339

Chong, J.L., E. Panjang, D. Willcox, H.C. Nash, G. Semiadi, W. Sodsai, N.T.L. Lim, L. Fletcher, A. Kurniawan & S. Cheema (2020). Chapter 6—Sunda Pangolin *Manis javanica* (Desmarest, 1822). *Pangolins.*

Science, Society and Conservation 2020: 89–108. https://doi.org/10.1016/B978-0-12-815507-3.00006-X

DiPaola, J.D., M. Yindee & J.M. Plotnik (2020). Investigating the use of sensory information to detect and track prey by the Sunda Pangolin (*Manis javanica*) with conservation in mind. *Scientific Reports* 10(1): 9787. https://doi.org/10.1038/s41598-020-65898-x

Dorji, D. (2017). Distribution, habitat use, threats and conservation of the critically endangered Chinese pangolin (*Manis pentadactyla*) in Samtse District, Bhutan. Unpublished. Rufford Small Grants, UK, 18 pp.

Duckworth, J.W., A. Pattanavibool, P. Newton & N.V. Nhuan (2008). *Manis javanica*. In: IUCN 2011. IUCN Red List of Threatened Species. Version 2010.4. http://www.iucnredlist.org.

Duporge, I., M.P. Spiegel, E.R. Thomson, T. Chapman, C. Lamberth, C. Pond, D.W. Macdonald, T. Wang & H. Klinck (2021). Determination of optimal flight altitude to minimise acoustic drone disturbance to wildlife using species audiograms. *Methods in Ecology and Evolution* 12(11): 2196–2207. https://doi.org/10.1111/2041-210X.13691

Fialho, M.A., M. Rocamora & L. Ziegler (2025). Detection of anthropogenic noise pollution as a possible chronic stressor in Antarctic Specially Protected Area N° 150, Ardley Island. *Ecological Informatics* 87: 103117. https://doi.org/10.1016/j.ecoinf.2025.103117

Gardner, P.C. & B. Goossens (2017). Danau Girang Field Centre The Bornean Banteng Programme: Conservation and management of the endangered wild cattle *Bos javanicus lowi* in Sabah. http://www.deramakot.sabah.gov.my/PDF/BantengSurveyReport_DeramakotForestReserve.pdf

Giordano, A.J., L.M. Winstead, M.A. Imron, Rustam, J. Sompud, J.V. Kumaran & K.J.C. Pei (2023). Dark Clouds Ahead? Anecdotal evidence for an illegal live trade in Sunda *Neofelis diardi* and Indochinese *N. nebulosa* Clouded Leopards (Mammalia: Carnivora: Felidae). *Journal of Threatened Taxa* 15(6): 23441–23445. https://doi.org/10.11609/jott.8425.15.6.23441-23445

Hearn, A.J., J. Ross, H. Bernard, S.A. Bakar, B. Goossens, L.T. Hunter & D.W. Macdonald (2019). Responses of Sunda clouded leopard Neofelis diardi population density to anthropogenic disturbance: refining estimates of its conservation status in Sabah. *Oryx* 53(4): 643–653. https://doi.org/10.1017/S0030605317001065

Hiew, S.E., B. Musta, M.S. Sarjadi, M. Maid, M. Muning, J. Kodoh, C. Goh, M. Jonalius & J. Sompud (2022). Monitoring of the habitat usage of Tembadau (*Bos javanicus lowi*) around salt lick in a forest plantation of Sabah, Malaysia. *Biodiversitas Journal of Biological Diversity* 23(11): 6062–6069. https://doi.org/10.13057/biodiv/d231162

Johansson, K., P. Sigray, T. Backström & C. Magnhagen (2016). Stress response and habituation to motorboat noise in two coastal fish species in the Bothnian Sea, pp. 513–521. In: *The Effects Of Noise On Aquatic Life II.* Conference Proceedings, Springer New York, xxx + 1292 pp.

Jomes, E.E., F. Tuh, W. Lintangah & J. Sompud (2023). The knowledge, attitude and practice of local Sabahan in Malaysia on Sunda Pangolin. *Biodiversitas Journal of Biological Diversity* 24(9): 4702–4710. https://doi.org/10.13057/biodiv/d240910

Khatiwada, A.P., W.M. Wright, K. Kunkel, M.P. Khatiwada, C. Waterman, S. Bhattarai, H.S. Baral, C.P. Pokheral & F. Dalerum (2022). Human influence on burrow activity of the Chinese pangolin in Nepal. *Wildlife Research* 50: 76–83. https://doi.org/10.1071/WR21024

Karawita, H., P. Perera & N. Dayawansa (2017). Habitat selection and burrow characterization of Indian Pangolin (*Manis Crassicaudata*) in a tropical lowland rainforest habitat in south west Sri Lanka. *Plos One* 13(11): e0206082. https://doi.org/10.1371/journal.pone.0206082

Lim, N.T. & P.K. Ng (2008). Home range, activity cycle and natal den usage of a female Sunda Pangolin *Manis javanica* (Mammalia: Pholidota) in Singapore. *Endangered Species Research* 4: 233–240. https://doi.org/10.3354/esr00032

Liu, Y. & Q. Weng (2014). Fauna in decline: Plight of the pangolin. *Science* 345(6199): 884–884. https://doi.org/10.1126/SCIENCE.345.6199.884-A

Majuakim, L.A., L.M. Ling & J. Gisil (2018). An Inventory of Flora in Urban Forests of Universiti Malaysia Sabah Campus, Sabah, Malaysia. *Journal of Tropical Biology and Conservation* 15: 173–188. https://doi.org/10.51200/jtbc.v15i.1491

Manci, K.M. (1988). Effects of aircraft noise and sonic booms on domestic animals and wildlife: a literature synthesis. US Fish and Wildlife Service, National Ecology Research Center, 88 pp.

Manshur, A., A.P. Kartono & B. Masy'ud (2015). Karakteristik Habitat Trenggiling Jawa (*Manis javanica*) Di Taman Nasional Gunung Halimun Salak. *Media Konservasi* 20: 77–83.

Nash, H.C., G.W. Low, S. W. Choo, J.L. Chong, G. Semiadi, R. Hari, M.H. Sulaiman, S.T. Turvey, T.A. Evans & F.E. Rheindt (2018). Conservation genomics reveals possible illegal trade routes and admixture across pangolin lineages in Southeast Asia. *Conservation Genetics* 19: 1083–1095. https://doi.org/10.1007/s10592-018-1080-9

Nash, H.C., P.B. Lee, N.T. Lim, S. Luz, C. Li, T.F. Chung, A. Olsson, B.C.N. Strange & M. Rao (2020). The Sunda Pangolin in Singapore: a multi-stakeholder approach to research and conservation, pp. 411–425. In: Challender, D.W.S., H.C. Nash & C. Waterman (eds.). *Pangolins. Biodiversity of World: Conservation from Genes to Landscapes*. Academic Press, 630 pp. https://doi.org/10.1016/B978-0-12-815507-3.00026-5

Newton, P.N., V. Thai, S. Roberton & D. Bell (2008). Pangolins in peril: using local hunters' knowledge to conserve elusive species in Vietnam. *Endangered Species Research* 6: 41–53. https://doi.org/10.3354/ESR00127

Nursamsi, I., Z. Amir, H. Decoeur, J.H. Moore & M.S. Luskin (2023). Sunda Pangolins show inconsistent responses to disturbances across multiple scales. *Wildlife Letters* 1(2): 59–70. https://doi.org/10.1002/wll2.12010

Panjang, E. (2015). *The Ecology of Sunda Pangolin in Kabili-Sepilok Forest Reserve, Sabah* Unpublished. (Doctoral dissertation, Universiti Malaysia Sabah).

Panjang, E., Lim, H.Y. Thomas, R.J. Goossens, B. Hearn, A.J. Macdonald, D.W. Ross, J. Wong, S.T. Guharajan, R. Mohamed, A. Gardner, P.C. Koh, S. Cheah, C. Ancrenas, M. Lackman, I. Ong, R. Nilus, R. Hastie, A. Brodie, J.F. Granados, A. Helmy, O. Lapis, O.M. Simon, D. Davies, G. Wong, S.T. Rampangajouw, M. Matsubayashi, H. Sano, C. Runting, R.K. Sipangkui, S. & N.K. Abram (2024). Mapping the distribution of the Sunda Pangolin (*Manis javanica*) within natural forest in Sabah, Malaysian Borneo. *Global Ecology and Conservation* 52: e02962. https://doi.org/10.1016/j.gecco.2024.e02962

Pantel, S. & N.A. Anak (2010). A preliminary assessment of pangolin trade in Sabah. TRAFFIC Southeast Asia, Petaling Jaya, 5 pp.

Peters, N.M., Kendall, J.G. Davies, C. Bracebridge, A. Nicholas, M.P. Mgumba & C.M. Beale (2023). Identifying priority locations to protect a wide-ranging endangered species. *Biological Conservation* 277: 109828. https://doi.org/10.1016/j.biocon.2022.109828

Sabin, K., C.S. Regmi, B. Pant, A. Nepali, H.B. Katuwal & H.P. Sharma (2024). Factors influencing Chinese Pangolin (*Manis pentadactyla*) burrow selection in the Chandragiri-Champadevi hills of Kathmandu Valley, Nepal. *Heliyon* 10(4): e25774. https://doi.org/10.1016/j.heliyon.2024.e25774

Semiadi, G., P.D. Muir, T.N. Barry, C.J. Veltman & J. Hodgson (1993). Grazing patterns of Sambar Deer (*Cervus unicolor*) and Red Deer (*Cervus elaphus*) in captivity. *New Zealand Journal of Agricultural Research* 36(2): 253–260. https://doi.org/10.1080/00288233.1993.10417761

Shannon, G., M.F. McKenna, L.M. Angeloni, K.R. Crooks K.M. Fristrup, E. Brown, K.A. Warner, M.D. Nelson, C. White, J. Briggs, S. McFarland & G. Wittemyer (2016). A synthesis of two decades of research documenting the effects of noise on wildlife. *Biological Reviews* 91: 982–1005. https://doi.org/10.1111/BRV.12207

Simo, F.T., G.F. Difouo, S. Kekeunou, I. G. Ichu, D. Olson, N.J. Deere & D.J. Ingram (2023). Adapting camera-trap placement based on animal behavior for rapid detection: A focus on the Endangered, White-bellied Pangolin (*Phataginus tricuspis*). *Ecology and Evolution*

13(5): 1–10. https://doi.org/10.1002/ece3.10064

Sing, Y.C. & S. Pantel (2009). Pangolin capture and trade in Malaysia. Proceedings of the Workshop on Trade and Conservation of Pangolins Native to South and Southeast Asia. Singapore Zoo, Singapore. TRAFFIC Southeast Asia, Petaling Jaya, Selangor, Malaysia, 30 June–2 July 2008.

Sompud, J., C.B. Sompud, K.J.C. Pei, N.C.M. Sun, R. Repin & F. Tuh (2019). Sunda Pangolin *Manis javanica* (Mammalia: Pholidota: Manidae) of Gaya Island. *Journal of Threatened Taxa* 11(5): 13552–13556. https://doi.org/10.11609/jot.4198.11.5.13552–13556

Sompud, J., A.Z. Adams, S.E. Hiew, M. Maid, J. Kodoh, M.S. Sarjadi, C. Goh, M. Jonalius & M. Baba (2022). Bornean Pygmy Elephant habitat usage of natural salt licks in Segaliud Lokan Forest Reserve. In *IOP Conference Series: Earth and Environmental Science* 1053(1): 012016. https://doi.org/10.1088/1755-1315/1053/1/012016

Sompud, J., N. Sahar, C. Adros, E. Richard & C.B. Sompud (2023). Notes on a new distribution record of the Critically Endangered Sunda Pangolin (*Manis javanica)* in Sabah, Malaysian Borneo. *Biodiversitas Journal of Biological Diversity* 24(2): 975–981. https://doi.org/10.13057/biodiv/d240237

Stehman, S. (1992). Comparison of systematic and random sampling for estimating the accuracy of maps generated from remotely sensed data. *PE & RS-Photogrammetric Engineering and Remote Sensing* 58(9): 1343–1350.

Subba, A., G. Tamang, S. Lama, J. H. Limbu, N. Basnet, R.C. Kyes & L. Khanal (2024). Habitat Occupancy of the Critically Endangered Chinese Pangolin (*Manis pentadactyla*) under Human Disturbance in an Urban Environment: Implications for Conservation. *Ecology and Evolution* 14(12): e70726. https://doi.org/10.1002/ece3.70726

Sulaksono, N., S. Pudyatmoko, S. Sumardi, W. Wardhana & A. Budiman (2023). The effects of anthropogenic disturbances on the spatiotemporal patterns of medium–large mammals in tropical volcanic landscapes. *Animals* 13(20): 3217. https://doi.org/10.3390/ani13203217

The Borneo Post (2022). UMS gazettes 62 acres of land as forest reserve. https://www.theborneopost.com/2022/06/22/ums-gazettes-62-acres-of-land-as-forest-reserve/

Trianni, G., E. Angiuli, G. Lisini & P. Gamba (2014). Human settlements from landsat data using google earth engine. 2014 IEEE Geoscience and Remote Sensing Symposium. QC, Canada, 2014: 1473–1476.

Universiti Malaysia Sabah (2015). *Accommodation*. Retrieved 10 October 2024 from https://www.ums.edu.my/v5/accommodation

Withaningsih, S.P. Parikesit & A. Nasrudin (2021). Correlation between landscape structure and distribution of Javan Pangolin (*Manis Javanica*) in an extreme landscape. *Biodiversitas Journal of Biological Diversity* 22(2): 920–932. https://doi.org/10.13057/biodiv/d220248

Zanvo, S., C.A. Djagoun, P. Gaubert, A.F. Azihou, C. Jézéquel, B. Djossa, B. Sinsin & B. Hugueny (2023). Modeling population extirpation rates of white-bellied and giant pangolins in Benin using validated local ecological knowledge. *Conservation Science and Practice* 5(8): https://doi.org/10.1111/csp2.12986

Malay: Tenggiling Sunda atau Manis javanica Desmarest, 1822 (Pholidota: Manidae) merupakan satu-satunya spesies tenggiling yang terdapat di Malaysia. Spesies ini dikategorikan sebagai “Sangat Terancam” (Critically Endangered) dalam Senarai Merah Spesies Terancam IUCN dan merupakan antara mamalia yang paling banyak diperdagangkan secara haram di dunia. Aktiviti antropogenik seperti pembangunan penempatan dan pergerakan manusia yang kerap berhampiran tepi hutan semakin mengancam keselamatan Tenggiling Sunda. Aktiviti ini bukan sahaja menyebabkan fragmentasi habitat, tetapi juga mendedahkan hidupan liar kepada tahap bunyi dan gangguan manusia yang tinggi akibat jarak yang dekat dengan kawasan penempatan. Oleh itu, kajian ini dijalankan untuk menentukan kesan aktiviti antropogenik terhadap taburan Tenggiling Sunda di Bukit Sepanggar menggunakan kaedah tinjauan kamera perangkap. Sebanyak sepuluh kamera perangkap dipasang secara sistematik dan rawak dari Mei 2023 hingga Januari 2024. Jarak antara penempatan manusia terdekat dengan lokasi kamera perangkap serta tahap bunyi antropogenik turut diukur. Data dikumpul setiap bulan bagi kedua-dua parameter tersebut. Sepanjang 2,724 malam pemasangan, kamera perangkap merekodkan lima kejadian tenggiling. Analisis korelasi Pearson menunjukkan hubungan yang sangat lemah (-0.24 hingga 0.32) antara kehadiran Tenggiling Sunda dengan jarak ke penempatan manusia berdasarkan 2,741 titik data. Walaupun tahap bunyi tinggi antara 44.3–57.0 dB, Tenggiling Sunda lebih kerap dikesan berhampiran kamera perangkap pertama (N = 348, r = 0.147, p = 0.006**), iaitu kawasan dengan tahap bunyi tertinggi, menunjukkan toleransi terhadap gangguan bunyi. Dapatan ini menonjolkan keupayaan adaptasi Tenggiling Sunda terhadap habitat terganggu selagi mereka tidak berasa terancam, serta menekankan keperluan usaha pemuliharaan bersasar untuk mengurangkan impak manusia. Pemeliharaan kawasan yang lebih tenang dan pengurangan gangguan manusia amat penting bagi memastikan kelangsungan hidup Tenggiling Sunda di Bukit Sepanggar. Kajian ini memberi panduan penting untuk merangka strategi pemuliharaan yang berkesan bagi melindungi spesies yang sangat terancam ini.

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ARTICLE

Preliminary notes on a coastal population of Striped Hyena *Hyaena hyaena* (Linnaeus, 1758) from Chilika lagoon, India

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Abstract: The Striped Hyena *Hyaena hyaena* (Linnaeus, 1758), India's only hyaena species, is a solitary scavenging carnivore. It typically thrives in arid and semi-arid regions. Limited documentation exists on its occurrence along the Indian eastern coast – the easternmost limit of the Striped Hyena's global distribution range. Information on the Striped Hyena's presence along Chilika's sandy coastline was received during Fishing Cat *Prionailurus viverrinus* (Bennett, 1833) focused interview surveys which encouraged this study. We used camera-traps, night surveys on foot (for direct sightings), and day-time surveys to examine animal remains near hyena denning sites in locations with reported hyena sightings. We documented a group of three individuals (plausibly a mother and cubs) during consecutive nights. We also collected data on its natural history and ecology, for example, behaviour, diet, co-scavengers, and sympatric species. Golden Jackal *Canis aureus* (Linnaeus, 1758), feral dogs, and Wild Boars *Sus scrofa* (Linnaeus, 1758) were found to be co-scavengers. Camera-trap videos and direct sightings revealed that the hyena took refuge inside *Pandanus* sp. foliage (a mangrove associate) in the Chilika landscape. We found den sites with animal remains, including bones that were tentatively identified as Bovidae and Suidae families. Triangulated by observations from the field and videos from camera traps, these could belong to feral cows, and wild boars. A turtle carapace piece was also detected. Furthermore, local fishermen reported that hyena scavenge on fish remains in fishing nets, Olive Ridley carcasses, and lifts newborn cattle. Residents reportedly killed hyenas misperceiving them as 'child-lifters'. We recommend detailed investigation of the ecology of this coastal population of the Striped Hyena, especially its diet, and urgent adoption of conservation programs.

Keywords: Behaviour, camera traps, coasts, diet, ecology, interview surveys, mangrove associate, natural history, scavenge, solitary.

Odia: ସାରାଂଶ: ହେଟାବାଘ ବା Striped Hyena Hyaena hyaena (Linnaeus, 1758) ଭାରତର ଏକମାତ୍ର Hyaena ପ୍ରଜାତି | ଏହା ଏକାକୀ ସ୍ୱଭାବର ଏବଂ ମେହେନ୍ତର-ଶ୍ରେଣୀୟ ବା ପରିଷ୍କାରକ-ମାଂସାହାରୀ। ଏହା ସାଧାରଣତଃ ଶୁଷ୍କ ଏବଂ ଅର୍ଦ୍ଧ-ଶୁଷ୍କ ଅଞ୍ଚଳରେ ବଢ଼ିଥାଏ। ଭାରତୀୟ ପୂର୍ବ ଉପକୂଳରେ ପୂର୍ବତମ ସୀମା ହେଉଛି ଏହି ହେଟାବାଘର ବିଶ୍ୱବ୍ୟାପୀ ବଣ୍ଟନ ପରିସର | ଏହି ହେଟାବାଘର ସ୍ଥିତି ବିଷୟରେ ସୀମିତ ମାତ୍ର ସମ୍ବଳିତ ତଥ୍ୟ ରହିଛି । ଅତୀତରେ ଚିଲିକାର ବାଲିଆ ଉପକୂଳରେ ହେଟାବାଘର ଉପସ୍ଥିତି ବିଷୟରେ ସୂଚନା ମିଳିଥିଲା | ମାଛ-ରଙ୍କା ବିଲେଇ (*Prionailurus viverrinus*) ପାଇଁ ସାକ୍ଷାତକାର ସର୍ଭେ ସମୟରେ ଆମେ ହେଟାବାଘ ଉପସ୍ଥିତି ସମ୍ପର୍କିତ ସୂଚନା ପାଇଥିଲୁ | ତାହା ଏହି ଅଧ୍ୟୟନକୁ ଉତ୍ସାହିତ କରିଥିଲା। ଆମେ କ୍ୟାମେରା-ଟ୍ରାପ୍ ବ୍ୟବହାର କରିଥିଲୁ | ପ୍ରତ୍ୟକ୍ଷ ଦର୍ଶନ ପାଇଁ ପାଦରେ ରାତି ସର୍ବେକ୍ଷଣ, ଏବଂ ହେଟାବାଘ ରହୁଥିବା ଗାଡ଼ ନିକଟରେ ପ୍ରାଣୀ ଅବଶେଷ ପରୀକ୍ଷା କରିବା ପାଇଁ ଦିବସକାଳୀନ ସର୍ବେକ୍ଷଣ କରିଥିଲୁ | ଏହି ସ୍ଥାନ ଗୁଡ଼ିକରେ ହେଟାବାଘକୁ ପ୍ରତ୍ୟକ୍ଷ ଦେଖାଯିବାର ରିପୋର୍ଟ କରାଯାଇଥିଲା। ରାତ୍ରୀ କାଳୀନ ଅଧ୍ୟୟନରେ ଆମେ ଲଗାତାର ତିନୋଟି ହେଟାବାଘଙ୍କୁ ଲିପିବଦ୍ଧ କରିଲୁ | ସମ୍ଭବତଃ ସେମାନେ ମା ଏବଂ ଶାବକଙ୍କର ଏକ ଗୋଷ୍ଠୀ । ଆମ ଅଧ୍ୟୟନରୁ ଆମେ ଏହା ମଧ୍ୟ ଜାଣିଲୁ ଯେ ହେଟାବାଘର ସହ ପରିଷ୍କାରକ-ମାଂସାହାରୀ ପ୍ରଜାତି ରୂପେ ସୁନେଲି ବିଲୁଆ (*Canis aureus*), ବୁଲା କୁକୁର ଏବଂ ଜଙ୍ଗଲୀ ବାରହା (*Sus scrofa*) ଅନ୍ତର୍ଭୁକ୍ତ | କ୍ୟାମେରା-ଟ୍ରାପ୍ ଭିଡିଓରୁ ଜଣାପଡ଼ିଲା ଯେ ହେଟାବାଘ ଚିଲିକା ଭୂଦୃଶ୍ୟରେ *Pandanus* ପ୍ରଜାତି ଜଙ୍ଗଲ ଭିତରେ ଆଶ୍ରୟ ନେଇଥିଲା। ଏହି ଗଛ ଗୁଡିକ ହେନ୍ତାଳ ବଣ ସହଯୋଗୀ ଅଟନ୍ତି | ହେଟାବାଘ ଗୁମ୍ଫା ସ୍ଥାନଗୁଡ଼ିକ ନିକଟରେ ଆମେ ପାଇଥିବା ପଶୁପକ୍ଷୀଙ୍କ ଅବଶେଷରେ ଯେଉଁ ହାଡ଼ ସାମିଲ ଥିଲା ସେଗୁଡିକ Bovidae ଏବଂ Suidae ପରିବାର ଭାବରେ ଚିହ୍ନଟ କରାଯାଇଥିଲା। ଏଗୁଡ଼ିକ ଜଙ୍ଗଲୀ ଗାଈ ଏବଂ ଜଙ୍ଗଲୀ ଘୁଷୁରିର ହୋଇପାରେ। ଛାଡି ଯାଇଥିବା ଖାଦ୍ୟ ଓ ହାଡ ଅଂଶରୁ ଗୋଟିଏ ସମୁଦ୍ର କଇଁଛର ପିଠି ଖୋଳପା ମଧ ଥିଲା | ସ୍ଥାନୀୟ ମତ୍ସ୍ୟଜୀବୀମାନେ ରିପୋର୍ଟ କରିଛନ୍ତି ଯେ, ମାଛ ଧରିବା ଜାଲରେ ଲାଗିଥିବା ଅଲିଭ୍ ରିଡଲେ ସମୁଦ୍ର କଇଁଛର ଶବକୁ ହେଟାବାଘ ଖାଇଥାଏ ଓ ସେମାନେ ନବଜାତ ଗୋରୁଙ୍କୁ ମଧ ଉଠାଇ ନିଅନ୍ତି | ମଣିଷ ଶିଶୁଙ୍କ ହତ୍ୟାକାରୀ ଭାବି ସ୍ଥାନୀୟ ବାସିନ୍ଦା ମାନେ ହେଟାବାଘଙ୍କୁ ଆକ୍ରମଣ କରି ହତ୍ୟା କରିଥାନ୍ତି | ଉପକୂଳବର୍ତ୍ତୀ ଅଂଚଳର ଏହି ହେଟାବାଘଙ୍କ ସଠିକ ସଂଖ୍ୟା, ସେମାନଙ୍କ ପରିବେଶ, ବିଶେଷକରି ଏହାର ଖାଦ୍ୟ, ଏବଂ ସଂରକ୍ଷଣ ଇତ୍ୟାଦିର ଅଧିକ ସର୍ଭେକ୍ଷଣ ଆବଶ୍ୟକ |

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INTRODUCTION

The Hyaenidae family encompasses four extant species: the Aardwolf *Proteles cristata* (Sparrman, 1783), the Brown Hyena *Parahyaena brunnea* (Thunberg, 1820), the Spotted Hyena *Crocuta Crocuta* (Erxleben, 1777), and Striped Hyena *Hyaena hyaena* (Linnaeus, 1758). The only hyena species present in India is the Striped Hyena (Prater 1980) which is a solitary and nocturnal scavenger (Reiger 1979). Although the Striped Hyena holds a widespread presence across Africa, the Middle East, central Asia, and the Indian subcontinent (Kruuk 1976; Hofer & Mills 1998; Kasparek et al. 2004), it is globally 'Near Threatened' in the IUCN Red List of Threatened Species and the Mediterranean population is Vulnerable (AbiSaid & Dloniak 2015). Key threats include poisoning and reduced natural & domestic carrion due to declines in other large carnivore populations (Hofer 1998). Striped Hyenas display scavenging habits across a broad spectrum of food items such as mammals, birds, reptiles, fish, insects, and fruits (Singh et al. 2010). They are opportunistic hunters, targeting small mammals, and livestock (Kruuk 1976). Denning preferences vary widely, from caves in rocks to dens dug underneath bushes, and tall grasses, utilization of holes along riverbanks, and even existing porcupine burrows (Prater 1971; Alam 2011).

India represents the easternmost boundary for the Striped Hyena in their global distribution and has primarily been recorded from arid & semi-arid regions (Reiger 1979). The species is absent in the northeastern region (Prater 1971). Reports of their existence in the east coast come solely from Odisha, India (Karnad 2017). The Zoological Survey of India listed two species of mammals in Chilka (Chilika) lake in Annandale (1921) and updated it in the list by Saha (1995), with 18 species, and separately mentioned about hyena from a particular field trip. Although the presence of 18 mammalian species in Chilika is mentioned elsewhere, a specific mention about hyena was overlooked (Mohanty et al. 2004; SWO 2007). But Mishra et al. (1996) mentioned about its occurrence all over Odisha including the mangrove swamps and coastal areas.

We were informed of their presence in Chilika during a Fishing Cat-focused interview survey. Here, locals refer to the Striped Hyena as 'hentabagha' or 'dhenkia', and people coming from other parts of Odisha also call it 'heta', 'hetabagha', 'lenkda', and 'hundala'. Based on this, we conducted camera-trap surveys in the coastal sandy banks of Chilika, along the Bay of Bengal, as suggested by the residents. Additionally, we conducted night patrolling on foot for possible direct sightings. During the day, we studied the animal remains near known hyena den sites. Lastly, we collated observations & perceptions of residents on the Striped Hyena, based on informal interviews, and discussions.

MATERIALS AND METHODS

Study site

Chilika (19.467°–19.900° N, 85.100°–85.583° E) is Asia's largest brackish-water lagoon. It was declared a Ramsar site under the Ramsar Convention on Wetlands in 1981, covering a total area of 1,165 km^2 during the monsoon, decreasing in expanse to 906 km^2 in the summer months. The lagoon is composed of three environments—freshwater, brackish, and marine—shaped by the inflow of freshwater from Mahanadi River's tributaries and streams of western catchment, and the inflow of saline water from the Bay of Bengal from sea mouth, and Palur channel. Our study site (6 km) is part of a 60-km long sand bar between Chilika Lagoon and the Bay of Bengal. This area is mainly covered by casuarina forests with intermittent patches of *Pandanus* (Odia, Kiya, Kia in Saxena & Brahmam 1996), a mangrove-associated species, interspersed with cashew plantations.

Methodology

To validate the presence of the species, we deployed five camera traps (BROWNING HD XD PRO) along the coastal islands of Chilika, covering a range of 6 km (19.467°–19.900° N, 85.100°–85.583° E) (Image 1). This opportunistic deployment of camera traps spanned a period of three months from May–August 2022. Cameras were deployed in the video mode and data was periodically retrieved from the SD cards, and saved. Out of these, videos with clarity, and in which the entire body of the target species could be seen were segregated. We then attempted to analyse the videos for individual identification of the hyenas, based on their stripe patterns on the flank. All videos where the hyenas were too close or too far from the traps were excluded because of lack of clarity. During our direct observations in the field, we identified several burrows in the sand near the *Pandanus*, with piles of bones nearby indicating their use by the hyenas. Fifteen pictures of bone piles as well as individual bones were taken opportunistically with mobile phones. These were later assigned tentative taxonomic identification by one of the authors (SN). We also recorded relevant information on Striped Hyena ecology emanating from discussions with local fishermen as well as their perceptions towards the species.

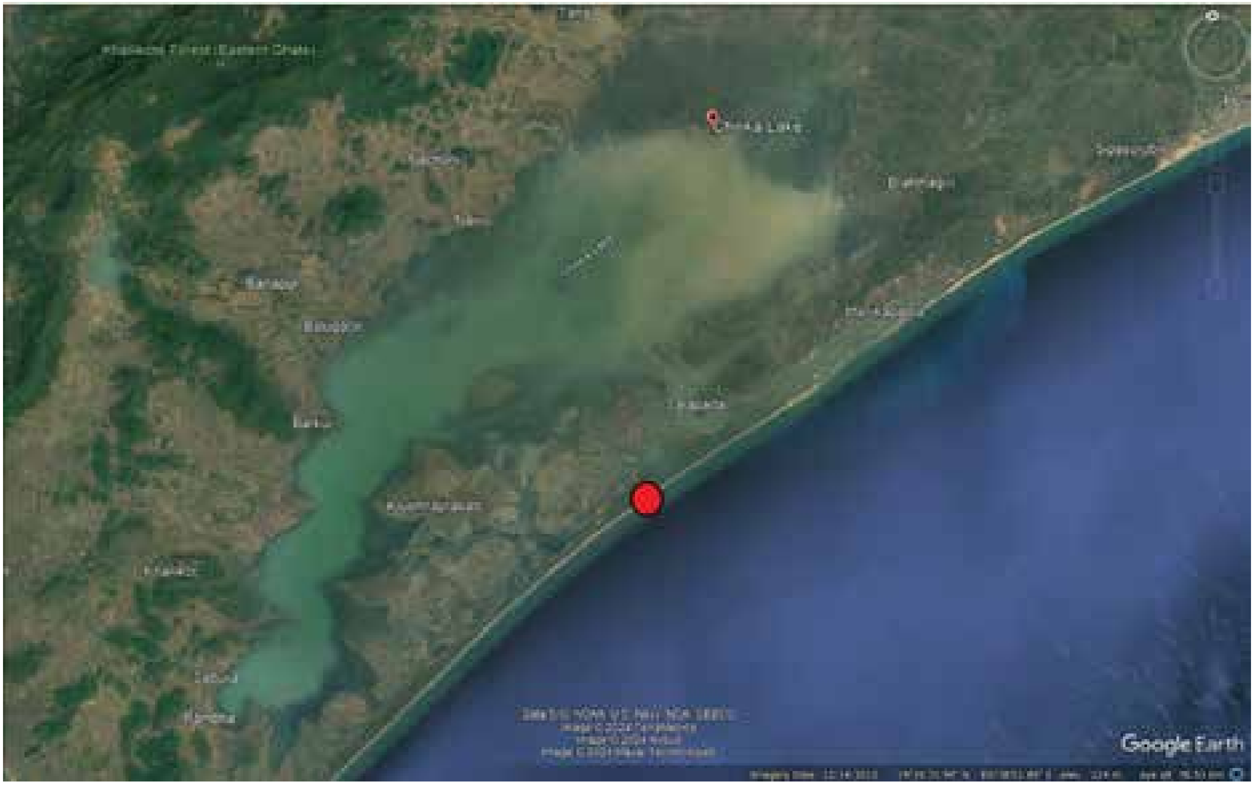

Image 1. Location of study site of Striped Hyaena in Chilika, Odisha: a sandy coastline with casuarina forest plantation, *Pandanus* patches and cashew plantations.

RESULTS

Camera Trap Results

a. Individual identification through camera trap: From the 71 video recordings captured through camera traps, 47 were selected for individual identification (based on clarity of the videos and clear pictures of the entire body of the study species). Fourteen videos were excluded because the hyenas were either too close or too far from the camera. Pictures of unique left and right flanks were segregated; since there were more unique right flanks than left, the right flank was chosen for the individual identification. With the available data, four individuals were successfully identified (Image 3–6). One of them was solitary, while the other three formed a group, presumably a mother, and two well-grown cubs (slightly smaller body size).

b. Behavioural Observations: From the camera trap videos, we observed the Striped Hyena engaged in various activities such as moving, resting, checking the camera traps with curiosity, and scratching them. In seven recordings, two hyaenas were observed together, engaging in activities such as playing, sniffing, playing with dried branches, and digging up the sand. Additionally, three hyenas were recorded together in six videos, where they were observed playing, resting, grooming, and engaging in allogrooming.

Detailed observation of the camera trap recordings showed the hyenas resting outside or going inside the *Pandanus*. The stilt roots of *Pandanus* could potentially serve as their daytime refuge.

c. Sympatric species and co-scavengers: Apart from the hyenas, the camera traps captured footage of various other animals in the area, including feral cows, Wild Boars *Sus scrofa* 'Barha' in Odia, Golden Jackals *Canis aureus* 'Bilua' in Odia, feral dogs, Indian Crested Porcupines *Hystrix indica* 'Jhinka' in Odia, and a Spotted Deer *Axis axis* 'Mruga' in Odia. Through a series of camera trap results from two consecutive days, we observed that the carcass of an adult feral cow was scavenged by Golden Jackals, feral dogs, and Wild Boars.

d. Denning and diet of Striped Hyena: In this landscape, the Striped Hyenas were found to make burrows in the sand beneath dense *Pandanus* vegetation (mangrove associates) (Image 9).

About 39 bone fragments seen from 10 field photographs could be identified as specimens—that belonged to the family Bovidae, and two to the family

Image 2. Camera trap image of the left flank of Striped Hyaena. Each flank has a unique stripe pattern which can be used for individual identification. © The Fishing Cat Project.

Suidae (Image 7). An eroded fragment of turtle carapace and a broken horn sheath were also found (Image 8). One specimen could not be identified. Since we observed feral cows and wild boars in the field, and recorded the same in camera traps, it can be inferred that the bone remains found near the hyena dens were primarily from feral cows, followed by Wild Boars. Chilika Buffalo, an indigenous buffalo breed, is a common livestock in the region and the broken horn sheath could tentatively belong to the same.

People's observations and perceptions of Striped Hyenas

During our interactions, residents reported hyenas scavenging on the carcasses of feral cows, fish bycatch from fishing nets, and Olive Ridley Turtles during mass nesting periods. They also reported instances of hyena depredation on newborn calves. Our conversations with the local fishermen revealed a prevalent perception of fear towards hyenas among community members due to the belief that hyenas lift human children. This perception has resulted in retaliatory killings, with two hyenas reportedly being killed in the last three years.

DISCUSSION

Shah (1995) mentions that "Tiger, Leopard, and Sloth Bear do occur in the vicinity of the (Chilika) Lake area". Other historical records from Chilika lagoon do not indicate the presence of large predators capable of providing carrion to the striped hyenas in the region. We documented a feral cow population that could be potential food for hyenas in our study area. Nevertheless, it remains uncertain whether this cow population extends throughout the Chilika coastline.

Carlton & Hodder (2003) classify Striped Hyenas as maritime carnivores, alongside 20 other terrestrial carnivores, highlighting their dependence on intertidal zones for sustenance and citing instances of crab consumption by Striped Hyenas along Kenya's coastline. Additionally, Karnad (2017) documented hyenas feeding on Olive Ridley Turtle eggs in Rushikulya, Odisha (45 km away from our study site). Notably, Odisha's coastline has the eastern-most hyena population, and this overlaps with one of the largest Olive Ridley mass nesting sites. Despite its importance as a key hyena habitat, there exists a dearth of knowledge regarding the ecology of coastal hyena populations. The Chilika coastline is sparsely populated by humans, although incidents of hyena killings have been reported. This remains a threat to hyaena populations across their global range (Hofer 1998). There is an urgent need for comprehensive studies on ecology of the coastal hyena population in Chilika, alongside conservation programs to promote tolerance of the Striped Hyena within local communities, and appreciation of its important ecological role.

Image 3–6. Camera trap images of the four right flanked Striped Hyaenas. Each flank has a unique stripe pattern which can be used for individual identification. © The Fishing Cat Project.

Table 1. List of tentatively identified bone specimens from Chilika, Odisha.

Image No.	Number of fragment in image	Elements identified	Tentative taxonomic identity*
Chilika bones 01	1	Broken mandible with third premolar and first to third molars	Class Mammalia Order Artiodactyla Family Bovidae *Bos indicus* Linn
	2	Tibia	
	3	Broken scapulae	
	4	Calcaneum bone	
	5	Broken scapulae	
	6	Humerus with broken proximal end	
	7	Metacarpal bone	
	8	First phalanx	
	9	Broken femur without distal end	
	10	Atlas vertebra	
	11	Broken rib	
	12	Broken rib	
	13	Broken lumber vertebra	
	14	Broken thoracic vertebra	
	15	Cervical vertebra	
	16	Cervical vertebra	
	17	Cervical vertebra	
	18	Broken lumber vertebra	
	19	Cervical vertebra	
	20	Astragalus	
	21	Fragment of thoracic vertebra	
	22	Fragment of thoracic vertebra	
	23	Fragment of thoracic vertebra	
	24	First phalanx	
	25	Fragment of thoracic vertebra (?)	
	26	Fragment of thoracic vertebra (?)	
	27	Broken vertebra	
	28	Fragment of horn core(?)/rib (?)	?
	29	Broken rib (?)	?
Chilika bones 02	-	Broken vertebra	Class Mammalia Order Artiodactyla Family Bovidae *Bos indicus* Linn
Chilika bones 03	-	Broken pelvic girdle	
Chilika bones 04	-	Fragment of Humerus without proximal end	
Chilika bones 05	-	Fragment of Ulna	
Chilika bones 06	-	Broken humerus without proximal portion	
Chilika bones 07	-	Broken shaft of tibia without epiphysis	
Chilika bones 08	-	Broken femur without distal end	
Chilika bones 09	-	Mandible with fragments of incisors, canines, premolars and molar teeth	
Chilika bones 10	-	Broken mandible	
Chilika bones 11	-	Broken pelvic girdle	
Chilika bones 12	1	Broken radius and ulna without distal end	
	2	Fragment of proximal portion of metacarpal	
Chilika bones 13	-	May be fragment of turtle carapace (very eroded)	Not identifiable
Chilika bones 14	-	May be fragment of horn sheath	Not identifiable
Chilika bones 16	-	Bone very fragmentary in nature	Not identifiable

*Identification is tentative, as material was not physically examined.

Image 7. The image displays a collection of bones identified as belonging to the Bovidae family, arranged in ascending order of numbering: 1— Broken mandible | 2—Tibia | 3—Broken scapulae | 4—Calcaneum | 5—Broken scapulae | 6—Humerus with broken proximal end | 7—Metacarpal | 8—First phalanx | 9—Broken femur without distal end | 10—Atlas vertebra | 11—Broken ribs | 12—Broken ribs | 13—Broken lumbar vertebra | 14—Broken thoracic vertebra | 15—Cervical vertebra | 16—Cervical vertebra | 17—Cervical vertebra | 18—Broken lumbar vertebra | 19—Cervical vertebra | 20—Astragalus | 21—Fragment of thoracic vertebra | 22—Fragment of thoracic vertebra | 23—Fragment of thoracic vertebra | 24—First phalanx | 25—Probably fragments of thoracic vertebra | 26—Probably fragments of thoracic vertebra | 27—Probably broken vertebra | 28—Probably fragment of horn core/rib | 29—Probably a broken rib. The Browning HD XD Pro camera trap, with dimensions of 13 cm in length and 8 cm in width, is included for scaling purposes. These bones were collected near hyaena dens. © Partha Dey.

Image 8. Fragment of turtle carapace. © Partha Dey.

REFERENCES

AbiSaid, M. & S.M.D. Dloniak (2015). *Hyaena hyaena*. The IUCN Red List of Threatened Species 2015: e.T10274A45195080. Accessed on 11.ix.2023. https://doi.org/10.2305/IUCN.UK.2015-2.RLTS.T10274A45195080.en

Alam, M. S. (2011). Status, ecology and conservation of striped hyaena *Hyaena hyaena* in Gir National Park and Sanctuary, Gujarat. PhD Thesis. Department of Wildlife Science, Aligarh Muslim University, vi + 103pp. http://hdl.handle.net/10603/58835

Annandale, N. (1921). The fauna of an island in Chilka lake. *Part I of the Records of the Indian Museum* 22(IV): 313–421.

Carlton, J.T. & J. Hodder (2003). Maritime mammals: terrestrial mammals as consumers in marine intertidal communities. *Marine Ecology Progress Series* 256: 271–286. https://www.int-res.com/articles/meps2003/256/m256p271.pdf

Hofer, H. (1998). Striped Hyaena *Hyaena* (*Hyaena*) *hyaena* (Linnaeus, 1758). In: Mills, G. and H. Hofer (compilers), *Hyaenas. Status Survey and Conservation Action Plan*, pp. 21–26. IUCN/SSC Hyaena Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK, vi + 154pp. https://portals.iucn.org/library/efiles/documents/1998-013.pdf

Hofer, H. & G. Mills (1998). Population Size, Threats and Conservation Status of Hyaenas. In: Mills, G. & H. Hofer (compilers), *Hyaenas. Status Survey and Conservation Action Plan*, pp. 64–79. IUCN/SSC Hyaena Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK, vi + 154 pp.

Kruuk, H. (1976). Feeding and social behaviour of the striped hyaena (*Hyaena vulgaris* Desmarest). *African Journal of Ecology* 14(2): 91–111. https://doi.org/10.1111/j.1365-2028.1976.tb00155.x

Kasparek, M., A. Kasparek, B. Gözcelioğlu, E. Çolak & N. Yiğit (2004). On the status and distribution of the Striped Hyena, *Hyaena hyaena*,

Image 9. Den site of Striped Hyaena consisting of burrows in the sand and thick vegetation of *Pandanus* which is a mangrove associate. © Partha Dey.

in Turkey. *Zoology in the Middle East* 33(1): 93–108. https://doi.org/10.1080/09397140.2004.10638068

Karnad, D. (2017). The persistence of the Striped Hyena *Hyaena hyaena* Linnaeus, 1758 (Mammalia: Carnivora: Hyaenidae) as a predator of Olive Ridley Sea Turtle *Lepidochelys olivacea* Eschscholtz, 1829 (Reptilia: Testudines: Cheloniidae) eggs. *Journal of Threatened Taxa* 9(12): 11100–11102. https://doi.org/10.11609/jott.3660.9.12.11100-11102

Mishra, Ch.G., S.K. Patnaik, S.K. Sinha, S.K. Kar, C.S. Kar & L.A.K. Singh (1996). *Wildlife Wealth of Orissa*. Forest Department, Wildlife Wing, ix+185 pp.

Mohanty, S.C., C.S. Kar, S.K. Kar & L.A.K. Singh (2004). *WILD ORISSA - 2004***.** Orissa Wildlife Organisation, Forest Department, Government of Orissa, Bhubaneswar, 82 pp.

OWO (2007). *Wildlands of Orissa*. Orissa Wildlife Organisation, Forest Department, Government of Orissa, 68 pp.

Prater, S.H. (1971). *The Book of Indian Animals*. Third Edition. Bombay Natural History Society, Bombay, India, 324 pp.

Prater, S.H (1980). *The Book of Indian Animals*. Bombay Natural History Society, Bombay, India, 324 pp.

Reiger, I. (1979). A review of the biology of Striped Hyenas, *Hyaena hyaena* (Linn. 1758). *Saugetierkunde Mittelungen* 27*:* 81–95.

Saha, S.S. (1995). Mammalia, pp. 601–610. In: Ghosh, A.K. (ed.). *Fauna of Chilka Lake*. Wetland Ecosystem Services, Zoological Survey of India 1: 672 pp.

Saxena, H.O. & M. Brahmam (1996). *The Flora of Orissa.* Volume IV. Regional Research Laboratory, Bhubaneswar and Orissa Forest Development Corporation, Bhubaneswar. 2009–2918 pp.

Singh, P., A.M. Gopalaswamy & K.U. Karanth (2010). Factors influencing densities of Striped Hyenas (*Hyaena hyaena*) in arid regions of India. *Journal of Mammalogy* 91(5): 1152–1159. https://doi.org/10.1644/09-MAMM-A-159.1

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WhatsApp Video 2023-09-22 at 12.48.

Video 1. Camera trap video recording of an adult and two cubs of Striped Hyena.

WhatsApp Video 2023-09-22 at 12.52

Video 2. Camera trap video recording of Porcupine.

WhatsApp Video 2023-09-22 at 12.51.

Video 3. Camera trap recording of Striped Hyaena going inside the *Pandanus*.

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ARTICLE

Wildlife management and conservation implications for Blackbuck corresponding with Tal Chhapar Wildlife Sanctuary, Rajasthan, India

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Abstract: Blackbuck *Antilope cervicapra are* native to the Indian subcontinent. Pressures from anthropogenic activities, including hunting, agriculture, urbanization, and deforestation, have led to the encroachment, and destruction of natural Blackbuck habitats. As a result, this species, once abundant, and often found close to human settlements, declined drastically in the 20th century. It almost became extinct in Bangladesh, Nepal, and Pakistan, leading to the Blackbuck being added to the IUCN Red List of Species. Nevertheless, many Blackbuck populations are still at risk owing to habitat loss, poaching, and threats from invasive species. This study addressed the issues related to Blackbuck conservation and management by examining conservation challenges in Tal Chhapar Wildlife Sanctuary as a case study. We describe protective measures and approaches for stakeholders in habitat management, and the mitigation of other conservation issues.

Keywords: Anthropogenic pressures, grassland ecosystems, habitat loss, habitat management, poaching threats, wildlife conservation, wildlife forensics.

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Author contributions: UG, YSR, KPS, SKG: conceptualization, methodology. UG, YSR: writing - original draft preparation. KPS, SKG: supervision. KPS, SKG: reviewing and editing.

INTRODUCTION

Growing human populations are a primary cause of the loss and fragmentation of natural habitats (Didenko et al. 2017), which threaten the survival of wildlife populations. These populations are often forced to adapt to altered and patchy habitats. Animals like the Blackbuck, with significant habitat and quality food requirements due to their large size, have been among the most affected animals. The Blackbuck *Antilope cervicapra* is an antelope endemic to the Indian subcontinent. The Blackbuck is the finest representative of arid and semi-arid grasslands, characterized by short grasses, and is considered the epitome of grassland habitat. It is a denizen of open short grasslands and avoids dense forest, and hilly areas. It prefers to graze on short to mid-length grasses, but the foraging behaviour primarily depends on food availability. It may switch to shrub species and even to crops depending on availability.

The Blackbuck is the only species under the genus *Antilope*. It is a medium-sized animal closely related to the gazelle (Hassanin & Douzery 1999). They are mainly found in the Indian subcontinent and distributed in various grasslands and open areas. In Nepal and Pakistan, they are limited to protected conservation habitats (Ranjitsinh 1989). The IUCN (International Union for Conservation of Nature and Natural Resources) has listed Blackbuck as 'Least Concern'. It is protected under Schedule I of the Wildlife (Protection) Act, 1972 (WPA) of India.

Tal Chhapar Wildlife Sanctuary is a small but diverse wildlife refuge located in Rajasthan's Churu District (Image 1). It is known for its enchanting natural beauty as well as its unique and imperilled habitat. The Tal Chhapar Sanctuary is well-known for its large population of Blackbucks. It is also known for attracting a lot of migratory birds. It's a flat saline basin with a unique and vulnerable ecosystem. Initially, it was kept as a private hunting reserve for the Maharaja of Bikaner. Later, it was designated a sanctuary in 1962. The sanctuary's landscape is largely flat, with wide grasslands in places. The grasslands are populated mainly by *Vachellia nilotica* (formerly *Acacia nilotica*), which is native to the Indian subcontinent, and *Prosopis juliflora*, an invasive species. The Tal Chhapar Wildlife Sanctuary's unique variety of grass is known as 'mothiya'. The grass has a pleasant flavour, and the seeds are pearl-shaped (Moti), preferred among Blackbucks.

Several researchers have studied blackbuck with a focus on understanding behaviour, ecology, threats, evolutionary biology, molecular composition, and identification of Blackbucks in an Indian context. This study gives special consideration to the Blackbuck population in Tal Chhapar Wildlife Sanctuary and reviews past, and present conservation activities, addresses the long-pending conservation issues, risks, and proposes recommendations, and a management strategy.

Distribution of blackbuck in the Indian subcontinent

Blackbucks are found in varied habitats, but the most suitable habitat is open and semi-arid grasslands (Bellis et al. 2003; Bell & Setchell 2017). In India, Blackbucks show growth in protected areas, especially in Gujarat, Rajasthan, and Haryana. Here, Blackbucks are distributed in 13 states in northern, northwestern, central, and peninsular India. The highest population density is found in Rajasthan, Gujarat, Maharashtra, and Haryana. During the late 1970s, Ranjitsinh (1989) estimated the total blackbuck population in India to be between 29,000–38,000. At present, its population could be more than 80,000. The recent wildlife census of Rajasthan (2019) has reported 25,298 Blackbucks in wildlife control areas and territorial control areas of Rajasthan (Rajasthan State Forest Department 2019). The total count of 2019 has come down from the state census of 2018, which was 29,458. In Gujarat, the state forest department has reported 1,428 in the 2015 census (Gujarat Forest Statistics 2019). India has designated areas for Blackbuck conservation; some of the notable areas are Tal Chhapar Wildlife Sanctuary (719 ha) in Rajasthan, Velavadar National Park (3,000 ha) in Gujarat, Ranebennur Wildlife Sanctuary (12,500 ha) in Karnataka, and Great Indian Bustard Wildlife Sanctuary (122,200 ha) in Maharashtra.

In Pakistan, Blackbucks were a common sight along the borders with India before their extinction in the wild. Especially on the edge of the Thar desert area. The most populated area of the Blackbuck was in the northern part of Cholistan (locally known as 'Rohi'). It is an extensive desert in the southern part of the Punjab province of Pakistan (Mirza & Waiz 1973). The Blackbuck count went down drastically in the 1950s. Later, Blackbucks from Texas were reintroduced in Pakistan in Lal Suhanra Sanctuary in April 1970 (Mirza & Waiz 1973). The reintroduction effort was a captive-breeding program under the auspices of the Worldwide Fund for Nature (WWF) and the government of Punjab.

Once on the brink of extinction in Nepal, Blackbucks have recovered well at the protected sites of Khairapur and Hirapur Phanta in Nepal. Owing to joint efforts of the state forest department and various public, and private stakeholders, there has been success in growing

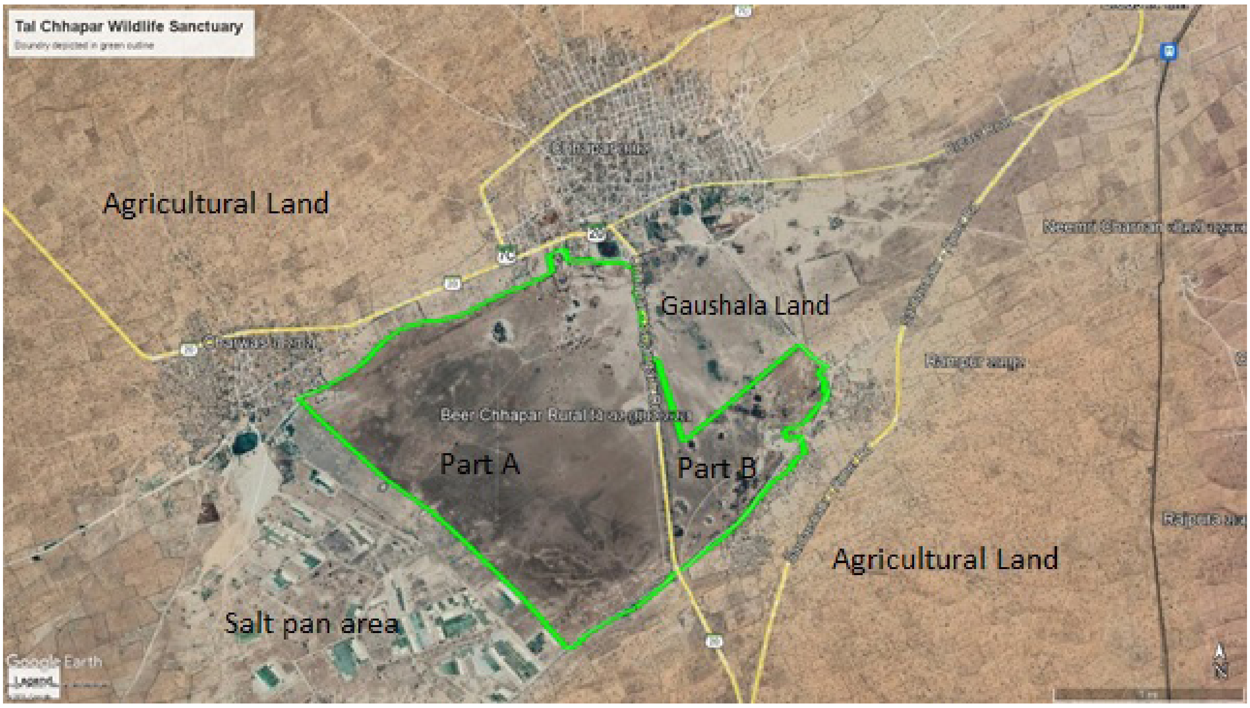

Image 1. Map of Tal Chhapar Wildlife Sanctuary in Rajasthan.

free-ranging Blackbuck in Nepal (Bist et al. 2021).

Threats

Poaching

Poaching has been a major threat to Blackbucks; protection at the national and international levels is provided to mitigate this threat. The Indian government declared Nilgai an agricultural pest in 1996 as a result of common crop depredation incidents, and it allowed retaliatory hunting of crop-raiding nilgais. This change also motivated retaliatory hunting of Blackbuck. Traditionally, some communities like Ban Bawri and Bhil in Rajasthan were engaged in illegal hunting of Blackbucks. People from these communities were also likely to be hired for their special hunting skills as ‘Field guard’ by land owners to protect their crops from Blackbucks. Crop-raiding Blackbucks have been hunted by such field guards in many instances in Rajasthan (Sinha & Singh 2020). In present times, poachers hunt Blackbucks for trophy hunting (PTI 2018), skin, antlers, and bushmeat.

Feral dogs

Dogs are the most abundant carnivores globally; they are cosmopolitan because of their relationship with humans. Negative interactions with wildlife involving dogs have been cited as a serious problem for wildlife conservation (Young et al. 2011; Hughes & Macdonald 2013; Sepúlveda et al. 2015; Lessa et al. 2016). Their presence around protected habitats has led to the hunting of native protected species by feral dogs (Bergman et al. 2009; Bell & Setchell 2017), altered activity patterns, and reduced abundance of native mammals (Zapata-Ríos & Branch 2016).

The Blackbucks are most vulnerable to these free-roaming dogs during their breeding season. The fawns are very susceptible to feral dogs. Porous fences offer a chance for feral dogs to enter Blackbuck protected areas and kill them. In certain Blackbuck sanctuaries, such loose fencing is even a requirement for the blackbucks. For example, the Tal Chhapar Blackbuck Sanctuary has only 719 ha reserved for the Blackbucks. The management plan suggests that one Blackbuck needs at least one hectare of area for freely roaming and stressless grazing. The Blackbuck population has been increasing in Tal Chhapar Sanctuary and has reached approximately 4,000. Secondly, a public road passes through this sanctuary, which has divided it into two parts across the road. Therefore, the sanctuary has loose-fencing around the enclosure, allowing the Blackbucks to pass in and out through this fencing to avoid intra-species competition for food and reproduction. On the other hand, it has become an opportunity for the feral dogs to enter the sanctuary and kill the Blackbucks.

Habitat loss

Blackbucks are endemic to grasslands and were once distributed across India (Ranjitsinh 1989). Similarly, the Tal Chhapar Wildlife Sanctuary has very little area (719 ha) for the amount of population of Blackbucks inhabiting it. The open grassland habitat is only developed within the sanctuary, and the surrounding areas are either invaded by *Prosopis juliflora* or stressed due to human constructions. A public road passing through this sanctuary is also a big trouble, resulting in habitat fragmentation [Part A and B are two fragments of the sanctuary, they are indicated in the image 1]. Due to this public road, the B part of the sanctuary is underutilized by Blackbucks and therefore underdeveloped. Additionally, the villagers of Rampur and Dewani villages had been given cremation rights in the B part during the settlement of rights before the declaration of this area as a sanctuary. Both of these factors are resulting in the habitat loss of B part of the Tal Chhapar Wildlife Sanctuary.

Human-wildlife interaction

Over-habituation and food conditioning of Blackbucks, through selective conservation efforts, have led to the origin of several human-wildlife negative interactions. The easiest way for authorities from past examples is to declare the species vermin and terminate them through the vermin extermination programme. Section 62 of the WPA allows the Indian government to declare animals other than rare and endangered species as vermin. Such actions may cheer a large portion of the population, as most people in India have their livelihoods dependent upon agriculture. However, it will be detrimental to their conservation.

The Blackbucks are herbivorous with high forage consumption during the monsoon and winter seasons. The abundance of crops in farming lands is also high during the monsoon season in the arid and semi-arid regions. This becomes the Blackbucks' temptation to enter the nearby crop fields for foraging. To prevent this, farmers use barbed-wire fencing around their agricultural lands (Image 2). During local migration to nearby agro-fields, the Blackbucks get stuck in the wire fencing and get injured.

Isolation of the Blackbuck population

Tal Chhapar is a 719 ha protected wildlife sanctuary occupied by the largest population of Blackbucks in Rajasthan. The area of the sanctuary is confined with loose fencing to allow local migratory movements of the Blackbucks. The Blackbucks have seasonal dispersal movement to nearby agricultural lands and can be seen even up to 10 km away from the sanctuary. The protected land under the Tal Chhapar Wildlife Sanctuary is insufficient to hold the present population, which is roughly four times the capacity of the sanctuary. Geographical isolation for a longer period of time can cause genetic isolation due to inbreeding. There is not enough evidence to prove genetic isolation yet; the authors are also involved with an ongoing study on the genetic diversity of the Blackbuck population in Tal Chhapar. This study will yield sufficient evidence to further understand the genetic isolation of the group.

Wildlife Management

Wildlife management is an integrated and interdisciplinary approach for conserving wild species, which includes several activities like administration, community participation, law enforcement, education, and research. It is guided by ecological principles such as carrying capacity, disturbance, succession, and environmental conditions to prevent the ongoing loss of the Earth's biodiversity. Wildlife management is a triad between wildlife, their habitat, and humans. Human control is an indispensable part of wildlife management.

Image 2. Barbed wire fencing near Tal Chhapar. © Ulhas. G (2022).

It has two basic types, namely: a) manipulative management and b) custodial management. In India, wildlife management is more or less wildlife conservation, which is primarily based on a custodial management approach. This approach is implemented in India mainly by setting up national parks (NPs) and wildlife sanctuaries (WSs), and to a lesser extent by conservation reserves and community reserves, where suitable environmental conditions are safeguarded and wildlife species are conserved by law.

The wildlife management of the Blackbuck is also implemented using this custodial management approach under the Centrally Sponsored Umbrella Scheme of Integrated Development of Wildlife Habitats (CSS-IDWH). In addition to the protection provided to Blackbuck by the Wildlife (Protection) Act, 1972, this umbrella scheme plays an important role by extending central help to the states for Blackbuck conservation. A pre-approved management plan is a prime requisite for the successful implementation of this umbrella scheme. Therefore, the management plan is the guiding document for the management or conservation of wildlife and, for that matter, for Blackbuck in the defined protected areas. Based on the management plan, the following components are involved for the effective management of Blackbuck in PAs/RAs: -

Protection Measures

(a) Construction of boundary wall and fencing

To effectively manage the wild population, the central and state government have to declare certain land as PAs or RAs within the ambit of the State Forest Act and further declare it as NP, WS, a conservation reserve, or community reserve by WPA. This helps the manager to exercise stringent law enforcement for the protection of the wild population in and near such areas. Such areas are then protected by raising walls, wire fences, and ditch fencings to minimize the human-animal interactions and biotic interference with wildlife habitats. The feral dogs and stray cattle are the most common biotic interference to the Blackbuck habitat. Stray cattle enter the protected lands for grazing and further disturb the grassland habitat of Blackbucks. Similarly, feral dogs have been a menace these days, killing fawns, and young Blackbucks. Therefore, walls and fencing prevent such stray cattle and feral dogs from entering the protected forest lands.

(b) Construction of guard chowkies

A continuous watch on the Blackbuck habitat is an essential part of the wildlife management of this species. Historically, game hunting was the most common reason for the sharp decline of this species in India. Hunting and poaching continue in some parts of the Thar Desert area. The guard chowkies are constructed around the periphery of protected lands to keep a continuous watch on any illegal activities. Additionally, the forest staff deployed in these chowkies keep observing the Blackbuck habitat for any adverse effects. Such observations help the manager to make decisions on various kinds of interventions in the Blackbuck habitat.

(c) Management against climate-induced disasters

Natural disasters are unpredictable and unavoidable events. Generally, Blackbucks are very sensitive to environmental shocks. In May 2009 and June 2010, high-velocity windstorms converted into hailstorms, and continued for 3–4 days in Tal Chhapar Wildlife Sanctuary, which resulted in the death of around 75 and 50 Blackbucks, respectively. A waterlogging situation had arisen in the sanctuary due to its flat tract with a moderate slope, and the Blackbucks got stuck in it to the death. Therefore, artificial earthen mounds have been created to cope with such climate-induced disasters in this sanctuary. These artificial mounds act as shelter for the wildlife during such adverse climatic conditions of heavy rainfall and storms.

(d) Development of an eco-sensitive zone

The blackbuck is a nomadic wild species, and thus it has a large foraging area. The protection is not only needed within the protected lands, but it is also required for the ecologically fragile areas around the PAs. Therefore, ESZs are notified by the MoEFCC, Government of India, under the Environment Protection Act, 1986, to minimise the negative impacts of certain activities on the fragile ecosystem encompassing the protected areas. It acts as a "shock absorber" or "transition zone" to minimize the impact of urbanisation on wildlife habitats.

(e) Fire control

Mostly, the blackbuck habitat in the country is arid or semi-arid grasslands with thinly forested areas. The grassy plains remain green during the monsoon season and turn into the 'yellow carpet' during the summer. Such dry, yellow grasslands are very prone to fire incidents, which are both natural, and anthropogenic. Therefore, fire lines are created in the grassy habitats of Blackbucks to prevent the fire from spreading. Maintenance of such fire lines is a recurring activity in the protected grassland areas.

(f) Animal disease control

During the summers, the arid and semi-arid grassland habitats of Blackbucks become devoid of grasses, which induces their local peripheral migration into the nearby crop fields. The chances of exposure to domestic animals increase during such local migration, and hence, exposure to many parasitic diseases also increases. The fawns and pregnant Blackbucks are more susceptible to such pathogens. Therefore, annual vaccination is required to prevent the spread of diseases from domestic animals to Blackbucks. Every year, such immunization camps are organized by the managing staff of the sanctuary in the surrounding villages to vaccinate their livestock. It helps in minimizing the chances of the spread of various infectious diseases to the Blackbuck population.

(g) Construction of rescue centres and rescue wards

Rescue centres and rescue wards are an integral part of wildlife management in the Blackbuck sanctuaries. The blackbucks are very sensitive to shocks, and urgent medical care is a prime requisite to save their lives. Various cases of dog bites, road accidents, dominance fights, and rescues come to the management staff requiring immediate care in rescue centres and wards.

Habitat Improvement

(a) Pasture development

Open grasslands with scattered trees are the most preferred habitat of the Blackbuck. It is important to manage the grasslands to ensure the availability of sufficient food for Blackbucks throughout the year. The selection of nutritious grass species is essential for the healthy growth of individuals. To improve this herbivore species, pasture development activities are executed annually. Every year, the patches of grasslands are identified, cleared off due to high grazing pressure in the sanctuary, and included in the annual plan of operation (APO). These patches are then ploughed with nutritious species of fodder grasses, resulting in the development of fresh grass patches in the habitation (Image 3). This recurrent activity ensures the optimum availability of food for the growing population in the sanctuary every year.

(b) Eradication of invasive species from the habitat

Invasive alien species, often exotic, get introduced into the natural habitats intentionally or unintentionally. During 1970–80, *Prosopis juliflora* and other hardy tree species were introduced worldwide to combat deforestation, desertification, and fuel wood shortage. These invading species are now becoming a severe threat to biodiversity and adversely affecting the natural habitats of many wild species, including blackbucks (Rajput et al. 2019). Blackbucks are less attracted to the *P. juliflora*-affected lands because it reduces the fodder availability during the pinch period. *Lantana camara* is another invasive species that has been proven to be a menace to natural wildlife habitats. All possible measures have been taken to eradicate such invasive species from the grassland habitats. Unfortunately, sometimes the

Image 3. Ploughed patches for pasture development in Tal Chhapar. © Ulhas G. (2022).

pods of *P. juliflora* are consumed by the Blackbucks from the periphery of the sanctuary, which results in their unintentional dispersion through their dung pile. Therefore, eradication of such invasive alien species is included as a recurrent activity in the management plan of the sanctuary to protect Blackbuck habitats from their spread and adverse effects.

(c) Water and soil moisture conservation and water management

Soil moisture conservation is an essential practice in arid and semi-arid grassland habitats. The area with scant rainfall faces drought-like conditions during the summer. The soil moisture conservation activities also help in habitat improvement by enhancing the growth of green grasses in the sanctuary area. Under SMC, V-ditches, and contour bunds are created in the sanctuary area to increase soil moisture. Additionally, rainwater is harvested by digging ponds, constructing tanks, and storing water for drinking during the pinch period. Artificial water holes are also constructed to ensure year-round water availability in the sanctuary. It is observed that the rainwater harvesting is not sufficient to cater to the drinking water needs of such a large Blackbuck population, and therefore, water pipelines are installed to pump water into these water points during the summer.

(d) Patch plantation/gap plantation and plantation grooves

Blackbucks prefer open grassland with intermittent tall grass and require scattered patches of trees for shelter, fawn nursing, and protection against predators, as well as rain, and heavy winds (Image 4). During summer, the herds of Blackbuck rest under the shade of trees and thus acquire tolerance against high temperatures. Interestingly, a stringent balance is required between open grassland and tree patches, as very dense tree growth negatively impacts the grassland development, and thus the availability of nutritious food. Therefore, patch plantation activities are carried out in the sanctuary by selecting tree species of *Ziziphus nummularia*, *Prosopis cineraria*, *Vachellia nilotica*, and *Dalbergia sissoo*, which offer both shelter & food in the form of pods, and leaves.

Image 4. A tree patch in Tal Chhapar. © Ulhas G. (2020).

Research and population estimation

Routine research activities in protected areas are vital for various reasons that can equally benefit a forest department and the scientific community. Action research targeting concerns on several problems associated with Blackbuck conservation, such as genetic diversity, and human-wildlife negative interactions, is highly warranted. Research activities are allowed in the protected areas after scrutinizing the research proposals at higher levels. Outputs of such research could help make policies of wildlife management sounder and species-specific. Additionally, population estimation is another important factor of wildlife management that tells us about the outcomes of human interventions on the habitats. A population estimate is a numerical estimation of the population size calculated from sample census data. Various direct and indirect methods of population estimation are available; a preferred method depends on the animal and the type of habitat. Positive human intervention always leads to the strengthening of the ecosystem and hence an increase in the number of resident wild species.

Community Involvement

Community participation is essential in wildlife conservation and ecological management of forest and non-forest areas. It ensures the involvement of locals in wildlife conservation and the protection of natural resources from external organized crime groups. The constitution of a Joint Forest Management Committee or Eco-Development Committee is a way forward to enable local stakeholders in the collective development and protection of the land. Such initiatives have been a helping hand to the forest departments' acute staff crunch problem. The development of guidelines is important to ensure uniformity of practice. The Tal Chhapar Wildlife Sanctuary is surrounded by at least four villages and a town that are situated within the boundaries of this sanctuary. The villagers are involved in various developmental activities, and the forest department ensures that it generates sustainable livelihood opportunities for the locals. As a result, a feeling of forest protection, and wildlife conservation develops in the villagers, and locals, which cumulatively improves the departmental efforts to save wildlife.

Recommendations

Wildlife managers must analyse the health and balance of the ecosystem periodically and promptly to include other positive factors in wildlife conservation. As described earlier, many Blackbucks' protected lands are not big enough to sustain the growing population with assured protection. The Tal Chhapar Wildlife Sanctuary has only 719 ha land for the Blackbucks, which is almost four times less than required. The population in this sanctuary has increased way beyond the carrying capacity of this area, and is expanding continuously. However, the western boundary of the sanctuary has been extended further to include 78 ha. Wasteland in the sanctuary was developed by the forest department in 2019–20. This is still not enough to sustain this big number, and therefore, further extension of the sanctuary is the prime concern at present.

Currently, the private land of the gaushala and the revenue lands of the salt pan area have great potential for the extension of the Sanctuary. The private land of gaushala is being managed under trust for the well-being of stray cattle, and therefore, the acquisition of this entire private land of gaushala is a little difficult. Attempts had been made by the forest department to acquire this land, but they failed. Temporary acquisition of some proximal part of this gaushala land for grazing has also been attempted on a rental basis. Additionally, the salt pan area on the western boundary can be utilized for the extension of the sanctuary. This saltpan land area is highly invaded by *Juliflora* and has many leases for salt manufacturing. On this side an area of 78 ha has already been acquired by the forest department for the proposed extension of the main sanctuary. Many leases are not operational at present, and therefore, this area has many open wells where Blackbucks accidentally fall in and get injured. Only a few salt leases are operational in this vast area. Therefore, a proposal can be made to the state government to acquire this revenue land for the extension. Acquisition of private lands on lease is a good option for the time being until a translocation or extension plan is achieved. This immediate intervention will reduce the grazing pressure in the sanctuary and will also generate income for the nearby local farmers who are not growing crops on their lands due to crop damage by these blackbucks. This will also help in minimizing the human-animal interaction in the area. Alternatively, procuring dry fodder is an essential practice due to the erratic rainfall situation in Rajasthan. Interestingly, the members of EDC and other locals come forward to donate fodder after their crop harvesting if drought-like conditions occur in the sanctuary. It is necessary to maintain a good harmony between wildlife and the local public for the conservation efforts to be successful, where the wildlife managers play a key role.

Translocation is another option to reduce the population pressure, where individuals will be removed

Image 5. Proposed translocation site Jaswantgarh (Red box) and present protected site Tal Chhapar (Green box).

in large numbers from the sanctuary and introduced to some other places with adequate protection and favourable habitat conditions. In this direction, the forest divisional office of the district of Churu acquired 278 ha. Area in Jaswantgarh Village in Nagaur District, which is located on the borders of Sujangarh tahsil. This land is around 12 km away (aerial distance) from the Tal Chhapar Wildlife Sanctuary (Image 5). Between this acquired land and the sanctuary, many agricultural lands are well fenced. Apart from this, there are major and minor roads present between these two areas. Therefore, translocation by simply luring these blackbucks is not a feasible option, as it happens with the African Boma technique. Villagers are not willing to allow the removal of their fencing around their farmland. Sardarshahar-Ajmer Road has very heavy traffic and therefore cannot be blocked to assist such translocation. Any translocation from Tal Chhapar would be conditional on prior restoration and governance at Jaswantgarh, considering ongoing grassland degradation and barrier-rich landscapes. Otherwise, it risks merely relocating Human-Blackbuck interactions rather than reducing them.

We must accept that conservation of wildlife and the environment is a shared responsibility between the governments and the public, and we must fulfil our parts to make it happen.

CONCLUSION

As the human population grows, demand for natural resources increases, which leads to the shrinking of wildlife habitats. This calls for long-term management plans for the conservation of Blackbucks. A conservation requirement may vary as per the situation and site. Hence, site-specific or micro-level management is required. The role of local communities and government has been proven essential for any conservation project; their inclusion must be for such conservation efforts (Kelly 2004; Ancrenaz et al. 2007).

REFERENCES

Ancrenaz, M., L. Dabek & S. O'Neil (2007). The costs of exclusion: recognizing a role for local communities in biodiversity conservation. *PLoS Biology* 5(11): e289. https://doi.org/10.1371/journal.pbio.0050289

Bell, S. & J.M. Setchell (2017). Dogs disrupting wildlife: domestic dogs harass and kill Barbary macaques in Bouhachem Forest, Northern Morocco. *African Primates* 12: 55–58.

Bergman, D., S.W. Breck & S. Bender (2009). Dogs gone wild: feral dog damage in the United States. USDA APHIS Wildlife Services, National Wildlife Research Center Resource Publication.

Bist, B.S., P. Ghimire, L.P. Poudyal, C.P. Pokharel, P. Sharma & K. Pathak (2021). From extinction to recovery: the case of blackbuck Antilope cervicapra from Nepal. *Mammal Research* 66(3): 519–523.

Didenko, N.I., D.F. Skripnuk & K.N. Kikkas (2017). Analysis of demographic pressure on nature, pp. 126–131. In: *International Conference on Trends of Technologies and Innovations in Economic and Social Studies 2017*. Atlantis Press. https://doi.org/10.2991/ttiess-17.2017.22

Groves, C. (2000). Phylogenetic relationships within recent Antilopini (Bovidae), pp. 223–229. In: Vrba, E. (ed.). *Antelopes, Deer and Relatives*. Yale University Press, New Haven, 348 pp.

Gujarat State Forest Department (2019). Gujarat Forest Statistics (Statistics report). Gujarat State Forest Department, 129 pp.

Gulati, S., K.K. Karanth, N.A. Le & F. Noack (2021). Human casualties are the dominant cost of human–wildlife conflict in India. *Proceedings of the National Academy of Sciences* 118(8): e1921338118. https://doi.org/10.1073/pnas.1921338118

Hajibabaei, M., G.A.C. Singer, P.D.N. Hebert & D.A. Hickey (2007). DNA barcoding: how it complements taxonomy, molecular phylogenetics and population genetics. *Trends in Genetics* 23(4): 167–172. https://doi.org/10.1016/j.tig.2007.02.001

Hassanin, A. & E.J.P. Douzery (1999). The tribal radiation of the family Bovidae (Artiodactyla) and the evolution of the mitochondrial cytochrome b gene. *Molecular Phylogenetics and Evolution* 13(2): 227–243. https://doi.org/10.1006/mpev.1999.0619

Hassanin, A., F. Delsuc, A. Ropiquet, C. Hammer, B.J. van Vuuren, C. Matthee, M. Ruiz-Garcia, F. Catzeflis, V. Areskoug & T.T. Nguyen (2012). Pattern and timing of diversification of Cetartiodactyla (Mammalia, Laurasiatheria), as revealed by a comprehensive analysis of mitochondrial genomes. *Comptes Rendus Biologies* 335(1): 32–50. https://doi.org/10.1016/j.crvi.2011.11.002

Hsieh, H.M., H.L. Chiang, L.C. Tsai, S.Y. Lai, N.E. Huang, A. Linacre & J.C.I. Lee (2001). Cytochrome b gene for species identification of the conservation animals. *Forensic Science International* 122(1): 7–18. https://doi.org/10.1016/S0379-0738(01)00403-0

Hughes, J. & D.W. Macdonald (2013). A review of the interactions between free-roaming domestic dogs and wildlife. *Biological Conservation* 157: 341–351. https://doi.org/10.1016/j.biocon.2012.07.005

IUCN (1993). Nature Reserves of the Himalaya and Central Asia. IUCN, Gland, Switzerland and Cambridge, UK, xxiv + 458 pp.

Jhala, Y.V. & K. Isvaran (2016). Behavioural ecology of a grassland antelope, the blackbuck Antilope cervicapra: linking habitat, ecology and behaviour, pp. 151–167. In: Ahrestani, S. & M. Sankaran (eds.). *The Ecology of Large Herbivores in South and Southeast Asia*. VIII Springer, Berlin, 257 pp.

Joly, S. & A. Bruneau (2006). Incorporating allelic variation for reconstructing the evolutionary history of organisms from multiple genes: an example from Rosa in North America. *Systematic Biology* 55(4): 623–636. https://doi.org/10.1080/10635150600863109

Shagun (2019). *Desertification in India: How a faulty government scheme degraded Gujarat's Banni grasslands*. Down To Earth. Published 6 September 2019. https://www.downtoearth.org.in/climate-change/desertification-in-india-how-a-faulty-government-scheme-degraded-gujarat-s-banni-grasslands-66572

Karanth, K.K., L. Naughton-Treves, R. DeFries & A.M. Gopalaswamy (2013). Living with wildlife and mitigating conflicts around three Indian protected areas. *Environmental Management* 52(6): 1320–1332. https://doi.org/10.1007/s00267-013-0162-1

Karanth, K.K., L. Naughton-Treves, R. DeFries & A.M. Gopalaswamy (2013). Living with wildlife and mitigating conflicts around three Indian protected areas. *Environmental Management* 52: 1320–1332.

Kelly, A.H.H. (2004). The role of local government in the conservation of biodiversity. A thesis of doctor of philosophy, submitted to University of Wollongong, xvi + 504 pp.

Kocher, T.D., W.K. Thomas, A. Meyer, S.V. Edwards, S. Pääbo, F.X. Villablanca & A.C. Wilson (1989). Dynamics of mitochondrial DNA evolution in animals: amplification and sequencing with conserved primers. *Proceedings of the National Academy of Sciences* 86(16): 6196–6200. https://doi.org/10.1073/pnas.86.16.6196

Kumar, V., N. Sharma & A. Sharma (2017). DNA barcoding of the Indian blackbuck (Antilope cervicapra) and their correlation with other closely related species. *Egyptian Journal of Forensic Sciences* 7: 31.

Kumar, V., N. Sharma, A. Sharma, K. Verma, K. Singal & M. Kumar (2018). A data-based study in support of Blackbuck related cases from Haryana. *Data in Brief* 17: 1196–1200. https://doi.org/10.1016/j.dib.2018.02.034

Lessa, I., T.C.S. Guimarães, H. de G. Bergallo, A. Cunha & E.M. Vieira (2016). Domestic dogs in protected areas: a threat to Brazilian mammals? *Natureza & Conservação* 14: 46–56. https://doi.org/10.1016/j.ncon.2016.05.001

Mallon, D. & S. Kingswood (2001). Antelopes. Part 4: North Africa, the Middle East, and Asia. Global Survey and Regional Action Plans. SSC Antelope Specialist Group, P. 260, IUCN, Gland, Switzerland and Cambridge, England.

Menon, R. (2000). Nature watch. *Resonance* 5: 69–79.

Mirza, Z.B. & A. Waiz (1973). Food availability for blackbuck (Antilope cervicapra) at Lal Suhanra Sanctuary, Pakistan. *Biological Conservation* 5: 119–122. https://doi.org/10.1016/0006-3207(73)90091-8

Naha, D., S.K. Dash, A. Chettri, A. Roy & S. Sathyakumar (2020). Elephants in the neighborhood: patterns of crop-raiding by Asian Elephants within a fragmented landscape of eastern India. *PeerJ* 8: e9399. https://doi.org/10.7717/peerj.9399

Nei, M. & S. Kumar (2000). *Molecular Evolution and Phylogenetics*. Oxford University Press, Oxford 352 pp.

Pandey, K. (2019). *India lost 31% of grasslands in a decade.* Down To Earth. Published 10 September 2019. https://www.downtoearth.org.in/agriculture/india-lost-31-of-grasslands-in-a-decade-66643

Prashanth, M., A. Saravanan, M. Mathivanan & T. Ganesh (2016). Conservation of a fragmented population of blackbuck (*Antilope cervicapra*). *Current Science* 110: 543–549.

PTI (2018). From being hunting trophies to protected species, the lure of Blackbuck. The Hindu.

Rajasthan State Forest Department (2019). Wildlife Population Estimation by Waterhole Method 2019 (Wildlife census report). Rajasthan State Forest Department, 5 pp.

Rajput, N., K. Baranidharan, M. Vijayabhama & A. Sawant (2019). Ecological impact of *Prosopis juliflora* on the habitat conditions of blackbuck in Sathyamangalam Tiger Reserve, Tamil Nadu, India. Methods (preprint/short communication).

Ranjitsinh, M. (1989). *The Indian Blackbuck*. Natraj Publishers, Dehradun, 155 pp.

Sepúlveda, M., K. Pelican, P.C. Cross, A. Eguren & R.S. Singer (2015). Fine-scale movements of rural free-ranging dogs in conservation areas in the temperate rainforest of the coastal range of southern Chile. *Mammalian Biology* 80: 290–297. https://doi.org/10.1016/j.mambio.2015.03.001

Sinha, B.L. & A. Singh (2020). Embodying a preparedness to die: Why Bishnois of Western Rajasthan rise in defence of the blackbuck and the chinkara? *Sociological Bulletin* 69: 34–50. https://doi.org/10.1177/0038022919899002

Young, J.K., K.A. Olson, R.P. Reading, S. Amgalanbaatar & J. Berger (2011). Is wildlife going to the dogs? Impacts of feral and free-roaming dogs on wildlife populations. *BioScience* 61(2): 125–132. https://doi.org/10.1525/bio.2011.61.2.7

Zapata-Ríos, G. & L.C. Branch (2016). Altered activity patterns and reduced abundance of native mammals in sites with feral dogs in the high Andes. *Biological Conservation* 193: 9–16. https://doi.org/10.1016/j.biocon.2015.10.016

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ARTICLE

Amphibians and reptiles of Chitwan National Park, Nepal: an updated checklist and conservation issues

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Abstract: An updated checklist of amphibians and reptiles of Chitwan National Park and its buffer zone is presented, which is essential for conservation management decision-making as the area is experiencing frequent stochastic events in recent years. A total of 89 species is listed from Chitwan National Park including—20 frogs & toads, 42 snakes, 14 lizards, 11 turtles, and two crocodile species. The confirmed record of Dudhwa Reed Frog *Chirixalus dudhwaensis* in Nepal is provided, and the occurrence of Eastern Bronze-back Tree Snake *Dendrelaphis proarchos* from Chitwan National Park, representing its westernmost known distribution in Nepal. In addition the presence of *Hylarana tytleri* and *Sitana sivalensis* is confirmed from Chitwan National Park. These findings contribute to filling critical knowledge gaps in species richness and offer updated insights into the taxonomy, natural history, and conservation status of herpetofauna in the park. Recent IUCN Red List mentions the geographic range of the Torrent Paha Frog *Nanorana ercepeae* from Chitwan National Park; based on the absence of verified records, we exclude it from updated checklist. We also suggest integrative taxonomic and ecological studies to uncover hidden diversity, and to inform evidence-based conservation strategies for amphibians and reptiles in Nepal.

Keywords: *Chirixalus dudhwaensis*, Chitwan-Annapurna Landscape, conservation, *Dendrelaphis proarchos*, diversity, herpetofauna, *Hylarana tytleri*, *Nanorana ercepeae*, new records, *Sitana sivalensis*, Terai-Arc Landscape.

Nepalese: **सारांश:** चितवन राष्ट्रिय निकुञ्ज र यसको मध्यवर्ती क्षेत्रमा पाइने उभयचर र सरीसृपहरूको अद्यावधिक सूची प्रस्तुत गरिएको छ, जसले विशेष गरी हालका वर्षहरूमा यस क्षेत्रले बारम्बार अनपेक्षित प्राकृतिक घटनाहरूको सामना गरिरहेको सन्दर्भमा संरक्षण व्यवस्थापनका निर्णयहरूमा आधार प्रदान गर्नेछ | चितवन राष्ट्रिय निकुञ्जमा हालसम्म कुल ८९ प्रजाति अभिलेखित छन्, जसमा २० थरी भ्यागुता प्रजाति, ४२ थरी सर्प प्रजाति, १४ थरी छेपारो प्रजाति, ११ थरी कछुवा प्रजाति, र २ थरी गोहि प्रजाति समावेश छन्। यस अध्ययनले नेपालमा दूधवा रिड भ्यागुता (*Chirixalus dudhwaensis*) को पहिलो पटक प्रमाणित अभिलेख प्रस्तुत गरेको छ। साथै, चितवन राष्ट्रिय निकुञ्जबाट ईस्टर्न ब्रोंज-ब्याक ट्री स्नेक (*Dendrelaphis proarchos*) को उपस्थिति पनि पुष्टि गरिएको छ, जुन नेपालभित्र यसको सबैभन्दा पश्चिमी वितरण सीमाको प्रतिनिधित्व गर्दछ। त्यसैगरी, *Hylarana tytleri* र *Sitana sivalensis* को उपस्थिति पनि निकुञ्जमा पुष्टि गरिएको छ। यी नयाँ विवरणहरूले प्रजातिगत विविधताको ज्ञान सुदृढीकरणमा सहयोग पुऱ्याउँछन् र चितवनका उभयचर र सरीसृपहरूको संरक्षण अवस्थाबारे अद्यावधिक जानकारी प्रदान गर्छन्। पछिल्लो आईयूसीएन रातो सूचीमा टोरेंट पाहा (*Nanorana ercepeae*) लाई चितवन राष्ट्रिय निकुञ्जमा वितरण भएको उल्लेख गरिएको भए पनि, प्रमाणित अभिलेख नभएकाले यसलाई यस अद्यावधिक सूचीबाट हटाइएको छ। नेपालका उभयचर र सरीसृपहरूको संरक्षणका लागि एकीकृत र पारिस्थितिक अनुसन्धानात्मक अध्ययनहरूलाई प्राथमिकता दिनु आवश्यक छ, जसले प्रमाणमा आधारित संरक्षण रणनीतिहरू बनाउन सहयोग पुऱ्याउनेछ।

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INTRODUCTION

Nepal's protected area network was designed and established to safeguard the country's rich biodiversity, encompassing species, ecosystems, habitats, and genetic resources (MPFS 1988). At present, Nepal comprises 20 protected areas, including 12 national parks, six conservation areas, one wildlife reserve, and one hunting reserve (DNPWC 2025). The Department of National Parks and Wildlife Conservation (DNPWC) is the central authority responsible for the management and conservation of wildlife and their habitats within these areas. An essential prerequisite for effective wildlife conservation and management is that park managers possess a comprehensive understanding of the existing faunal diversity within their jurisdictional areas. Such knowledge is critical to identify species and populations that are in urgent need of targeted conservation interventions. Biodiversity documentation and periodic inventories, supported by validated scientific information, are foundational to evidence-based conservation planning (Boone et al. 2005). Conversely, gaps in biodiversity knowledge can hinder progress toward national and international biodiversity targets (Girardello et al. 2018).

In Nepal, wildlife conservation efforts have predominantly focused on large charismatic megafauna such as the Royal Bengal Tiger *Panthera tigris*, Greater One-horned Rhinoceros *Rhinoceros unicornis*, Asian Elephant *Elephas maximus* in the lowlands, and Snow Leopard *Panthera uncia* in the high Himalaya (Bhattarai et al. 2017a; Gautam et al. 2022). The increase in the population sizes of these species is often cited as indicators of conservation success (Rawat et al. 2020). Non-charismatic taxa, particularly herpetofauna (amphibians and reptiles), remain comparatively understudied, and largely neglected in conservation priorities (Bhattarai et al. 2017a, 2020; Gautam et al. 2020). Despite this general oversight, some targeted conservation actions have been implemented for select herpetofauna species. For instance, the conservation of the Gharial *Gavialis gangeticus* involves both in situ, and ex situ strategies, and its population status is relatively well documented (Acharya et al. 2017; Bhattarai et al. 2018; Poudyal et al. 2018; Yadav et al. 2022).

The present study aims to update the checklist of amphibians and reptiles of Chitwan National Park (CNP) and its buffer zone, thereby contributing to the broader understanding of the herpetofauna diversity in the park. The foundational work on the herpetofauna of CNP was conducted by Zug & Mitchell (1995), who reported 55 species. Earlier records, such as those by Fleming & Fleming (1973), and Kramer (1977), also documented snake species in Chitwan. Subsequent field guides and inventories (Schleich & Kästle 2002; Shah & Tiwari 2004; Kästle et al. 2013) enriched the knowledge base by including species with known distributions in the park.

More recently, efforts have been made to compile species-specific and locality-based lists, particularly of snakes (Pandey 2012), including the first record of the Siamese Cat Snake *Boiga siamensis* in Nepal (Pandey et al. 2018). Additionally, *Psammodynastes pulverulentus* was recently recorded for the first time in CNP (Bhattarai et al. 2017b). Many herpetological surveys have been locality or taxonomically restricted. For example, Lamsal (2014) conducted surveys exclusively in the Madi Valley of Chitwan, while Bhattarai et al. (2017a) focused on the Beeshazar and associated lakes complex – a Ramsar site of international importance. Other notable contributions include the descriptions of *Rana chitwanensis* (now treated as *Hylarana chitwanensis*) and *Sphaerotheca maskeyi* from the CNP (Das 1998; Schleich & Anders 1998), life history observations of turtles (Mitchell & Rhodin 1996), studies on turtle distribution (Khadka & Lamichhane 2020), studies on population and determinants of crocodile distribution and their socioeconomics (Nishan et al. 2023; Pathak et al. 2023) and post release growth of gharial (Khadka et al. 2022).

Importantly, herpetofauna taxonomy and nomenclature have undergone significant revisions in recent years. These changes, have yet to be incorporated into key conservation and management documents, including the official management plan of the Chitwan National Park (see CNP 2018). To address this gap, the present study provides an updated, taxonomically revised checklist of amphibians & reptiles of the CNP, and its buffer zone. The aim is to deliver up-to-date species list to support evidence-based management decisions and to highlight emerging conservation priorities.

MATERIAL AND METHODS

Study area

Chitwan National Park is the oldest national park of Nepal (Established in 1973, area 952.63 km^2, buffer zone 730 km^2) and designated as UNESCO's World Heritage Site in 1984 (under the criteria vii, ix, & x) for its exceptional natural beauty, supporting outstanding natural & biological systems, and processes, and for providing natural habitats for endangered fauna

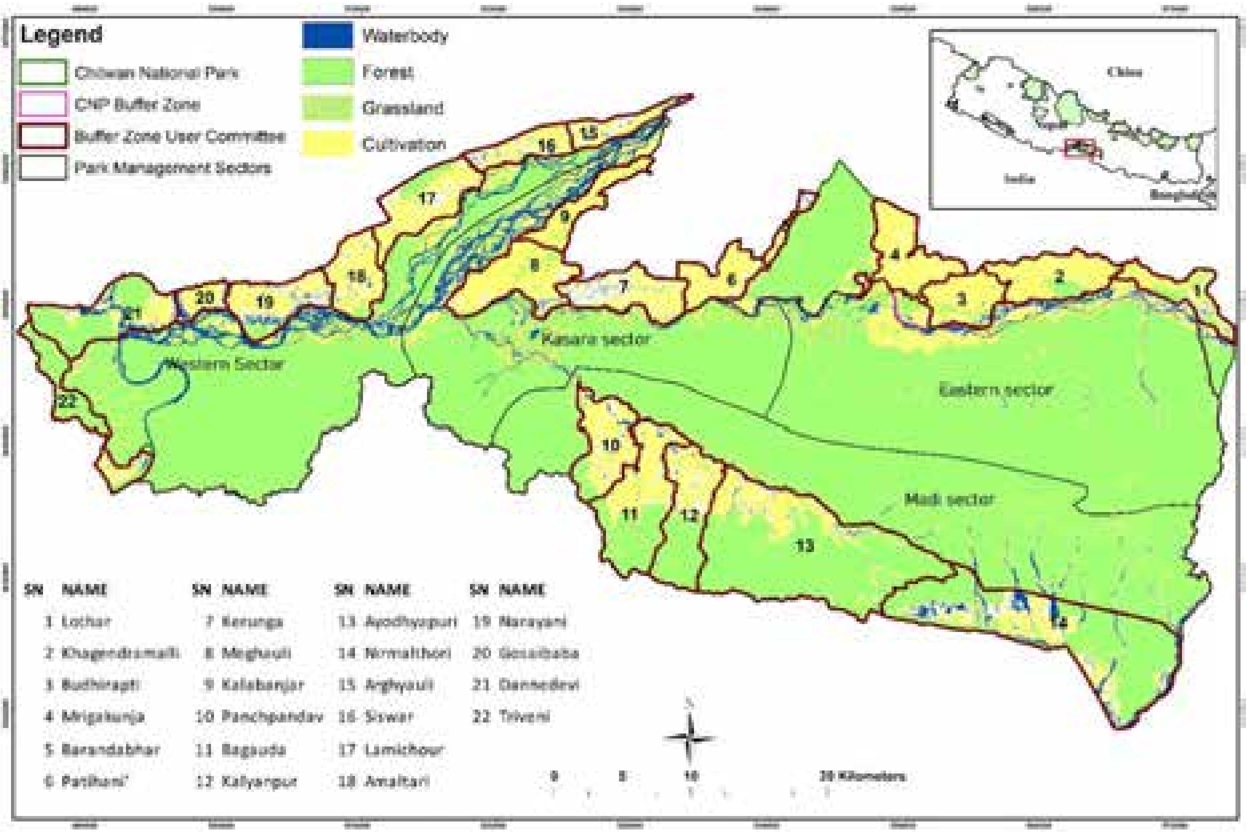

Image 1. Map showing study area Chitwan National Park and the buffer zone area.

& flora (Image 1). The park comprises a mosaic of physiographic regions, including the Himalayan foothills, floodplains, Dun valleys, and the Siwalik (Chure) hills, with elevations ranging 100–900 m. The vegetation is primarily dominated by Sal *Shorea robusta* forests (DNPWC 2020), interspersed with 425 grassland patches that cover about 6.24% of the park's area (CNP 2016). Additionally, 58 small and large natural wetlands within the park serve as critical habitats for numerous aquatic and semi-aquatic species, including a wide range of herpetofauna (CNP 2018). The landscape of the CNP has been shaped by three river systems: the Narayani, Rapti, and Reu rivers. Among these, the Narayani River—also known as the Gandaki and Trishuli Rivers upstream and as Gandak downstream in India—is of Himalayan origin, carrying a significant volume of meltwater from the Himalayas and serving as a perennial watercourse with substantial influence on the park's hydrology, and sediment dynamics (Dahal et al. 2015). In contrast, the Rapti and Reu rivers originate from the Siwalik, and mid-hill regions to the east, and south of the park, respectively. These rivers are primarily rain-fed and exhibit strong seasonal fluctuations in discharge, particularly during the monsoon period (Gurung & Thapa 2016). Collectively, these river systems support a mosaic of aquatic and riparian habitats that are critical for the park's biodiversity, including the 'Critically Endangered' Gharial *Gavialis gangeticus* (Bhuju et al. 2007; Poudyal et al. 2018; Yadav et al. 2022).

In 2003, the Beeshazar and associated lakes, located within the buffer zone of the CNP, were designated as a Ramsar Site—a wetland of international importance—further emphasizing the conservation value of the CNP's aquatic habitats.

Methods

The data presented in this study are derived from a combination of field observations, rescue call records, and existing literature. Diurnal and nocturnal visual encounter surveys (VES) were conducted following Heyer et al. (1994) during multiple field visits across various habitats within both the core and buffer zones of CNP (Image 2). Surveys were conducted during the following periods: 02–08 August 2018, 17–30 July 2019, 8–15 August 2019, 3–14 September 2019, 2–5 February 2020, 16–24 June 2020, 14–29 July 2020, 10–21 August

Image 2. Some representative habitats where surveys were conducted: a—Rapti River | b—Baikuntha Tal | c—Jay Mangala Phanta | d—Riverine grassland | e—Beeshazar lake | f—Triveni Dham area. © Santosh Bhattarai.

2020, 5–15 June 2021, 19–25 July 2021, 11–19 August 2021, and 15–25 July 2023.

Survey teams consisted of three to four observers, who systematically searched all potential microhabitats that likely support amphibians and reptiles. This included active searches involving the turning of logs & stones, inspecting under leaf litter, peeling bark from fallen dead trees, and examining vegetation near water bodies, and forest edges. Diurnal surveys were conducted at 0900–1700 h, while nocturnal surveys were conducted at 1900–2300 h. In addition to systematic surveys, opportunistic data were also collected from rescue calls, mainly involving snakes, and crocodiles, received from local communities in the buffer zone. These opportunistic records contributed to the overall species richness data.

All individuals observed during surveys and rescue calls were identified to species level based on morphological characteristics, and photographic documentation, using standard field guides, and taxonomic literature (Smith 1935; Schleich & Kästle 2002; Shah & Tiwari 2004; Whitaker & Captain 2004; Lajmi et al. 2016; Das & Das 2017; David & Vogel 2021; Garg & Biju 2021; Gowande et al. 2021; Khatiwada et al. 2021; Vogel et al. 2022; Köhler et al. 2023). For taxonomic nomenclature, Frost (2025) for amphibians, and Uetz et al. (2025) for reptiles was followed.

RESULTS

Species richness

The herpetofauna of CNP comprises 89 species, including 20 species of amphibians representing 14 genera, and five families; two species of crocodilians from two genera and two families; 11 species of turtles in seven genera and three families; 14 species of lizards across eight genera and four families; and 42 species of snakes representing 30 genera and 10 families (Table 1; Images 7–11). The Dhudhwa Reed Frog *Chirixalus dudhwaensis* Ray, 1992, is reported as a new species record for Nepal. Additionally, confirmed locality records of the Eastern Bronze-back Tree Snake *Dendrelaphis proarchos* (Wall, 1909), representing CNP as the westernmost known distribution of the species in Nepal is provided.

Among the 20 amphibian species recorded, three are classified as Vulnerable, 15 as Least Concern, one as Data Deficient, and one remains Not Evaluated, based on the IUCN Red List of Threatened Species. Similarly, among the 69 recorded reptile species, three species are classified as Critically Endangered, five species as Endangered, six species as Vulnerable, and four species as Near Threatened according to the IUCN Red List. Additionally, six species have not yet been evaluated, while the remaining 45 species are currently listed as Least Concern. These assessments reflect the varying conservation needs of amphibians and reptiles in the park, and underscore the importance of targeted conservation actions, especially for species at risk.

New records from Chitwan National Park, Nepal

Dhudhwa Reed Frog *Chirixalus dudhwaensis* Ray, 1992 is reported as a confirmed new country record for Nepal based on observation from CNP (Image 3). This record is located approximately 365 km east (air distance) from its type locality in Dudhwa National Park in India. The individual was observed calling in sympatry with *Uperodon globulosus*, *Uperodon taprobanicus,* and *Microhyla nilphamarensis* after a heavy rainfall. Later, we also recorded this frog from Dhangadhi, Kailali in Sudoorpaschim Province.

The occurrence of Eastern Bronze-back Tree Snake *Dendrelaphis proarchos* (Wall, 1909) from Chitwan National Park is documented, representing the westernmost known distribution of the species in Nepal (Image 4). The *D. proarchos* were frequently observed in the Sauraha and Amaltari of the park. The record from CNP is approximately 900 km west of its type locality in Assam, India. *D. proarchos* was also observed from eastern Nepal, from Dharan forest, Miklajung, and Pathari, Morang in Koshi Province. Furthermore, *Hylarana tytleri* in Bandevi buffer zone community forest was also observed, which is a part of Barandabhar corridor forest (Image 5), and the Siwalik Fan-throated Lizard *Sitana sivalensis* from Triveni area of the park connected with Valmiki Tiger Reserve in India (Image 6).

DISCUSSION

The present study provides an update in the understanding of amphibian and reptile diversity in the CNP and its buffer zone. The documentation of 89 species underscores the park and buffer zone as a critical stronghold for amphibians and reptiles. This update represents a significant increase from earlier works, notably the 55 species of herpetofauna reported by Zug & Mitchell (1995), and 32 species of snakes reported by Pandey et al. (2018), and highlights the need for continuous, and systematic biodiversity assessments. The documentation of the Dudhwa Reed Frog *Chirixalus dudhwaensis* from the CNP as a new country record for Nepal indicates that suitable habitats for this species may be more continuous across the lowland Terai. Similarly, the observations of Eastern Bronze-back Tree Snake *Dendrelaphis proarchos* in the park's Sauraha and Amaltari extends the known distribution of this species by nearly 900 km westward from its type locality in Assam, India. Although the occurrence of *D. proarchos* in Nepal was previously mentioned by Das & Das (2017), it lacked specific locality data; therefore, the observations from Chitwan National Park and from eastern Nepal provide

Table 1. Checklist of amphibians and reptiles of Chitwan National Park, Nepal with their current IUCN Red List status.

	Species name	Common name	Red List status
AMPHIBIANS			
Family: Bufonidae Gray, 1825			
1	*Duttaphrynus melanostictus* (Schneider, 1799)	Common Asian Toad	LC
2	*Firouzophrynus stomaticus* (Lütken, 1864)	Marbled Toad	LC
Family: Microhylidae Günther, 1858 (1843)			
3	*Microhyla nilphamariensis* Howlader, Nair, Gopalan, & Merilä, 2015	Nilphamari Narrow-mouth Frog	LC
4	*Uperodon globulosus* (Günther, 1864)	Globular Balloon Frog	LC
5	*Uperodon taprobanicus* (Parker, 1934)	Painted Frog	LC
Family: Dicroglossidae Anderson, 1871			
6	*Euphlyctis adolfi* (Gunther, 1860)	Skittering Frog	LC
7	*Fejervarya orissaensis* (Dutta, 1997)	Odisha Cricket Frog	LC
8	*Hoplobatrachus tigerinus* (Daudin, 1802)	Indian Bull Frog	LC
9	*Minervarya chilapata* Ohler, Deuti, Grosjean, Paul, Ayyaswamy, Ahmed, & Dutta, 2009	Chilapata Rainpool Frog	VU
10	*Minervarya nepalensis* (Dubois, 1975)	Nepal Cricket Frog	LC
11	*Minervarya pierrei* (Dubois, 1975)	Pierre's Cricket Frog	LC
12	*Minervarya* cf. *syhadrensis* (Annandale, 1919)	Syhadra Cricket Frog	LC
13	*Minervarya teraiensis* (Dubois, 1984)	Terai Cricket Frog	LC
14	*Sphaerotheca maskeyi* (Schleich & Anders, 1998)	Maskey's Burrowing Frog	LC
Family: Ranidae Batsch, 1796			
15	*Amolops mahabharatensis* Khatiwada, Shu, Wang, Zhao, Xie, & Jiang, 2020	Mahabharat Cascade Frog	VU
16	*Hylarana chitwanensis* (Das, 1998)	Chitwan Frog	DD
17	*Hylarana tytleri* Theobald, 1868	Yellow-striped Frog	LC
Family: Rhacophoridae Hoffman, 1932 (1858)			
18	*Chirixalus dudhwaensis* Ray, 1992	Dudhwa Reed Frog	VU
19	*Polypedates maculatus* (Gray, 1830)	Common Tree Frog	LC
20	*Polypedates taeniatus* (Boulenger, 1906)	Six-lined Bush Frog	LC
REPTILES			
Family: Crocodylidae Cuvier, 1807			
21	*Crocodylus palustris* (Lesson, 1831)	Mugger Crocodile	VU
Family: Gavialidae Adams 1854			
22	*Gavialis gangeticus* (Gmelin, 1789)	Gharial	CR
Family: Geoemydidae Theobald 1868			
23	*Batagur dhongoka* (Gray, 1834)	Three-striped Roofed Turtle	CR
24	*Melanochelys tricarinata* (Blyth, 1856)	Tricarinate Hill Turtle	EN
25	*Melanochelys trijuga* (Schweigger, 1812)	Black Pond Turtle	LC
26	*Pangshura smithii* (Gray, 1863)	Brown Roofed Turtle	NT
27	*Pangshura tecta* (Gray, 1830)	Indian Roofed Turtle	VU
28	*Pangshura tentoria* (Gray, 1834)	Indian Tent Turtle	LC
Family: Testudinidae Batsch, 1788			
29	*Indotestudo elongata* (Blyth, 1854)	Elongated tortoise	CR
Family: Trionychidae Gray, 1835			
30	*Chitra indica* (Gray 1831)	Narrow-headed Softshell Turtle	EN
31	*Lissemys punctata* (Bonnaterre, 1789)	Indian Flapshell Turtle	VU

	Species name	Common name	Red List status
32	*Nilssonia gangetica* (Cuvier, 1825)	Gangetic Softshell Turtle	EN
33	*Nilssonia hurum* (Gray, 1830)	Peacock Softshell Turtle	EN
Family: Agamidae Gray, 1827			
34	*Calotes vultuosus* (Harlan, 1825)	Changeable Lizard	LC
35	*Sitana sivalensis* Schleich, Kästle, & Shah, 1998	Sivalik Fan-throated Lizard	LC
Family: Gekkonidae Gray, 1825			
36	*Hemidactylus* cf. *kushmorensis* Murray, 1884	Kushmore House Gecko	
37	*Hemidactylus flaviviridis* Rüppell, 1835	Yellow-bellied House Gecko	LC
38	*Hemidactylus frenatus* Duméril & Bibron, 1836	Common House Gecko	LC
39	*Hemidactylus garnotii* Duméril & Bibron, 1836	Fox Gecko	LC
Family: Scincidae Gray, 1825			
40	*Ablepharus sikimmensis* (Blyth, 1854)	Sikkim Ground Skink	LC
41	*Eutropis carinata* (Schneider, 1801)	Common Ground Skink	LC
42	*Eutropis macularia* (Blyth, 1853)	Bronze Ground Skink	LC
43	*Eutropis trivittata* (Hardwicke & Gray, 1827)	Striped Ground skink	LC
44	*Riopa albopunctata* Gray, 1846	White-spotted Supple Skink	LC
45	*Sphenomorphus maculatus* (Blyth, 1853)	Spotted Forest Skink	LC
Family: Varanidae Merrem, 1820			
46	*Varanus bengalensis* (Daudin, 1802)	Bengal Monitor	NT
47	*Varanus flavescens* (Hardwicke & Gray, 1827)	Golden Monitor	EN
Family: Erycidae Bonaparte, 1831			
48	*Eryx conicus* (Schneider, 1801)	Common Sand Boa	NT
49	*Eryx johnii* (Russell, 1801)	Red Sand Boa	NT
Family: Pythonidae Fitzinger, 1826			
50	*Python bivittatus* Kuhl, 1820	Burmese Python	VU
Family: Colubridae Oppell, 1811			
51	*Ahaetulla laudankia* Deepak, Narayanan, Sarkar, Dutta & Mohapatra, 2019	Laudanka Vine Snake	LC
52	*Ahaetulla longirostris* Mirza, Pattekar, Verma, Stuart, Purkayastha, Mohapatra, & Patel, 2024	Long-snout Vine Snake	
53	*Boiga stoliczkae* (Wall, 1909)	Tawny Cat Snake	LC
54	*Boiga siamensis* Nootphand, 1971	Siamese Cat Snake	LC
55	*Boiga trigonata* (Schneider, 1802)	Common Cat Snake	LC
56	*Boiga westermanni* (Reinhardt, 1863)	Indian Egg-eating Snake	LC
57	*Chrysopelea ornata* (Shaw, 1802)	Ornate Flying Snake	LC
58	*Coelognathus helena* (Daudin, 1803)	Common Trinket Snake	LC
59	*Coelognathus radiatus* (Boie, 1827)	Copper-headed Trinket Snake	LC
60	*Dendrelaphis tristis* (Daudin, 1803)	Common Bronze-back Tree Snake	LC
61	*Dendrelaphis proarchos* Wall, 1909	Eastern Bronze-back Tree Snake	
62	*Gongylosoma calamaria* (Günther, 1858)	Calamaria Reed Snake	LC
63	*Lycodon aulicus* (Linnaeus, 1758)	Common Wolf Snake	LC
64	*Lycodon jara* (Shaw, 1802)	Twin-spotted Wolf Snake	LC
65	*Lycodon striatus* (Shaw, 1802)	Barred Wolf Snake	LC
66	*Oligodon kheriensis* Acharji & Ray, 1836	Coral Red Kukri Snake	LC
67	*Oligodon russelius* (Daudin, 1803)	Russell's Kukri Snake	
68	*Ptyas mucosa* (Linnaeus, 1758)	Common Rat Snake	LC

	Species name	Common name	Red List status
69	*Sibynophis sagittarius* (Cantor, 1839)		LC
Family: Homalopsidae Bonaparte, 1845			
70	*Enhydris enhydris* (Schneider, 1799)	Rainbow Water Snake	LC
71	*Ferania sieboldii* (Schlegel, 1837)	Siebold's Water Snake	LC
Family: Psammophidae Bourgeois, 1968			
72	*Psammophis condanarus* (Merrem, 1820)	Common Sand Snake	LC
Family: Psammodynastidae Das, Greenbaum, Brecko, Pauwels, Ruane, Pirro, & Merilä, 2024			
73	*Psammodynastes pulverulentus* (Boie, 1827)	Common Mock Viper	LC
Family: Natricidae Bonaparte, 1838			
74	*Amphiesma stolatum* (Linnaeus, 1758)	Striped Keelback Snake	LC
75	*Fowlea piscator* (Schneider, 1799)	Checkered Keelback Snake	LC
76	*Herpetoreas platyceps* (Blyth, 1854)	Mountain Keelback Snake	LC
77	*Rhabdophis helleri* Schmidt, 1925	Red-necked Keelback Snake	
78	*Xenochrophis cerasogaster* (Cantor, 1839)	Painted Keelback Snake	VU
Family: Elapidae F. Boie, 1827			
79	*Bungarus caeruleus* (Schneider, 1801)	Common Krait	LC
80	*Bungarus fasciatus* (Schneider, 1801)	Banded Krait	LC
81	*Bungarus lividus* Cantor, 1839	Lesser Black Krait	LC
82	*Naja kaouthia* Lesson, 1831	Monocled Cobra	LC
83	*Naja naja* (Linnaeus, 1758)	Common Cobra	LC
84	*Ophiophagus hannah* (Cantor, 1836)	King Cobra	VU
85	*Sinomicrurus macclellandi* (Reinhardt, 1844)	MacClelland's Coral Snake	LC
Family: Typhopidae Merrem, 1820			
86	*Argyrophis diardii* (Schlegel, 1839)	Diard's Blind Snake	LC
87	*Indotyphlops braminus* (Daudin, 1803)	Common Blind Snake	LC
Family: Viperidae Oppel, 1811			
88	*Daboia russelii* (Shaw & Nodder, 1797)	Russell's Viper	LC
89	*Trimeresurus salazar* Mirza, Bhosale, Phansalkar, Sawant, Gowande, & Patel, 2020	Salazar Pit-viper	

LC—Least Concern | DD—Data Deficient | VU—Vulnerable | NT—Near Threatened | EN—Endangered | CR—Critically Endangered.

the confirmed locality records for the species within the country. Likewise, the observation of *Hylarana tytleri* and *Sitana sivalensis* in CNP underpins the need for fine-scale herpetofauna surveys in the region. *Hylarana tytleri*, previously reported primarily from eastern Nepal (Schleich & Kästle 2002; Shah & Tiwari 2004) and with a single record from the Ghodaghodi Lake Complex in far-western Nepal (Shah & Tiwari 2004), warrants further confirmation to validate its occurrence in the far-western region.

The record of *Sitana sivalensis* from the Triveni area of the CNP is ca. 105 km east (air distance) from its type locality, Shivapur, Kapilbastu, Nepal, emphasizing the need for further targeted surveys along the Siwalik foothills. Given that the Triveni area is contiguous with the Valmiki Tiger Reserve in Bihar, India, species likely to be *S. sivalensis* from Valmiki Tiger Reserve was also observed during the transboundary rhino rescue.

Recently, Mirza et al. (2024) described a new species of a vine snake, *Ahaetulla longirostris*, from adjoining Valmiki Tiger Reserve. Accordingly, *Ahaetulla* cf. *nasuta* can be recognized from Chitwan National Park as *A. longirostris*, since the true *A. nasuta* is now considered restricted to Sri Lanka (Mallik et al. 2020). Similarly, Gowande et al. (2021) reassessed the taxonomy of the *Calotes versicolor* complex in southern Asia and assigned the populations from the Gangetic plains to *Calotes vultuosus* (Harlan, 1825), based on a combination of morphological characters, including a smaller to medium body size, and a dorsal crest composed of relatively

Image 3. Dudhwa Reed Frog *Chirixalus dudhwaensis* from Sauraha, Chitwan. © Santosh Bhattarai.

Image 4. Eastern Bronze-back Tree Snake *Dendrelaphis proarchos* in Nepal: a—from Chitwan National Park | b—from Pathari, Morang. © a—Santosh Bhattarai | b—Bivek Gautam.

smaller scales that gradually decrease in size towards the tail compared to *C. versicolor*. The observations of *Calotes* from CNP agree with the diagnostic characters of *C. vultuosus*. Therefore, the Chitwan population is considered to represent *C. vultuosus*. Likewise, the Banded Kukri Snake *Oligodon arnensis* is treated as *O. russelius,* as suggested by Bandara et al. (2022), for *Eutropis macularia* as *E. trivittata* (Amarsinghe et al. 2022), *Rabdophis subminiatus* as *R. helleri* (David & Vogel 2021),*Hemidactylus brookii* as *H. kushmorensis* (Lajmi et al. 2016) and *Boiga ochracea* as *B. stoliczkae* (Köhler et al. 2023). A detailed specimen-based study is recommended, incorporating both morphological and molecular approaches, to confirm the taxonomic status of above-mentioned species in Nepal.

Malhotra et al. (2025) recently downgraded *Trimeresurus salazar* to a subspecies of *Trimeresurus septentrionalis*, noting that whole genome analyses are currently underway. The field observations of *Trimeresurus* populations from CNP and other lowland regions of Nepal, differ from *T. septentrionalis* specimens collected from its type locality in Pokhara, situated in the mid-mountain region of Nepal, and are more consistent with the description provided by Vogel et al. (2022). Accordingly, the Chitwan population is treated as *T. salazar* (Mirza et al. 2020). Furthermore, earlier literature reports a GenBank accession number (AF171909) for a specimen collected from Mahottari District in Madhesh Province located in the lowland Terai region of Nepal (Malhotra & Thorpe 2004), mentioned as *Trimerusurus albolabris*. To resolve these uncertainties, a comprehensive sampling of *Trimerusurus* from lowland, mountains, and valleys are needed for a detailed comparative study to clarify taxonomic status, and evolutionary relationship within *Trimeresurus sepentrionalis* complex.

Two frog species, namely, *Sphaerotheca maskeyi* (Schleich & Anders, 1998) and *Rana chitwanensis* (now *Hylarana chitwanensis*) (Das, 1998), were described from CNP, while Narayanghat Whipping Frog *Polypedates zed* (Dubois, 1987) was described from Narayanghat, Chitwan; hardly 5 km away from the CNP, and Barandabhar (Bhattarai et al. 2017a). The known distributions of *H. chitwanensis* and *Polypedates zed* remain restricted to their respective type localities at Kasara, CNP, and Narayanghat, respectively. *Hylarana chitwanensis* was recorded from the Temple Tiger area and the Bagai area of the CNP, and observed calling males from Bagai during the monsoon season. These observations provide additional locality records for *Hylarana chitwanensis*, a species that has been poorly documented since its description. No *Polypedates zed* were detected during the survey, although *P. maculatus* was observed from the area. Given the significant urban

Image 5. Yellow-striped Frog *Hylarana tytleri* from Bandevi Buffer Zone Community Forest, Barandabhar Corridor. © Dip Prasad Chaudhary.

Image 6. Siwalik Fan-threated Lizard *Sitana sivalensis* from Triveni. © Dip P. Chaudhary.

expansion of Narayanghat into a metropolitan area, it is imperative to conduct targeted surveys combining fieldwork, and molecular methods, including comparison with the holotype, and related congeners, to ascertain the continued presence of *P. zed* in the wild. As for the dicroglossid frog *Minervarya syhadrensis* (Annandale, 1919), current scholarship suggests that it may be restricted to the hills of Peninsular India, especially the Western Ghats (Phuge et al. 2020). Some publications (Khatiwada et al. 2021) report *M. syhadrensis* also from Nepal, which may require additional re-confirmation. Hence, the sightings are conservatively represented from Nepal as *M.* cf. *syhadrensis*, requiring additional confirmation of their species identity.

Conservation concerns

This article highlights the erroneous inclusion of Torrent Paha Frog *Nanorana ercepeae* in the CNP and Shuklaphanta National Park in the recent IUCN Red List assessment. *Nanorana ercepeae* was originally described from Bajhang in far-western Nepal. The species is known to inhabit temperate forests associated with montane streams in the proximity of coniferous forests; occurring at elevations of 1700–2700 m (Schleich & Kästle 2002; Shah & Tiwari 2004; Alley et al. 2013). In contrast, CNP is characterized by sub-tropical forests with a known elevation of approximately 100–900 m (DNPWC 2020), which likely represent unsuitable habitats for *Nanorana ercepeae*. Furthermore, no verified records for the species exist within the park. This correction is crucial, as inaccurate species lists can mislead conservation priorities, and management interventions.

Many reptile species such as Yellow Tortoise *Indutestudo elongata*, Three Striped-roofed Turtle *Batagur dhongoka* face critical endangerment similar to the gharial *Gavialis gangeticus*. These species, unlike the Gharial, receive no conservation attention in Nepal. This neglect is particularly concerning for *Batagur dhongoka*; for which further verification is needed to confirm its occurrence in Nepal. Likewise, earlier literature reports the occurrence of Red-crowned Roofed Turtle *Batagur kachuga* from Nepal (Schleich & Kästle 2002; Shah & Tiwari 2004; Aryal et al. 2010). The known population of *Batagur dhongoka* and *B. kachuga* is not known from Nepal (Das et al. 2019; Praschag et al. 2019) and the distribution of *B. kachuga* in Nepal is erroneous, and unlikely to occur as its known distribution is only from Chambal River system in India, and Ganga River is the northern-most distribution limit (S. Singh pers. comm.). Similarly, 'Endangered' species such as *Chitra indica*; *Nilssonia gangetica*, *N. hurum*, and *Varanus flavscens* also require urgent conservation attention due to continuing threats such as habitat loss, pollution, and illegal exploitation similar to those impacting Gharials (Poudyal et al. 2018; Yadav et al. 2022).

Conservation implications

The tigers and rhinos are the nucleus of conservation interventions in the CNP. All the conservation activities such as grassland management through cutting, slash & burn practices, and wetland restoration are primarily designed, and implemented to support these species. Additionally, community engagement activities such as outreach sessions, and involvement of community-

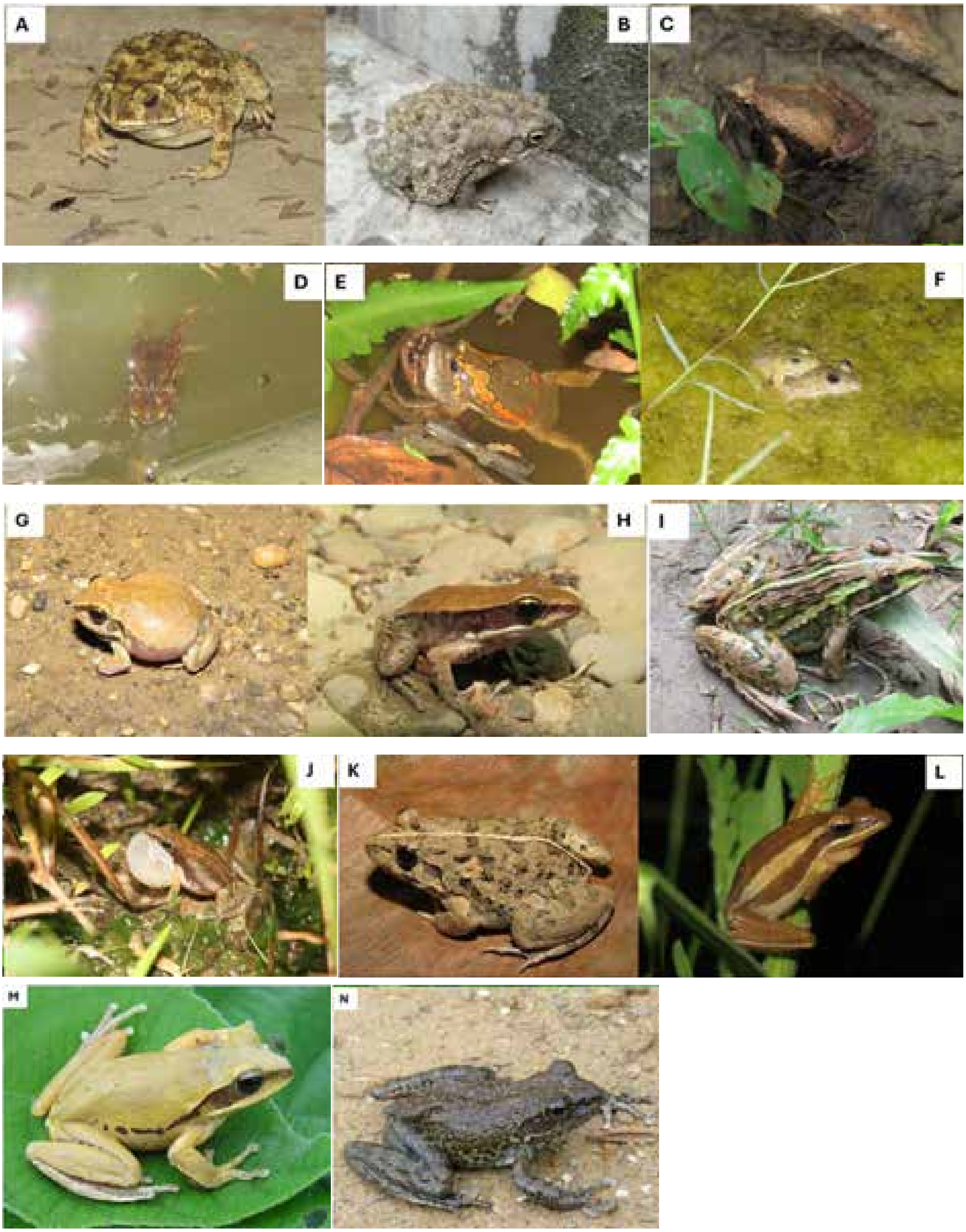

Image 7. Amphibian species from Chitwan National Park. A—Common Asian Toad *Duttaphrynus melanostictus* | B—Marbled Taod *Firouzophrynus stomaticus* | C—Nilphamari Narrow-mouth Frog *Microhyla nilphamarensis* | D—Globular Balloon Frog *Uperodon globulosus* | E—Painted Frog *Uperodon taprobanicus* | F—Skittering Frog *Euphlyctis adolfi* | G—Maskey's Burrowing Frog *Sphaerotheca maskeyi* | H—Chitwan Frog *Hylarana chitwanensis* | I—Common Bull Frog *Hoplobatrachus tigerinus* | J—Chilapata Rain-pool Frog *Minervarya chilapata* | K—Terai Cricket Frog *Minervarya teraiensis* | L—Six-lined Bush Frog *Polypedates taeniatus* | M—Common Tree Frog *Polypedates maculatus* | N—Mahabharat Cascade Frog *Amolops mahabharatensis*. © Santosh Bhattarai.

Image 8. Lizards of Chitwan National Park: A—Changeable Lizard *Calotes vultousus* | B—Yellow-bellied House Gecko *Hemidactylus flaviviridis* | C—Kushmore House Gecko *Hemidactlylus* cf. *kushmorensis* | D—Common House Gecko *Hemidactylus frenatus* | E—Common Grass Skink *Eutropis carinata* | F—Bronze-grass Skink *Eutropis macularia* | G—Striped-grass Skink *Eutropis trivittata* | H—White-spotted Supple Skink *Riopa albopunctata* | I—Bengal Monitor Lizard *Varanus bengalensis* | J—Golden Monitor Lizard *Varanus flavescens*. © A-F,H,J—Santosh Bhattarai; G,I—Dip Prasad Chaudhary.

based anti-poaching units, focus mainly on these priority taxa. These units receive frequent specialized training in species-specific conservation practices, particularly for tigers and rhinos.

The 'Critically Endangered' Gharial has attracted targeted conservation efforts such as population monitoring, nest monitoring, protection, and nest relocation have been implemented to safeguard the Gharial population in the rivers of the CNP and at Gharial Conservation and Breeding Center (GCBC), located at the headquarters of the CNP at Kasara (Poudyal et al 2018; Khadka et al. 2022a). The GCBC is well managed, with hundreds of Gharials reared annually, and released into the wild through a head-start program. In contrast, management efforts at the Turtle Breeding Center (TBC) remain limited, with only a few documented initiatives, such as the successful nest relocation of *Chitra indica* (Khadka et al. 2022b). Despite these initiatives, the aquatic habitats of the CNP remain under significant anthropogenic pressure. Both legal and illegal activities, including the distribution of fishing licenses to selected river-dependent communities, and the widespread illegal use of gill nets threaten the Gharial's survival. Entanglement in fishing nets is among the greatest direct

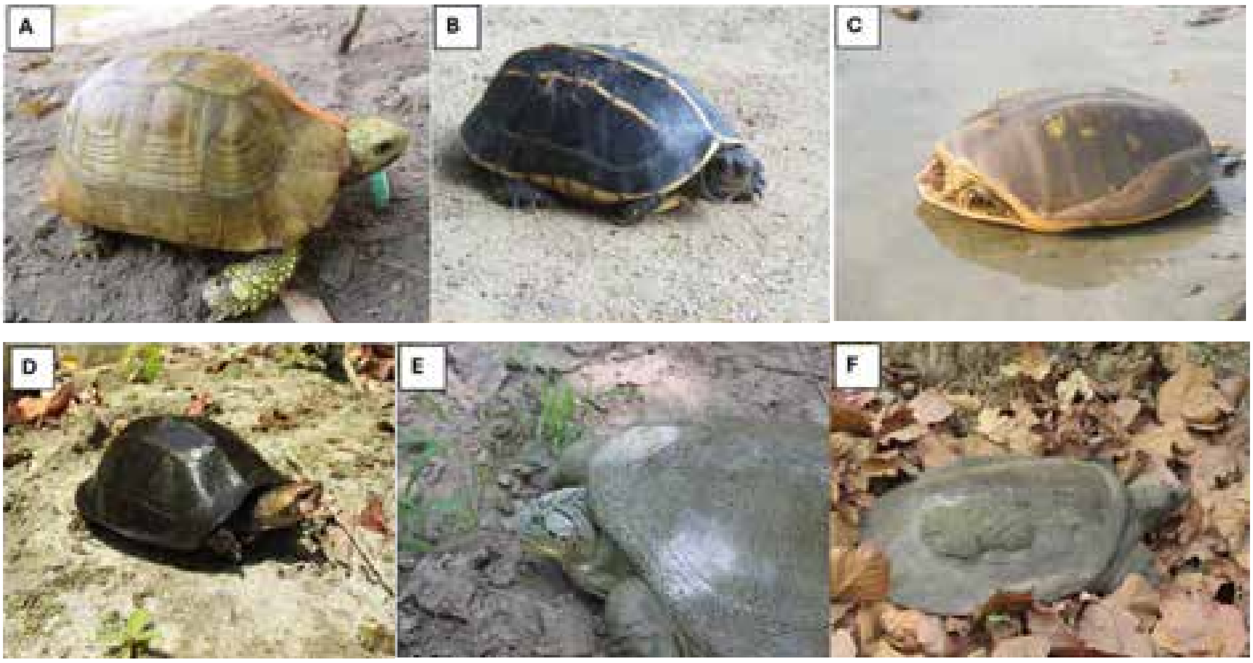

Image 9. Tortoise and some turtle species of Chitwan National Park: A—Yellow Tortoise *Indotestudo elongata* | B—Tricarinate Hill Turtle *Melanochelys tricarinata* | C—Flapshell Turtle *Lissemys punctata* | D—Black pond Turtle *Menanochelys trijuga* | E—Peacock Softshell Turtle *Nilssonia hurum* | F—Gangetic Softshell turtle *Nilssonia gangetica*. © B,C,E—Santosh Bhattarai; A,D,F—Dip Prasad Chaudhary.

threats, often resulting in injury or mortality. Given these challenges, it is imperative that conservation efforts in the CNP adopt more inclusive activities that address the shared threats faced by amphibians and reptiles, beyond the priority taxa.

The updated checklist in this study offers a baseline for future herpetological research and conservation planning in the CNP. The findings highlight the herpetofauna richness of the CNP and its buffer zone. Given the increasing frequency of stochastic events such as floods, wildfires, and anthropogenic pressures, maintaining updated information, and implementing adaptive management strategies are essential to ensure the long-term persistence of herpetofauna communities in the park. Therefore, it is recommended to use integrative taxonomic approaches, combining molecular, morphological, and ecological data to resolve cryptic diversity for effective conservation actions.

REFERENCES

Acharya, K.P., B.K. Khadka, S.R. Jnawali, S. Malla, S. Bhattarai, E. Wikramanayake & M. Kohl (2017). Conservation and population recovery of Gharials *Gavialis gangeticus* in Nepal. *Herpetologica* 73(2): 129–135.

Alley, L., D. Musahary & S. Sengupta (2013). Amphibians of east district of Sikkim, with notes on their natural history. *NeBIO* 4(3): 28–31.

Amarasinghe, A.A.T., S.R. Ganesh, Z.A. Mirza, P.D. Campbell, O.S.G. Pauwels, S. Schweiger, A. Kupfer, H. Patel, S. Karunarathna, K. Deuti, I. Ineich, J. Hallermann, A. Abinawanto & J. Supriatna (2022). The delusion of stripes: a century-old mystery of five-lined sun skinks (Reptilia: Scincidae: *Eutropis*) of Peninsular India elucidated. *Zoologischer Anzeiger* 296: 71–90. https://doi.org/10.1016/j.jcz.2021.11.004

Aryal, P.C., M.K. Dhamala, B.B. Bhurtel, M.K. Suwal & B. Rijal (2010). *Turtles of Nepal: A field Guide for Species Accounts and Distribution*. Environmental Graduates in Himalaya, Resources Himalaya Foundation, and Companions for Amphibians and Reptiles. Kathmandu, Nepal, 37 pp.

Bandara, S.K., S.R. Ganesh, A.S. Kanishka, A.D. Danushka, V.R. Sharma, P.D. Campbell & A.T. Amarasinghe (2022). Taxonomic composition of the *Oligodon arnensis* (Shaw, 1802) species complex (Squamata: Colubridae) with the description of a new species from India. *Herpetologica* 78(1): 51–73. https://doi.org/10.1655/Herpetologica-D-21-00026.1

Bhattarai, S., C.P. Pokheral, B.R. Lamichhane & N. Subedi (2017a). Herpetofauna of a Ramsar Site: Beeshazar and associated lakes, Chitwan National Park Nepal. *Reptiles and Amphibians* 24(1): 17–29.

Bhattarai, S., A. Gurung, L. Chalise & C.P. Pokheral (2017b). Geographic distribution: *Psammodynastes pulverulentus* (Mock Viper). *Herpetological Review* 48(1): 129.

Bhattarai, S., C.P. Pokheral, B.R. Lamichhane, U.R. Regmi, A.K. Ram & N. Subedi (2018). Amphibians and reptiles of Parsa National Park, Nepal. *Amphibian and Reptile Conservation* 12(1): 35–48 (e155).

Bhattarai, S., A. Gurung, B.R. Lamichhane, R. Regmi, M. Dhungana, B. Kumpakha & N. Subedi (2020). *Amphibians and Reptiles of Chure Range, Nepal*. President Chure Terai-Madhesh Conservation Development Board and National Trust for Nature Conservation, Khumaltar, Lalitpur, Nepal, 60 pp.

Bhuju, U.R., P.R. Shakya, T.B. Basnet & S. Shrestha (2007). *Nepal Biodiversity Resource Book: Protected Areas, Ramsar Sites, and World Heritage Sites.* International Centre for Integrated Mountain

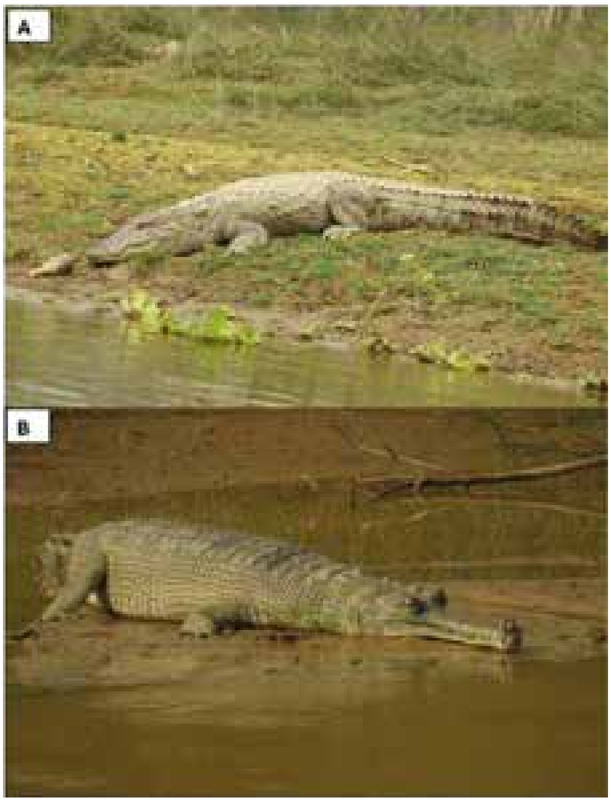

Image 10. Crocodiles of Chitwan National Park: A—Mugger Crocodile *Crocodylus palustris* | B—Male Gharial *Gavialis gangeticus*. © A—Santosh Bhattarai; B—Dip Prasad Chaudhary.

Development (ICIMOD), Ministry of Environment, Science and Technology (MOEST), and United Nations Environment Programme (UNEP), Kathmandu, Nepal, 160 pp.

Boone, J.H., C.G. Mahan & K.C. Kim (2005). Biodiversity Inventory: Approaches, Analysis, and Synthesis. Technical Report NPS/NER/NRTR--2005/015. National Park Service, Philadelphia, 54 pp.

CNP (2016). *Grassland Habitat Mapping in Chitwan National Park*. Chitwan National Park, Kasara, Chitwan.

CNP (2018). *Management Plan of Chitwan National Park and its Buffer Zone (2075/76-2079/80)*. Chitwan National Park Office, Kasara, Chitwan, 192 pp.

Dahal, N., M. Bista & A. Aryal (2015). Hydrological and geomorphological dynamics of the Narayani River system in Nepal. *Journal of Hydrology and Meteorology* 9(1): 23–34.

Das, I. (1998). A new species of *Rana* from the Terai of Nepal. *Journal of Herpetology* 32(2): 223–229.

Das, I. & A. Das (2017). *A Naturalist's Guide to Reptiles of India*. Prakash Books. New Delhi, India, 176 pp.

Das, I., B.C. Choudhury, P. Praschag, M.F. Ahmed & S. Singh (2019). *Batagur dhongoka*. The IUCN Red List of Threatened Species 2019: e.T10953A152042542. https://doi.org/10.2305/IUCN.UK.2019-1.RLTS.T10953A152042542.en. Accessed on 28.i.2025.

David, P. & G. Vogel (2021). Taxonomic composition of the *Rhabdophis subminiatus* (Schlegel, 1837) species complex (Reptilia: Natricidae) with the description of a new species from China. *Taprobanica* 10(2): 89–120.

DNPWC (2020). Assessment of Ecological Carrying Capacity of Royal Bengal Tiger in Chitwan-Parsa Complex, Nepal. Department of National Parks and Wildlife Conservation, Babarmahal, Kathmandu, 36 pp.

DNPWC (2025). Protected Areas of Nepal. https://dnpwc.gov.np/en/. Accessed on 08.ii.2025.

Dubois, A. (1987). Miscellanea taxonornica batrachologica (I). *Alytes* 5: 7–95.

Fleming, R.L. Jr. & R.L. Fleming Sr. (1973). Some snakes from Nepal. *Journal of Bombay Natural History Society*. 3: 426–437.

Frost, D.R. (2025). Amphibian Species of the World: An Online Reference. Version 6.0. American Museum of Natural History, New York http://research.amnh.org/vz/herpetology/amphibia/. Accessed on 08.ii.2025.

Garg, S. & S.D. Biju (2021). DNA barcoding and systematic review of minervaryan frogs (Dicroglossidae: *Minervarya*) of peninsular India: resolution of a taxonomic conundrum with description of a new species. *Asian Herpetological Research* 12(4): 345–378. https://doi.org/10.16373/j.cnki.ahr.210023

Gautam, B., M.K. Chalise, K.B. Thapa & S. Bhattarai (2020). Distributional patterns of amphibians and reptiles in Ghandruk, Annapurna Conservation Area, Nepal. *Reptiles & Amphibians* 27(1): 18–28. https://doi.org/10.17161/randa.v27i1.14440

Gautam, B., S. Bhattarai & R.C. Kandel (2022). First record of *Takydromus sikkimensis* Günther, 1888 (Squamata, Lacertidae) from Nepal. *Herpetozoa* 35: 159–163. https://doi.org/10.3897/herpetozoa.35.e89497

Girardello, M., S. Martellos, A. Pardo & S. Bertolino (2018). Gaps in biodiversity occurrence information may hamper the achievement of international biodiversity targets: insights from a cross-taxon analysis. *Environmental Conservation* 45(4): 370–377. https://doi.org/10.1017/S0376892918000115

Gowande, G., S. Pal, D. Jablonski, R. Masroor, P.U. Phansalkar, P. Dsouza, A. Jayarajan & K. Shanker (2021). Molecular phylogenetics and taxonomic reassessment of the widespread agamid Lizard *Calotes versicolor* (Daudin, 1802) (Squamata: Agamidae) across South Asia. *Vertebrate Zoology* 71: 669–696. https://doi.org/10.3897/vz.71.e62787

Gurung, S. & R. Thapa (2016). Seasonal variation in water discharge and sediment load of the Rapti and Reu Rivers in Chitwan. *Nepal Journal of Environmental Science* 4(2): 45–52.

Heyer, W.R., M.A. Donnelly, R.W. McDiarmid, L.C. Hayek & M.S. Foster (1994). *Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians*. Smithsonian Institution Press. Washington, DC, 364 pp.

Kästle, W., K. Rai & H.H. Schleich (2013). *Reptiles of Nepal*. ARCO-Nepal e.V. Munich, Germany, 625 pp.

Khadka, B.B., A. Bashyal & P. Griffith (2022a). Post-release growth of captive-reared Gharial *Gavialis gangeticus* (Gmelin, 1789) (Reptilia: Crocodilia: Gavialidae) in Chitwan National Park, Nepal. *Journal of Threatened Taxa* 14(5): 21002–21009. https://doi.org/10.11609/jott.6692.14.5.21002-21009

Khadka, B.B., S. Lamichhane & S. Bhattarai (2022b). Notes on successful nest relocation of *Chitra indica* (Gray, 1831) from Chitwan National Park, Nepal. *Tropical Natural History* 22: 51–55.

Khadka, B.B. & S. Lamichhane (2020). First distribution records of *Pangshura tentoria, Chitra indica,* and *Nilssonia gangetica* in the major rivers of Chitwan National Park, Nepal. *Herpetology Notes* 13: 157–159.

Khatiwada, J.R., B. Wang, T. Zhao, F. Xie & J.P. Jiang (2021). An integrative taxonomy of amphibians of Nepal: an updated status and distribution. *Asian Herpetological Research* 12(1): 1–35. https://doi.org/10.16373/j.cnki.ahr.200050

Köhler, G., P.T. Charunrochana, L. Mogk, N.L. Than, N. Kurniawan, A.M. Kadafi, A. Das, F. Tillack & M. O'Shea (2023). A taxonomic revision of *Boiga multomaculata* (Boie, 1827) and *B. ochracea* (Theobald, 1868), with the description of a new subspecies (Squamata: Serpentes: Colubridae). *Zootaxa* 5270(2): 151–193. https://doi.org/10.11646/zootaxa.5270.2.1

Kramer, E. (1977). Zur Schlangenfauna Nepals. *Revue Suisse de Zoologie* 84: 721–761.

Lajmi, A., V.B. Giri & K.P. Karanth (2016). Molecular data in conjunction with morphology help resolve the *Hemidactylus brookii* complex (Squamata: Gekkonidae). *Organisms Diversity & Evolution* 16(3):

Image 11. Some snakes of Chitwan National Park: A—Striped Keelback snake *Amphiesma stolatum* | B—Common Wolf Snake *Lycodon aulicus* | C—Common Rat Snake *Ptyas mucosa* | D—Common Bronzeback Tree Snake *Dendrelaphis tristis* | E—Siamese Cat Snake *Boiga siamensis* | F—Tawny Cat Snake *Boiga stoliczkae* | G—Long-snouted Vine Snake *Ahaetulla longirostris* | H—Red Sand Boa *Eryx johnii* | I—Ornate Flying Snake *Chrysopelea ornata* | J—Painted Keelback *Xenochrophis cerasogaster* | K—Common Sand Boa *Eryx conicus* | L—Coral Kukri Snake *Oligodon kheriensis*.© Santosh Bhattarai.

659–677. https://doi.org/10.1007/s13127-016-0271-9

Lamsal, D. (2014). Diversity and uses of herpetofauna of Madi Valley, Chitwan, Nepal. M.Sc. Dissertation, Tribhuvan University, Kathmandu, Nepal, 55 pp.

Malhotra, A. & R.S. Thorpe (2004). A phylogeny of four mitochondrial gene regions suggests a revised taxonomy for Asian Pitvipers (*Trimeresurus* and *Ovophis*). *Molecular Phylogenetics and Evolution* 32(1): 83–100. https://doi.org/10.1016/j.ympev.2004.02.008

Malhotra, A., M. Walter, G.L. Russel & R.S. Thorpe (2025). Integrative analysis of geographic variation and species boundaries in the White-lipped Pitviper complex (Squamata: Viperidae: Crotalinae: *Trimeresurus albolabris*). *Vertebrate Zoology* 75: 191–225. https://doi.org/10.3897/vz.75.e142775

Mallik, A.K., A.N. Srikanthan, S.P. Pal, P.M. Dsouza, K. Shanker &

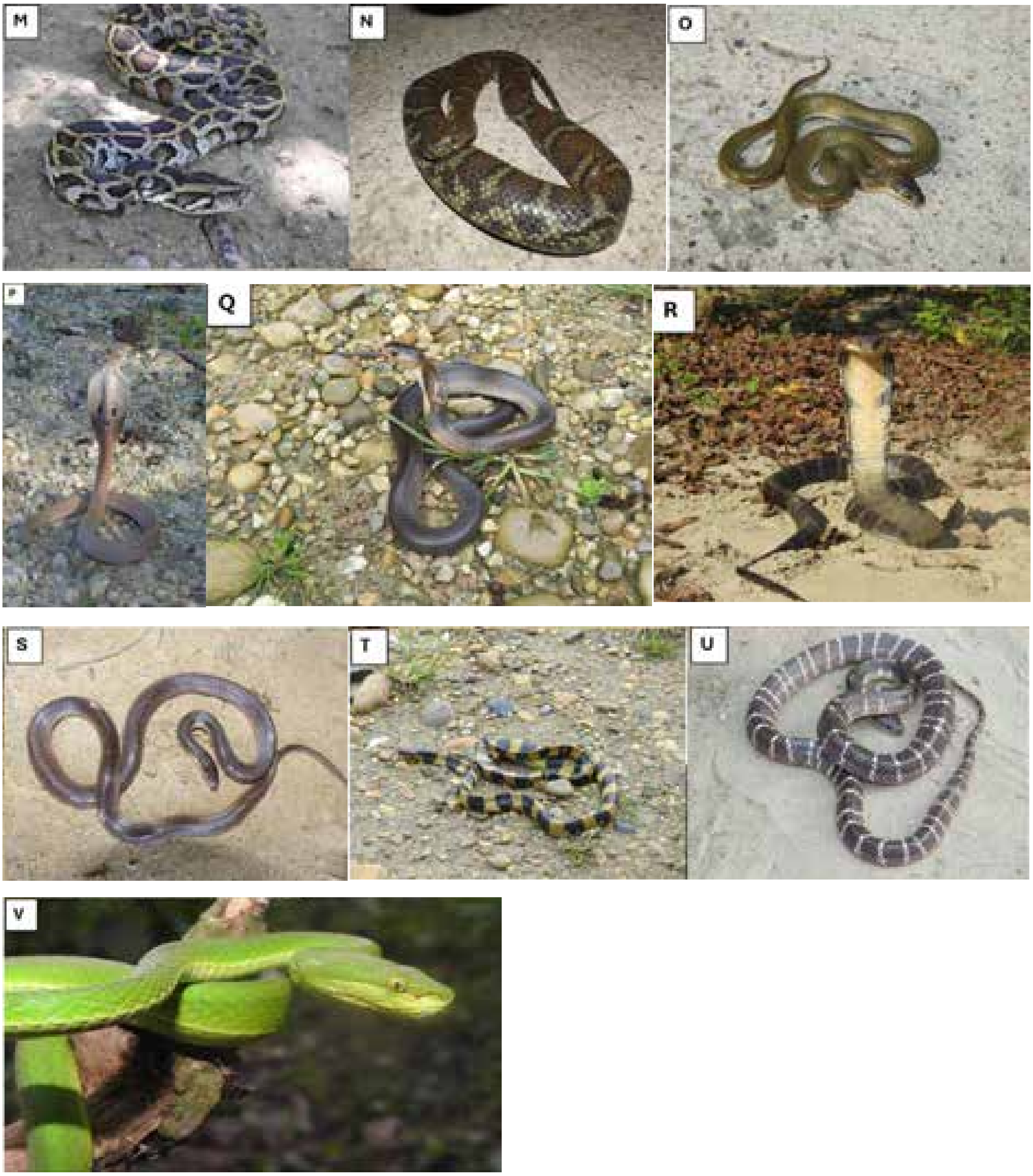

Image 11. Some snakes of Chitwan National Park: M—Burmese Python *Python bivittatus* | N—Siebold's Water Snake *Ferania sieboldii* | O—Twin-spotted Wolf Snake *Lycodon jara* | P—Common Cobra *Naja naja* | Q—Monocled Cobra *Naja kaouthia* | R—King Cobra *Ophiophagus hannah* | S—Lesser-black Krait *Bungarus lividus* | T—Banded Krait *Bungarus fasciatus* | U—Common Krait *Bungarus caeruleus* | V—Salazar Pit-viper *Trimerusurus salazar*. © Santosh Bhattarai.

S.R. Ganesh (2020). Disentangling vines: a study of morphological crypsis and genetic divergence in vine snakes (Squamata: Colubridae: *Ahaetulla*) with the description of five new species from Peninsular India. *Zootaxa* 4874: 1–62. https://doi.org/10.11646/zootaxa.4874.1.1

Mirza, Z.A., H.S. Bhosale, P.U. Phansalkar, M. Sawant, G.G. Gowande & H. Patel (2020). A new species of Green Pit Viper of the genus *Trimeresurus* Lacépède, 1804 (Reptilia: Serpentes: Viperidae) from western Arunachal Pradesh, India. *Zoosystematics and Evolution* 96(1): 123–138. https://doi.org/10.3897/zse.96.48431

Mirza, Z.A., S. Pattekar, S. Verma, B.L. Stuart, J. Purkayastha, P.P. Mohapatra & H. Patel (2024). A new Long-snouted vine snake species in the genus *Ahaetulla* Link, 1807 (Colubridae: Chrysopeleinae) from India. *Journal of Asia-Pacific Biodiversity* 17(4): 696–703. https://doi.org/10.1016/j.japb.2024.04.017

Mitchell, J.C. & A.G.J. Rhodin (1996). Observations on the natural history and exploitation of turtles of Nepal, with life history notes on *Melanochelys tricarinata*. *Chelonian Conservation and Biology* 2(1): 66–72.

MPFS (1988). Master Plan for the Forestry Sector Nepal: Main Report. Ministry of Forests and Soil Conservation, His Majesty's Government of Nepal, Kathmandu, 186 pp.

Nishan, K.C., B. Neupane, B. Belbase, B. Dhami, B.S. Bist, C.R. Basyal & S. Bhattarai (2023). Factors influencing the habitat selection of Mugger Crocodile *Crocodylus palustris* and its conservation threats in the Rapti River of Chitwan National Park, Nepal. Global Ecology and Conservation, 42 pp. https://doi.org/10.1016/j.gecco.2023.e02406

Pandey, D.P. (2012). Snakes in the vicinity of Chitwan National Park, Nepal. *Herpetological Conservation and Biology* 7: 46–57.

Pandey, D.P., D. Jelic, S. Sapkota, H.M. Lama, B. Lama, K. Pokharel, M. Goode & U. Kuch (2018). New records of snakes from Chitwan National Park and vicinity, Central Nepal. *Herpetology Notes* 11: 679–696.

Pathak, A., A. Bashyal, B.N. Oli, B. Thapaliya, S. Bhattarai, S. Khanal & P. Paudel (2023). Understanding the perception of buffer zone communities to Gharial Gavialis gangeticus conservation in Chitwan National Park, Nepal. *Global Ecology and Conservation* 47: e02634. https://doi.org/10.1016/j.gecco.2023.e02634

Phuge, S., A.B. Patil, R. Pandit, N.U. Kulkarni, B.H.C.K. Murthy, P. Deepak & K.P. Dinesh (2020). Importance of genetic data in resolving cryptic species: a century old problem of understanding the distribution of *Minervarya syhadrensis* Annandale, 1919 (Anura: Dicroglossidae). *Zootaxa* 4869(4): 451–492. https://doi.org/10.11646/zootaxa.4869.4.1

Poudyal, L.P., B. Dahal, B.R. Lamichhane, S.R. Giri, B. Rayamajhi, P. Shrestha, B.B. Khadka & S. Bhattarai (2018). *Population Status and Distribution of Gharial in Rivers of Chitwan National Park*. Government of Nepal, Ministry of Forest and Environment, Kathmandu, Nepal, 19 pp.

Praschag, P., M.F. Ahmed, I. Das & S. Singh (2019). *Batagur kachuga*. The IUCN Red List of Threatened Species 2019: e.T10949A152043133. https://doi.org/10.2305/IUCN.UK.2019-1.RLTS.T10949A152043133.en. Accessed on 28.i.2025.

Rawat, Y.B., S. Bhattarai, L.P. Poudyal & N. Subedi (2020). Herpetofauna of Shuklaphanta National Park, Nepal. *Journal of Threatened Taxa* 12(5): 15587–15611. https://doi.org/10.11609/jott.5611.12.5.15587-15611

Schleich, H.H. & C.C. Anders (1998). *Tompterna maskeyi* spec. nov. from Nepal (Amphibia, Anura). In: Schleich, H.H. & W. Kästle (eds.). Contributions to the Herpetology of South Asia (Nepal, India). 4: 57–72.

Schleich, H.H. & W. Kästle (eds.) (2002). *Amphibians and Reptiles of Nepal*. Koenigstein: Koeltz Scientific Books, Germany, 1,200 pp.

Shah, K.B. & S. Tiwari (2004). *Herpetofauna of Nepal: A Conservation*. IUCN Nepal, Kathmandu, Nepal, 237 pp.

Smith, M.A. (1935). *The Fauna of British India, Including Ceylon and Burma. Reptilia and Amphibia, Vol. 2, Sauria*. Taylor and Francis, London, 440 pp.

Uetz, P., P. Freed, R. Aguilar, F. Reyes, J. Kudera & J. Hošek (eds.) (2025). The Reptile Database, http://www.reptile-database.org. Accessed on 08.ii.2025.

Vogel, G., A.K. Mallik, S.R. Chandramouli, V. Sharma & S.R. Ganesh (2022). A review of records of the *Trimeresurus albolabris* Gray, 1842 group from the Indian subcontinent: expanded description and range extension of *Trimeresurus salazar*, redescription of *Trimeresurus septentrionalis* and rediscovery of historical specimens of *Trimeresurus davidi* (Reptilia: Viperidae). *Zootaxa* 5175(3): 343–366. https://doi.org/10.11646/zootaxa.5175.3.2

Whitaker, R. & A. Captain (2004). *Snakes of India: The Field Guide*. Draco Books, Chennai, India, 481 pp.

Yadav, R.K., S. Lamichhane, D.R. Thanet, T. Rayamajhi, S. Bhattarai, A. Bashyal & B.R. Lamichhane (2022). Gharial (*Gavialis gangeticus* Gmelin, 1789) abundance in the Rapti River, Chitwan National Park, Nepal. *Ecology and Evolution* 12: e9425. https://doi.org/10.1002/ece3.9425

Zug, G.R. & J.C. Mitchell (1995). Amphibians and reptiles of the Royal Chitwan National Park, Nepal. *Smithsonian Herpetological Information Service* 107: 1–38.

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Author contributions: SB and BG conducted field surveys. SB generated funds, prepared manuscript, and submitted. BG, CPP and RCK reviewed the draft. CPP and RCK acquired necessary permissions for field surveys.

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ARTICLE

Butterfly diversity in Nagarahole (Rajiv Gandhi) National Park of Karnataka, India: an updated checklist

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Abstract: This study provides a comprehensive insight into the species richness and diversity of butterflies recorded from Nagarahole (Rajiv Gandhi) National Park (NNP), a protected area in southern Western Ghats of Karnataka, India. An updated checklist of 210 species, including previous records of 138 species, by adopting random and opportunistic sampling methods across different vegetation types of NNP from June 2021 to June 2023. The Nymphalidae was the most species-rich butterfly family, represented by 63 species, followed by Lycaenidae (57 species), Hesperiidae (49), Pieridae (23), Papilionidae (16), and Riodinidae (2). Of the total, 35 species are listed under various schedules of the Wildlife (Protection) Act, 1972, including the Indian Wildlife (Protection) Amendment Act, 2022. Additionally, four species are endemic to the Western Ghats. The population status of butterflies in NNP indicates that 38% of species are very common, 19% are common, 23% are not rare, and 10% are rare. However, 20 butterfly species (10%) are classified as very rare in their status. This highlights the importance of conservation measures to protect these butterfly species in this area.

Keywords: Biodiversity hotspots, butterfly status, conservation planning, Kodagu, lepidoptera, Nilgiri Biosphere Reserve, protected species, protected area, Rhopalocera, Western Ghats.

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INTRODUCTION

The Western Ghats (WG) is recognized as one of the world's eight 'hottest hotspots' with a high level of biological diversity and endemism (Myers et al. 2000). During the last century, between 1920 and 1990, approximately 40% of its natural vegetation has been lost because of forest fragmentation (Myers et al. 2000). Out of 1,85,500 km^2 of preliminary forest of WG, only 6.8% of primary forest cover exists today (Myers et al. 2000; Padhye et al. 2012) and an estimated area of approximately 40,000 km^2 in southern stretch of the WG has experienced significant land use change, and 1.16% of forest area is degraded annually due to deforestation, and other anthropogenic activities (Jha et al. 2000). Presently, only 10% of its land cover is under protection and there are fewer opportunities to keep large tracts of native habitats (Dolia et al. 2008). Nagarahole National Park (NNP) is one of the largest Protected Areas (PA) in the southern zone of WG and harbours rich irreplaceable flora & fauna assemblages, which therefore warrant conservation importance for protection, and management.

Biodiversity inventories, carefully tested for their potential to serve as proxies for estimating general health, and conservation of overall biodiversity, and as indicators for various terrestrial ecosystems at multiple spatial scales (McGeoch 1998; Kerr et al. 2000; Naik et al. 2022), suggests that butterflies meet many of the criteria proposed for defining a definitive path in conservation planning (Ehrlich & Murphy 1987; Nelson & Andersen 1994; DeVries et al. 1997; Lomov et al. 2006; Bhuyan et al. 2013). Butterflies are often highly co-evolved with plants for their larval host and nectar plant needs, and their diversity will directly depict the plant diversity in the given area (Ehrlich & Raven 1964; Ehrlich & Murphy 1987; Nelson & Andersen 1994; DeVries et al. 1997; Hayes et al. 2009). They are very sensitive to microclimatic variations in their habitat (Kocher & Williams 2000; Sawchik et al. 2005), many of the species are strictly seasonal (Kunte 1997), migratory or locally extinct (Kunte 2000; Schtickzelle et al. 2006). Thus, butterflies are used as an umbrella group of species for insects' conservation planning, and management (Fleishman et al. 2001, 2005; Betrus et al. 2005).

India being a vast country with one of the most varied flora and fauna in the world (Rodgers 1989) hosts about 1,403 species of butterflies (Smetacek 2025) and accounts for about 8.7% of the butterfly species of the world (Kunte 2005). Out of these 1,403 species, 350 species are recorded from peninsular India, Pandhye et al. (2012) reported 334 species from Western Ghats. A more recent update by Sadasivan & Sengupta (2024) of 353 species from WG, of which 317 species, including 33 endemics to Karnataka, and 42 species are endemic to southern India (Rajagopal et al. 2011). Recently, Padhye et al. (2012) have revised the distribution and abundance of butterfly species along the latitudinal and habitat gradients in the WG, Kunte et al. (2024) has recently described new species *Cigaritis conjuncta* species from Honey Valley, which is part of the WG in Kodagu District, Karnataka, and Naicker et al. (2023) has described *Cigaritis meghamalaiensis* (Lycaenidae, Aphnaeinae) from the Meghamalai Hills of the Periyar landscape of the southern WG. But increasing global habitat destruction has resulted in modern studies of species diversity which are of vital importance in understanding biological communities and their conservation (Purvis & Hector 2000). The present study has aided a lot in the knowledge of butterfly species' diversity, and a sustained exploration was undertaken from June 2021 to June 2023 across different habitats of NNP.

MATERIAL AND METHODS

Study area

Nagarahole National Park (NNP) or Rajiv Gandhi National Park is located in Kodagu and Mysuru districts of Karnataka State, India with a coordinate of 76.116–75.929° E, 11.836–12.346° N at 700–1002 m altitude with an area of 843 km^2, and is bordered by Wayanad Wildlife Sanctuary in the south-west, and by Kabini Reservoir in the southeast which further connects to Bandipur Tiger Reserve (Figure 1). Nagarhole National Park, which was established as a Wildlife Sanctuary (WS) in 1955, and NP in 1988 is one of the most important wildlife refuges in the country. The National Park derives its name from the meandering stream '*Nagarahole*', a tributary of the river Taraka which eventually joins the river Kabini. The forest type of NNP is majorly composed of moist deciduous, dry deciduous, scrub, and semi evergreen vegetation (Champion & Seth 1968) followed by very small portions of evergreen forest type at 1,002 m. The mean annual rainfall ranges from 900 mm in the east to 1,500 mm in the west (Habib et al. 2020).

Methods

We studied the butterfly diversity across eight forest ranges, viz., Anechowkur, Antharasanthe, D.B.

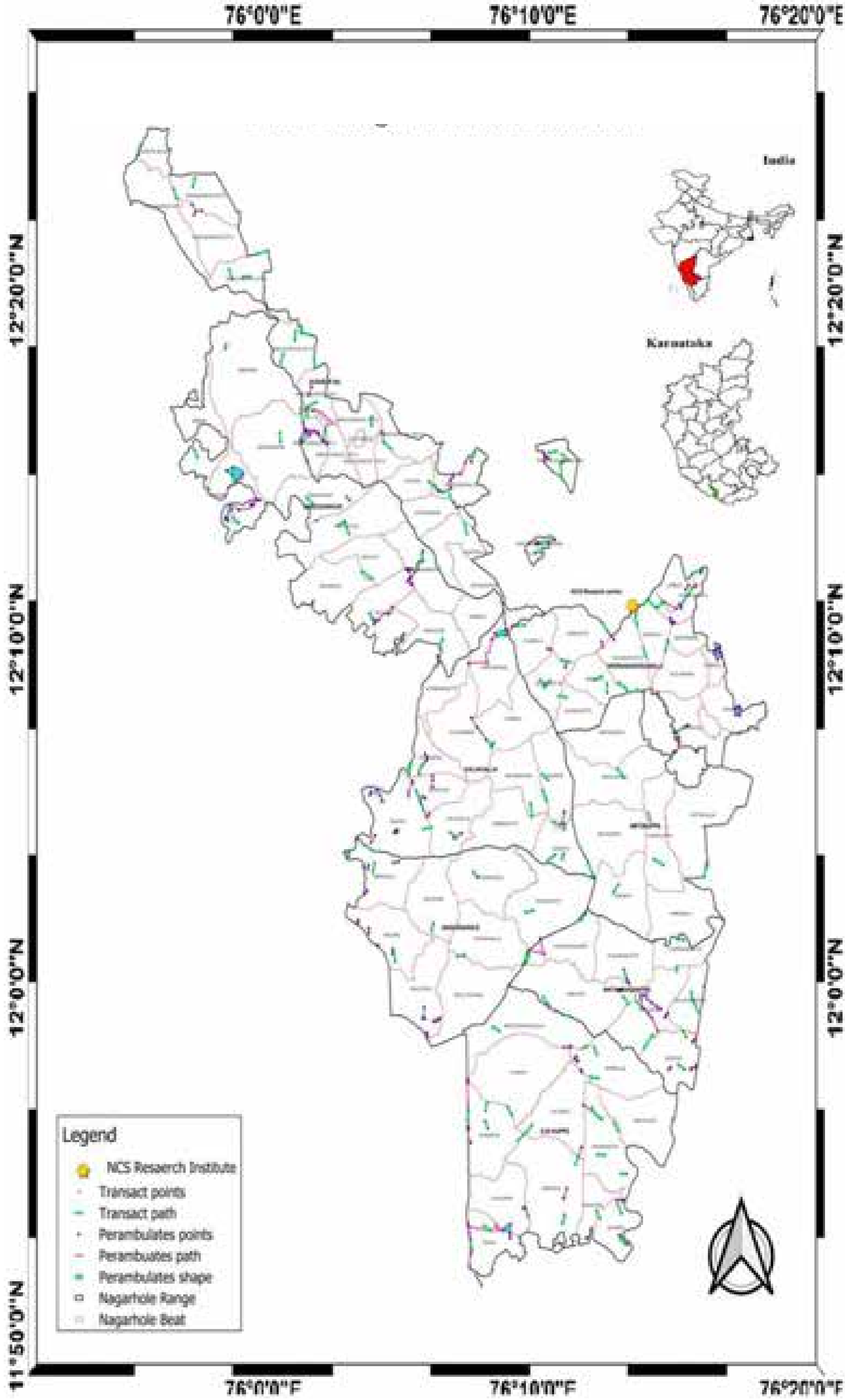

Figure 1. Transects and perambulated sites at different areas of Nagarahole National Park.

Kuppe, Hunsuru (Hunsuru Wildlife Range), Kallahalla, Metikuppe, Nagarahole, and Veeranahosahalli of NNP. A total of 189 random transects were established for sampling butterflies from June 2021–June 2023, across different seasons (Monsoon, Winter and Summer) (Figure 1). Modified Pollard Walk method (Caldas & Robbins 2003) was followed for recording butterflies while walking along fixed transects. The length of each transect was 500 m, and they were traversed in a time frame of 45 minutes during two periods: from 0900–1300 h and from 1500–1800 h. Butterflies within a 5 x 5 x 5 m box around the observer were recorded. In addition to conducting transects, we also executed opportunistic surveys at mud puddles, nectar sources, jeep roads, fire lines, D lines (Dividing lines between the two ranges and beats) and other potential areas to increase the inventory (Figure 1). Photographic documentation was made using Canon and Nikon DSLR cameras, and all the photographs are copyright to Nagarahole Conservation Society (NCS), Bangalore. Butterflies were identified in the field using different field guides by Evans (1932), Wynter-Blyth (1957), Kehimkar (2016), and Bhakare & Ogale (2018). The classification followed guidelines outlined by Heppner (1998) and recent nomenclature was followed as per Sadasivan & Sengupta (2024). The protected butterfly species are recorded as per different schedules of WPA 1997 and The Indian Wildlife (Protection) Amendment Act, 2022, and population status of butterflies at NNP based on the occurrence data on the transects with status as Very Common (VC) when seen in >75% of transects, Common (C) seen in 50–75%, Not Rare (NR) seen in 25–50% transects, Rare (R) seen in 5–25%, and Very Rare (VR) is seen in <5% of the transects (Sadasivan & Sengupta 2024).

RESULTS

Analyses of results suggest that NNP is rich in butterfly diversity with 210 species, including 138 species from previous records of Basavarajappa (2015). These species belong to six families and 127 genera (Table 1), with 73 species added to the earlier record. Nymphalidae was the largest representative family with (63) species followed by Lycaenidae (57) species, Hesperiidae (49 species), Pieridae (23 species), Papilionidae (16 species), and Riodinidae (2 species), which correspond to about 59.49% of the estimated species of the WG, and 24% of the state of Karnataka. *Gerosis bhagava bhagava* (Moore, [1866]) was recorded in the earlier study by Basavarajappa (2015), it was not sighted during the present investigation. The population status of butterflies in NNP indicates that 38% of species are very common, 19% are common, 23% are not rare, and 10% are rare. However, twenty butterfly species (10%) are classified as very rare in their status, among which *Appias* (*Hiposcritia*) *indra shiva* (Swinhoe, 1885), *Elymnias caudata* (Butler, 1871), *Athyma ranga karwara* (Fruhstorfer, 1906), *Dophla evelina laudabilis* (Swinhoe, 1890), *Charaxes solon solon* (Fabricius, 1793), *Kallima horsfieldii* (Kollar, 1844), *Libythea myrrha rama* (Moore, 1872), *Thaduka multicaudata kanara* (Evans, 1925), *Zesius chrysomallus* (Hübner, 1819), *Rachana jalindra macanita* (Fruhstorfer, 1912), *Tajuria cippus cippus* (Fabricius, 1798), *Creon cleobis cleobis* (Godart, 1824), *Tarucus ananda* (de Nicéville, 1884), and *Thoressa astigmata* (Swinhoe, 1890) were recorded only once or twice during two years of study period.

Members of the subfamily Danaine, such as *Tirumala limniace exoticus* (Gmélin, 1790), *T. septentrionis dravidarum* (Fruhstorfer, 1899), *Euploea core core* (Cramer, 1780) and *E. sylvester coreta* (Godart, 1819) were most frequently recorded on *Heliotrophium indicum*, and *Crotolaria* plant species during the months between October and February. These butterflies are known to migrate from the WG during the pre-monsoon period in May. Among the 210 butterflies recorded from NNP, 35 species like *Graphium teredon* (Felder & Felder, 1865), *Papilio clytia clytia* (Linnaeus, 1758), *Troides minos* (Cramer, 1779), *P. crino* (Fabricius, 1793), *P. buddha* (Westwood, 1872), *Pachliopta hector* (Linnaeus, 1758), *Eurema* (*Terias*) *andersoni shimai* (Yata & Gaonkar, 1999), *Appias* (*Catophaga*) *albina swinhoei* (Moore, 1905), *Appias lyncida latifasciata* (Moore, 1881), *Appias* (*Hiposcritia*) *indra shiva* (Swinhoe, 1885), *Charaxes bharata* (Felder & Felder, 1867), *C. solon solon* (Fabricius, 1793), *C. psaphon imna* (Butler, 1870), *Lethe europa europa* (Fabricius, 1775). *Athyma ranga karwara* (Fruhstorfer, 1906), *Neptis jumbah nalanda* (Fruhstorfer, 1908), *Phaedyma columella nilgirica* (Moore, 1889), *Euthalia aconthea meridionalis* (Fruhstorfer, 1906), *Tanaecia lepidea miyana* (Fruhstorfer, 1913), *Dophla evelina laudabilis* (Swinhoe, 1890), *Hypolimnas misippus* (Linnaeus, 1764), *Kallima horsfieldii* (Kollar, 1844), *Arhopala alea* (Hewitson, 1862), *Thaduka multicaudata kanara* (Evans, 1925), *Catapaecilma major callone* (Fruhstorfer, 1915), *Tajuria cippus cippus* (Fabricius, 1798), *Hypolycaena othona othona* (Hewitson, 1865), *Rapala varuna lazulina* (Moore, 1879), *Cigaritis lohita lazularia* (Moore, 1881), *Anthene lycaenina lycaenina* (Felder, 1868), *Prosotas dubiosa indica* (Evans, 1925), *P. noreia hampsonii* (de Nicéville, 1885), *Jamides*

Table 1. Checklist of butterfly species recorded during study period (2021–2023) in Nagarahole National Park.

	Taxon		WLPA	EN	ST
	Family: Papilionidae				
1	*Graphium agamemnon menides* (Fruhstorfer, 1904)	Dakhan Tailed Jay			VC
2	*Graphium teredon* (Felder & Felder, 1865)	Narrow Banded Bluebottle	Sch II		C
3	*Graphium doson eleius* (Fruhstorfer, 1907)	Dakhan Common Jay			VC
4	*Graphium nomius nomius* (Esper, 1799)	Indian Spot Swordtail			R
5	*Papilio clytia clytia* (Linnaeus, 1758)	Oriental Common Mime	Sch II		R
6	*Papilio dravidarum* (Wood-Mason, 1880)	Malabar Raven			R
7	*Papilio polytes romulus* (Cramer, 1775)	Indian Common Mormon			VC
8	*Papilio agenor polymnestor* (Cramer, 1775)	Indian Blue Mormon			VC
9	*Papilio daksha daksha* (Moore, 1889)	Sahyadri Large-spotted Helen			C
10	*Papilio demoleus demoleus* (Linnaeus, 1758)	Lime Swallowtail			VC
11	*Troides minos* (Cramer, 1779)	Sahyadri Birdwing	Sch II & IV		NR
12	*Papilio paris tamilana* (Moore, 1881)	Sahyadri Paris Peacock			NR
13	*Papilio crino* (Fabricius, 1793)	Common Banded Peacock	Sch II		NR
14	*Papilio buddha* (Westwood, 1872)	Malabar Banded Peacock	Sch II	EWG	VR
15	*Pachliopta aristolochiae aristolochiae* (Fabricius, 1775)	Indian Common Rose			C
16	*Pachliopta hector* (Linnaeus, 1758)	Crimson Rose	Sch II		VC
	Family: Pieridae				
17	*Eurema* (*Teriasi hecabe hecabe* (Linnaeus, 1758)	Oriental Common Grass Yellow			VC
18	*Eurema* (*Terias*) *andersoni shimai* (Yata & Gaonkar, 1999)	Sahyadri One-spot Grass Yellow	Sch II		C
19	*Eurema* (*Terias*) *blanda silhetana* (Wallace, 1867)	Sylhet Three-spot Grass Yellow			VC
20	*Eurema laeta laeta* (Boisduval, 1836)	Indian Spotless Grass Yellow			NR
21	*Eurema drona rubella* (Wallace, 1867)	Red-line Small Grass Yellow			NR
22	*Catopsilia pyranthe pyranthe* (Linnaeus, 1758)	Oriental Mottled Emigrant			VC
23	*Catopsilia pomona pomona* (Fabricius, 1775)	Oriental Lemon Emigrant			VC
24	*Colotis amata amata* (Fabricius, 1775)	Desert Small Salmon Arab			NR
25	*Colotis danae danae* (Fabricius, 1775)	Indian Crimson-tip			NR
26	*Colotis etrida etrida* (Boisduval, 1836)	Indian Little Orange-tip			C
27	*Colotis aurora* (Cramer, 1780)	Plain Orange Tip			C
28	*Ixias marianne* (Cramer, 1779)	White Orange-tip			C
29	*Ixias pyrene sesia* (Fabricius, 1777)	Dakhan Yellow Orange-tip			VC
30	*Hebomoia glaucippe australis* (Butler, 1898)	Oriental Great Orange-tip			C
31	*Leptosia nina nina* (Fabricius, 1793)	Oriental Psyche			VC
32	*Pareronia hippia* (Fabricius, 1787)	Indian Wanderer			NR
33	*Appias* (*Catophaga*) *albina swinhoei* (Moore, 1905)	Sahyadri Common Albatross	Sch II		NR
34	*Appias libythea* (Fabricius, 1775)	Western Striped Albatross			NR
35	*Appias lyncida latifasciata* (Moore, 1881)	Sahyadri Chocolate Albatross	Sch II		R
36	*Appias* (*Hiposcritia*) *indra shiva* (Swinhoe, 1885)	Sahyadri Plain Puffin	Sch II		VR
37	*Cepora nerissa phryne* (Fabricius, 1775)	Dakhan Common Gull			VC
38	*Belenois aurota aurota* (Fabricius, 1793)	Indian Pioneer			VC
39	*Delias eucharis* (Drury, 1773)	Indian Jezebel			VC
	Family: Nymphalidae				
40	*Danaus genutia genutia* (Cramer, 1779)	Oriental Striped Tiger			VC

	Taxon		WLPA	EN	ST
41	*Danaus chrysippus chrysippus* (Linnaeus, 1758)	Oriental Plain Tiger			VC
42	*Tirumala limniace exoticus* (Gmélin, 1790)	Oriental Blue Tiger			VC
43	*Tirumala septentrionis dravidarum* (Fruhstorfer, 1899)	Dakhan Dark Blue Tiger			VC
44	*Parantica aglea aglea* (Stoll, 1782)	Coromandel Glassy Tiger			C
45	*Euploea core core* (Cramer, 1780)	Indian Common Crow			VC
46	*Euploea sylvester coreta* (Godart, 1819)	Double-branded Black Crow			C
47	*Euploea klugii kollari* (Felder & Felder, 1865)	Brown King Crow			R
48	*Charaxes bharata* (Felder & Felder, 1867)	Indian Nawab	Sch II		C
49	*Charaxes solon solon* (Fabricius, 1793)	Pale Black Rajah	Sch II		NR
50	*Charaxes psaphon imna* (Butler, 1870)	Indian Plain Tawny Rajah	Sch II		NR
51	*Discophora lepida lepida* (Moore, 1857)	Sahyadri Duffer			R
52	*Melanitis leda leda* (Linnaeus, 1758)	Oriental Common Evening Brown			VC
53	*Melanitis phedima varaha* (Moore, 1857)	Sahyadri Dark Evening Brown			NR
54	*Lethe europa europa* (Fabricius, 1775)	Dakhan Bamboo Treebrown	Sch I & II		NR
55	*Lethe rohria neelgheriensis* (Guérin-Méneville, 1843)	Dakhan Common Treebrown			C
56	*Lethe drypetis todara* (Moore, 1881)	Dakhan Two-eyed Treebrown			NR
57	*Elymnias caudata* (Butler, 1871)	Tailed Palmfly			VR
58	*Mycalesis perseus tabitha* (Fabricius, 1793)	Dakhan Common Bushbrown			VC
59	*Mycalesis mineus polydecta* (Cramer, 1777)	Dakhan Dark-branded Bushbrown			VC
60	*Mycalesis visala visala* (Moore, 1858)	Indian Long-branded Bushbrown			C
61	*Mycalesis subdita* (Moore, 1890)	Tamil Bushbrown			R
62	*Mycalesis orcha* (Evans, 1912)	Pale-brand Bushbrown		EWG	NR
63	*Mycalesis patnia junonia* (Butler, 1868)	Malabar Glad-eye Bushbrown			VC
64	*Orsotriaena medus mandata* (Moore, 1857)	Sahyadri Medus Brown			VC
65	*Ypthima asterope mahratta* (Moore, 1884)	Indian Common Three-ring			VC
66	*Ypthima huebneri* (Kirby, 1871)	Common Four-ring			VC
67	*Ypthima ceylonica* (Hewitson, 1865)	White Four-ring			C
68	*Ypthima baldus madrasa* (Evans, 1923)	Sahyadri Common Five-ring			VC
69	*Ypthima striata* (Hampson, 1888)	Striated Five-ring			R
70	*Acraea terpsicore* (Linnaeus, 1758)	Tawny Coster			VC
71	*Cirrochroa thais thais* (Fabricius, 1787)	Sahyadri Yeoman			C
72	*Cupha erymanthis maja* (Fruhstorfer, 1898)	Sahyadri Rustic			VC
73	*Phalanta phalantha phalantha* (Drury, 1773)	Oriental Common Leopard			VC
74	*Moduza procris undifragus* (Fruhstorfer, 1906)	Sahyadri Commander			C
75	*Athyma ranga karwara* (Fruhstorfer, 1906)	Karwar Blackvein Sergeant	Sch II		R
76	*Athyma selenophora kanara* (Evans, 1924)	Sahyadri Staff Sergeant			C
77	*Athyma inara inara* (Westwood, 1850)	Himalayan Colour Sergeant			NR
78	*Neptis hylas varmona* (Moore, 1872)	Indian Common Sailer			VC
79	*Neptis nata hampsoni* (Moore, 1899)	Sahyadri Clear Sailer			C
80	*Neptis jumbah nalanda* (Fruhstorfer, 1908)	Nalanda Chestnut-streaked Sailer	Sch II		C
81	*Phaedyma columella nilgirica* (Moore, 1889)	Dakhan Short-banded Sailer	Sch II		NR
82	*Pantoporia hordonia hordonia* (Stoll, 1790)	Oriental Common Lascar			VC
83	*Euthalia aconthea meridionalis* (Fruhstorfer, 1906)	Dakhan Common Baron	Sch II		C
84	*Euthalia lubentina arasada* (Fruhstorfer, 1913)	Sahyadri Gaudy Baron			R

	Taxon		WLPA	EN	ST
85	*Symphaedra nais* (Forster, 1771)	Baronet			VC
86	*Tanaecia lepidea miyana* (Fruhstorfer, 1913)	Peninsular Grey Count	Sch II		C
87	*Dophla evelina laudabilis* (Swinhoe, 1890)	Sahyadri Redspot Duke	Sch II		VR
88	*Cyrestis thyodamas indica* (Evans, 1924)	Indian Map Butterfly			NR
89	*Ariadne merione merione* (Cramer, 1777)	Dakhan Common Castor			VC
90	*Ariadne ariadne indica* (Moore, 1884)	Indian Angled Castor			VC
91	*Kaniska canace viridis* (Evans, 1924)	Sahyadri Blue Admiral			VR
92	*Vanessa indica pholoe* (Fruhstorfer, 1912)	Sahyadri Red Admiral			VR
93	*Junonia orithya swinhoei* (Butler, 1885)	Pale Blue Pansy			VC
94	*Junonia hierta hierta* (Fabricius, 1798)	Oriental Yellow Pansy			VC
95	*Junonia iphita iphita* (Cramer, 1779)	Oriental Chocolate Pansy			VC
96	*Junonia atlites atlites* (Linnaeus, 1763)	Oriental Grey Pansy			VC
97	*Junonia almana almana* (Linnaeus, 1758)	Oriental Peacock Pansy			VC
98	*Junonia lemonias lemonias* (Linnaeus, 1758)	Chinese Lemon Pansy			VC
99	*Hypolimnas bolina jacintha* (Drury, 1773)	Oriental Great Eggfly			VC
100	*Hypolimnas misippus* (Linnaeus, 1764)	Danaid Eggfly	Sch II		VC
101	*Kallima horsfieldii* (Kollar, 1844)	Sahyadri Blue Oakleaf	Sch II		VR
102	*Libythea myrrha rama* (Moore, 1872)	Sri Lankan Club Beak			VR
	Family: Lycaenidae				
103	*Curetis thetis* (Drury, 1773)	Indian Sunbeam			NR
104	*Curetis acuta dentata* (Moore, 1879)	Indian Acute Sunbeam			C
105	*Spalgis epius epius* (Westwood, [1851])	Oriental Apefly			R
106	*Arhopala centaurus pirama* (Moore, 1881)	Tamil Centaur Oakblue			VR
107	*Arhopala alea* (Hewitson, 1862)	Sahyadri Rosy Oakblue	Sch I		VR
108	*Thaduka multicaudata kanara* (Evans, 1925)	Karwar Many-tailed Oakblue	Sch II		VR
109	*Zesius chrysomallus* (Hübner, 1819)	Redspot			VR
110	*Amblypodia anita dina* (Fruhstorfer, 1907)	Indian Purple Leaf Blue			VC
111	*Horaga onyx onyx* (Moore, 1858)	Variable Common Onyx			VR
112	*Loxura atymnus atymnus* (Stoll, 1780)	Sahyadri Yamfly			R
113	*Catapaecilma major callone* (Fruhstorfer, 1915)	Sahyadri Common Tinsel	Sch II		NR
114	*Rathinda amor* (Fabricius, 1775)	Monkey Puzzle			NR
115	*Rachana jalindra macanita* (Fruhstorfer, 1912)	Sahyadri Banded Royal			VR
116	*Tajuria cippus cippus* (Fabricius, 1798)	Indian Peacock Royal	Sch II		VR
117	*Creon cleobis cleobis* (Godart, 1824)	Bengal Broad-tail Roya			VR
118	*Hypolycaena othona othona* (Hewitson, 1865)	Oriental Orchid Tit	Sch I		NR
119	*Virachola isocrates* (Fabricius, 1793)	Common Guava Blue			R
120	*Deudorix epijarbas epijarbas* (Moore, 1857)	Oriental Cornelian			R
121	*Rapala manea schistacea* (Moore, 1879)	Bengal Slate Flash			VC
122	*Rapala varuna lazulina* (Moore, 1879)	Lazuli Flash	Sch II		VC
123	*Cigaritis lohita lazularia* (Moore, [1881])	Tamil Long-banded Silverline	Sch II		R
124	*Cigaritis vulcanus vulcanus* (Fabricius, 1775)	Indian Common Silverline			R
125	*Cigaritis schistacea* (Moore, 1881)	Plumbeous Silverline			R
126	*Leptotes plinius plinius* (Fabricius, 1793)	Asian Zebra Blue			VC
127	*Anthene emolus emolus* (Godart, 1824)	Bengal Common Ciliate Blue			C

	Taxon		WLPA	EN	ST
128	*Anthene lycaenina lycaenina* (Felder, 1868)	Dakhan Pointed Ciliate Blue	Sch II		VC
129	*Caleta decidia* (Hewitson, 1876)	Angled Pierrot			VC
130	*Discolampa ethion ethion* (Westwood, 1851)	Oriental Banded Blue Pierrot			VC
131	*Castalius rosimon rosimon* (Fabricius, 1775)	Continental Common Pierrot			VC
132	*Tarucus ananda* (de Nicéville, 1884)	Dark Pierrot			VR
133	*Petrelaea dana* (de Nicéville, 1884)	Dingy Lineblue			VC
134	*Nacaduba kurava canaraica* (Toxopeus, 1927)	Karwar Transparent Six-Lineblue			NR
135	*Nacaduba beroe gythion* (Fruhstorfer, 1916)	Assam Opaque Six-Lineblue			NR
136	*Prosotas nora ardates* (Moore, 1875)	Indian Common Lineblue			VC
137	*Prosotas dubiosa indica* (Evans, 1925)	Indian Tailless Lineblue	Sch II		VC
138	*Prosotas noreia hampsonii* (de Nicéville, 1885)	Indian White-tipped Lineblue	Sch II		NR
139	*Jamides bochus bochus* (Stoll, 1782)	Indian Dark Cerulean			VC
140	*Jamides celeno celeno* (Cramer, 1775)	Oriental Common Cerulean			VC
141	*Jamides alecto eurysaces* (Fruhstorfer, 1915)	Himalayan Metallic Cerulean	Sch II		NR
142	*Catochrysops strabo strabo* (Fabricius, 1793)	Oriental Forget-me-not			VC
143	*Talicada nyseus nyseus* (Guérin-Méneville, 1843)	Indian Red Pierrot			C
144	*Lampides boeticus* (Linnaeus, 1767)	Pea Blue			VC
145	*Pseudozizeeria maha ossa* (Swinhoe, 1885)	Dakhan Pale Grass Blue			VC
146	*Zizeeria karsandra* (Moore, 1865)	Dark Grass Blue			VC
147	*Zizina otis indica* (Murray, 1874)	Indian Lesser Grass Blue			VC
148	*Zizula hylax hylax* (Fabricius, 1775)	Indian Tiny Grass Blue			VC
149	*Freyeria putli* (Kollar, 1844)	Black-spotted Grass Jewel			VC
150	*Azanus jesous gamra* (Lederer, 1855)	Syrian Babul Blue			NR
151	*Cupido lacturnus syntala* (Cantlie, 1963)	Dakhan Orange-crowned Cupid			VC
152	*Chilades parrhasius parrhasius* (Fabricius, 1793)	Parrhasius Small Cupid			VC
153	*Euchrysops cnejus cnejus* (Fabricius, 1798)	Oriental Gram Blue			VC
154	*Chilades lajus lajus* (Stoll, 1780)	Indian Lime Blue			VC
155	Neopithecops zalmora dharma (Moore, 1881)	Sri Lankan Common Quaker			VC
156	*Megisba malaya thwaitesi* (Moore, 1881)	Tailless Malayan	Sch II		VC
157	*Acytolepis puspa felderi* (Toxopeus, 1927)	Common Hedge Blue			C
158	*Celastrina lavendularis lavenduris* (Moore, 1877)	Sri Lankan Plain Hedge Blue			NR
159	*Udara akasa mavisa* (Fruhstorfer, [1917])	Sahyadri White Hedge Blue			NR
	Family: Riodinidae				
160	*Abisara bifasciata suffusa* (Moore, 1882)	Suffused Double-banded Judy			VC
161	*Abisara echerius prunosa* (Moore, 1879)	Lankan Plum Judy			NR
	Family: Hesperiidae				
162	*Hasora chromus chromus* (Cramer, 1780)	Oriental Common Banded Awl			VC
163	*Badamia exclamationis* (Fabricius, 1775)	Brown Awl			VC
164	*Abaratha angulata angulata* (Felder, 1862)	Oriental Chestnut Angle			NR
165	*Abaratha ransonnettii potiphera* (Hewitson, 1873)	Dakhan Golden Angle			NR
166	*Sarangesa dasahara davidsoni* (Swinhoe, 1912)	Indian Common Small Flat			C
167	*Sarangesa purendra hopkinsi* (Evans, 1921)	Dakhan Spotted Small Flat			NR
168	*Pseudocoladenia dan* (Fabricius, 1787)	Fulvous Pied Flat			C
169	*Coladenia indrani indra* (Evans, 1926)	Dakhan Tricolour Pied Flat			C

	Taxon		WLPA	EN	ST
170	*Gerosis bhagava bhagava* (Moore, 1866)	Bengal Common Yellow-breasted Flat			VR
171	*Tagiades litigiosa litigiosa* (Möschler, 1878)	Sylhet Water Snow Flat			NR
172	*Tagiades silvia* (Evans, 1934)	Dakhan Suffused Snow Flat			C
173	*Tagiades obscurus* (Mabille, 1876)	Common Snow Flat			C
174	*Spialia galba galba* (Fabriciuc 1793)	Indian Grizzled Skipper			VC
175	*Taractrocera maevius* (Fabricius, 1793)	Grey-veined Grass Dart			VC
176	*Cupitha purreea* (Moore, 1877)	Wax Dart			VR
177	*Telicota bambusae bambusae* (Moore, 1878)	Oriental Dark Palm-Dart			R
178	*Telicota colon colon* (Fabricius, 1775)	Indian Pale Palm-Dart			R
179	*Cephrenes acalle oceanica* (Mabille, 1904)	Variable Plain Palm-Dart			R
180	*Oriens goloides* (Moore, 1881)	Smaller Dartlet			C
181	*Oriens concinna* (Elwes & Edwards, 1897)	Sahyadri Dartlet		EWG	NR
182	*Potanthus pseudomaesa* (Moore, 1881)	Common Dart			VC
183	*Potanthus palnia palnia* (Evans, 1914)	Palni Dart			NR
184	*Potanthus diana* (Evans, 1932)	Chinese Dart			NR
185	*Potanthus pava pava* (Fruhstorfer, 1911)	Pava Dart			NR
186	*Gangara thyrsis thyrsis* (Fabricius, 1775)	Oriental Giant Redeye			R
187	*Borbo cinnara* (Wallace, 1866)	Rice Swift			C
188	*Pseudoborbo bevani* (Moore, 1878)	Bevan's Swift			C
189	*Parnara bada bada* (Moore, 1878)	Ceylon Swift			C
190	*Parnara ganga* (Evans, 1937)	Continental Swift			C
191	*Baoris farri* (Moore, 1878)	Paint-brush Swift			C
192	*Caltoris canaraica* (Moore, 1884)	Karwar Swift			C
193	*Caltoris kumara kumara* (Moore, 1878)	Sahyadri Blank Swift			NR
194	*Caltoris philippina philippina* (Herrich-Schäffer, 1869)	Continental Philippine Swift			NR
195	*Pelopidas subochracea subochracea* (Moore, 1878)	Bengal Large Branded Swift			NR
196	*Pelopidas mathias mathias* (Fabricius, 1798)	Dakhan Small Branded Swift			NR
197	*Pelopidas agna agna* (Moore, 1866)	Bengal Obscure Branded Swift			NR
198	*Pelopidas conjuncta narooa* (Moore, 1878)	Sahyadri Conjoined Swift			NR
199	*Polytremis lubricans lubricans* (Herrich-Schäffer, 1869)	Oriental Contiguous Swift			R
200	*Ampittia dioscorides dioscorides* (Fabricius, 1793)	Indian Bush Hopper			VC
201	*Aeromachus pygmaeus* (Fabricius, 1775)	Pygmy Scrub Hopper			VC
202	*Iambrix salsala luteipalpis* (Plötz, 1886)	Southern Chestnut Bob			VC
203	*Suastus gremius gremius* (Fabricius, 1798)	Indian Palm Bob			NR
204	*Arnetta vindhiana* (Moore, 1884)	Vindhyan Bob			NR
205	*Ancistroides curvifascia curvifascia* (Felder & Felder, 1862)	Restricted Demon			C
206	*Ancistroides paralysos mangla* (Evans, 1949)	Common Banded Demon			C
207	*Ancistroides folus* (Cramer, 1775)	Grass Demon			VC
208	*Halpe hindu* (Evans, 1937)	Sahyadri Banded Ace	Sch II		NR
209	*Halpe porus* (Mabille, 1877)	Bispot Banded Ace			R
210	*Thoressa astigmata* (Swinhoe, 1890)	Southern Spotted Ace		EWG	VR

Note: Legal protection status as per the Wildlife Protection Act (1972) and the Wildlife (Protection) Amendment Act, 2022 (WPA), WLPA Schedules (Sch.). Status of butterflies at Nagarahole National Park with their population status (ST): VC—Very common | C—Common | NR—Not Rare | R—Rare | VR—Very Rare | EWG—Endemic to Western Ghats.

alecto eurysaces (Fruhstorfer, 1915), *Megisba malaya thwaitesi* (Moore, 1881), and *Halpe hindu* (Evans, 1937) are enlisted under different schedules of WPA 1972 and The Indian Wildlife (Protection) Amendment Act, 2022. However, four species *Papilio buddha* (Westwood, 1872), *Mycalesis orcha* (Evans, 1912), *Oriens concinna* (Elwes & Edwards, 1897), and *Thoressa astigmata* (Swinhoe, 1890) are endemic to the WG (Sadasivan & Sengupta 2024).

DISCUSSION

A thorough investigation of regional biodiversity is essential before implementing conservation measures for the respective taxa of interest. The present study provides comprehensive baseline data on butterfly diversity in NNP, a regional segment of the WG. Peninsular India hosts 350 species (Padhya et al. 2012) and more recent update by Sadasivan & Sengupta (2024) of 353 species from WG, of which 317 species including 33 endemics to Karnataka. We did not expect to record as many butterfly species in smaller sites like NNP, as it lacks evergreen and shola forests at higher elevations (>1,000 m). The area is mainly composed of dry deciduous, moist deciduous, and scrub forests. However, our study documented 210 butterfly species. The total numbers of species reflect their family-wise richness for the subtropical regions of southern WG, which is a part of Karnataka. The 210 species recorded correspond to about 59.49% of the estimated species of the WG and 66. 24% of the state of Karnataka.

During the present investigation 38% of species were found to be very common, 19% common, 23% not rare, and 10% are rare, while 20 species (10%) were classified as very rare to their population status. *Papilio dravidarum* (Wood-Mason, 1880), *Papilio buddha* (Westwood, 1872), *Discophora lepida lepida* (Moore, 1857), *Lethe europa europa* (Fabricius, 1775), *Athyma ranga karwara* (Fruhstorfer, 1906), *Euthalia lubentina arasada* (Fruhstorfer, 1913), *Dophla evelina laudabilis* (Swinhoe, 1890), *Kallima horsfieldii* (Kollar, 1844), *Rachana jalindra macanita* (Fruhstorfer, 1912), *Tajuria cippus cippus* (Fabricius, 1798), *Creon cleobis cleobis* (Godart, 1824), *Tarucus ananda* (de Nicéville, 1884), *Abisara echerius prunosa* (Moore, 1879), and *Gerosis bhagava bhagava* (Moore, 1866) were recorded predominantly in moist deciduous forest of NNP. Whereas *Horaga onyx onyx* (Moore, 1858), *Catapaecilma major callone* (Fruhstorfer, 1915), *Appias (Hiposcritia) indra shiva* (Swinhoe, 1885), and *Libythea myrrha rama* (Moore, 1872) are recorded very rarely towards Coorg (Kodagu) part of NNP. But *Elymnias caudata* (Butler, 1871) was recorded towards the fringe areas of the forest towards Veeranahosahalli Range of NNP. The distribution pattern of these butterflies emphasizes the need for further studies and conservation measures.

Studies of Kunte (2005) and Vinayan et al. (2023) have documented the migration of *Tirumala limniace exoticus* (Gmélin, 1790), *T. septentrionis dravidarum* (Fruhstorfer, 1899), *Euploea core core* (Cramer, 1780) and *E. sylvester coreta* (Godart, 1819) from WG to eastern plains, likely to avoid the extreme conditions of the south-west monsoon. The congregation of these butterflies on *Heliotrophium indicum* and *Crotolaria* plant species during the months of October to February observed in the present study is consistent with these earlier findings. Vinayan et al. (2023) recorded breeding activity of *E. core* in the Wayanad Forest Division, highlighting the need for further studies to confirmation of breeding of these species within NNP.

Additionally, this number contributes to the existing tally of 138 species of butterflies reported from Basavarajappa (2015) at NNP. The species diversity includes 35 species which are listed under Schedules I & II of WPA 1972 and The Indian Wildlife (Protection) Amendment Act, 2022 and four species are endemic to the WG. This could help to develop better conservation measures for the protected and endemic butterfly species in their natural habitats. Thus, NNP not only possesses large number of legally protected butterfly species but also supports enough endemic species indicating the vegetation richness of the forest. Therefore, NNP should be considered as top priority within the protected areas of southern WG for long term conservation of butterfly species to avoid regional extinction and safeguard butterflies against human induced disturbances (Watson et al. 2014; Maxwell et al. 2020). Further, information on habitat preference, distribution, seasonality, larval host plants distribution, and status of endemic, and protected species listed under the Wildlife (Protection) Amendment Act, 2022, are still lacking as their diversity is largely dependent on floral richness (Gordon & Kerr 2022). Therefore, a more thorough study would surely result in identification of more species at NNP and there is a further need for periodic assessment of habitat, and host plant preferences which will help enhance the depth of historical data, and be used as an elementary tool to mitigate species loss, and plan further conservation measures.

Image 1–15. 1—*Graphium agamemnon menides* | 2—*Graphium teredon* | 3—*Graphium doson eleius* | 4—*Graphium nomius nomius* | 5—*Papilio clytia clytia* | 6—*Papilio dravidarum* | 7—*Papilio polytes romulus*| 8—*Papilio agenor polymnestor* | 9—*Papilio daksha daksha* | 10—*Papilio demoleus demoleus* | 11—*Troides minos* | 12—*Papilio paris tamilana* | 13—*Papilio crino* | 14—*Papilio buddha* | 15—*Pachliopta aristolochiae aristolochia*. © Gopi Krishna, Surya & Santhosh S.

Image 16–30. 16—*Pachliopta hector* | 17—*Eurema* (*Terias*) *hecabe hecabe* | 18—*Eurema* (*Terias*) *andersoni shimai* | 19—*Eurema* (*Terias*) *blanda silhetana* | 20—*Eurema laeta laeta* | 21—*Eurema drona rubella* | 22—*Catopsilia pyranthe pyranthe* | 23—*Catopsilia pomona pomona* | 24—*Colotis amata amata* | 25—*Colotis danae danae* | 26—*Colotis etrida etrida* | 27—*Colotis aurora* | 28—*Ixias marianne* | 29—*Ixias pyrene sesia* | 30—*Hebomoia glaucippe australis.* © Gopi Krishna, Nithesh & Santhosh S.

Image 31–45. 31—*Leptosia nina nina* | 32—*Pareronia hippia* | 33—*Appias* (*Catophaga*) *albina swinhoei* | 34—*Appias libythea* | 35—*Appias lyncida latifasciata* | 36—*Appias* (*Hiposcritia*) *indra shiva* | 37—*Cepora nerissa phryne* | 38—*Belenois aurota aurota* | 39—*Delias eucharis* | 40—*Danaus genutia genutia* | 41—*Danaus chrysippus chrysippus* | 42—*Tirumala limniace exoticus* | 43—*Tirumala septentrionis dravidarum* | 44—*Parantica aglea aglea* | 45—*Euploea core core.* © Gopi Krishna, Nithesh & Santhosh S.

Image 46-60. 46—***Euploea sylvester coreta*** | 47—***Euploea klugii kollari*** | 48—***Charaxes bharata*** | 49—***Charaxes solon solon*** | 50—***Charaxes psaphon imna*** | 51—***Discophora lepida lepida*** | 52—***Melanitis leda leda*** | 53—***Melanitis phedima varaha*** | 54—***Lethe europa europa*** | 55—***Lethe rohria neelgheriensis*** | 56—***Lethe drypetis todara*** | 57—**Elymnias caudata** | 58—***Mycalesis perseus tabitha*** | 59—***Mycalesis mineus polydecta*** | 60—***Mycalesis visala visala***. © Gopi Krishna, Nithesh & Santhosh S.

Image 61–75. 61—*Mycalesis subdita* | 62—*Mycalesis orcha* | 63—*Mycalesis patnia junonia* | 64—*Orsotriaena medus mandata* | 65—*Ypthima asterope mahratta* | 66—*Ypthima huebneri* | 67—*Ypthima ceylonica* | 68—*Ypthima baldus madrasa* | 69—*Ypthima striata* | 70—*Acraea terpsicore* | 71—*Cirrochroa thais thais* | 72—*Cupha erymanthis maja* | 73—*Phalanta phalantha phalantha* | 74—*Moduza procris undifragus* | 75—*Athyma ranga karwara*. © Gopi Krishna, Santhosh S & Surya.

Image 76–90. 76—*Athyma selenophora kanara* | 77—*Athyma inara inara* | 78—*Neptis hylas varmona* | 79—*Neptis nata hampsoni* | 80—*Neptis jumbah nalanda* | 81—*Phaedyma columella nilgirica* | 82—*Pantoporia hordonia hordonia* | 83—*Euthalia aconthea meridionalis* | 84—*Euthalia lubentina arasada* | 85—*Symphaedra nais* | 86—*Tanaecia lepidea miyana* | 87—*Dophla evelina laudabilis* | 88—*Cyrestis thyodamas indica* | 89—*Ariadne merione merione* | 90—*Ariadne ariadne indica*. © Gopi Krishna, Amulya & Santhosh S.

Image 91–105. 91—*Kaniska canace viridis* | 92—*Vanessa indica pholoe* | 93—*Junonia orithya swinhoei* | 94—*Junonia hierta hierta* | 95—*Junonia iphita iphita* | 96—*Junonia atlites atlites* | 97—*Junonia almana almana* | 98—*Junonia lemonias lemonias* | 99—*Hypolimnas bolina jacintha* | 100—*Hypolimnas misippus* | 101—*Kallima horsfieldii* | 102—*Libythea myrrha rama* | 103—*Curetis thetis* | 104—*Curetis acuta dentata* | 105—*Spalgis epius epius*. © Gopi Krishna, Surya & Santhosh S.

Image 106–120. 106—*Arhopala centaurus pirama* | 107—*Arhopala alea* | 108—*Thaduka multicaudata kanara* | 109—*Zesius chrysomallus* | 110—*Amblypodia anita dina* | 111—*Horaga onyx onyx* | 112—*Loxura atymnus atymnus* | 113—*Catapaecilma major callone* | 114—*Rathinda amor* | 115—*Rachana jalindra macanita* | 116—*Tajuria cippus cippus* | 117—*Creon cleobis cleobis* | 118—*Hypolycaena othona othona* | 119—*Virachola isocrates* | 120—*Deudorix epijarbas epijarbas*. © Gopi Krishna, Amulya & Santhosh S.

Image 121–135. 121—*Rapala manea schistacea* | 122—*Rapala varuna lazulina* | 123—*Cigaritis lohita lazularia* | 124—*Cigaritis vulcanus vulcanus* | 125—*Cigaritis schistacea* | 126—*Leptotes plinius plinius* | 127—*Anthene emolus emolus* | 128—*Anthene lycaenina lycaenina* | 129—*Caleta decidia* | 130—*Discolampa ethion ethion* | 131—*Castalius rosimon rosimon* | 132—*Tarucus ananda* | 133—*Petrelaea dana* | 134—*Nacaduba kurava canaraica* | 135—*Nacaduba beroe gythion.* © Gopi Krishna, Santhosh S & Nithesh.

Image 136–150. 136—*Prosotas nora ardates* | 137—*Prosotas dubiosa indica* | 138—*Prosotas noreia hampsonii* | 139—*Jamides bochus bochus* | 140—*Jamides celeno celeno* | 141—*Jamides alecto eurysaces* | 142—*Catochrysops strabo strabo* | 143—*Talicada nyseus nyseus* | 144—*Lampides boeticus* | 145—Pseudozizeeria maha ossa | 146—*Zizeeria karsandra* | 147—*Zizina otis indica* | 148—*Zizula hylax hylax* | 149—*Freyeria putli* | 150—*Azanus jesous gamra*. © Gopi Krishna, Santhosh S & Nithesh.

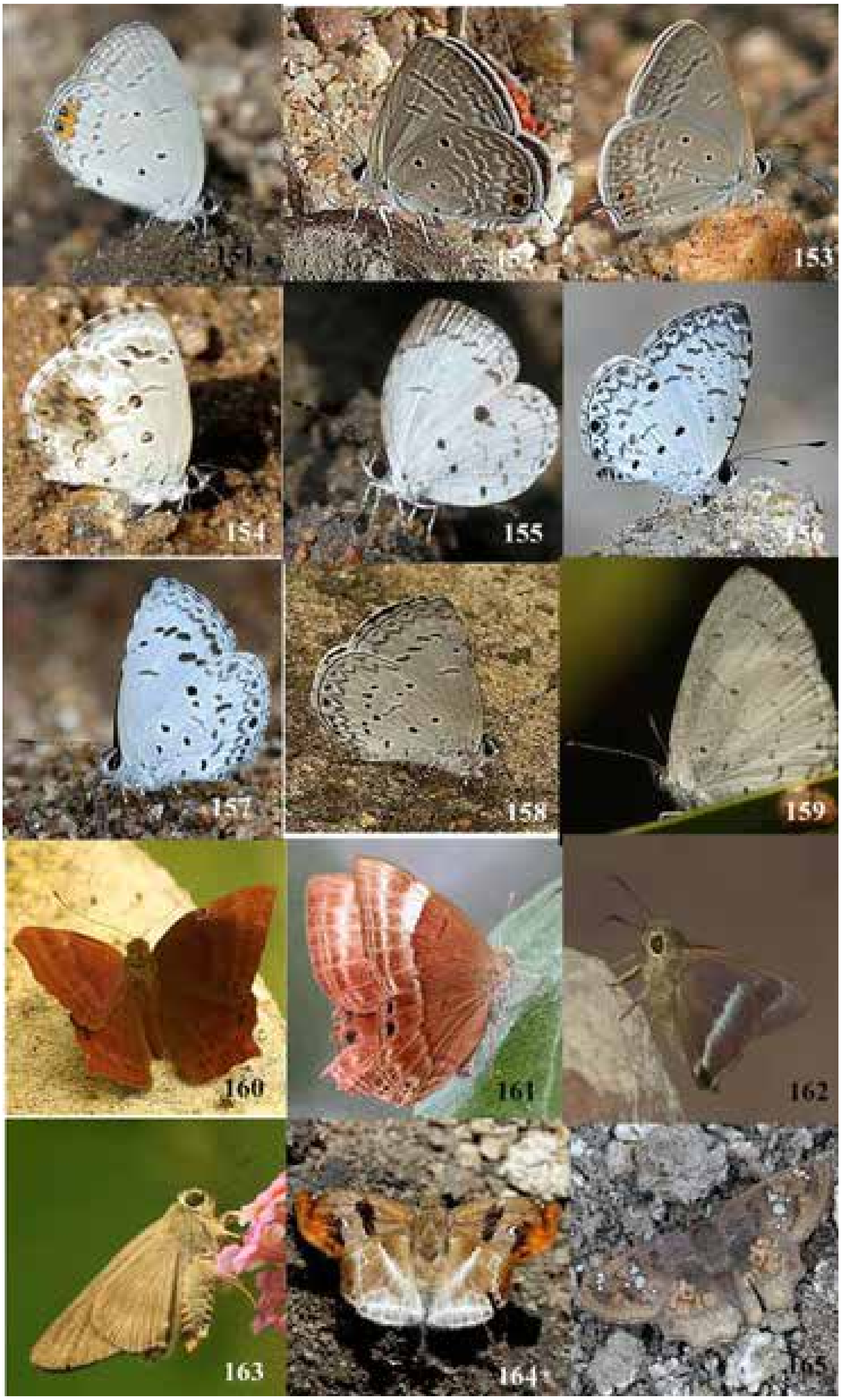

Image 151–165. 151—*Cupido lacturnus syntala* | 152—*Chilades parrhasius parrhasius* | 153—*Euchrysops cnejus cnejus* | 154—*Chilades lajus lajus* | 155—*Neopithecops zalmora dharma* | 156—*Megisba malaya thwaitesi* | 157—*Acytolepis puspa felderi* | 158—*Celastrina lavendularis lavenduris* | 159—*Udara akasa mavisa* | 160—*Abisara bifasciata suffusa* | 161—*Abisara echerius prunosa* | 162—*Hasora chromus chromus* | 163—*Badamia exclamationis* | 164—*Abaratha angulata angulata* | 165—*Abaratha ransonnettii potiphera*. © Gopi Krishna, Amulya & Santhosh S.

Image 166–180. 166—*Sarangesa dasahara davidsoni* | 167—*Sarangesa purendra hopkinsi* | 168—*Pseudocoladenia dan* | 169—*Coladenia indrani indra* | 170—*Gerosis bhagava bhagava* | 171—*Tagiades litigiosa litigiosa* | 172—*Tagiades silvia* | 173—*Tagiades obscurus* | 174—*Spialia galba galba* | 175—*Taractrocera maevius* | 176—*Cupitha purreea* | 177—*Telicota bambusae bambusae* | 178—*Telicota colon colon* | 179—*Cephrenes acalle oceanica* | 180—*Oriens goloides*. © Gopi Krishna, Nithesh & Santhosh S.

Image 181–195. 181—*Oriens concinna* | 182—*Potanthus pseudomaesa* | 183—*Potanthus palnia palnia* | 184—*Potanthus diana* | 185—*Potanthus pava pava* | 186—*Gangara thyrsis thyrsis* | 187—*Borbo cinnara* | 188—*Pseudoborbo bevani* | 189—*Parnara bada bada* | 190—*Parnara ganga* | 191—*Baoris farri* | 192—*Caltoris canaraica* | 193—*Caltoris kumara kumara* | 194—*Caltoris philippina philippina* | 195—*Pelopidas subochracea subochracea*. © Gopi Krishna, Sheily & Santhosh S.

Image 196–210. 196—*Pelopidas mathias mathias* | 197—*Pelopidas agna agna* | 198—*Pelopidas conjuncta narooa* | 199—*Polytremis lubricans lubricans* | 200—*Ampittia dioscorides dioscorides* | 201—*Aeromachus pygmaeus* | 202—*Iambrix salsala luteipalpis* | 203—*Suastus gremius gremius* | 204—*Arnetta vindhiana* | 205—*Ancistroides curvifascia curvifascia* | 206—*Ancistroides paralysos mangla* | 207—*Ancistroides folus* | 208—*Halpe hindu* | 209—*Halpe porus* | 210—*Thoressa astigmata.* © Gopi Krishna & Santhosh S.

REFERENCES

Basavarajappa, S. (2015). Report of Research study on Butterflies in Nagarahole National Park. Nagarahole Conservation Society & Univeristy of Mysore, Karnatka, India, 150 pp.

Betrus, C.J., E. Fleishman & R.B. Blair (2005). Cross-taxonomic potential and spatial transferability of an umbrella species index. *Journal of Environmental Management* 74(1): 79–87. https://doi.org/10.1016/j.jenvman.2004.08.010

Bhakare, M & H. Ogale (2018). *A Guide to Butterflies of Western Ghats (India) Includes Butterflies of Kerala, Tamil Nadu, Karnataka, Goa, Maharashtra and Gujarat states*. Publisher Milind Bhaker, 496 pp.

Bhuyan, M., J. Mech, R. Choudhary, K. Rakshit, A.J. Duarah, B. Sarma, S. Sharma & P.R. Bhattacharyya (2013). Altitudinal shiftiness of butterflies due to increase of air temperature – A case study in West Kameng district of Arunachal Pradesh. Climate Change & Himalayan Ecosystem-Indicator, Bio & Water Resources. India, 196–202 pp.

Caldas, A. & R.K. Robbins (2003). Modified Pollard transects for assessing tropical butterfly abundance and diversity. *Biological Conservation* 110(2): 211–219. https://doi.org/10.1016/S0006-3207(02)00190-8

Champion, H.G. & S.K. Seth (1968). *A Revised Survey of the Forest Types of India*. Government of India Press, New Delhi, India, 404 pp.

DeVries, P.J., D. Murray & R. Lande (1997). Species diversity in vertical, horizontal, and temporal dimensions of a fruit-feeding butterfly community in an Ecuadorian rainforest. *Biological Journal of the Linnean Society* 62(3): 343–364. https://doi.org/10.1111/j.1095-8312.1997.tb01630.x

Dolia, J., M.S. Devy, N.A. Aravind & A. Kumar (2008). Adult butterfly communities in coffee plantations around a protected area in the Western Ghats, India. *Animal Conservation* 11(1): 26–34. https://doi.org/10.1111/j.1469-1795.2007.00143.x

Ehrlich, P.R. & P.H. Raven (1964). Butterflies and plants: a study in coevolution. *Evolution* 18(4): 586–608. https://doi.org/10.2307/2406212

Ehrlich, P.R. & D.D. Murphy (1987). Conservation lessons from long-term studies of checkerspot butterflies. *Conservation Biology* 1(2): 122–131. https://doi.org/10.1111/j.1523-1739.1987.tb00021.x

Evans, W.H. (1932). *The Identification of Indian Butterflies*. Bombay Natural History Society, Bombay, India, 454 pp.

Fleishman, E., R,M. Nally, J.P. Fay & D.D. Murphy (2001). Modeling and predicting species occurrence using broad-scale environmental variables: an example with butterflies of the Great Basin. *Conservation Biology* 15(6): 1674–1685. https://doi.org/10.1046/j.1523-1739.2001.00053.x

Fleishman, E., J.R. Thomson, R. Mac Nally, D.D. Murphy & J.P. Fay (2005). Using indicator species to predict species richness of multiple taxonomic groups. *Conservation Biology* 19(4): 1125–1137. https://doi.org/10.1111/j.1523-1739.2005.00168.x

Gordon, S.C. & J.T. Kerr (2022). Floral diversity increases butterfly diversity in a multitrophic metacommunity. *Ecology* 103(8): e3735. https://doi.org/10.1002/ecy.3735

Habib, B., A. Saxena, Mahima, Y.V. Jhala & A. Rajvanshi (2020). *Assessment of Impacts of State Highway 33 on Flora and Fauna of Nagarahole Tiger Reserve*, India, 70 pp.

Hayes, L., D.J. Mann, A.L. Monastyrskii & O.T. Lewis (2009). Rapid assessments of tropical dung beetle and butterfly assemblages: contrasting trends along a forest disturbance gradient. *Insect Conservation and Diversity* 2(3): 194–203. https://doi.org/10.1111/j.1752-4598.2009.00058.x.

Jha, C.S., C.B.S. Dutt & K.S. Bawa (2000). Deforestation and land use changes in Western Ghats, India. *Current Science* 79(2): 231–238.

Kehimkar, I. (2016). *Butterflies of India. Bombay Natural History Society*. Calcutta, India, 497 pp.

Kerr, J.T., A. Sugar & L. Packer (2000). Indicator taxa, rapid biodiversity assessment, and nestedness in an endangered ecosystem. *Conservation Biology* 14(6): 1726–1734. https://doi.org/10.1111/j.1523-1739.2000.99275.x

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

Kunte, K.J. (1997). Seasonal patterns in butterfly abundance and species diversity in four tropical habitats in northern Western Ghats. *Journal of Bioscience* 22: 593–603. https://doi.org/10.1007/BF02703397

Kunte, K. (2000). *India, A Lifescape: Butterflies of peninsular India*. Indian Academy of Science. Universities Press. Hydrabad, 254 pp.

Kunte, K. (2005). Species composition, sex-ratios and movement patterns in danaine butterfly migrations in southern India. *Journal of the Bombay Natural History Society* 102(3): 280–286.

Kunte, K., A. Sengupta, U Pawar & V. Nawge (2024). A new species of Silverline butterfly, Cigaritis Donzel, 1847 (Lepidoptera: L-ycaenidae), from the Western Ghats biodiversity hotspot, India. *Zootaxa* 5399(1–10): 85–95. https://doi.org/10.11646/zootaxa.5399.1.7

Lomov, B., D.A. Keith, D.R. Britton & D.F. Hochuli (2006). Are butterflies and moths useful indicators for restoration monitoring? A pilot study in Sydney's Cumberland Plain Woodland. *Ecological Management & Restoration* 7(3): 204–210. https://doi.org/10.1111/j.1442-8903.2006.00310.x

Maxwell, S.L., V. Cazalis, N. Dudley, M. Hoffmann, A.S. Rodrigues, S. Stolton & J.E. Watson (2020). Area-based conservation in the twenty-first century. *Nature* 586: 217–22. https://doi.org/10.1038/s41586-020-2773-z

McGeoch, M.A. (1998). The selection, testing and application of terrestrial insects as bioindicators. *Biological reviews* 73(2): 181–201. https://doi.org/10.1017/S000632319700515X

Myers, N., R.A. Mittermeier, C.G. Mittermeier, G.A. Da Fonseca & J. Kent (2000). Biodiversity hotspots for conservation priorities. *Nature* 403(6772): 853–858.

Naik, D., R.S.P. Rao, K. Kunte & M.S. Mustak (2022). Ecological monitoring and indicator taxa: Butterfly communities in heterogeneous landscapes of the Western Ghats and Malabar coast, India. *Journal of Insect Conservation* 26(1): 107–119. https://doi.org/10.1007/s10841-022-00368-5

Naicker, S.R.K., S.P. Chandrika, B. Kochunarayanan, J. Jose, M. Kripakaran, R.C. Palaniappan, V.P. Nair & K. Sadasivan (2023). A new species of *Cigaritis* Donzel, 1847 (Lycaenidae, Aphnaeinae) from the southern Western Ghats of Peninsular India. *Entomon* 48(4): 553–566.

Nelson, S.M. & D.C. Andersen (1994). An assessment of riparian environmental quality by using butterflies and disturbance susceptibility scores. *The Southwestern Naturalist* 39(2): 137–142. https://doi.org/10.2307/3672237

Padhye, A., S. Shelke & N. Dahanukar (2012). Distribution and composition of butterfly species along the latitudinal and habitat gradients of the Western Ghats of India. *Check List* 8(6): 1197–1215.

Purvis, A. & A. Hector (2000). Getting the measure of biodiversity. *Nature* 405: 212–219. https://doi.org/10.1038/35012221

Rajagopal, T., M. Sekar, A. Manimozhi, N. Baskar & G. Archunan (2011). Diversity and community structure of butterfly of Arignar Anna Zoological Park, Chennai, Tamil Nadu. *Journal of Environmental Biology* 32(2): 201–207.

Rodgers, W.A. (1989). Policy issues in wildlife conservation. *Indian Journal of Public Administration* 35(3): 461–468.

Sadasivan, K., & A. Sengupta (2024). The Butterflies of Western Ghats: their status and distribution. *Journal of the Bombay Natural History Society* 121(2): 126–174.

Sawchik, J., M. Dufrêne & P. Lebrun (2005). Distribution patterns and indicator species of butterfly assemblages of wet meadows in southern Belgium. *Belgian Journal of Zoology* 135(1): 43–52.

Schtickzelle, N., G. Mennechez & M. Baguette (2006). Dispersal depression with habitat fragmentation in the bog fritillary butterfly. *Ecology* 87(4): 1057–1065. https://doi.org/10.1890/0012-

9658(2006)87[1057:DDWHFI]2.0.CO;2

Smetacek, P. (2025). *Synoptic Catalogue of the Butterflies of India*. Second Edition. Butterfly Research Trust, Bhimtal, Uttarakhand, India, 302 pp.

Vinayan, P.A., M.A. Yathumon, N.S. Sujin, B.A. Kumar, P.A. Ajayan, P.K. Muneer, N.M. Vishnu, C.B. Answar & N. R. Anoop (2023). Pattern and drivers of danaine butterfly migration in Southern India: implications for conservation. *Journal of Insect Conservation* 27(3): 505–516.

Watson, J., N. Dudley, D.B. Segan & M. Hockings (2014). The performance and potential of protected areas. *Nature* 515: 67–73. https://doi.org/10.1038/nature13947

Wynter-Blyth, M.A. (1957). *Butterflies of the Indian region*. Today and Tomorrow Printers and Publishers. Ansari Road, Daryaganj, New Delhi, India, 523 pp.

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ARTICLE

Floral traits, pollination syndromes, and nectar resources in tropical plants of Western Ghats

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Abstract: Tropical regions are known to have a high percentage of animal-pollinated plants. This study explores the natural history of pollination in an understudied biodiversity hotspot, the tropical forests of India's Western Ghats. It is the first-ever attempt to gain insights into three critical aspects of pollination simultaneously, i.e., pollination syndromes, floral visitors, and standing nectar crop. Data on the attributes of floral visitors of 62 plant species were collected through regular field visits for three years allowing for sampling across seasons. 'Tube' was the most dominant flower type (20) followed by 'Dish to bowl' with 18 species, 'Brush or Head' (13), and 'Gullet' with nine species. The range of nectar quantity per flower varied from 0.05–13.7 µL. Nearly 40 percent of plant species observed by us have only Lepidopteran visitors. Fifteen plant species were visited by hymenopterans and lepidopterans, whereas five plant species had hymenopteran visitors only. In the light of rapidly declining pollinator diversity, our study highlights the significance of floral visitors in the pollination of some conservation-significant species, as well as points to determinants of floral visitation and success.

Keywords: Biodiversity hotspot, floral visitor diversity, flower colour, flower shape, pollinators, standing nectar crop, northern Western Ghats.

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INTRODUCTION

Flowering plants play a critical role in the ecosystem by not only providing food and rewards to different animal visitors, but also by providing sites for predation, mating, and as oviposition & brooding sites (Larson et al. 2001). Pollination is a crucial ecosystem service provided by diverse floral visitors to both wild and cultivated plants. Plants and pollinators interact in diverse, and complex ways. Pollination syndromes—defined by floral traits such as morphology, phylogeny, and rewards—help predict plant visitors (Barrios et al. 2016). The amount of nectar, its composition, and placement are also determinants of plant-pollinator interactions (Parachnowitsch et al. 2019).

Bees are assumed to be the most important pollinators for crops as well as wild plants. Globally, 56% of plant species rely on bees and wasps for pollination, while butterflies & moths account for 11%, flies 10%, beetles 3%, birds 12%, and 8% are wind-pollinated (Sanchez & Wyckhyus 2019). Without floral visitors, about 1/3rd of the flowering species would be unable to contribute to seed formation, germination, and the survival of the species (Ollerton et al. 2011).

Pollination syndromes are a set of floral characters including colour, presence of nectar guides, flower scent, nectar reward, pollen, and flower shape that play a role in attracting a particular type of pollinator towards the plant (Yan et al. 2016; Dellinger 2020). They are named after the most typical pollinators (Faegri & van der Pijl 1979; Fenster et al. 2004). The blossom classes (flower types) are correlated to a particular pollinating agent. For instance, flowers with long corolla tubes are pollinated by insects having long proboscis, such as butterflies & moths, and are a part of psychophily pollination syndrome. Ollerton et al. (2011) stated that the percentage of animal-pollinated plants is above 90% in case of tropical regions. This has led to increase in the proportion of plants with functionally specialized pollination systems (i.e., pollination by only one functional group of animals such as lepidopterans or hymenopterans) in tropical regions.

The need to shift the focus from studies related to 'bee only pollination process' to pollination carried out by 'non-bee pollinators' have been highlighted by many researchers (Garibaldi et al. 2013; Bartomeus et al. 2014). Cusser et al. (2021), in their recent paper, have shown that non-bee pollinators such as butterflies, and flies contribute much more than reported, and credited for so far. They play a role in providing pollination service to spatially and temporally unique flowers, which would otherwise remain unpollinated by conventional pollinators such as bees. Considering the significant role played by non-bee pollinators in the process of pollination, there is a need for study of other insects such as butterflies, wasps, flies, and beetles for developing strategies for increasing pollination of wild, and cultivated plant species. In such cases, studying floral visitor networks can be the first step towards understanding the role of diverse pollinators in an ecosystem.

Global studies are underway to investigate the roles of pollinators in sustaining both wild and cultivated plant species. In diverse tropical forests, flower-visiting insects remain underexplored for their relationship with plants (Tan et al. 2017). Though there are few studies focusing on identifying floral visitors of agricultural crop species in India (Chaudhary 2006; Sinu & Shivanna 2007), there is dearth of comparative studies involving multiple species of wild forest flora. Certain studies have attempted to explore the plant-floral visitor relationship, but they were largely species specific (Somanathan & Borges 2001; Sharma et al. 2011). Despite extensive research on agricultural pollination in India (Chaudhary 2006; Sinu & Shivanna 2007), studies on pollination syndromes in wild forest flora remain scarce.

According to Johnson & Steiner (2000) and Ollerton & Watts (2000), plants were often categorized according to their perceived syndrome, but mostly in absence of actual data of flower visitation or pollination by animals. Especially in Western Ghats and tropical forests, where the documentation of pollinator data mainly focused on one or few species (Grindeland et al. 2005; Huang et al. 2006; Sharma et al. 2011; Lemaitre et al. 2014). Our study investigates floral traits and visitor diversity across 62 plant species, addressing the following questions:

1. How is floral visitor diversity influenced by flower morphology, color, pollination syndrome, and sexual organ placement?

2. What are the patterns of standing nectar crop (SNC) across species?

3. Is there a relationship between nectar volume, blossom type, and flower color?

MATERIALS AND METHODS

Experimental study sites

Present study was conducted at two locations - evergreen forests of Amboli in northern Western Ghats (NWG) and dry scrub hill forests within the city of Pune (Image 1).

Amboli (15.950° N, 74.000° E), situated at 700 m is located in Sawantwadi Taluka of Sindhudurg District of Maharashtra (Image 1C) in northern Western Ghats. These seasonal forests receive annual rainfall ranging 6,000–7,000 mm, dry period length (DPL) of 7–8 months, and average temperatures of minimum 8°C, and maximum 35°C. Primary vegetation type is evergreen. The forests harbour several endemic and threatened plant species. The area is proposed as ecologically sensitive zone and also forms a part of geographically, and ecologically important Sahyadri–Konkan Ecological Corridor (Bawa et al. 2007).

Pune (18.516° N, 73.850° E) is a plateau city situated near the western margin of the Deccan plateau. It lies on the leeward side of the Western Ghats. It is situated at an altitude of 560 m. The city is surrounded by hills on the east and the south. The climate is typical monsoon, with three distinct seasons, viz., summer, rainy, and winter. The hill forests (Bhamburda–Vetal Hill and Parvati–Pachgaon) are located in the heart of Pune city. The temperature ranges between 10–43 °C with annual rainfall range of 600–700 mm, and DPL of 8–9 months. The fragile hill forests primarily harbour scrub forests and grasslands, but now witnessed plantation drives of exotic species such as *Glyricidia sepium*, *Dalbergia melanoxylon,* and are 'Habitat Islands' surrounded by ever-increasing urbanization from all sides (Image 1B).

Plant species selection

A total of 62 flowering plant species (48 wild and 14 cultivated) belonging to 30 families were studied for floral visitor documentation. These plant species are found in the study areas 1 and 2. Species - level identification and nomenclature were done using regional flora (Almeida 1990; Singh et al. 2001) and by referring to Plants of the World Online database (https://powo.science.kew.org). Endemicity and IUCN Red List status of the species were assigned by referring to standard literature (Pascal 1988; BIOTIK 2008; Singh et al. 2015; https://www.iucnredlist.org/). For species-specific floral visitor documentation, individual plants were selected based on peak flowering season, flowering percentage, and ease of access to the flowering branches.

Floral attributes

Each species was classified by flower type such

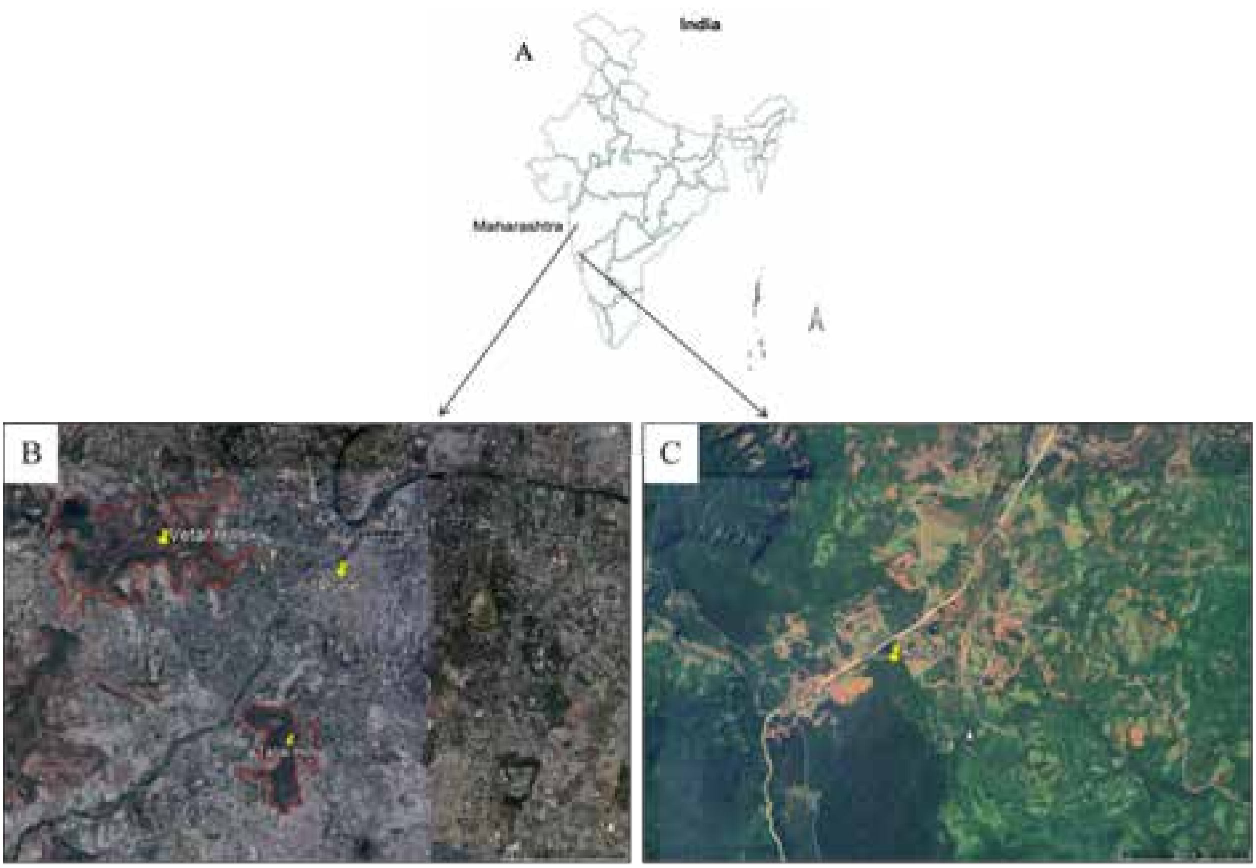

Image 1. Study Area: A—Map of India depicting state of Maharashtra | B—Pune hill forests | C—Evergreen forests of Amboli.

as dish to bowl, brush or head, bell or funnel, gullet, flag, tube, and trap, based on the description, and classification of flower type given by Faegri & Van der Pijl (1979) as represented in Image 2. Flower colour was also assigned based on field observations. Dish to bowl type has the reproductive organs more or less at the centre of the blossom and is actinomorphic. Brush or head type defines itself and the external surface as exclusively or partly formed by the sexual organs and is actinomorphic or asymmetric. Bell or funnel type has rim which advertises functions and sexual organs that are distinctly centric, and is actinomorphic. Gullet type has sexual organs that are restricted to the functionally upper side of the blossom, and pollen is deposited on the back of the pollinator, and are zygomorphic. Flag types have sexual organs that are found in the lower part of the blossom, and pollen is deposited on the ventral part of the pollinator, and are actinomorphic or zygomorphic. Tube types are large and narrow, the tubes may be central, subcentric (as a spur) or excentric, excluding all visitors with mouth-parts shorter than effective tube length. In case of trap types pollinators are temporarily held in the blossom. or experience difficulty in leaving the blossom, and are actinomorphic or zygomorphic.

Floral visitor documentation

The data were collected for three years (2018–2021). An uncontrolled observation method was used for data collection. Regular field surveys once in every month for five days were conducted. The areas included Choukul Road, Mahadevgad Road, Hiranyakeshi (Amboli), and various areas of Pune's hill forests (Taljai, ARAI). All the floral visitors observed contacting the reproductive organs of flowers were systematically documented in the morning (0700–1000 h) and evening session (1600–1800 h) with the naked eye, and binoculars (Nikon Action 8 X 40). These time slots were decided based on a literature review Pachpor et al. (2022) and pilot survey conducted in the study area. Digital SLR camera (Nikon D7100, 105 mm macro lens, Sigma 150–500 mm telephoto lens and Canon 1200 D with 18 X 55 mm lens and 55 X 250 mm telephoto lens) was used for the photo-documentation. Insects were also collected using a sweep net method. Floral visitors were identified using standard literature (McGavin 2002; Grimmett et al. 2011; Bhakare & Ogale 2018). For shortlisted species, floral visitors' occurrence was counted based on the number of times the particular visitor foraged on the flower using a 30-minute count method. Floral visitors were assigned to one of the following taxonomic groups: Hymenoptera, Hemiptera, Diptera, Coleoptera, Lepidoptera, Aranae, and Passeriformes. Butterflies were identified at the species level. Other insect visitors were identified up to the order level.

Nectar collection and standing nectar crop estimation

Nectar was sampled from at least 50 bagged and 50 unbagged individual flowers in the morning hours between 0700–1000 h by probing each flower with a calibrated Drummonds 0.5 µL micro-capillary tube, measuring the lengths of nectar in the tube in order to determine nectar volumes. For the flowering species with large sized nectaries and larger nectar volume, nectar was estimated using Biohit Proline micropipettes of 5–10 µl (FAO 1995). Standing nectar crop was estimated by bagging the inflorescence/flowers with the fine mesh bridal vein the previous evening to ensure that the nectar was not robbed by the floral visitors before sampling.

Statistical analyses

It was observed that the nectar values do not follow normal distribution. The distributions of nectar values are highly skewed. Since median is a better measure of central tendency in skewed data sets, we used non-parametric multi sample bootstrap-based string for differences in the median nectar value for different flower types and different colours. For each flower type and each colour, we have generated 5,000 bootstrap samples, of the same size as in the original data and estimated the mean difference between the medians for each pair of types, and colours. We have also constructed quantile-based confidence interval for the difference of medians. The confidence intervals which do not contain zero, correspond to the pairs which have significantly different values of medians.

RESULTS

Floral attributes

Sixty-two plant species belonging to 30 families were studied for floral morphology and visitors' diversity. Table 1 provides data on flower morphology, flower colour, flower type, odour, primary attractants, sexual organs, and types of floral visitors. Out of 62 plant species (including wild and cultivated varieties), 41 were actinomorphic and 21 exhibited zygomorphic symmetry. In total six flower types were recorded. 'Tube' was the most dominant flower type (20) followed by 'dish to bowl' with 18 species, 'brush or head' (13), and 'gullet' type with nine species, whereas 'flag' and 'bell or funnel' type was each represented by a solitary species. White colour flowers were seen in case of 25 species. Coloured flowers included orange, lavender, blue, yellow, orange, pink, and red flowers. Sexual organs were exposed in 41 species and concealed in 21 plant species. Twenty seven species possess both flower colour and nectar as primary attractants, whereas in 22 species nectar serves as the sole attractant. Eleven species have characteristic odour associated with them. Seven species had nectar guides, while extra floral nectaries were found only in *Euphorbia*.

Floral visitors

The floral visitors that were encountered during the present study belonged to seven different orders. Floral visitors primarily belonged to Hymenoptera (bees, wasps, and ants), Diptera (flies), and Lepidoptera (butterflies and moths) orders. Few plants were also visited by members of Araneae (spiders), Coleoptera (beetles), Hemiptera (bugs), and Passeriformes (birds). Members of Araneae (spiders) were seen ambushing prey in the flowers. Nearly 40 percent plant species observed by us have only lepidopteran visitors (Table 1). Fifteen plant species were visited by hymenopterans and lepidopterans, and five plant species visited by only hymenopterans. Less than three plants species were visited by Diptera and Hymenoptera; Coleoptera, Diptera, Hymenoptera, and Lepidoptera; Passeriformes; Hymenoptera and Passeriformes; Diptera, Hymenoptera, Lepidoptera, and Passeriformes; Araneae, Diptera, Hymenoptera, and Lepidoptera; Hymenoptera, Lepidoptera, and Passeriformes; Coleoptera, Lepidoptera, and Passeriformes; Coleoptera, Hymenoptera, and Passeriformes; and Coleoptera, Diptera, Hemiptera, and Hymenoptera. Rest all other insect orders were found to be visiting less than 5 percent species (Table 1).

Out of 62 total plant species, we further shortlisted eight species from evergreen forests for detailed investigation of floral visitor study. This selection was based on either their endemic status (for e.g., *Holigarna grahamii, Moullava spicata*, and *Ligustrum robustum* ssp. *perrottetii),* or significance for conservation (*Syzygium caryophyllatum* is endangered) or potential for medicinal value (*Mappia nimmoniana, Symplocos racemosa, Salacia chinensis*, and *Lagerstroemia microcarpa*). In depth investigation of actual floral visits by different visitors revealed their foraging patterns (Figure 1). Of the total visits recorded, Diptera (flies) and Hymenoptera (bees) were the primary floral visitors, accounting for 39% and 28% of the visits, respectively, followed by Lepidoptera (18%). Members of Hymenoptera, Diptera, and Lepidoptera were amongst the most common foragers in all the species studied. Maximum observations of lepidopteran visitors were recorded on *Holigarna grahamii.* In species like *Mappia nimmoniana* nearly 50% observations were of dipteran flies. Three species of *Apis* were found to be foraging on *Syzygium caryophyllatum*. Ants were main floral visitors of *Salacia chinensis*. Few spiders (Order Araneae) were seen ambushing in the flowers and preyed upon the floral visitors, while insects like thrips were observed residing in the flowers of *Holigarna grahamii.* Birds like Crimson-backed Sunbird *Leptocoma minima* and Pale-billed Flowerpecker *Dicaeum erythrorhynchos*, were observed foraging on flowers of *H. grahamii* and *M. spicata.* Although we did not specifically compare the diversity of floral visitors between the two sites (wild vs. urban), we did record certain observations. For example, *Leptocoma minima* was found visiting plant species such as *Leea indica* in the wild, whereas, the same plant species in the urban area was found attracting Purple Sunbird *Cinnyris asiaticus*. Figure 1 illustrates the dominance of Hymenoptera and Diptera in floral visits, with Lepidoptera showing species-specific preferences.

Standing nectar crop

Nectar serves as a primary reward for most pollinators. Pollinators' visit to a particular flower is guided by various factors. Various olfactory & visual cues and nectar rewards play a role in predicting which pollinator visits, and successfully pollinates the plant (Barrios et al. 2016). Standing nectar crop (SNC) is the total amount of nectar available for pollinators at a given time. We collected data on the standing nectar crop for 52 plant species. Nectar volume ranged from 0.05–13.7 µl.

Association of nectar volume with flower type and flower colour

Mean difference between median values of nectar volume was calculated for each pair of flower types. We have considered five flower types. Hence, there are 10 possible pairs. The mean difference between median nectar volumes ranged from 0.19–8.8 µl. Maximum mean difference between median nectar values (>8) was observed between 'flag' type and other flower types (rush or head, gullet, dish to bowl and tube). Thus, flag type flowers contain significantly more nectar than the other types.

Similarly, mean difference between median values of nectar volume was calculated for each pair of colours. We have considered 17 colours. Hence, there are 136

Table 1. Pollination syndromes, floral attributes, and floral visitors of plant species in the study area.

	Plant species	Family	Flower symmetry	Colour	Type	Odour	Primary attractants	Sexual organs	Nectar volume (µl) (Mean± SD)	Floral visitors (present study)	Floral visitors (previous study)
1	*Crossandra undulifolia* Salisb.[** $]	Acanthaceae	Zygomorphic	Orange	Tube	Not significant	Colour and nectar	Concealed	0.27 ± 0.23	Hymenoptera and Lepidoptera	–
2	*Cynarospermum asperrimum* Nees[* $]	Acanthaceae	Zygomorphic	Blue	Gullet	Not significant	Colour and nectar	Exposed	0.68 ± 0.18	Lepidoptera	–
3	*Eranthemum roseum* (Vahl) R.Br.[* $]	Acanthaceae	Zygomorphic	Blue	Tube	Not significant	Colour and nectar	Concealed	1.87 ± 0.55	Lepidoptera	–
4	*Hygrophila serpyllum* (Nees) T.Anderson[* $]	Acanthaceae	Zygomorphic	Blue	Gullet	Not significant	Colour and nectar; nectar guides present	Exposed	0.44	Lepidoptera	–
5	*Justicia santapaui* Bennet[* $]	Acanthaceae	Zygomorphic	White	Gullet	Not significant	Nectar; nectar guides present	Exposed	10.06 ± 0.16	Hymenoptera and Lepidoptera	–
6	*Holigarna grahamii* (Wight) Kurz [*]	Anacardiaceae	Actinomorphic	Cream	Dish to Bowl	Not significant	Nectar	Exposed	-	Coleoptera, Lepidoptera and Passeriformes	–
7	*Carissa spinarum* L[* $]	Apocynaceae	Actinomorphic	White	Tube	Mild sweet	Odour and nectar	Concealed	4.27	Lepidoptera	Lepidoptera (Raju et al. 2004)
8	*Catharanthus roseus* (L.) G.Don[** $]	Apocynaceae	Actinomorphic	Pink	Tube	Not significant	Colour and nectar	Concealed	0.69 ± 0.32	Lepidoptera	Lepidoptera (Raju et al. 2004)
9	*Gymnema sylvestre* (Retz.) R.Br. ex Schultes[* $]	Apocynaceae	Actinomorphic	Yellowish white	Dish to Bowl	Not significant	Nectar	Exposed	0.57 ± 0.17	Lepidoptera	–
10	*Schefflera* spp. [* $]	Araliaceae	Actinomorphic	Pinkish White	Dish to Bowl	Not significant	Colour and nectar	Exposed	0.04 ± 0.2	Hymenoptera	–
11	*Adelocaryum coelestinum* (Lindl.) Brandis [* $]	Boraginaceae	Actinomorphic	Bluish white	Dish to Bowl	Mild sweet	Colour, odour and nectar, nectar guides present	Exposed	0.522 ± 0.28	Lepidoptera	–
12	*Boswellia serrata* Roxb. [*]	Burseraceae	Actinomorphic	White	Dish to Bowl	Not significant	Nectar	Exposed	-	Hymenoptera and Lepidoptera	Hymenoptera (Sunnichan et al. 2005)
13	*Capparis moonii* Wight[* $]	Capparaceae	Actinomorphic	White	Brush or Head	Not significant	Nectar	Exposed	3.34 ± 0.27	Hymenoptera	–
14	*Salacia chinensis* L.[*]	Celastraceae	Actinomorphic	Green	Dish to Bowl	Pungent	Nectar	Exposed	-	Diptera and Hymenoptera	–
15	*Garcinia talbotii* Raiz. ex Sant.[* $]	Clusiaceae	Actinomorphic	White	Dish to Bowl	Strong unpleasant	Odour and nectar	Exposed	0.8 ± 0.41	Hymenoptera and Passeriformes	–
16	*Euphorbia terracina* L.[* $]	Euphorbiaceae	Zygomorphic	Green	Dish to Bowl	Not significant	Nectar, extra floral nectary present	Exposed	0.095 ± 0.11	Hymenoptera and Lepidoptera	–
17	*Albizia chinensis* (Osbeck) Merr.[*]	Fabaceae	Actinomorphic	Pink	Brush or Head	Not significant	Colour and nectar	Exposed	-	Hymenoptera	–

	Plant species	Family	Flower symmetry	Colour	Type	Odour	Primary attractants	Sexual organs	Nectar volume (µl) (Mean± SD)	Floral visitors (present study)	Floral visitors (previous study)
18	*Crotalaria retusa* L.[*$]	Fabaceae	Zygomorphic	Yellow	Flag	Not significant	Colour and nectar	Concealed	8.4 ± 0.54	Lepidoptera	Lepidoptera and Hymenoptera (Raju et al. 2022)
19	*Moullava spicata* (Dalz.) Nicols. [*$]	Fabaceae	Zygomorphic	Red and Yellow	Gullet	Not significant	Colour and nectar	Exposed	12.01 ± 0.18	Coleoptera, Hymenoptera and Passeriformes	–
20	*Senegalia rugata* (Lam.) Britton & Rose[*]	Fabaceae	Actinomorphic	White	Brush or Head	Not significant	Nectar	Exposed	-	Diptera and Hymenoptera	–
21	*Mappia nimmoniana* (J.Graham) Byng & Stull [*$]	Icacinaceae	Actinomorphic	Yellowish green	Dish to Bowl	Strong foetid rotten	Odour and nectar	Exposed	1.37 ± 0.49	Coleoptera, Diptera, Hymenoptera and Lepidoptera	Diptera, Hymenoptera (Sharma et al. 2011)
22	*Callicarpa tomentosa* (L) Murr. [*]	Lamiaceae	Actinomorphic	Pink	Brush or Head	Mild sweet	Colour, odour, and nectar	Exposed	-	Diptera and Hymenoptera	–
23	*Clerodendrum infortunatum* L.[*$]	Lamiaceae	Zygomorphic	White	Gullet	Mild sweet	Odour and nectar	Exposed	1.36 ± 0.52	Lepidoptera	Hymenoptera (Laha et al. 2020)
24	*Clerodendrum paniculatum* L[**$]	Lamiaceae	Zygomorphic	Orange	Tube	Not significant	Colour and nectar	Exposed	0.088 ± 0.067	Lepidoptera	Lepidoptera (Kato et al. 2008)
25	*Leucas stelligera* Wall. [*$]	Lamiaceae	Zygomorphic	White	Gullet	Mild sweet	Odour and nectar	Concealed	0.526 ± 0.4	Hymenoptera and Lepidoptera	Lepidoptera (Kulkarni et al. 2023)
26	*Vitex negundo L*[*$]	Lamiaceae	Zygomorphic	Blue	Gullet	Not significant	Colour and nectar	Exposed	0.134 ± 0.075	Lepidoptera	–
27	*Saraca asoca – Bisexual* (Roxb.)[*$]	Leguminosae	Actinomorphic	Orange	Tube	Not significant	Colour and nectar	Exposed	0.35	Lepidoptera	–
28	*Torenia fournieri* Linden ex E. Fourn[**$]	Linderniaceae	Zygomorphic	Pink	Gullet	Not significant	Colour and nectar, nectar guides present	Concealed	0.3 ± 0.37	Lepidoptera	–
29	*Torenia fournieri* Linden ex E. Fourn.[**$]	Linderniaceae	Zygomorphic	Violet	Gullet	Not significant	Colour and nectar, nectar guides present	Concealed	2.14 ± 1.44	Lepidoptera	–
30	*Lagerstroemia microcarpa* Wight[*]	Lythraceae	Actinomorphic	White	Dish to Bowl	Not significant	Nectar	Exposed	-	Coleoptera, Diptera, Hemiptera and Hymenoptera	Hymenoptera (Kumar & Khanduri 2016)
31	*Woodfordia fruticosa* (L.) Kurz [*$]	Lythraceae	Zygomorphic	Red	Brush or Head	Not significant	Colour and nectar	Exposed	6.33 ± 0.76	Passeriformes	–
32	*Sida acuta* Burm.f.[*$]	Malvaceae	Actinomorphic	Yellow	Dish to Bowl	Not significant	Colour and nectar	Exposed	0.1	Lepidoptera	Lepidoptera (Raju et al. 2004), Hymenoptera (Laha et al. 2020)

	Plant species	Family	Flower symmetry	Colour	Type	Odour	Primary attractants	Sexual organs	Nectar volume (µl) (Mean± SD)	Floral visitors (present study)	Floral visitors (previous study)
33	*Memecylon umbellatum* Burm.f.*	Melastomataceae	Actinomorphic	Blue	Dish to Bowl	Not significant	Colour and nectar	Exposed	-	Hymenoptera	Hymenoptera (Nayak & Davidar 2010)
34	*Syzygium caryophyllatum* Alston* $	Myrtaceae	Actinomorphic	White	Brush or Head	Not significant	Nectar	Exposed	0.34 ± 0.20	Coleoptera, Diptera, Hymenoptera and Lepidoptera	–
35	*Syzygium cumini* (L.) Skeels * $	Myrtaceae	Actinomorphic	White	Brush or Head	Not significant	Nectar	Exposed	0.26 ± 0.019	Diptera, Hymenoptera, Lepidoptera and Passeriformes	Lepidoptera (Raju et al. 2004)
36	*Syzygium hemisphericum* (Wight) Alston * $	Myrtaceae	Actinomorphic	White	Brush or Head	Not significant	Nectar	Exposed	13.7 ± 20.3	Hymenoptera, Lepidoptera and Passeriformes	–
37	*Syzygium zeylanicum* (L.) DC. * $	Myrtaceae	Actinomorphic	White	Brush or Head	Not significant	Nectar	Exposed	-	Hymenoptera and Lepidoptera	–
38	*Ligustrum robustum subsp. perrottetii* (A.DC.) de Juana * $	Oleaceae	Actinomorphic	White	Tube	Not significant	Nectar	Exposed	0.28 ± 0.135	Coleoptera, Diptera, Hymenoptera and Lepidoptera	Lepidoptera (Pachpor et al. 2022)
39	*Parasopubia delphiniifolia* (L.) H.-P.Hofm. & Eb.Fisch* $	Orobanchaceae	Zygomorphic	Pink	Bell or Funnel	Not significant	Colour and nectar, nectar guides present	Concealed	0.06	Lepidoptera	–
40	*Persicaria chinensis* (L.) H.Gross* $	Polygonaceae	Actinomorphic	White	Dish to Bowl	Not significant	Nectar	Exposed	0.27± 0.17	Lepidoptera	–
41	*Catunaregam spinosa* (Thunb.) Tirveng* $	Rubiaceae	Actinomorphic	White and Yellow	Tube	Not significant	Colour and nectar	Exposed	9.34 ± 2.4	Hymenoptera and Lepidoptera	Lepidoptera (Kato et al. 2008)
42	*Ixora coccinea* L.** $	Rubiaceae	Actinomorphic	Peach	Tube	Not significant	Colour and nectar	Concealed	0.058 ± 0.019	Lepidoptera	–
43	*Ixora coccinea* L. ** $	Rubiaceae	Actinomorphic	Pink	Tube	Not significant	Colour and nectar	Concealed	0.11 ± 0.055	Lepidoptera	–
44	*Ixora coccinea* L.** $	Rubiaceae	Actinomorphic	Red	Tube	Not significant	Colour and nectar	Concealed	0.06 ± 0.022	Lepidoptera	Lepidoptera (Kulkarni et al. 2023)
45	*Pentas lanceolata* (Forssk.)** $	Rubiaceae	Actinomorphic	Lavender	Tube	Not significant	Colour and nectar	Concealed	0.24 ± 0.17	Lepidoptera	–
46	*Pentas lanceolata* (Forssk.)** $	Rubiaceae	Actinomorphic	Pink	Tube	Not significant	Colour and nectar	Concealed	0.144 ± 0.16	Lepidoptera	–
47	*Psydrax dicoccos* (Gaertn.)* $	Rubiaceae	Actinomorphic	White	Dish to Bowl	Strong sweet	Colour, odour, and nectar	Exposed	1.27± 0.322	Lepidoptera and Hymenoptera	Lepidoptera (Kato et al. 2008; Pachpor et al. 2022)
48	*Wendlandia thyrsoidea* (Roth) Steud.* $	Rubiaceae	Actinomorphic	White	Tube	Mild sweet	Nectar	Concealed	0.09 ± 0.03	Lepidoptera and Hymenoptera	Lepidoptera (Pachpor et al. 2022)

	Plant species	Family	Flower symmetry	Colour	Type	Odour	Primary attractants	Sexual organs	Nectar volume (µl) (Mean± SD)	Floral visitors (present study)	Floral visitors (previous study)
49	*Atalantia racemosa* Wight* $	Rutaceae	Actinomorphic	White	Dish to Bowl	Not significant	Nectar	Exposed	0.36 ± 0.17	Diptera and Hymenoptera	–
50	*Allophylus cobbe* (L.) Forsyth f.* $	Sapindaceae	Zygomorphic	White	Dish to Bowl	Not significant	Nectar	Exposed	0.37 ± 0.18	Lepidoptera	Hymenoptera (Laha et al. 2020)
51	*Dimocarpus longan* Lour.*	Sapindaceae	Actinomorphic	White	Dish to Bowl	Not significant	Nectar	Exposed	-	Hymenoptera and Lepidoptera	Diptera, Lepidoptera and Hymenoptera (Riswanta et al. 2021)
52	*Lepisanthes tetraphylla* (Vahl) Radlk.* $	Sapindaceae	Zygomorphic	White	Brush or Head	Not significant	Nectar	Exposed	0.42 ± 0.22	Hymenoptera and Lepidoptera	Hymenoptera (Nayak & Davidar 2010)
53	*Symplocos cochinchinensis* (Lour.) S.Moore* $	Symplocaceae	Actinomorphic	White	Brush or Head	Not significant	Nectar	Exposed	0.3 ± 0.2	Hymenoptera	–
54	*Symplocos racemosa* Roxb.*	Symplocaceae	Actinomorphic	White	Brush or Head	Not significant	Nectar	Exposed	-	Araneae, Diptera, Hymenoptera and Lepidoptera	–
55	*Lasiosiphon glaucus* (Fresen.)* $	Thymelaeaceae	Actinomorphic	Yellow	Tube	Mild bitter	Colour, odour, and nectar	Concealed	0.17± 0.096	Lepidoptera	–
56	*Grewia spp.** $	Tiliaceae	Actinomorphic	White	Brush or Head	Not significant	Nectar	Exposed	0.42 ± 0.19	Passeriformes	–
57	*Lantana camara* L.** $	Verbenaceae	Actinomorphic	Yellow	Tube	Mild sweet	Colour, odour, and nectar	Concealed	0.128 ± 0.13	Hymenoptera and Lepidoptera	Lepidoptera (Raju et al. 2004)
58	*Lantana camara* L.* $	Verbenaceae	Actinomorphic	Pink and Yellow	Tube	Mild sweet	Colour, odour, and nectar	Concealed	0.18 ± 0.16	Hymenoptera and Lepidoptera	Lepidoptera (Raju et al. 2004)
59	*Stachytarpheta indica* (L.) Vahl** $	Verbenaceae	Zygomorphic	Blue	Tube	Not significant	Colour and nectar	Concealed	0.3 ± 0.08	Hymenoptera and Lepidoptera	–
60	*Stachytarpheta jamaicensis* (L.) Vahl** $	Verbenaceae	Zygomorphic	Purple	Tube	Not significant	Colour and nectar	Concealed	0.24 ± 0.11	Hymenoptera and Lepidoptera	Lepidoptera (Raju et al. 2004)
61	*Stachytarpheta mutabilis* (Jacq.) Vahl** $	Verbenaceae	Zygomorphic	Red	Tube	Not significant	Colour and nectar	Concealed	2.28 ± 0.39	Hymenoptera and Passeriformes	–
62	*Leea indica* (Burm. f.) Merr. * $	Vitaceae	Actinomorphic	White	Dish to Bowl	Not significant	Nectar	Exposed	0.71 ± 0.73	Diptera, Hymenoptera, Lepidoptera and Passeriformes	–

*—Wild | **—Cultivated | $—nectar sample collected.
Plant species area arranged family-wise in alphabetical order.

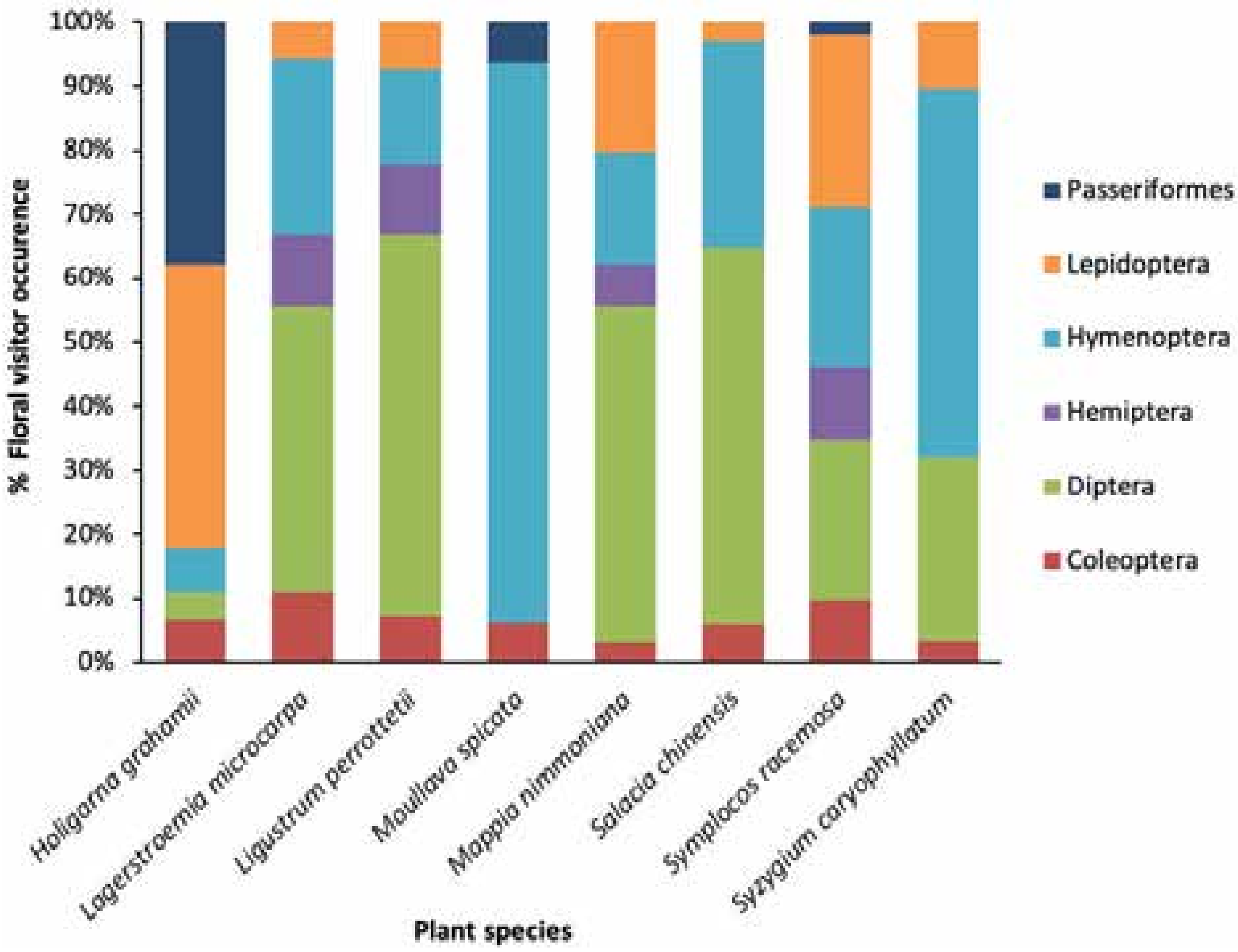

Figure 1. Floral visitor diversity in selected endemic and conservation-significant plant species.

possible pairs. Maximum mean difference between median nectar values (>9) was observed between 'white & yellow' flowers and coloured flowers (peach, orange, green, red & yellow, pink, yellowish-white, pink & yellow, lavender, purple, pinkish-white, blue, white).

DISCUSSION

Documentation of floral visitor diversity is important for understanding the role of specific pollinators in the survival of particular plant species (Rader et al. 2016). In tropical forests, the relationships between plants, and insect visitors remain largely unexplored (Tan et al. 2017). Though attempts have been made to document floral visitors of economically important agricultural crop species, there is dearth of studies pertaining to wild plants. Most studies on pollinator diversity in wild plants have focused on single species (Raju & Medabalimi 2016; Balducci et al. 2019; Cusser et al. 2021). Juan Fernandez Islands in Chile were explored in detail for studies related to floral traits, breeding systems, floral visitors, and pollination systems, by Bernardello et al. (2001). Widespread presence of 'dish-shaped' flowers, followed by 'tubular' flowers, and dominance of green coloured flowers, followed by white & yellow coloured flowers, was reported by them. However, in the present study, we observed that 'tube' was the most dominant flower type followed by 'dish to bowl'. White colour flowers were seen in case of 42% species followed by yellow, and pink coloured flowers.

Few researchers have attempted to show how floral colour influences pollinator partitioning in plant communities (Reverté et al. 2016). Sourakov et al. (2012) has shown the preferences for flower colour influencing the type of butterfly visitors. Selwyn & Parthasarathy (2006) recorded white as the most common flower colour (similar to the present study) with predominance of night-blooming flowers. Present study showed dominance of day blooming species.

Image 2. Representative flower types in the study area: A—Dish to bowl type flowers of *Leea indica* | B—Tube flowers of *Lantana camara* | C—Brush or head type flowers of *Syzygium caryophyllatum* | D—Gullet type flowers of *Hygrophila serpyllum* | E—Bell or funnel shaped flowers of *Parasopubia delphinifolia* | F—Flag type flowers of *Crotalaria retusa*. © Ankur Patwardhan.

According to Leppik (1969) and Faegri & van der Pijl (1979) the blossom classes (flower types) are correlated to a particular pollinating agent. Many species in the tropics may have morphologically simple flowers, allowing the access of different categories of visitors, such as bees, butterflies, moths, flies, and wasps (Bawa 1990). The 'dish' and 'brush' type of flower morphology thus provide a simple entry to the floral resources for a diverse range of floral visitors. In the present study, out of seven orders of floral visitors, 'dish to bowl' and 'brush or head' flower type supported six orders each.

In the mid-elevation evergreen forests of Western Ghats, majority of the plant species were categorized as specialized for single pollinator taxa – bee, beetle or moth (Devy & Davidar 2003). The study also revealed the importance of bees as pollinating agents, as majority of the plants were visited by bees across varied floral traits. The plant species in the current study could not be assigned to a specific pollinating agent as many plant species were visited by a wide variety of pollinators ranging from bees to birds. Our findings are in accordance with studies conducted by Bawa et al. (1985) in the tropical lowland forest at La Selva, which showed that most of the plant species in the study area were found to have pollinators with wide foraging ranges. The bipartite network shows that lepidopterans visit and pollinate the highest number of plant species.

Available nectar at the time of foraging and the nectar composition are other key factors that determine the floral visits by pollinators. As per the observations by Kaeser et al. (2008), standing nectar crop is affected by both rate of nectar production (that will depend on nectar production mechanism and will vary from flower to flower) as well as nectar consumption by pollinators. We recorded a wide range of nectar volumes 0.05–13.7 µl during the present study.

CONCLUSION

Our study documents the pollinators of tropical plant species in India and indicates that, although pollination syndromes are important in defining the diversity of floral visitors, other factors such as nectar composition, and flower type may play a more significant role in the process. Further exploration of this aspect is essential to understand the relationship between nectar volume, nectar production rate, and the number of visits by pollinators. More efforts to study the extent to which flower colour and other visual cues influence visitors' flower choice are needed for improved understanding of the costs, and rewards of the pollination process to the plants, and the pollinators. These trade-offs will be valuable in understanding the evolution of pollinator-plant relationships.

REFERENCES

Almeida, S.M. (1990). *The Flora of Sawantwadi, Maharashtra, India*. Scientific Publishers, Jodhpur, India, Vol I, 411 pp. & Vol II, 304 pp.

Balducci, M.G., T. Van-der-Niet & S.D. Johnson (2019). Butterfly pollination of *Bonateacassidea* (Orchidaceae): Solving a puzzle from the Darwin era. *South African Journal of Botany* 123: 308–316. https://doi.org/10.1016/j.sajb.2019.03.030

Barrios, B., S.R. Pena, A. Salas & S. Koptur (2016). Butterflies visit more frequently, but bees are better pollinators: the importance of mouthpart dimensions in effective pollen removal and deposition. *AoB Plants* 8: plw 001. https://doi.org/10.1093/aobpla/plw001AoB

Bartomeus, I., S.G. Potts, I. Steffan-Dewenter, B.E. Vaissière, M. Woyciechowski, K.M. Krewenka, T. Tscheulin, S.P. Roberts, H. Szentgyörgyi, C. Westphal & R. Bommarco (2014). Contribution of insect pollinators to crop yield and quality varies with agricultural intensification. *PeerJ* 2: e328. https://doi.org/10.7717/peerj.328

Bawa, K.S. (1990). Plant-pollinator interactions in tropical rain forests. *Annual Review of Ecology and Systematics* 21(1): 399–422. https://doi.org/10.1146/annurev.es.21.1101900.002151

Bawa, K.S., S.H. Bullock, D.R. Perry, R.E. Coville & M.H. Grayum (1985). Reproductive Biology of Tropical Lowland Rain Forest Trees. II. Pollination Systems. *American Journal of Botany* 72(3): 346–356. https://doi.org/10.2307/2443527

Bernardello, G., G.J. Anderson, T.F. Stuessy & D.J. Crawford (2001). A survey of floral traits, breeding systems, floral visitors, and pollination systems of the angiosperms of the Juan Fernández Islands (Chile). *The Botanical Review* 67(3): 255–308. https://doi.org/10.1007/BF02858097

Bhakare, M. & H. Ogale (2018). A Guide to Butterflies of Western Ghats (India): Includes Butterflies of Kerala, Tamil Nadu, Karnataka, Goa, Maharashtra and Gujarat State. Milind Bhakare (privately published), x + 496 pp.

BIOTIK (2008). Biodiversity Informatics and Co-operation in Taxonomy for Interactive Shared Knowledge Base**.** http://www.biotik.org/. Accessed on 08.iv.2020.

Bawa, K.S., A. Das, J. Krishnaswamy, K.U. Karanth, N.S. Kumar & M. Rao (2007). Ecosystem profile: Western Ghats and Sri Lanka Biodiversity Hotspot Western Ghats Region. A report by Critical Ecosystem Partnership Fund, 100 pp. https://www.cepf.net/sites/default/files/western-ghats-ecosystem-profile-english.pdf

Chaudhary, O.P. (2006). Diversity, foraging behaviour of floral visitors and pollination ecology of fennel (*Foeniculum vulgare* Mill.). *Journal of Spices and Aromatic Crops* 15(1): 34–41.

Cusser, S., N.M. Haddad & S. Jha (2021). Unexpected functional complementarity from non-bee pollinators enhances cotton yield. *Agriculture, Ecosystems and Environment* 314: 107415. https://doi.org/10.1016/j.agee.2021.107415

Dellinger, A. (2020). Pollination syndromes in the 21st century: Where do we stand and where may we go? *New Phytologist* 228(4): 1193–1213. https://doi.org/10.1111/nph.16793

Devy, M.S. & P. Davidar (2003). Pollination systems of trees in Kakachi, a mid-elevation wet evergreen forest in Western Ghats, India. *American Journal of Botany* 90(4): 650–657. https://doi.org/10.3732/ajb.90.4.650

Faegri, K. & L. Van-der-Pijl (1979). *The Principles of Pollination Ecology.* Pergamon Press, Oxford, UK, 244 pp.

Food and Agriculture Organization of the United Nations (1995). *Pollination of Cultivated Plants in the Tropics.* Rome, Italy, 4 pp.

**Fenster, C.B., W.S. Armbruster, P. Wilson, M.R. Dudash & J.D.

Thomson (2004). Pollination Syndromes and Floral Specialization. *Annual Review of Ecology, Evolution, and Systematics* 35: 375–403. https://doi.org/10.1146/annurev.ecolsys.34.011802.132347

Garibaldi, L.A., I. Steffan-Dewenter, R. Winfree, M.A. Aizen, R. Bommarco, S. Cunningham, C. Kremen, L.G. Carvalheiro, L.D. Harder, O. Afik, I. Bartomeus, F. Benjamin, V. Boreux, D. Cariveau, N.P. Chacoff, J.H. Dudenhöffer, B.M. Freitas, J. Ghazoul, S. Greenleaf, J. Hipólito & Holzs (2013). Wild pollinators enhance fruit set of crops regardless of honey bee abundance. *Science* 339(6127): 1608–1611. https://doi.org/10.1126/science.1230200

Grimmett, R., C. Inskipp & T. Inskipp (2011). *Birds of the Indian Subcontinent. 2nd Edition*. Oxford University Press & Christopher Helm, London, 528 pp.

Grindeland, J., N. Sletvold & R. Ims (2005). Effects of floral display and plant density on pollinator visitation rate in a natural population of *Digitalis purpurea*. *Functional Ecology* 19: 383–390. https://doi.org/10.1111/j.1365-2435.2005.00988.x

Huang, S.Q., L.L. Tang, J.F. Sun & Y. Lu (2006). Pollinator response to female and male floral display in a monoecious species and its implications for the evolution of floral dimorphism. *New Phytologist* 171: 417–424. https://doi.org/10.1111/j.1469-8137.2006.01766.x

Johnson, S.D. & K.E. Steiner (2000). Generalization versus specialization in plant pollination systems. *Trends in Ecology & Evolution* 15(4): 140–143. https://doi.org/10.1016/S0169-5347(99)01811-X

Kaeser, T., A. Sadeh & A. Shimda (2008). Variablity in nectar production and standing crop, and their relation to pollinator visits in a Meditarranean shrub. *Arthropod-Plant Interactions* 2: 117–123.

Kato, M., Y. Kosaka, A. Kawakita, Y. Okuyama, C. Kobayashi, T. Phimminith & D. Thongphan (2008). Plant-pollinator interactions in tropical monsoon forests in Southeast Asia. *American Journal of Botany* 95(11): 1375–1394. https://doi.org/10.3732/ajb.0800114

Kulkarni, S., P. Mestry, T. Pachpor & A. Patwardhan (2023). Nectar dynamics and butterfly floral visitors of Leucas stelligera Wall. ex Benth. and Ixora coccinea L. *Arthropod-Plant Interactions* 17: 43–49. https://doi.org/10.1007/s11829-022-09938-5

Kumar, K.S. & V.P. Khanduri (2016). Flower pollinator interactions within two tropical tree species of Mizoram, North East India. *Notulae Scientia Biologicae* 8(2): 256–262. https://doi.org/10.15835/nsb829789

Laha, S., S. Chatterjee, A. Das, B. Smith & P. Basu (2020). Exploring the importance of floral resources and functional trait compatibility for maintaining bee fauna in tropical agricultural landscapes. *Journal of Insect Conservation* 24: 431-443. https://doi.org/10.1007/s10841-020-00225-3

Larson, B.M.H., P.G. Kevan & D.W. Inouye (2001). Flies and flowers: Taxonomic diversity of anthophiles and pollinators. *The Canadian Entomologist* 133(4): 439–465. https://doi.org/10.4039/Ent133439-4

Lemaitre, A.B., C.F. Pinto & H.M. Niemeyer (2014). Generalized pollination system: Are floral traits adapted to different pollinators? *Arthropod-Plant Interactions* 8: 261–272. https://doi.org/10.1007/s11829-014-9308-1

Leppik, E.E. (1969). Morphogenic classification of flower types. *Phytomorphology* 18: 451–466.

McGavin, G.C. (2002). Insects, Spiders and other Terrestrial Arthropods. Dorling Kindersley, London.

Nayak, G.K. & P. Davidar (2010). Pollination and breeding systems of woody plant species in tropical dry evergreen forests, southern India. *Flora - Morphology, Distribution, Functional Ecology of Plants* 205(11): 745–753. https://doi.org/10.1016/j.flora.2009.12.041

Ollerton, J. & S. Watts (2000). Phenotype space and floral typology: towards an objective assessment of pollination syndromes. *Det Norske Videnskaps-Akademi. I. Matematisk-Naturvidenskapelige Klasse, Skrifter, Ny Series* 39: 149–159.

Ollerton, J., R. Winfree & S. Tarrant (2011). How many flowering plants are pollinated by animals? *Oikos* 120: 321–326. https://doi.org/10.1111/j.1600-0706.2010.18644.x

Pachpor, T., M. Sonne, A. Bhatt, K. Parkar, S. Shahane, P. Mestry, S. Kulkarni, H. Ogale & A. Patwardhan (2022). Nectar sugar composition, standing nectar crop and floral visitor diversity of three endemic plant species from Western Ghats Biodiversity Hot-Spot of India. *Chemistry & Biodiversity* 19(6): e202200001. https://doi.org/10.1002/cbdv.202200001

Parachnowitsch, L.A., J.S. Manson & N. Sletvold (2019). Evolutionary ecology of nectar. *Annals of Botany* 123: 247–261. https://doi.org/10.1093/aob/mcy132

Pascal, J. (1988). Wet evergreen forests of Western Ghats: ecology, structure, floristic composition and succession. Insitut Francais Pondicherry, Travaux. De la Science et Technique, Pondicherry, 365 pp.

Plants of the World Online. https://powo.science.kew.org. Accessed on 18 March 2025.

Rader, R., I. Bartomeus, L.A. Garibaldi, M.P. Garratt, B.G. Howlett, R. Winfree, S.A. Cunningham, M.M. Mayfield, A.D. Arthur, G.K. Andersson & R. Bommarco (2016). Non-bee insects are important contributors to global crop pollination. *Proceedings of the National Academy of Sciences* 113(1): 146–151. https://doi.org/10.1073/pnas.1517092112

Raju, A.J.S. & M.R. Medabalimi (2016). Flowering phenology, breeding system, pollinators and fruiting behaviour of *Pavetta tomentosa* (Rubiaceae) Roxb. Ex. Sm., a keystone shrub species in the southern Eastern Ghats Forest, Andhra Pradesh, India. *Annali Di Botanica* 6: 9–20. https://doi.org/10.4462/annbotrm-13160

Raju, A.J.S., A. Bhattacharya & S.P. Rao (2004). Nectar host plants of some butterfly species at Visakhapatnam. *Science and Culture* 70(5/6): 187–190.

Raju, A.J.S., S.S. Kumar, G. Lakshminarayana, G.U. Rao, C.P. Rao & K.V. Ramana (2022). Bee-pollination in *Crotalaria laburnifolia*, *Crotalaria medicaginea*, *Crotalaria retus*a and *Crotalaria verrucosa* and *C. retusa* as a source of alkaloids for nymphalid butterflies. *Discovery* 58(317): 399–408.

Reverté, S., Retana, J., Gómez, J.M., Bosch, J. (2016). Pollinators show flower colour preferences but flowers with similar colours do not attract similar pollinators. *Annals of Botany* 118(2): 249–257. https://doi.org/10.1093/aob/mcw103

Riswanta, U.R., N.C. Aditya, A. Sobri & S. Sukirno (2021). Diversity and abundance of insect pollinator on *Dimocarpus longan* L. in Sawitsari research station, Sleman, Yogyakarta. In *IOP Conference Series: Earth and Environmental Science* 819(1): 012070.

Sanchez, B.F. & K.A.G. Wyckhyus (2019). Worldwide decline of the entomofauna: A review of its drivers. *Biological Conservation* 232: 8–27. https://doi.org/10.1016/j.biocon.2019.01.020

Selwyn, M.A. & N. Parthasarathy (2006). Reproductive traits and phenology of plants in tropical dry evergreen forest on the coromandel coast of India. *Biodiversity and Conservation* 15(10): 3207–3234. https://doi.org/10.1007/s10531-005-0035-x

Sharma, M., S.R. Uma, S. Leather, R. Vasudeva & K.R. Shivanna (2011). Floral resources, pollinators and fruiting in a threatened tropical deciduous tree. *Journal of Plant Ecology* 4: 259–267. https://doi.org/10.1093/jpe/rtq029

Singh, N.P., P. Lakshminarasimhan, S. Karthikeyan & P. Prasanna (2001). *Flora of Maharashtra State*. Botanical Survey of India, Vol. I (898+228pp) & Vol. II (1079+182pp).

Singh, P.K., Karthigeyan, P. Lakshminarasimhan & S.S. Dash (2015). *Endemic Vascular Plants of India*. Botanical Survey of India, Kolkata, xvi + 143 pp.

Sinu, P.A. & K.R. Shivanna (2007). Pollination biology of large cardamom (*Amomum subulatum*). *Current Science* 93(4): 548–552.

Somanathan, H. & R.M. Borges (2001). Nocturnal pollination by the Carpenter Bee *Xylocopa tenuiscapa* (Apidae) and the effect of floral display on fruit set of *Heterophragma quadriloculare* (Bignoniaceae) in India. *Biotropica* 33(1): 78–89. https://doi.org/10.1111/j.1744-7429.2001.tb00159x

Sourakov, A., A. Duehl & A. Sourakov (2012). Foraging Behavior of the Blue Morpho and Other Tropical Butterflies: The Chemical and Electrophysiological Basis of Olfactory Preferences and the Role of Color. *Psyche: A Journal of Entomology* 2012: 1–10. https://doi.org/10.1155/2012/378050

Sunnichan, V.G., H.Y. Mohan-Ram & K.R. Shivanna (2005). Reproductive biology of *Boswellia serrata*, the source of salai guggul, an important gum-resin. *Botanical Journal of the Linnean Society* 147: 73–82. https://doi.org/10.1111/j.1095-8339.2005.00349x

Tan, M.K., T. Artchwakom, R. Abdul-Wahab C.Y. Lee, D.M. Belabut & H.T. Wah-Tan (2017). Overlooked flower-visiting Orthoptera in Southeast Asia. *Journal of Orthoptera Research* 26(2): 143–153. https://doi.org/10.3897/jor.26.15021

Yan, J., Gang-Wang, Yi-Sui, Menglin-Wang & Ling-Zhang (2016). Pollinator responses to floral colour change, nectar and scent promote reproductive fitness in *Quisqualis indica* (Combretaceae). *Scientific Reports* 6(1): 1–10. https://doi.org/10.1038/srep24408

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ARTICLE

Ecological status, distribution, and conservation strategies of *Terminalia coronata* in the community forests of southern Haryana, India

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Abstract: *Terminalia coronata* is one of the economically and ecologically important native species of the arid and semi-arid region of south-west Haryana in India. However, the information on the distribution pattern and population structure of this species is very limited. Therefore, a study was aimed to inventorise, characterize, and map the distribution of *T. coronata* in the state of Haryana, India. Population inventory indicated that *T. coronata* is one of the fast-depleting species in the studied region. Consequently, further study was conducted to assess the threat and extinction risk of *T. coronata* in the southern and southwestern Haryana. Some efforts have also been made to design various conservation strategies, such as, development of standard protocols for nurseries, and formulation of government policies for ex situ & in situ conservation of *T. coronata* in Haryana. Results revealed that the distribution of *T. coronata* was limited to only seven districts of Haryana, including Nuh, Rewari, Mahendergarh, Charkhi Dadri, Bhiwani, Jhajjar, and Rohtak. Only 475 individuals of the species were found at 47 sites. The natural regeneration of the species was almost absent. It was suggested that species extinction could be prevented by reducing overexploitation, heavy lopping, land use change, heavy biotic pressure, habitat fragmentation, and climate change. Immediate measures are needed to conserve and develop the species population through appropriate propagation techniques.

Keywords: Biotic pressure, climate change, endemic, habitat fragmentation, Indrok, population structure, threatened.

Hindi: संक्षेपः टर्मिनलिया कोरोनाटा भारत के दक्षिण-पश्चिम हरियाणा प्रदेश के शुष्क और अर्ध-शुष्क क्षेत्रों की आर्थिक और पारिस्थितिक रूप से महत्वपूर्ण देशी वृक्ष प्रजातियों में से एक है। हालाँकि, इस प्रजाति के वितरण, स्वरूप और जनसंख्या संरचना के बारे में जानकारी बहुत सीमित है। अतः हरियाणा राज्य में इस वृक्ष के वितरण को सूचीबद्ध करने, विशेषतावर्णन करने और मानचित्रण करने के उदेश्य से एक अध्ययन कियागया। जनसंख्या आंकड़ों से संकेत मिलते है कि अध्ययन किए गए क्षेत्र में टर्मिनलिया कोरोनाटा तेजी से कम हो रही प्रजातियों में से एक है। परिणामस्वरूप, दक्षिणी और दक्षिण-पश्चिमी हरियाणा में इस वृक्ष के खतरे और विलुप्त होने के जोखिम का आकलन करने के लिए आगे का अध्ययन किया गया। विभिन्न संरक्षण नीतियों को अभिकल्प करने के लिए कुछ प्रयास भी किए गए हैं, जैसे कि पौधशाला के लिए मानक संलेख का विकास और हरियाणा प्रदेश में टर्मिनलिया कोरोनाटा के अपने प्राकृतिक आवास व प्राकृतिक परिवेश के बाहर के लिए सरकारी नीतियों का निर्धारण शामिल है। परिणामों से पता चलता है कि टर्मिनलिया कोरोनाटा का वितरण हरियाणा राज्य के केवल सात जिलों तक ही सीमित है, जिनमें नूंह, रेवाड़ी, महेन्द्रगढ, चरखीदादरी, भिवानी, झज्जर और रोहतक शामिल है। 47 स्थलों पर इस प्रजाति के केवल 475 वृक्ष पाए गए। इस प्रजाति का प्राकृतिक पुनर्जनन लगभग नगण्य दर्ज किया गया। यह सुझाव दिया गया कि अतिदोहन, अत्यधिक कटाई, भूमि उपयोग परिवर्तन, भारी जैविक दबाव, आवास विखंडन और जलवायु परिवर्तन को कम करके प्रजातियों के विलुप्त होने को रोका जा सकता है। उपयुक्त प्रसारत कनीकों के माध्यम से इस प्रजातियों की आबादी के संरक्षण और विकास के लिए तत्काल उपाय किए जाने की आवश्यकता है।

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INTRODUCTION

The genus *Terminalia* L. (Combretaceae) comprises approximately 200 species of trees and shrubs distributed across tropical, and subtropical zones, many of which yield high-value non-timber forest products (NTFPs) (Zhang et al. 2019). In India, *Terminalia* species play fundamental ecological and socioeconomic roles, particularly in dry deciduous and thorn forest ecosystems by providing fuelwood, fodder, medicines, and ecosystem stability. *Terminalia coronata* (Stapf) Gere & Boatwr. is among the lesser-studied species in this complex, with its taxonomy recently clarified through molecular revision, wherein *Anogeissus* genus is assimilated into *Terminalia* (Maurin et al. 2017).

Terminalia coronata is a drought-adapted species native to northwestern and central India, occurring in seasonally dry tropical biomes and presently reported as 'endemic and threatened' in the arid, and semi-arid regions of northwestern India, noting its occurrence in patches—especially in sandy-loam to loamy-sandy soils of depressed landforms (Singh et al. 2021). Within Haryana, especially in the seven districts of Nuh, Rewari, Mahendergarh, Charkhi Dadri, Jhajjar, Rohtak, and Bhiwani, the species is largely confined to the Aravalli hill system, and associated rocky outcrops, configured as a mosaic of community forests, village commons, and degraded scrublands. These landscapes fall under the northern tropical thorn and dry deciduous forest types (Champion & Seth 1968). *Terminalia coronata* tends to appear in small subpopulations along shallow colluvial soils and edges of degraded forest, often co-occurring with species such as *Senegalia senegal*, *Vachellia leucophloea*, *Balanites aegyptiaca,* and *Boswellia serrata*, which are dominant components of biomass in similar landscapes. Its socio-economic uses are consistent with related species, serving as fuelwood and small timber; stems are coppiced for poles, and implements; leaves are occasionally used as fodder; and bark or foliage may serve in traditional remedies as astringents. Similar ethnopharmacological uses are common in *Anogeissus* (now *Terminalia*) species in India and Asia, including treatment of gastric disorders, skin conditions, and wound healing (Zhang et al. 2019). Despite this ecological and socio-economic significance, scientific knowledge of *T. coronata* in Haryana remains fragmentary. Existing literature (regional floras and forest working plans) makes only incidental mentions, lacking quantitative data on distribution patterns, population density, regeneration potential, habitat associations, or responses to disturbance. Also missing are insights into reproductive ecology, genetic diversity, or propagation methods tailored to local restoration efforts.

This knowledge gap presents a pressing conservation challenge, without a clear understanding of the species' spatial occurrence, population health, regeneration dynamics, and threats, it is impossible to properly assess its IUCN Red List status at the state level, design effective management interventions, or include it in Aravalli restoration and enrichment initiatives. Haryana, one of the distributional ranges of *T. coronata*, is a northwestern state in India with a total geographical area of 44,212 km^2. Various theories have proved that the distribution of species is primarily determined by its evolution base, biogeography, and conservation actions taken from time to time (Barik et al. 2018). All these theories have also suggested that biotic, abiotic, and anthropogenic factors played a vital role in the spatial distribution pattern of the species (McKinney 2002). Therefore, the present study provides the first comprehensive species-level assessment of *T. coronata* across community forests in Nuh, Rewari, Mahendergarh, Charkhi Dadri, Jhajjar, Rohtak, and Bhiwani. Outcomes of the study will map its current distribution and habitat associations; quantify population structure based on Diameter at Breast Height (DBH) and regeneration modes; evaluate environmental and anthropogenic influences on its occurrence and formulate community-compatible conservation. These efforts aim to inform species-specific conservation planning, guide propagation and restoration protocols, and strengthen biodiversity resilience in southern Haryana, India.

MATERIALS & METHODS

Study site

Present study was conducted in seven districts of southern part of Haryana State in India. A total of 47 locations were identified in seven districts in Haryana (Nuh, Rewari, Mahendergarh, Charkhi Dadri, Jhajjar, Bhiwani, and Rohtak) (Figure 1, 2). The climatic conditions of the study area vary from arid to semi-arid. Rainfall pattern varies 350–650 mm annually, with majority (75%) of the rainfall during July–September. The area has a distinct topography with flat alluvial plains with local undulations of sand-dunes and Aravalli outcrops with altitude varying 215–275 m. Tropical dry deciduous forests and thorn scrub forests characterized the vegetation. The study area covers about 31% of the total geographical area and about 28% of the state's total population (ISFR 2023).

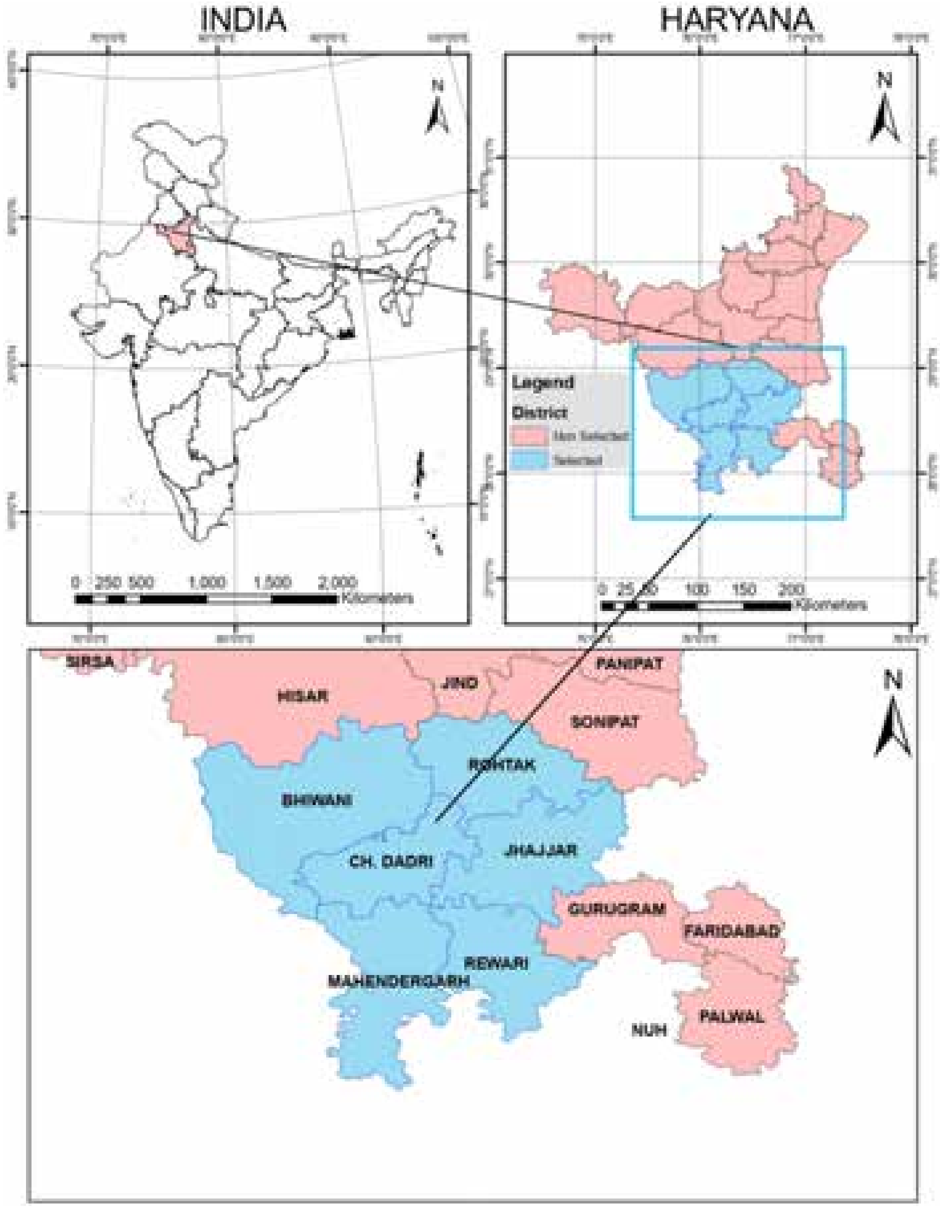

Figure 1. Study area.

Literature survey

An extensive literature survey was conducted to determine historical and contemporary records of *Terminalia coronata* in Haryana following district gazetteers for all districts, forest division working plans, regional floras, tree census records, biodiversity occurrence data, and people's biodiversity registers (PBRs) obtained via district coordinators. Additional location records were gathered through district-wise consultations with forest officials and semi-structured interview with elderly residents of villages possessing community forest patches with open-ended questionnaire. The obtained data were used to corroborate secondary data and identify potential *T. coronata* sites not reflected in official records.

Field investigation

Field investigations were conducted from April 2023 to March 2025 to verify the presence of *T. coronata* across all identified locations. In each site, all individuals—including mature trees, saplings, and seedlings—were enumerated. Botanical identification followed regional floras and taxonomic revisions of *Terminalia*. For each individual, diameter at breast height (DBH), total height, crown diameter, ownership status, and micro-habitat description were recorded.

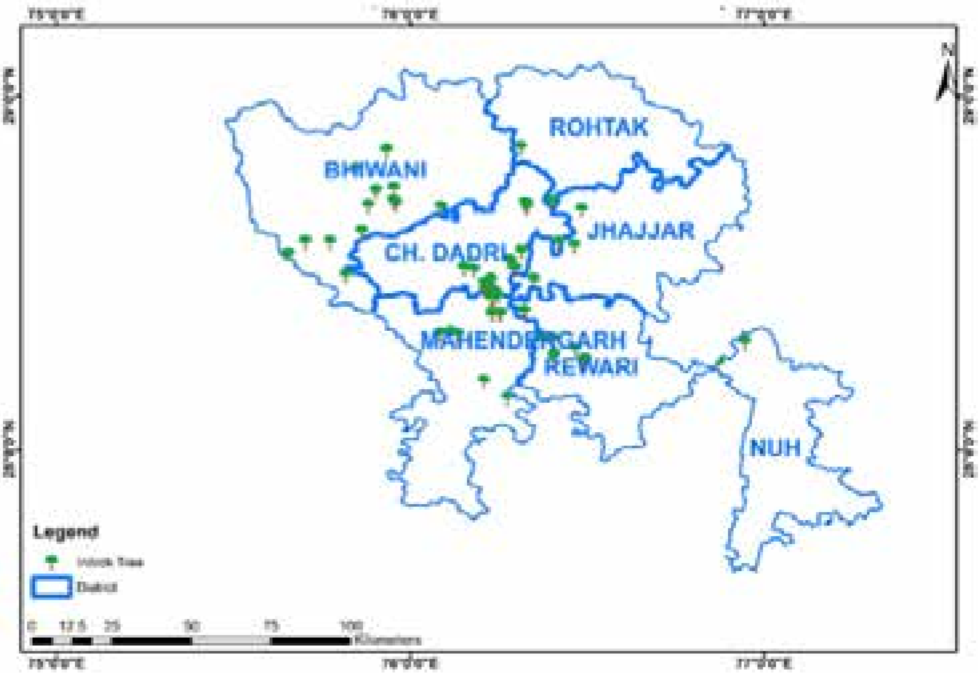

Figure 2. Distribution map of *Terminalia coronata* in Haryana.

The individuals of each tree species were segregated based on their DBH (measured at 1.37 m above ground) exceeding 30 cm were classified as mature trees. Those with DBH less than 10 cm were categorised as seedlings, while individuals with DBH values between these two limits were considered saplings (Malik & Bhatt 2015). The geographic coordinates of each tree were recorded using a handheld GPS receiver. These point data were later imported into GIS software (QGIS v3.28) for spatial analysis & mapping of the species' distribution within, and across districts.

Data management and analysis

Data from all field sites were compiled into a relational database. Summary statistics were generated for population structure (seedling, sapling and mature classes), size-class distribution, and health status. District-wise abundance and density were calculated. The spatial dataset was used to prepare thematic maps illustrating current known distribution, overlaid with administrative boundaries, and forest type layers.

RESULTS AND DISCUSSION

Taxonomic treatment

Terminalia coronata (Stapf) Gere & Boatwr. Bot. J. Linn. Soc. 184: 319. 2017. *Anogeissus coronata* Stapf, Kew Bull. 4: 153. 1914; Bhandari Fl. Indian Desert 140. 1990. *Anogeissus sericea* Brandis, Indian Forester 25: 287. 1899. *Anogeissus sericea* var. *nummularia* King ex Duthie, Fl. Upp. Gang. Pl. 1: 340. 1903; Scott in Kew Bull. 33: 559.1979. *Anogeissus rotundifolia* Blatt. & Hallb., Journal Bombay Nat. Hist. Soc., 36: 525.1919.

Botanical Description

Small tree, 4–6 m high; bark rough to fissured, tomentose; branchlets 1–4 mm thick. Leaves 0.6–2 × 0.4–2 cm, orbicular to flabellate or obovate, rounded, obtuse, truncate or subacute at base, rounded, retuse, obcordate or truncate and mucronulate at apex, coriaceous, tomentellous, pale green when dry; lateral nerves 4–6 pairs, faint, arcuate; tertiary nerves inconspicuous; petioles 1–3 mm long. Inflorescence heads 10–20 mm in diam., axillary, and terminal, rarely branched; peduncles 5–25 mm long, tomentellous; bracts on peduncles two pairs, 1–5 mm long, deciduous; bracteoles 1–2 mm long. Flowers tomentellous. Calyx-tube 3–4 mm long; teeth triangular, c. 0.5 mm long. Stamens 2.5–3.5 mm long. Style 1.5–2.5 mm long. Fruits 3.5–5 × 6–8 mm (excluding beak), brown, glabrous; beak 3–4 mm long; wings undulate.

Flowering & Fruiting

September to February.

Table 1. Distribution of *Terminalia coronata* in different districts.

Name of district	Name of locations/ village	No. of trees	No. of sites with a solitary tree	Geo-coordinates of the site
Nuh	Bissar Akberpur	1	1	N28.302579, E76.945815
	Rathiwas	1	1	N28.243575, E76.871532
	Total (2 sites)	**2**	**2**	
Bhiwani	Danger	10	0	N28.3933, E75.5523
	Dhab Dhani	1	1	N28.3846, E75.5250
	Kairu	1	1	N28.4118, E75.5251
	Legha Bhanan	28	0	N28.4132, E75.5731
	Jitanwas	4	0	N28.42 12, E75.7616
	Mansarbas	9	0	N28.4349, E75.5472
	Kalinga	1	1	N28.8535, E76.3132
	Dhani Gurjan	1	1	N28.41227, E76.51098
	Kudal	13	0	N28.61559, E75.86287
	Nangal	5	0	N28.536213, E75.640266
	Jhumpa Kalan	4	0	N28.492037, E75.817452
	Alampur	2	2	N28.792458, E75.845365
	Kharkari Sohan	17	0	N28.846084, E75.932219
	Dhanimahu	3	0	N28.737760, E75.953110
	Chahar Khurd	10	0	N28.586316, E75.702753
	Total (15 sites)	**109**	**6**	
Charkhi Dadri	Changroad	2	0	N28.281121, E76.123303
	Sanwar-Bhageswari Road	2	0	N28.4143316, E76.1931944
	Bhageswari	7	0	N28.684206, E76.330160
	Dudhwa	4	0	N28.28410, E76.13473
	Balali	1	1	N28.506163, E76.180407
	Jhojhu Kalan	3	0	N28.513453, E76.153785
	Jhojhu Kalan-Java Road	2	0	N28.512821, E76.152611
	Mauri	41	0	N28.31602, E76.16551
	Santokhpura	11	0	N28.511648, E76.297968
	Kheri Sawal	10	0	N28.560042, E76.314431
	Nimli	24	0	N28.584679, E76.418903
	Total (11 sites)	**107**	**1**	
Rewari	Nangal	100	0	N28.254975, E76.492723
	Kanwali	7	0	N28.311535, E76.404094
	Dhahina	3	0	N28.306407, E76.373366
	Siha	1	1	N28.26815, E76.406971
	Luhana	1	1	N28.262377, E76.406163
	Bawwa	12	0	N28.388872, E76.323138
	Motla Khurd	2	0	N28.283086, E76.467445
	Total (7 sites)	**126**	**2**	
Mahen-dergarh	Zerpur	4	0	N28.325651 E76.084061
	Sayana	71	0	N28.50271 E76.201376
	Pota	7	0	N28.424729 E76.229263
	Kheri	18	0	N28.38012 E76.231071
	Jharli	3	0	N28.3824 E76.25757
	Pali	5	0	N28.32423 E76.13451
	Baghot	1	1	N28.1449083 E76.274884
	Dongra Ahir	1	1	N28.191936 E76.208685
	Total (8 sites)	**103**	**2**	
Jhajjar	Dubaldhan	3	0	N28.678285 E76.485047
	Khanpur Khurd	11	0	N28.479334 E76.349895
	Matenhail	10	0	N28.589292 E76.41828
	Total (3 sites)	**24**	**0**	
Rohtak	Pilana	4	0	N28.4157 E76.2466
	Total (1 site)	**4**	**0**	
Grand Total	**47**	**475**	**11**	

Distribution

Terminalia coronata is endemic to northwestern India, common in dry habitats at 300–600 m in Rajasthan, Gujarat, Haryana, and Punjab. Earlier studies have reported its distribution in arid and semi-arid parts of Gujarat, Rajasthan, Haryana, and Punjab (Meena et al. 2018). The species occurrence was reported from Banaskantha and Mehsana districts in Gujarat (Kumar & Kalavathy 2010). In Rajasthan, the species was reported from Ajmer, Udaipur, Pratapgarh, Chittorgarh,

Table 2. Diameter at breast height of *Terminalia coronata* in different districts

District	Diameter at breast height (DBH in cm)											Total
	0–10	10–20	20–30	30–40	40–50	50–60	60–70	70–80	80–90	90–100	>100	
Nuh	0	0	0	0	0	0	1	1	0	0	0	**2**
Bhiwani	0	2	22	12	22	18	16	5	7	3	2	**109**
Charkhi Dadri	1	2	8	11	20	13	25	12	6	4	5	**107**
Rewari	0	4	11	30	40	22	12	4	1	1	1	**126**
M/Garh	5	34	7	9	13	10	13	6	3	1	2	**103**
Jhajjar	0	2	1	2	3	3	3	2	2	0	6	**24**
Rohtak	1	0	0	3	0	0	0	0	0	0	0	**4**
TOTAL	**7**	**44**	**49**	**67**	**98**	**66**	**70**	**30**	**19**	**9**	**16**	**475**
%	1.47	9.26	10.32	14.11	20.63	13.89	14.74	6.32	4.0	1.89	3.37	**100**

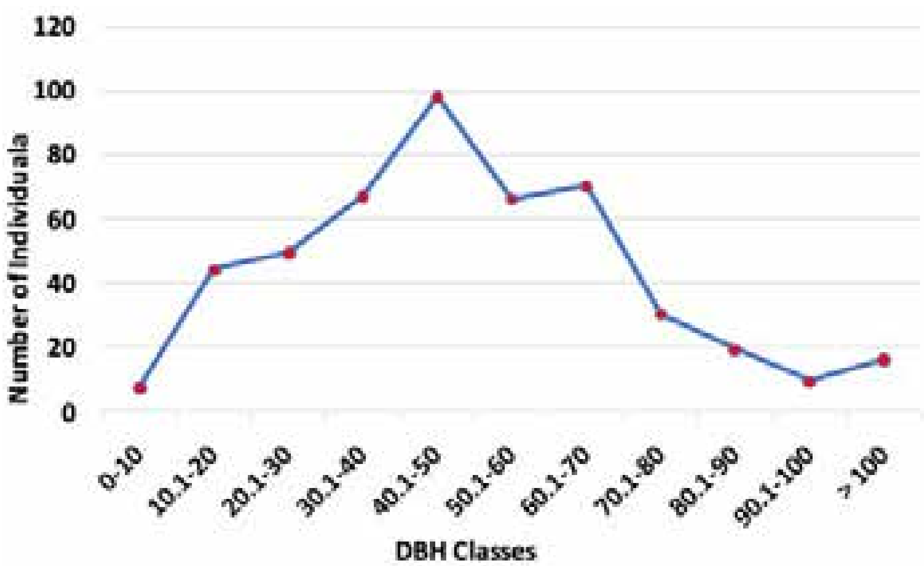

Figure 3. The d-d curve of *Terminalia coronata* in different districts of Haryana.

Pali Rajsamand, Sirohi, Jodhpur, and Alwar (Singh 2016). Additionally, distribution of *T. coronata* was also reported from the Aravalli Hills and Mahendergarh District of Haryana (Singh et al. 2021).

Taxonomic note

Various molecular studies have supported that *Terminalia* (Combretaceae: Terminaliinae) is paraphyletic, with the genera *Pteleopsis, Buchenavia*, and *Anogeissus* incorporated (Maurin et al. 2010). The molecular results confirmed that *Anogeissus*, *Buchenavia,* and *Pteleopsis* are embedded in *Terminalia*. These three genera were formally transferred to *Terminalia* (Maurin et al. 2017). Accordingly, all eight species of the earlier genus *Anogeissus* were put under *Terminalia*.

Ecology & Population Structure

Terminalia coronata grows luxuriantly in areas with lime-rich sandy loam to loamy sand with good water-holding capacity, and prefers low-lying areas near village ponds, earthen bunds, moist valleys, seasonal waterways, and foothills. It is generally found in gregarious form in pure patches near water bodies or low-lying areas. Similar growth pattern was also reported from Gujarat, Madhya Pradesh, and Bundelkhand region of Uttar Pradesh (Kumar & Kalavathy 2010; Meena et al. 2018).

After an extensive survey of the study area, *T. coronata* population was found at 47 sites only (Figure 2). Majority of the populations were situated in Bhiwani District (15 sites), followed by 11 sites in Charkhi Dadri,

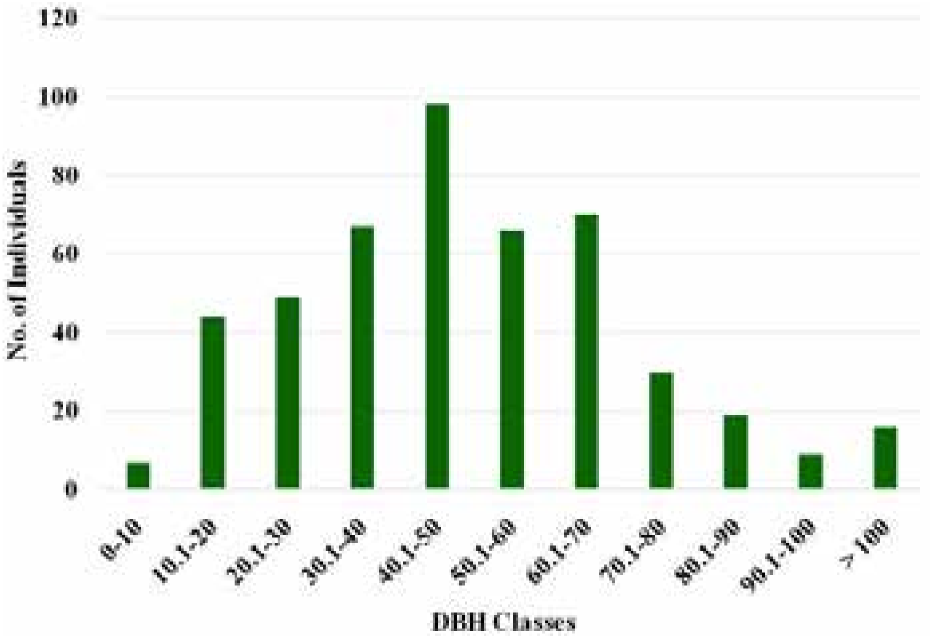

Figure 4. Distribution of diameter class of *Terminalia coronata* in Haryana.

eight sites in Mahendergarh, seven sites in Rewari, two sites in Nuh, and three sites in Jhajjar districts. In Rohtak, only one location of *T. coronata* population was found. Cumulatively, 428 trees were found in the seven districts. Habitat distribution of the species indicates its highly fragmented pattern concentrated in small patches, which were basically remnants of community forests. At 11 locations, only a single mature individual was present. Such solitary populations of *T. coronata* always remain vulnerable to disappearance by anthropogenic disturbances.

The tree with a maximum girth of 540 cm (172 cm DBH) was found in the Kharkhari Sohan Village of Bhiwani District. The maximum group population of 100 individual trees was found in village Nangal in Rewari District, followed by 41 trees in Mauri Village of Charkhi Dadri District, and 28 trees in village Legha Bhanan in Bhiwani District. The highest number of trees in a population was found in Rewari District, followed by Bhiwani, Charkhi Dadri, Mahendergarh, Jhajjar, Rohtak, and Nuh Districts (Tables 1,2). Results of the study also revealed that total stem density (trees with a diameter ≥10 cm) increases with diameter up to a certain threshold, specifically within the intermediate diameter class (30–34.9 cm). As a result, the diameter-density curve takes on a bell-shaped pattern (Figure 3). Diameter-wise distribution is a key indicator of forest dynamics, structural diversity, and the functioning of various forest ecosystems (Lutz et al. 2013), reflecting the mature status of the population of a species (Dar et al. 2017). This pattern may be attributed to past disturbances that potentially reduced the species' regeneration and the removal of large trees (Nizami 2012).

Table 3. The ownership pattern of *Terminalia coronata* in different districts of Haryana.

District	Ownership pattern			
	Panchayats	Forest	Temple	Private
Nuh	1	0	0	1
Bhiwani	76	0	32	1
Jhajjar	24	0	0	0
Rohtak	4	0	0	0
Mahendergarh	93	0	10	0
Charkhi Dadri	104	2	0	1
Rewari	121	1	4	0
Total	**423**	**3**	**46**	**3**
Percentage	89.05	0.63	9.68	0.63

The present study revealed the highest population (58.45%) in the middle-class diameter having 30–60 cm DBH. About 13.84% of the population has DBH of more than 100 cm, while 27.71% has less than 30 cm DHB (Figure 4). Most of the over-mature trees having more than 100 cm DBH are half-dried or diseased. Maximum over-mature trees were found in the district of Mahendergarh whereas the highest population of young trees was found in the district of Bhiwani, followed by

Image 1. Sapling and young *Terminalia coronata* plants at community forests in Sayana Mahendergarh. © Authors.

Mahendergarh District and Rewari District. A population with a higher number of seedlings and saplings (new recruits) in comparison to a mature population indicates a stable population. A smaller proportion of juveniles present a declining population, considered an unstable population (Lutz et al. 2013). The DBH size distribution curve comes out almost bell-shaped (Figure 3), if the population of over-mature trees are deducted from the total population. This indicates the dominance of middle-size classes (Dar et al. 2017). This pattern may be due to anthropogenic disturbance in the past, the removal of healthy big-size trees and the effect of climate change, which resulted in episodic recruitment.

Natural regeneration was almost absent in the sites except for the village of Sayana in Mahendergarh District (Image 1). Only few seedlings and samplings in Sayana Village in Mahendergarh District, and almost no natural regeneration in other sites indicated negligible regeneration of the species. At other sites, the lower-size class of young plants was more than 20 years old. They have shown no regeneration in the recent past. The species prefer moist and deeper soils, and grow along the natural drainage lines. The natural drainage system was highly disturbed or disappeared due to anthropogenic activities in the region, which might also be responsible for its negligible natural regeneration.

Threat status of *Terminalia coronata* population

Terminalia coronata is endemic to northwestern India and currently faces severe conservation concerns. It has been listed as indeterminate globally, included in CITES Appendix I, categorized as 'Rare' nationally, and more recently assessed as 'Endangered' under the IUCN Red List (Kaushal et al. 2021) reflecting its restricted distribution, overexploitation, habitat loss, and extremely poor regeneration.

A semi-structured interview with villagers, particularly elderly residents, across the study sites in southern and southwestern Haryana revealed multiple interlinked factors contributing to the decline of *T. coronata*. Most large mature trees have become hollow, half-dried, and diseased due to regular heavy lopping, and have become susceptible to fungal attacks, whereas roots were exposed due to soil. Historically, indiscriminate and unsustainable harvesting for its high-quality, durable timber—used in making carts, agricultural implements, furniture, and for construction—along with frequent lopping of branches for fodder and fuelwood, led to severe overexploitation of mature trees Land-use change posed another significant threat. Recent researches (Rajendrakumar & Kalavathy 2010; Meena 2013) also reported that agricultural expansion, driven by population growth and canal irrigation development, resulted in the clearance of large tracts of wasteland—once important habitats for *T. coronata*—with the species now nearly absent from cultivated lands; groundwater depletion and changing rainfall patterns have exacerbated this decline. Natural regeneration remains critically poor, with extremely low seed viability (0.1–0.2%) and high proportions of empty seeds, further aggravated by insect damage, overgrazing, climate change, and biotic pressures (Saxena & Dhawan 2001; Kanther 2019; Dadhich et al. 2022). Invasion by alien plants including *Parthenium hysterophorus*, *Lantana camara*, and *Xanthium strumarium* further degrade the habitat. Lastly, climate change, particularly declining precipitation, and rising temperatures in the fragile arid, and semi-arid ecosystems, has altered phenological patterns with reduced seed production leading to gradual decline in existing *T. coronata* populations.

Conservation strategies

The conservation of *T. coronata* in Haryana requires a multifaceted, community-inclusive approach that integrates protection, propagation, and policy measures. Immediate steps should focus on safeguarding existing populations through legal protection of key habitats, prevention of land-use change in biodiversity-rich community forests, and incentivising communities, and landowners for conservation efforts. Interaction with the locals revealed that *T. coronata* is well conserved in the village community forests (Bani) and sacred groves protected by the local communities primarily due to religious faiths, and beliefs. Parallelly, ex situ strategies must be strengthened by developing and standardising nursery, vegetative propagation, and tissue culture techniques to overcome poor seed viability, and limited natural regeneration. Lastly, large-scale reintroduction programs should be integrated into state plantation schemes, reviving traditional planting practices near ponds, temples, and grazing areas, thereby combining cultural heritage with ecological restoration.

CONCLUSION

The distribution of *Terminalia coronata* in the state of Haryana was confined to only seven districts falling in the southern and southwestern regions where its occurrence exists in small patches of community forests, and sacred groves. Over the years, its population has experienced a steep decline due to excessive exploitation for timber, which has historically been prized for its strength, and durability. The overexploitation, narrow extent of distributional presence, minimal natural stands, biotic pressure, habitat loss, poor generation, slow growing habit, susceptibility to grazing, and lack of awareness among the local residents are the main driving factors for the decreasing population of this species of economic significance. Many existing mature trees show signs of decay, hollowness, and disease, while regeneration in natural habitats remain extremely poor. The species suffers from very low seed viability and high seed predation, which, combined with heavy lopping, prevents successful recruitment of seedlings. and saplings. The species faces serious threats and extinction risks in the study area. There is an urgent need for both ex situ and in situ conservation of the species to ensure their protection, conservation, and propagation as well as to bring it out of the threatened status.

REFERENCES

Barik, S.K., O.N. Tiwari, D. Adhikari, P.P. Singh, R. Tiwary & S. Barua (2018). Geographic distribution pattern of threatened plants of India and steps taken for their conservation. *Current Science* 114(3): 470–503.

Champion, H.G. & S.K. Seth (1968). *A Revised Survey of the Forest Types of India*. Manager of Publications, Delhi, 404 pp.

Dadhich, A., L. Sharma, M. Dhiman, P. Dhawan, A. Singh & M.M. Sharma (2022). Anogeissus Species in Rajasthan (India): A Comprehensive Review on an Unexplored Plant. *Proceedings of the National Academy of Sciences, India Section B: Biological Sciences* 92(4): 723–729. https://doi.org/10.1007/s40011-022-01359-x

Dar, J.A., M.Y. Rather, K. Subashree, S. Sundarapandian & M.L. Khan (2017). Distribution patterns of tree, understorey, and detritus biomass in coniferous and broad-leaved forests of Western. Himalaya, India. *Journal of Sustainable Forestry* 36: 787–805.

ISFR (2023). India State of Forest Report. https://fsi.nic.in/forest-report-2023 Accessed on 13.i.2025.

Kanther, R.P. (2019). Dominant Flora of Todgarh- Raoli Wildlife Sanctuary Rajasthan, India. *The Journal of Indian Botanical Society* 98(1&2): 59–70.

Kaushal, S., R.L.S. Sikarwar & D. Mishra (2021). Status, Distribution and Conservation of *Terminalia coronata* (Stapf) Gere & Boatwr. in India. *Indian Forester* 147(12): 1204–1207.

Kumar, S.R. & S. Kalavathy (2010). Status and distribution of the 'rare' (r) tree species, *Anogeissus sericea* Brandis var. *nummularia* King ex Duthie. in the forest of North Gujarat Region (NGR), Gujarat, India. *Life Sciences Leaflets* 6: 178–181.

Lutz, J.A., A.J. Larson, J.A. Freund, M.E. Swanson & K.J. Bible (2013). The importance of large diameter trees to forest structural heterogeneity. *PLoS One* 8: e82784. https://doi.org/10.1371/journal.pone.0082784

Malik, Z.A. & A.B. Bhatt (2015). Phytosociologicalanalysis of woody species in KedarnathWildlife Sanctuary and its adjoining areasin western Himalaya, India. *Journal of Environmental Sciences* 31(3): 149–163. https://doi.org/10.7747/JFES.2015.31.3.149

Maurin, O., M.W. Chase, M. Jordaan & M. van der Bank (2010). Phylogenetic relationships of Combretaceae inferred from nuclear and plastid DNA sequence data: implications for generic classification. *Botanical Journal of the Linnean Society* 162: 453–476. https://doi.org/10.1111/j.1095-8339.2010.01027.x

Maurin, O., J. Gere, M. van der Bank & J.S. Boatwright (2017). The inclusion of *Anogeissus, Buchenavia* and *Pteleopsis* in *Terminalia* (Combretaceae: Terminaliinae). *Botanical Journal of the Linnean Society* 184(3): 312–325. https://doi.org/10.1093/botlinnean/box029

McKinney, M.L. (2002). Effects of national conservation spending and amount of protected area on species threat rates. *Conservation Biology* 16(2): 539–543.

Meena, D., S. Bhatnagar & A. Singh (2018). A critical review of *Anogeissus pendula*: an important species of arid zone. *International Journal of Conservation Science* 9(1): 165–172.

Meena, K.L. (2013). Conservation priorities for endemic and threatened species Anogeissus sericea var. nummularia King ex Duthie-from Rajasthan, India. *Journal of Economic and Taxonomic Botany* 37(4): 636–643.

Nizami, S.M. (2012). The inventory of the carbon stocks in sub-tropical forests of Pakistan for reporting under Kyoto Protocol. *Journal of Forestry Research* 23: 377–384.

Rajendrakumar, S. & S. Kalavathy (2010). Status of Mature Trees, Seedlings and Saplings in Tropical Thorn Forest (TTF) of North Gujarat Region (NGR), Gujarat, India. *Life Sciences Leaflets* 6: 188–193.

Saxena, S. & V. Dhawan (2001). Large-scale production of Anogeissus pendula and A latifolia by micropropagation. *In Vitro Cellular & Developmental Biology-Plant* 37(5): 586–591. https://doi.org/10.1007/s11627-001-0103-1

Singh, K. (2016). Effect of Land use types on floral diversity and carbon sequestration in Jodhpur district of Rajasthan. Ph.D. Thesis. Forest Research Institute (Deemed) University, Dehradun, 182 pp.

Singh, K., R.L.S. Sikarwar & D. Mishra (2021). Status, Distribution and Conservation of *Terminalia coronata* (Stapf) Gere & Boatwr. in India. *Indian Forester* 147(12): 1204–1207. https://doi.org/10.36808/if/2021/v147i12/158802

Zhang, X.R., J.S. Kaunda, H.T. Zhu, D. Wang, C.R. Yang & Y.J. Zhang (2019). The genus Terminalia (Combretaceae): An ethnopharmacological, phytochemical and pharmacological review. *Natural Products and Bioprospecting* 9(6): 357–392.

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ARTICLE

Pterocarpus santalinus L.f. (Magnoliopsida: Fabales: Fabaceae) associated arboreal diversity in Seshachalam Biosphere Reserve, Eastern Ghats of Andhra Pradesh, India

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Abstract: The present study was carried out to assess the arboreal diversity associated with *Pterocarpus santalinus* in the Seshachalam Biosphere Reserve, southern Eastern Ghats of Andhra Pradesh, India. A total of 118 tree species (>10 cm GBH), belonging to 88 genera, and 41 families were enumerated in the study area. Among 118 species, 92 were deciduous, 23 were evergreen, and three were semi-evergreen. Of the total species, 13 were common, 39 were occasional, and 66 were found to be rare in occurrence. The family Fabaceae is dominant with 20 species, followed by Rubiaceae with 12 species, Combretaceae & Rutaceae, each with six species, and Anacardiaceae & Malvaceae each with five species. Of the total, 12 species were IUCN Red Listed, and 16 were endemic, which indicates that there is a need for their conservation and management.

Keywords: Conservation, deciduous, endemic, evergreen, IUCN Red List, occasional, rare, semi-evergreen.

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Author contributions: BSK involved in field work, data collection, photographs and manuscript writing, AMR involved in the plan of work, conducted field work and compiled the manuscript. CN and NRR involved in the field work and data collection, MVSB involved in analysis, VJSR and SS involved in the field work and herbarium preparation.

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INTRODUCTION

Trees form the backbone of the Earth's ecosystems, emphasizing their ecological significance in shaping the environment. Several scientists have given different definitions for a tree. According to Lawrence (1962), all woody plants that reach a height of at least 3 m, and have a single stem with a definite crown shape can be considered trees. Ford-Robertson (1971) stated that a tree is typically large. Crystal (1997) mentions a self-supporting stem as an extra feature. Quite a few sources refer to the minimum size of a tree, a height of 3 m (Deliĭska & Manoilov 2004), or a diameter of 12.7 cm, and a height of 4.6 m (Helms 1998). Allaby (1998) gives a minimum height of more than 10 m. International tree and shrub definitions use similar characteristics to specify the features of trees and shrubs (UNECE/FAO 2000; FAO 2004). Based on the above definitions, a tree has three main features: it is a perennial woody plant with a single main stem, or a coppice of several stems, and has a more or less definite crown. The trees differ from other plants in having cambium tissue that accounts for the woody nature of the stem (Gschwantner et al. 2009). Trees support biodiversity by creating habitats for innumerable species and forming complex relationships that sustain life across various ecosystems. Trees provide the basic needs of human beings in the form of air, food, timber, paper, fuel wood, and medicine (Pullaiah & Rani 1999).

The floristic studies play an important role in biodiversity conservation, ecosystem management, environmental monitoring & impact assessment, research, education, and public awareness. Floristic studies carried out by several workers (Ellis 1966; Pullaiah & Rani 1999; Madhava et al. 2008; Reddy et al. 2009; Babu & Rao 2010; Reddy et al. 2019) have not provided any information on trees that are close associates of *Pterocarpus santalinus*. In this context, the present study was contemplated to provide information on trees associated with *P. santalinus* in the Seshachalam Biosphere Reserve, Eastern Ghats of Andhra Pradesh, India.

MATERIALS AND METHODS

Study area

Seshachalam Biosphere Reserve is located in the Seshachalam hill ranges and lies between 13.011^0 N, 79.002^0 E, and 13.015^0 N, 79.007^0 E, spread across two districts, Kadapa and Chittoor, in the Eastern Ghats of southern Andhra Pradesh, India (Image 1). The vegetation type is deciduous (Champion & Seth 1968), and the forest reserve bearing *P. santalinus* trees is grouped as 5A/C2 (Sudhakar 2012). To undertake activities relating to biodiversity conservation and development of sustainable management aspects, the areas are demarcated into three interrelated zones: a) core zone, the central part of the reserve covering an area of 750.589 km^2 which is completely free from human habitation, remains undisturbed, and spread over 183 compartments; b) buffer or manipulation zone, covers an area of 1,865.156 km^2 spread over 455 forest compartments. The outer boundary of the core zone forms the inner boundary of the buffer zone, and the outer boundary of the forest compartment forms the outer boundary of the buffer zone; and c) the transition or restoration zone covers an area falling within a 5-km radius from the outer boundary of the buffer zone and spread over 41 forest beats. The study area has a typical monsoonal climate with three distinct seasons: summer, rainy, and winter. The summer is warm to extremely hot with minimum temperatures ranging from 9.7–25 ^{0}C and maximum temperatures ranging from 26–46^{0}C. The area receives moderate to heavy rainfall with a mean of 690–760 mm. The winter is mild, pleasant, and cooler with temperatures ranging from 13–25°C. The Eastern Ghats belt is commonly referred to as the Eastern Ghat granulite belt in the geological nomenclature. The Archaean or peninsular gneisses dominate the rock formation in the study area, consisting of sandstones, limestones, and shales with granite intrusions. The soil is red ferruginous loam, shallow, and nutrient-poor with a mixture of loose boulders of varying sizes in the hills & deep valleys, and certain areas are covered with prominent quartzite outcrops.

Methodology

The present data is an outcome of field research carried out as part of phytosociological studies in the red sandal natural forest sites of Seshachalam Biosphere Reserve in 2021–2024. All the tree species of ≥ 10 cm girth at breast height (GBH) were enumerated from 100 quadrates of size 31.7 x 31.7 m. The collected specimens were identified with the help of the 2nd edition of Flora of Andhra Pradesh Vol I to IV (Pullaiah et al. 2018a,b) and Flora of Presidency of Madras (J.S Gamble 1915–1934). Later, the herbarium was prepared according to the standard methodology described by Santapu (1955) and Jain & Rao (1977). Finally, the voucher specimens were deposited in the Department of Botany, Yogi Vemana University, Kadapa. The list of angiosperm tree species

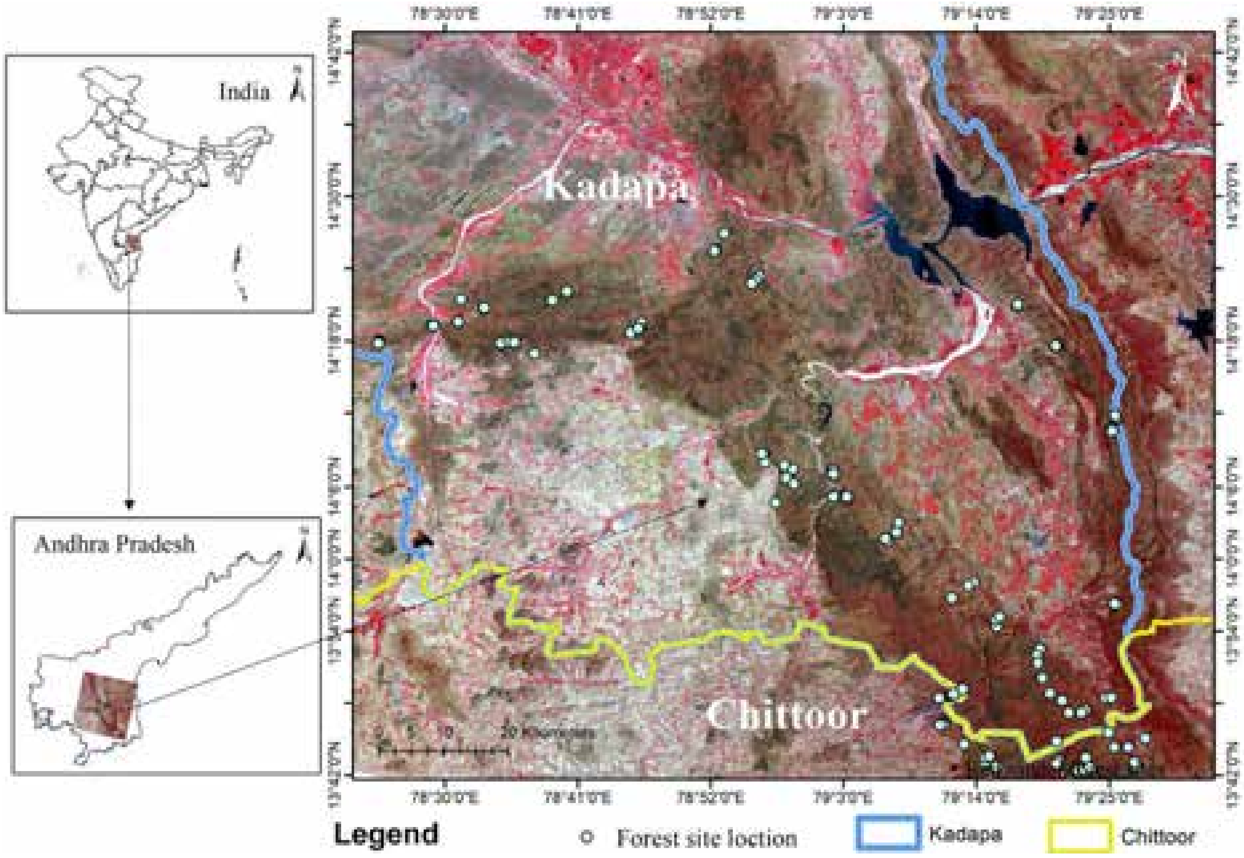

Image 1. Location map of the study area (Seshachalam Biosphere Reserve).

associated with *P. santalinus* were tabulated according to the latest Angiosperm Phylogeny Group (Chase et al. 2016) system of classification, specifying the family, nature of trees, voucher number, and distribution in the study sites (Table 1).

RESULTS AND DISCUSSION

The present study recorded 118 species belonging to 88 genera and 41 families (Table 1; Images 1–5). The top 10 dominant families are: Fabaceae with 11 genera and 18 tree species (17%) followed by Rubiaceae with 10 genera, and 12 species (10%), Rutaceae with six genera, and six species (5%), Combretaceae with one genus, and six species (5%), Anacardiaceae with four genera, and five species (4%), Malvaceae with three genera, and five species (4.3%), Euphorbiaceae & Lamiaceae each with four genera, and four species (3.5% each) while the families, Apocynaceae & Phyllanthaceae each with three genera, and four species (3.4% each). Four families, Burseraceae, Celastraceae, Meliaceae, and Rhamnaceae, were represented by three species each. Ten families, Annonaceae, Arecaceae, Boraginaceae, Dipterocarpaceae, Ebenaceae, Loganiaceae, Melastomataceae, Moraceae, Salicaceae, and Sapotaceae, were represented by two species each. Seventeen families, Bignoniaceae, Bixaceae, Capparaceae, Clusiaceae, Cornaceae, Cycadaceae, Erythroxylaceae, Hernandiaceae, Lauraceae, Lecythidaceae, Lythraceae, Myrtaceae, Ochnaceae, Oleaceae, Poaceae, Santalaceae, and Sapindaceae were represented by one species each..

Floristic studies carried out by different researchers showed variations in the dominance of angiosperm families in different forest areas of India. Kadavul & Parthasarathy (1999) reported that Moraceae, Euphorbiaceae, and Verbenaceae families were dominant in a tropical semi-evergreen forest of Kalrayan Hills. Chittibabu & Parthasarathy (2000) reported that Moraceae, Lauraceae, and Euphorbiaceae were the dominant families in evergreen forest sites of Kolli Hills. Reddy et al. (2007, 2008) documented that Rubiaceae and Euphorbiaceae were dominant in the tropical forest of Similipal Biosphere Reserve, Odisha, and in the tropical dry deciduous forest of southern Andhra

Table 1. List of *Pterocarpus santalinus* L.f. associated arboreal diversity in Seshachalam Biosphere Reserve, India.

	Name of the taxon/family	Nature	Voucher number	Occurrence
	Annonaceae			
1	*Miliusa tomentosa* (Roxb.) Finet & Gagnep.	Deciduous	5290	Rare
2	*Polyalthia cerasoides* (Roxb.) Bedd.	Semi-evergreen	5244	Rare
	Hernandiaceae			
3	*Gyrocarpus americanus* Jacq.	Deciduous	0274	Rare
	Lauraceae			
4	*Actinodaphne madraspatana* Bedd. ex Hook.f.	Evergreen	5101	Rare
	Arecaceae			
5	*Phoenix loureiroi* Kunth.	Evergreen	5347	Rare
6	*Phoenix sylvestris* (L.) Roxb.	Evergreen	5348	Rare
	Poaceae			
7	*Bambusa vulgaris* Schrad.	Deciduous	5349	Rare
	Fabaceae			
8	*Acacia catechu* (L.f.) Willd.	Deciduous	5353	Occasional
9	*Acacia chundra* (Rottl.) Willd.	Deciduous	5354	Occasional
10	*Acacia concinna* Wall.	Deciduous	-	Rare
11	*Albizia amara* (Roxb.) Boivin	Deciduous	5350	Rare
12	*Albizia lebbeck* (L.) Willd	Deciduous	5351	Rare
13	*Albizia odoratissima* (L.f.) Benth.	Evergreen	4629	Rare
14	*Bauhinia purpurea* L.	Deciduous	5352	Rare
15	*Bauhinia racemosa* Vahl	Deciduous	0563	Rare
16	*Cassia fistula* L.	Deciduous	0359	Occasional
17	*Cassia siamea* Lam.	Deciduous	-	Rare
18	*Dalbergia paniculata* Roxb.	Deciduous	4614	Occasional
19	*Dichrostachys cinerea* (L.) Wight & Arn.	Deciduous	-	Rare
20	*Hardwickia binata* Roxb.	Deciduous	5209	Occasional
21	*Leucaena leucocephala* (Lam.) de Wit	Deciduous	-	Rare
22	*Pterocarpus marsupium* Roxb.	Deciduous	5281	Rare
23	*Pterocarpus santalinus* L.f.	Deciduous	5208	Common
24	*Senna spectabilis* (DC.) H.S.Irwin & Barneby	Deciduous	-	Rare
25	*Tamarindus indica* L.	Evergreen	5355	Rare
	Moraceae			
26	*Ficus arnottiana* (Miq.) Miq.	Deciduous	5356	Rare
27	*Ficus hispida* L.f.	Deciduous	5357	Rare
	Rhamnaceae			
28	*Ziziphus mauritiana* Lam.	Deciduous	5327	Rare
29	*Ziziphus oenopolia* (L.) Mill.	Deciduous	5228	Occasional
30	*Ziziphus xylopyrus* (Retz.) Willd.	Deciduous	5358	Common
	Celastraceae			
31	*Elaeodendron glaucum* (Rottb.) Pers.	Evergreen	5313	Occasional
32	*Maytenus emarginata* (Willd.) Ding Hou	Deciduous	5329	Common
33	*Pleurostylia opposita* (Wall.) Alston	Semi-evergreen	5274	Rare
	Clusiaceae			
34	*Garcinia* sp.	Evergreen	-	Rare

	Name of the taxon/family	Nature	Voucher number	Occurrence
	Erythroxylaceae			
35	*Erythroxylum monogynum* Roxb.	Evergreen	5315	Common
	Euphorbiaceae			
36	*Cleistanthus collinus* (Roxb.) Benth. ex Hook.f.	Deciduous	5271	Occasional
37	*Croton scabiosus* Bedd.	Deciduous	5213	Occasional
38	*Givotia moluccana* (L.) Sreem.	Deciduous	5359	Rare
39	*Macaranga peltata* Müll.Arg.	Evergreen	5360	Rare
	Ochnaceae			
40	*Ochna obtusata* DC.	Deciduous	0481	Common
	Phyllanthaceae			
41	*Bridelia retusa* (L.) A. Juss.	Deciduous	5279	Occasional
42	*Glochidion velutinum* Wight	Evergreen	5289	Rare
43	*Phyllanthus indofischeri* Bennet	Deciduous	5273	Occasional
44	*Phyllanthus polyphyllus* Willd.	Deciduous	5272	Occasional
	Salicaceae			
45	*Flacourtia indica* (Burm.f.) Merr.	Deciduous	5319	Rare
46	*Homalium zeylanicum* (Gardner) Benth.	Evergreen	5261	Rare
	Combretaceae			
47	*Terminalia alata* Roth	Deciduous	5106	Occasional
48	*Terminalia anogeissiana* Gere & Boatwr.	Deciduous	5212	Common
49	*Terminalia bellirica* (Gaertn.) Roxb.	Deciduous	5264	Rare
50	*Terminalia chebula* Retz.	Deciduous	5339	Common
51	*Terminalia crenulata* Roth	Deciduous	5295	Rare
52	*Terminalia pallida* Brandis	Deciduous	5325	Occasional
	Lythraceae			
53	*Lagerstroemia parviflora* Roxb.	Deciduous	5331	Rare
	Melastomataceae			
54	*Memecylon umbellatum* Benth.	Evergreen	-	Rare
	Myrtaceae			
55	*Syzygium alternifolium* (Wight) Walp.	Deciduous	5233	Occasional
	Anacardiaceae			
56	*Buchanania axillaris* (Desr.) Ramamoorthy	Deciduous	5342	Occasional
57	*Buchanania lanzan* Spreng.	Evergreen	-	Rare
58	*Lannea coromandelica* (Houtt.) Merr.	Deciduous	-	Occasional
59	*Mangifera indica* L.	Evergreen	5361	Rare
60	*Semecarpus anacardium* L.f.	Evergreen	-	Rare
	Burseraceae			
61	*Boswellia ovalifoliolata* N.P. Balakr. & A.N. Henry	Deciduous	5210	Rare
62	*Boswellia serrata* Roxb.	Deciduous	4862	Occasional
63	*Commiphora caudata* (Wight & Arn.) Engl.	Deciduous	5211	Occasional
	Meliaceae			
64	*Azadirachta indica* A. Juss.	Semi-evergreen	5362	Rare
65	*Soymida febrifuga* (Roxb.) A. Juss.	Deciduous	5134	Occasional
66	*Walsura trifoliolata* (A. Juss.) Harms	Evergreen	5257	Rare
	Rutaceae			

	Name of the taxon/family	Nature	Voucher number	Occurrence
67	*Atalantia monophylla* (L.) DC.	Deciduous	0282	Rare
68	*Aegle marmelos* (L.) Corrêa	Deciduous	-	Rare
69	*Chloroxylon swietenia* DC.	Deciduous	5224	Common
70	*Limonia acidissima* L.	Deciduous	-	Rare
71	*Murraya koenigii* (L.) Spreng.	Deciduous	5308	Occasional
72	*Naringi crenulata* (Roxb.) Nicolson	Deciduous	0281	Rare
	Sapindaceae			
73	*Sapindus emarginatus* Vahl	Deciduous	0715	Rare
	Bixaceae			
74	*Cochlospermum palakondense*		5176	Rare
75	*Cochlospermum religiosum* (L.) Alston	Deciduous	5225	Occasional
	Dipterocarpaceae			
76	*Shorea roxburghii* G. Don	Deciduous	5075	Rare
77	*Shorea tumbuggaia* Roxb.	Deciduous	5298	Rare
	Malvaceae			
78	*Grewia hirsuta* Vahl	Deciduous	5218	Common
79	*Grewia flavescens* Juss.	Deciduous	-	Rare
80	*Grewia orbiculata* Rottler	Deciduous	5227	Common
81	*Grewia tiliifolia* Vahl	Deciduous	5140	Occasional
82	*Pterospermum xylocarpum* (Gaertn.) Oken.	Evergreen	5300	Rare
83	*Sterculia urens* Roxb.	Deciduous	5160	Occasional
	Capparaceae			
84	*Maerua apetala* (B. Heyne ex Roth) M. Jacobs	Deciduous	0418	Occasional
	Santalaceae			
85	*Santalum album* L.	Evergreen	5243	Rare
	Cornaceae			
86	*Alangium salviifolium* (L.f.) Wangerin	Deciduous	5270	Rare
	Ebenaceae			
87	*Diospyros chloroxylon* Roxb.	Evergreen	5307	Rare
88	*Diospyros melanoxylon* Roxb.	Deciduous	4891	Occasional
	Lecythidaceae			
89	*Careya arborea* Roxb.	Deciduous	5334	Rare
	Sapotaceae			
90	*Madhuca longifolia* (J. Koenig ex L.) J.F. Macbr.	Deciduous	5223	Occasional
91	*Manilkara hexandra* (Roxb.) Dubard	Evergreen	-	Rare
	Apocynaceae			
92	*Carissa spinarum* L.	Deciduous	-	Occasional
93	*Holarrhena pubescens* Wall. ex G.Don	Deciduous	5292	Occasional
94	*Wrightia arborea* (Dennst.) Mabb.	Deciduous	-	Rare
95	*Wrightia tinctoria* R.Br.	Deciduous	5262	Occasional
	Loganiaceae			
96	*Strychnos nux-vomica* L.	Deciduous	5306	Rare
97	*Strychnos potatorum* L.f.	Deciduous	5216	Occasional
	Rubiaceae			
98	*Adina cordifolia* (Roxb.) Brandis	Deciduous	5287	Occasional

	Name of the taxon/family	Nature	Voucher number	Occurrence
99	*Canthium coromandelicum* (Burm.f.) Alston	Deciduous	-	Occasional
100	*Catunaregum spinosa* (Thumb.) Tirv.	Deciduous	-	Common
101	*Ceriscoides turgida* (Roxb.) Tirveng.	Deciduous	5263	Rare
102	*Deccania pubescens* (Roth) Tirveng.	Deciduous	5265	Occasional
103	*Gardenia gummifera* L.f.	Deciduous	5320	Common
104	*Gardenia latifolia* Schltdl. ex Hook.f.	Deciduous	-	Occasional
105	*Gardenia resinifera* Roth.	Deciduous	5322	Rare
106	*Ixora pavetta* Andrews	Deciduous	5234	Occasional
107	*Morinda pubescence* Buch.-Ham.	Deciduous	5221	Occasional
108	*Psydrax dicoccos* Gaertn.	Evergreen	5296	Occasional
109	*Wendlandia gamblei* Cowan	Deciduous	-	Rare
	Boraginaceae			
110	*Cordia monoica* Roxb.	Deciduous	-	Rare
111	*Ehretia aspera* Willd.	Deciduous	5204	Rare
	Bignoniaceae			
112	*Dolichandrone atrovirens* (Roth) K. Schum.	Deciduous	5255	Common
	Lamiaceae			
113	*Gmelina arborea* Roxb. ex Sm.	Deciduous	0326	Rare
114	*Premna tomentosa* Willd.	Deciduous	5267	Rare
115	*Tectona grandis* L.f.	Deciduous	-	Rare
116	*Vitex altissima* L.f.	Deciduous	0472	Occasional
	Oleaceae			
117	*Schrebera swietenioides* Roxb.	Deciduous	5268	Rare
	Cycadaceae			
118	*Cycas beddomei* Dyer	Evergreen	4701	Rare

Pradesh. Euphorbiaceae, Rubiaceae, and Moraceae families have been reported to be dominant in tropical hill forests of southern Eastern Ghats (Pragasan & Parthasarathy 2010), in the Seshachalam hill ranges of Andhra Pradesh (Babu & Rao 2010), and in the Chittoor East & West forest divisions of southern Andhra Pradesh (Rao et al. 2011). Fabaceae, Rubiaceae, and Euphorbiaceae have been reported to be dominant in the northern Andhra Pradesh, India (Reddy et al. 2011), and in the northcentral Eastern Ghats, Andhra Pradesh (Naidu et al. 2018). Fabaceae and Rubiaceae have been reported to be dominant in the northern Andhra Pradesh (Naidu & Kumar 2015), and these two families along with Meliaceae have been documented to be dominant in the tropical moist deciduous forests of Odisha (Sahoo et al. 2020). The present study shows that the most dominant family is Fabaceae in the study area. The dominance of this family has also been reported in other forest areas of Eastern Ghats of Andhra Pradesh by Reddy et al. (2011), Naidu & Kumar (2015), and Naidu et al. (2018), and in deciduous forests of Neotropical regions by Gentry (1995), Gillespie et al. (2000), Killeen et al. (1998), and Sampaio (1995). Although the Rutaceae family was ranked third in the present study, none of the studies above showed its dominance (one of the top three ranks). Parathasarathy & Karthiykeyan (1997) mentioned that Rutaceae, which ranked fifth in their study, is one of the important families in the tropical deciduous forests of India. The dominant plant families reported are similar in most of the studies, due to the presence of the same phytogeographic pattern.

The present study indicates that the majority of the tree species of Fabaceae, Rubiaceae, and Rutaceae are close associates of *P. santalinus* in the Seshachalam Biosphere Reserve. Vegetation-wise analysis of 118 tree species revealed that 80% of them are deciduous, 17% evergreen, and 3% semi-evergreen. Of the total species, 13 are common, 39 are occasional, and 66 are rare in occurrence (Table 1).

IUCN Red List and endemic taxa associated with *P. santalinus*

Of the total 118 tree species recorded, two are 'Near Threatened' (*Aegle marmelos* and *Pterocarpus marsupium*), six 'Vulnerable' (*Boswellia ovalifoliolata, Chloroxylon swietenia, Phyllanthus indofischeri, Santalum album, Shorea roxburghii,* and *Terminalia pallida*), and five 'Endangered' (*Cycas beddomei, Pterocarpus santalinus, Shorea tumbuggaia,* and *Syzygium alternifolium*) (IUCN 2025). A total of 16 endemic species were recorded from the study area. Of these, four are endemic to Andhra Pradesh (*Boswellia ovalifoliolata, Cycas beddomei, Syzygium alternifolium,* and *Terminalia pallida*), five endemic to the Eastern Ghats occur in Andhra Pradesh (*Actinodaphne madraspatana, Croton scabiosus, Pterocarpus santalinus, Shorea tumbuggaia,* and *Wendlandia gamblei*), and remaining are endemic to Peninsular India (*Deccania pubescens, Dolichandrone atrovirens, Maerua apetala, Ochna obtusata, Phyllanthus indofischeri, Polyalthia cerasoides* and *Shorea roxburghii*) (Ahmedullah & Nayar 1986; Reddy & Raju 2008).

CONCLUSION

The present study shows that there is rich and varied tree flora in close association with *Pterocarpus santalinus* in the Seshachalam Biosphere Reserve. The most dominant families include Fabaceae, Rubiaceae, and Rutaceae. Majority of the species recorded here are deciduous type with only a small fraction of evergreen or semi-evergreen ones. The study indicates that a significant number of species are under threat, with 12 species being IUCN Red Listed and 16 being endemic to the region. The status of these species indicates that there is a need for their protection in their natural sites. Given the ecological importance of *P. santalinus* and its associated species, continued monitoring, protection, and sustainable management strategies are required to safeguard the rich biodiversity of this region for future generations.

REFERENCES

Ahmedullah, M. & M.P. Nayar (1986). *Endemic plants of the Indian region, Volume 1*. Botanical Survey of India, Calcutta, 262 pp.

Allaby, M. (1998). *A Dictionary of Plant Sciences.* Oxford University Press, 508 pp.

Babu, M.S. & B.R.P. Rao (2010). Diversity and quantification of trees in Seshachalam hill ranges, Eastern Ghats, India. *Indian Journal of Tropical Biodiversity* 18(2): 143–161.

Champion, H.G. & S.K. Seth (1968). *A Revised Survey of the Forest Types of India*. Manager of Publications, Delhi, India, 606 pp.

Chase, M.W., M.J. Christenhusz, M.F. Fay, J.W. Byng, W.S. Judd, D.E. Soltis, D.J. Mabberley, A.N., Sennikov, P.S. Soltis, P.F. Stevens & B. Briggs (2016). An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants. *APG Botanical Journal of the Linnean Society* 181: 1–20. https://academic.oup.com/botlinnean/article-lookup/doi/10.1111/boj, 12385

Chittibabu, C.V. & N. Parthasarathy (2000). Attenuated tree species diversity in human-impacted tropical evergreen forest sites at Kolli hills, Eastern Ghats, India. *Biodiversity & Conservation* 9: 1493–1519. https://doi.org/10.1023/A:1008971015545

Crystal, D. (eds.) (1997). *The Cambridge Encyclopedia.* Cambridge University Press, 1303 pp.

Deliĭska, B. & P. Manoilov (2004). *Elsevier's Dictionary of Forestry*. Elsevier, Amsterdam, 1051 pp.

Ellis, J.L. (1966). A contribution to the vascular flora of Balapalle range of Seshachellam Reserve Forest, Cuddapah district, Andhra Pradesh. *Nelumbo* 9(1): 328–340. https://doi.org/10.20324/nelumbo/v9/1967/76133

FAO. (2004). Global Forest Resources Assessment update 2005 (FRA 2005): Terms and Definitions. FRA Working Paper 83/E, FAO Forestry Department, Rome, 34 pp.

Gamble, J.S. & C.E.C. Fischer (1915–1935). *Flora of Presidency of Madras Volume 1–3*. Adlard and Son Ltd, London, UK, 112–305 pp.

Gentry, A.H. (1995). Diversity and floristic composition of neotropical dry forests. *Seasonally Dry Tropical Forests* 1: 146–194. https://doi.org/10.1017/CBO9780511753398.007

Gillespie, T.W., A. Grijalva & C.N. Farris (2000). Diversity, composition, and structure of tropical dry forests in central America. *Plant Ecology* 147: 37–47. https://doi.org/10.1023/A:1009848525399

Gschwantner, T., K. Schadauer, C. Vidal, A. Lanz, E. Tomppo, L. Di Cosmo, N. Robert, D. Englert Duursma & M. Lawrence (2009). Common tree definitions for national forest inventories in Europe. *Silva Fennica* 43(2): 302–321.

Helms, J.A. (ed.) (1998). *The Dictionary of Forestry.* CAB International: The Society of American Foresters, Wallingford, 210 pp.

IUCN (2025). The IUCN Red List of Threatened Species. Version 2025-1. https://www.iucnredlist.org

Jain, S.K. & R.R. Rao (1977). *A Handbook of Field and Herbarium Methods.* Todays and Tomorrow's Printers and Publishers, New Delhi, India, 157 pp.

Kadavul, K. & N. Parthasarathy (1999). Structure and composition of woody species in tropical semi-evergreen forest of Kalrayan hills, Eastern Ghats, India. *Tropical Ecology* 40: 247–260.

Killeen, T.J., A. Jardim, F. Mamani & N. Rojas (1998). Diversity, composition, and structure of a tropical semideciduous forest in the Chiquitania region of Santa Cruz, Bolivia. *Journal of Tropical Ecology* 14(6): 803–827. https://doi.org/10.1017/S0266467498000583

Lawrence, G.H.M. (1962). *Taxonomy of Vascular Plants*. Scientific Publishers, Jodhpur, India, 823 pp.

Madhava C.K., K. Sivaji & K.T. Rao (2008). *Flowering plants of Chittoor district, Andhra Pradesh, India.* Tirupati, Student Offset Printers, 600 pp.

Naidu, M.T., D. Premavani, S. Suthari & M. Venkaiah (2018). Assessment of tree diversity in tropical deciduous forests of northcentral Eastern Ghats, India. *Geology, Ecology, and Landscapes* 2(3): 216–227. https://doi.org/10.1080/24749508.2018.1452479

Naidu, M.T. & O.A. Kumar (2015). Tree species diversity in the Eastern Ghats of northern Andhra Pradesh, India. *Journal of Threatened Taxa* 7(8): 7443–7459. https://doi.org/10.11609/JoTT.o3764.7443-59

Parthasarathy, N. & R. Karthikeyan (1997). Plant biodiversity inventory and conservation of two tropical dry evergreen forests on the Coromandel coast, south India. *Biodiversity & Conservation* 6: 1063–1083. https://doi.org/10.1023/A:1018328016810

Pragasan, L.A. & N. Parthasarathy (2010). Landscape-level tree

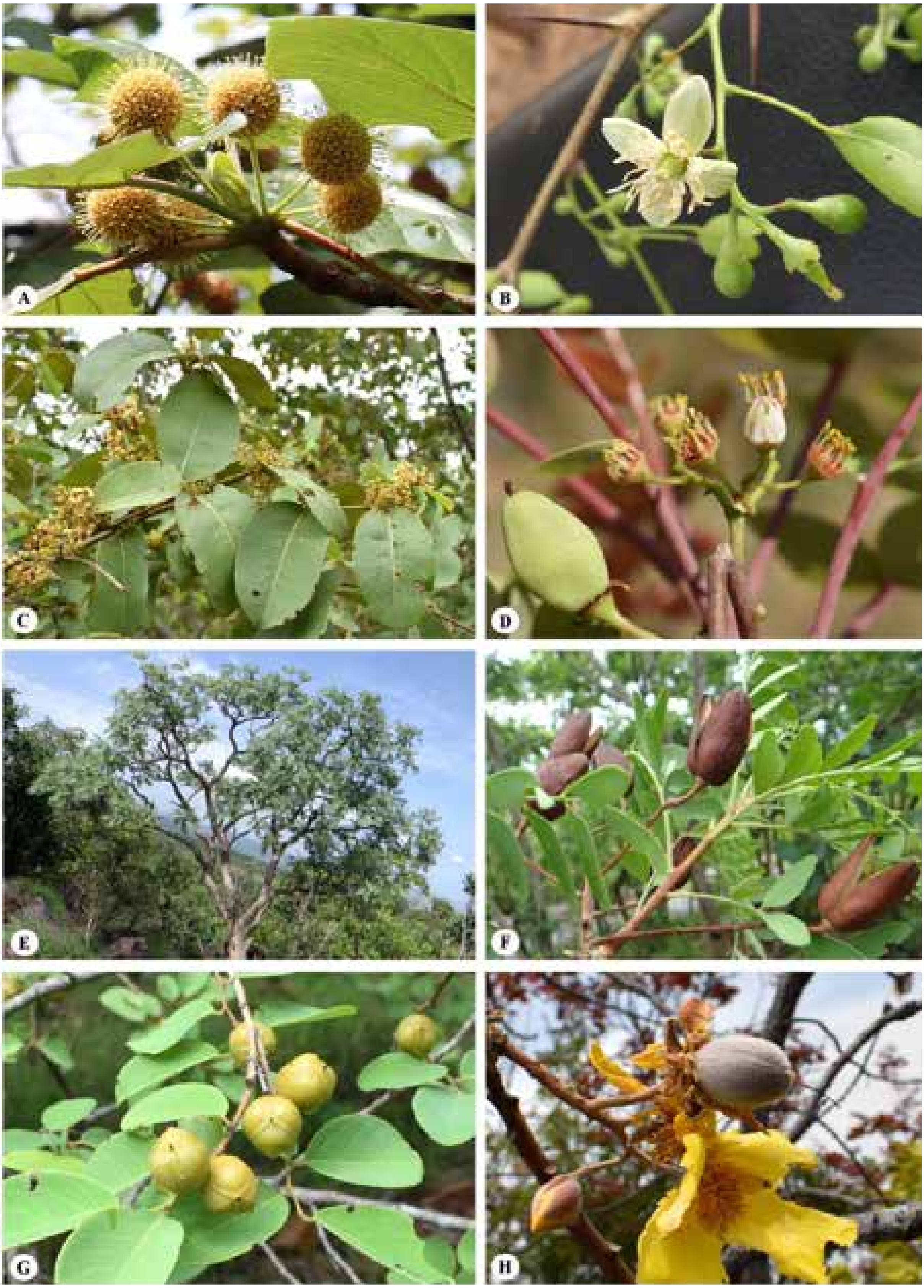

Image 2 (A–H). A—*Adina cordifolia* | B—*Aegle marmelos* | C—*Anogeissus latifolia* | D—*Boswellia ovalifoliolata* | E—*Boswellia serrata* | F—*Chloroxylon swietenia* | G—*Cleistanthus collinus* | H—*Cochlospermum palakondense*. © Buchanapalli Sunil Kumar & Araveeti Madhusudhana Reddy.

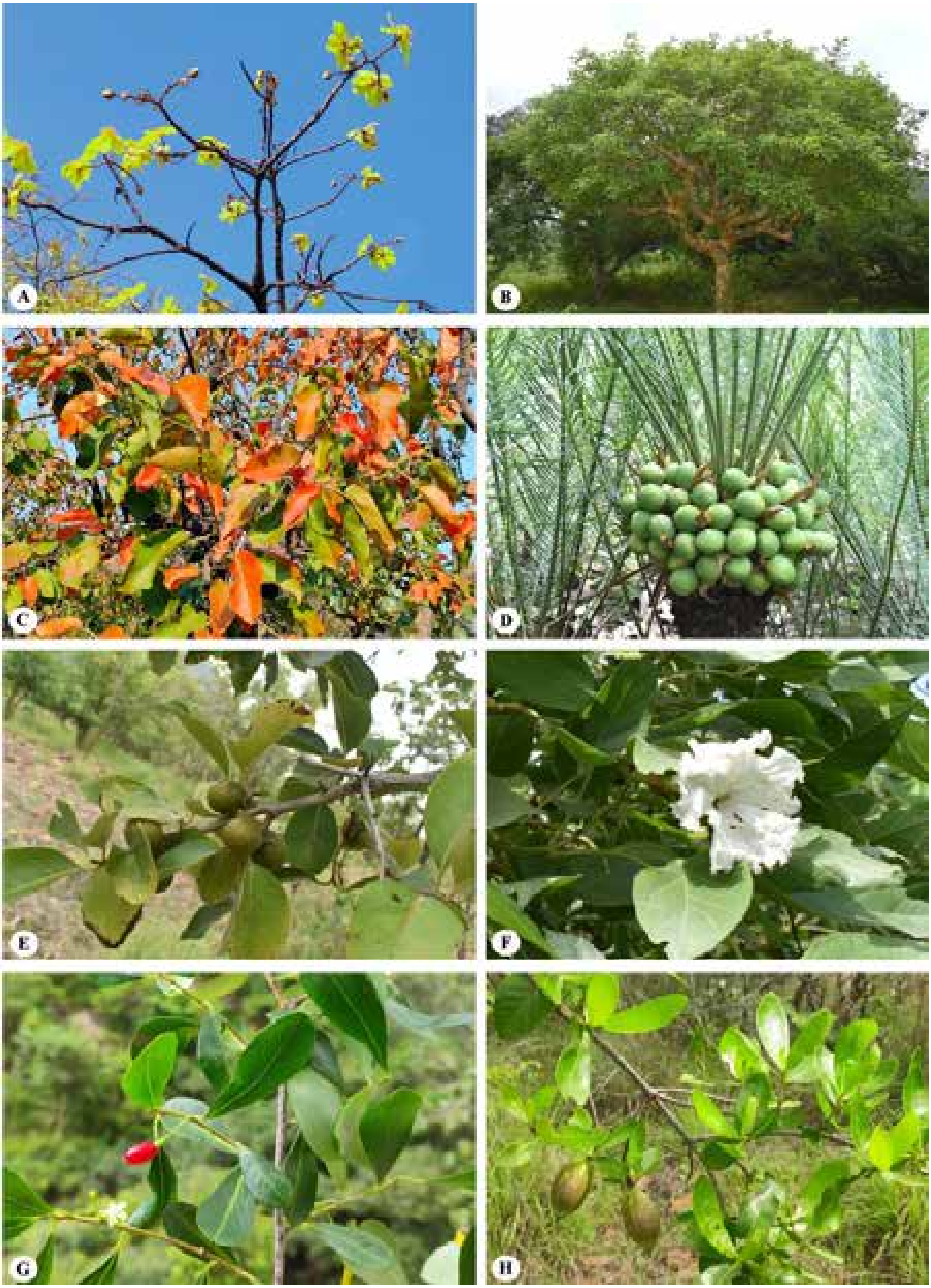

Image 3(A–H). A—*Cochlospermum religiosum* | B—*Commiphora caudata* | C—*Croton scabiosus* | D—*Cycas beddomei* | E—*Diospyros melanoxylon* | F—*Dolichandrone atrovirens* | G—*Erythroxylum monogynum* | H—*Gardenia gummifera*. © Buchanapalli Sunil Kumar & Araveeti Madhusudhana Reddy.

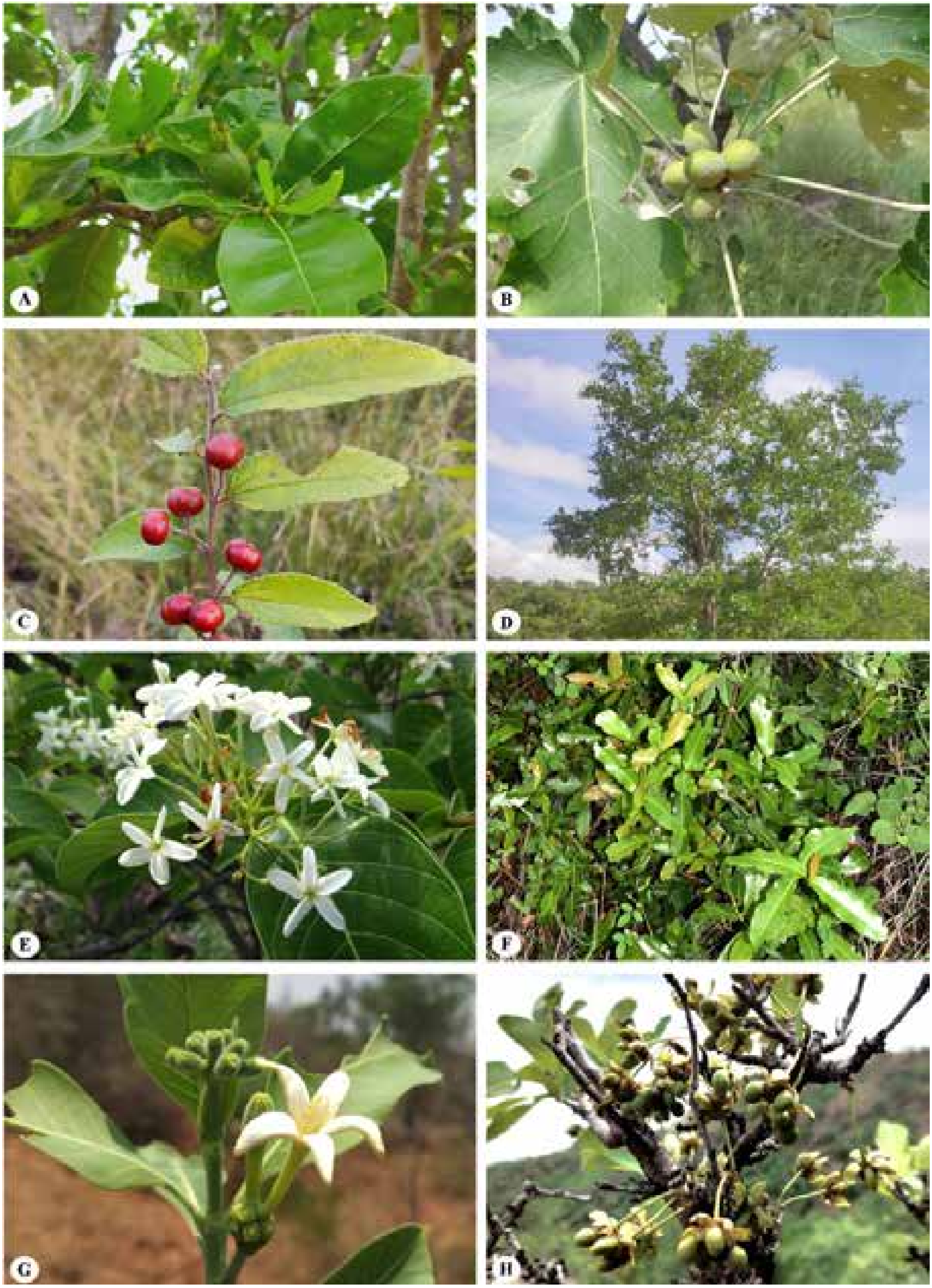

Image 4(A–H). A—*Gardenia resinifera* | B—*Givotia moluccana* | C—*Grewia hirsuta* | D—*Hardwickia binata* | E—*Holarrhena pubescens* | F—*Ixora pavetta* | G—*Morinda pubescens* | H—*Ochna obtusata*. © Buchanapalli Sunil Kumar & Araveeti Madhusudhana Reddy.

Image 5(A–H). A—*Phoenix sylvestris* | B—*Phyllanthus indofischeri* | C—*Phyllantus polyphyllus* | D—*Polyalthia cerasoides* | E—*Pterocarpus marsupium* | F—*Pterocarpus santalinus* | G—*Santalum album* | H—*Shorea talura*. © Buchanapalli Sunil Kumar & Araveeti Madhusudhana Reddy.

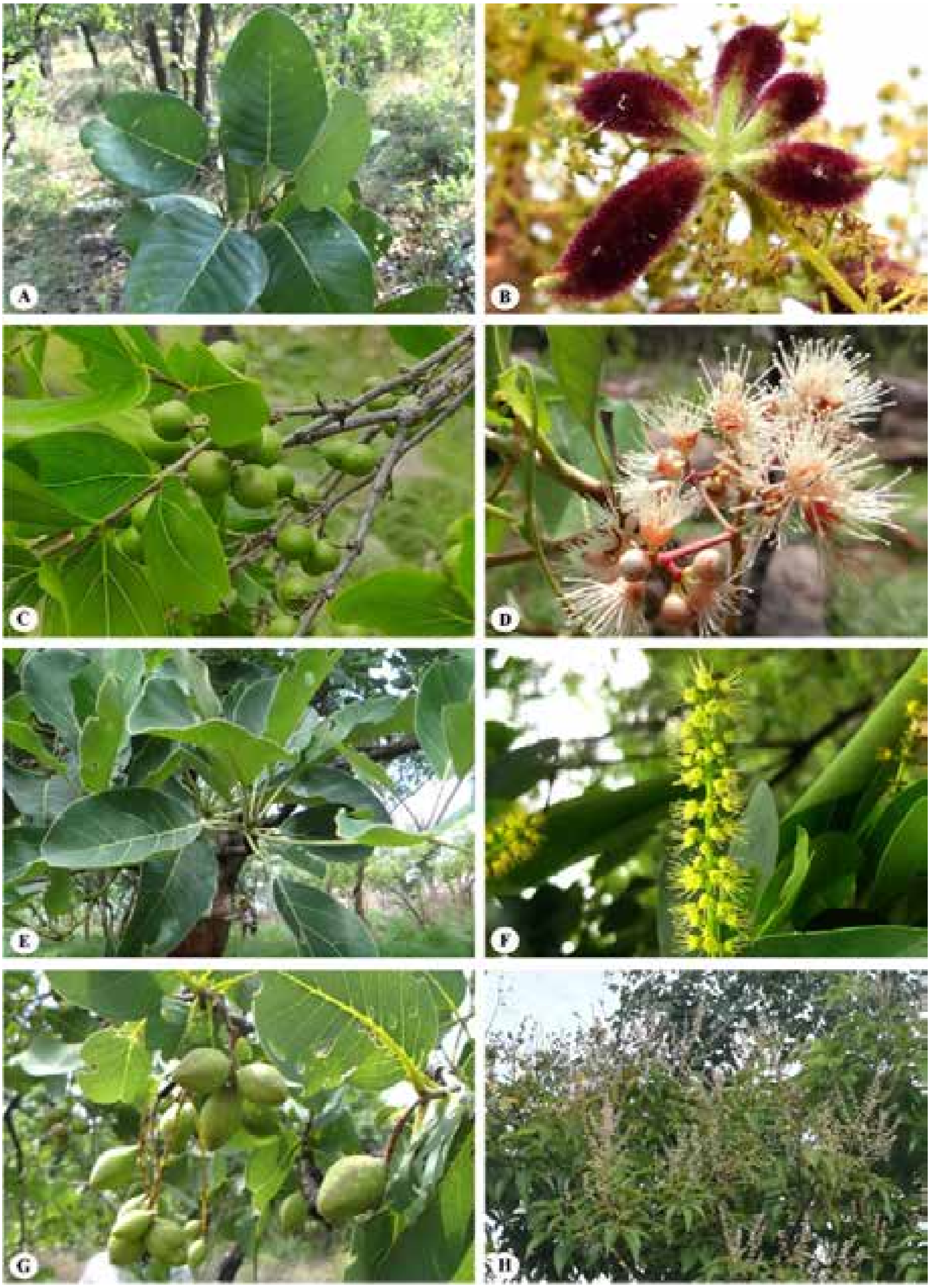

Image 6(A–H). A—*Shorea tumbuggaia* | B—*Sterculia urens* | C—*Strychnos potatorum* | D—*Syzygium alternifolium* | E— *Terminalia bellirica* | F—*Terminalia chebula* | G—*Terminalia pallida* | H—*Vitex altissima*. © Buchanapalli Sunil Kumar & Araveeti Madhusudhana Reddy.

diversity assessment in tropical forests of southern Eastern Ghats, India. *Flora-Morphology, Distribution, Functional Ecology of Plants* 205(11): 728–737. https://doi.org/10.1016/j.flora.2010.04.011

Pullaiah, T., E. Chennaiah & S.S. Rani (eds.) (2018a). *Flora of Andhra Pradesh. Volume 1*. Scientific Publishers, Jodhpur, 397 pp.

Pullaiah, T. & K.S.R. Murthy (eds.) (2018). *Flora of Andhra Pradesh. Volume 2*. Scientific Publishers, Jodhpur, 399–835 pp.

Pullaiah, T. & S. Karuppusamy (eds.) (2018). *Flora of Andhra Pradesh. Volume 3*. Scientific Publishers, Jodhpur, 839–1305 pp.

Pullaiah, T., D.A. Moulali & S.S. Rani (eds.) (2018b). *Flora of Andhra Pradesh. Volume 4*. Scientific Publishers, Jodhpur, 1317–1831 pp.

Pullaiah, T. (eds.) (2018). *Flora of Andhra Pradesh. Volume 5*. Scientific Publishers, Jodhpur, 1833–2363 pp.

Pullaiah, T. & S.S. Rani (1999). *Trees of Andhra Pradesh, India*. Regency Publications, New Delhi, India, 470 pp.

Rao, B.R.P., M.S. Babu, M.S. Reddy, A.M. Reddy, V.S. Rao, S. Sunitha & K.N. Ganeshaiah (2011). Sacred groves in southern Eastern Ghats, India: are they better managed than forest reserves? *Tropical Ecology* 52(1): 79–90.

Reddy, A.M., M.V.S. Babu & R.R. Rao (2019). Ethnobotanical study of traditional herbal plants used by local people of Seshachalam Biosphere Reserve in Eastern Ghats, India. *Herba Polonica* 65(1): 40–54.

Reddy, C.S., C. Pattanaik, A. Mohapatra & A.K. Biswal (2007). Phytosociological observations on tree diversity of tropical forest of Similipal Biosphere Reserve, Orissa, India. *Taiwania* 52(4): 352–359. https://doi.org/10.6165/tai.2007.52(4).352

Reddy, C.S. & V.S. Raju (2008). Endemic spermatophytes of Andhra Pradesh, India. *Proceedings of Andhra Pradesh Akademi of Sciences* 12: 48–75 pp.

Reddy, C.S., S.B. Shilpa Babar, A. Giriraj, K.N. Reddy & K.T. Rao (2008). Structure and floristic composition of tree diversity in tropical dry deciduous forest of Eastern Ghats, southern Andhra Pradesh, India. *Asian Journal of Scientific Research* 1(1): 57–64.

Reddy, C.S., K.N. Reddy, E.N. Murthy & V.S. Raju (2009). Tree wealth of Eastern Ghats of Andhra Pradesh, India: an updated checklist. *Check List 5*(2): 173–194. https://doi.org/10.15560/5.2.173

Reddy, C.S., S. Babar, G. Amarnath & C. Pattanaik (2011). Structure and floristic composition of tree stand in tropical forest in the Eastern Ghats of northern Andhra Pradesh, India. *Journal of Forestry Research* 22: 491–500. https://doi.org/10.1007/s11676-011-0193-5

Robertson, F.C.F. (1971). *Terminology of Forest Science: Technology, Practice and Products: English-language Version*. Society of American Foresters, xxii + 349 pp.

Sahoo, T., L. Acharya & P.C. Panda (2020). Structure and composition of tree species in tropical moist deciduous forests of Eastern Ghats of Odisha, India, in response to human-induced disturbances. *Environmental Sustainability* 3(1): 69–82. https://doi.org/10.1007/s42398-020-00095-0

Sampaio, E.S.B. (1995). Overview of the Brazilian caatinga. *Seasonally Dry Tropical Forests* 35–63. https://cir.nii.ac.jp/crid/1571417124668610944

Santapau, H. (1955). *Botanical Collector's Manual*. Government Press, New Delhi, 62 pp.

Sudhakar, G. (2012). Seshachalam Biosphere Reserve–Deccan South, India. *Compendium on Indian Biosphere Reserve, Progression during two decades of Conservation*. Ministry of Environment & Forests, New Delhi, 178–183.

UNECE/FAO (2000). Forest resources of Europe, CIS, North America, Australia, Japan, and New Zealand. Global forest resources assessment 2000. Main report. Geneva Timber and Forest Study, papers, No. 17. United Nations. New York and Geneva, 467 pp.

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ARTICLE

Potential distribution, habitat composition, preference and threats to Spikenard *Nardostachys jatamansi* (D.Don) DC. in Sakteng Wildlife Sanctuary, Trashigang, Bhutan

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Abstract: Bhutan stands out as one of the native areas where *Nardostachy jatamansi* grows. At an international level, a rampant rate of harvesting of its rhizome for medicinal and religious purposes has resulted in the species being categorized as 'Critically Endangered' as per the IUCN Red List Assessment, 2025. A survey was conducted in August 2021 within Sakteng Wildlife Sanctuary to identify the growing area of *N. jatamansi* within the sanctuary, determine species composition in the *N. jatamansi* growing area, assessing the threat within the sanctuary, and the potential distribution using current, and future climate scenarios. The survey found most of the species favouring rocky outcrops and high altitudes, given the harsh climatic conditions it tolerates. The studies recorded 19 individuals per m^2 of the species across Merak and Sakteng and presented Shrubs as dominant life forms and *Carex* spp as the indicator species in *N. jatamansi* growing area. We found 49.8 km^2 of the sanctuary area as the potential suitable habitat for *N. jatamansi,* with elevation and temperature-related variables as the most contributing factors in determining its distribution. Change in area under the ssp 245 future climate scenario for year 2041–2060 and 2061–2080 showed net increase in area of 125.5 ha and 126 ha respectively from current to future.

Keywords: AUC, climate, elevation, habitat, indicator, maxent modelling, Pangpoi, temperature, threat.

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Author contribution: Dorji Phuntsho and Pema Rinzin—conceptualization, conducted fieldwork, curated the data, performed formal analysis, investigated the study, and drafted the original manuscript. Namgay Shacha and Tshewang Tenzin— conducted formal analysis, curated the data & visualized the outputs, conducted formal & software analyses, visualized the outputs, and editing. All authors contributed to manuscript final writing and editing.

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INTRODUCTION

Nardostachys jatamansi locally known as 'Pangpoi', belonging to a family Caprifoliaceae (Sahu et al. 2016) is an alpine medicinal and aromatic herb, monotypic species of the genus *Nardostachys,* which has been enlisted in Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES) Appendix II and the Red Data Book of Indian Plants (Mulliken 2000). The species has been listed as 'Critically Endangered' under criteria A2cd of the IUCN Red List of Threatened Species (Chauhan 2021). The typical habitat preference of *N. grandiflora* includes rocky outcrop, but it also inhabits alpine meadows, juniper scrubs, dwarf rhododendron forest, open pine forests, and turf of glacial flats, characterized by typical monsoon precipitation (Weberling 1975; Amatya & Sthapit 1994; Ghimire et al. 2005). *Nardostachys jatamansi* is listed under Schedule II of Forest and Nature Conservation Act of Bhutan, 2023 (FNCA 2023; RGoB 2023). It is the only species within its genus, and it is native to Bhutan, China, India, Myanmar, and Nepal, and grows in high-altitude alpine Himalayan regions (CITES 2022) at elevations ranging from 3,810–5,155 m (Grierson & Long 2001). In Bhutan, it is found in Thimphu, Haa, Paro, Bumthang, Chukha, Gasa, Samtse, Trashigang, Tashi Yangtse, Wangdue Phodrang, Dagana, and Tsirang districts. The growing season is short, starting in May and ending by early October. Flowering occurs in June–July and fruiting from August onwards. It grows into a dense clump because successive shoots emerge very close together from a given mother plant (Ghimire et al. 2005).

A huge variety of medicinal plants, which make up a substantial percentage of non-timber forest products (NTFPs) collected from the Himalaya, are seriously threatened due to increased demand from medicinal plant enterprises (Tandon et al. 2001). Globally the species is threatened as more than 80% of the world's population currently use this species for some form of traditional medicine as a primary means of healthcare, given its low side effects (Sherpa et al. 2023; WHO 2023). The *N. jatamansi* has a wide range of uses, ranging from medicinal purposes to making perfumes globally, and in Bhutan, it is generally confined to the production of traditional medicine, and incense (Gyeltshen et al. 2022). In countries like Nepal, it is used as brain & uterine tonics, stimulants, external pain killers, antiseptic, treatment for epilepsy, hysteria, convulsions, heart palpitations, high blood pressure, and insomnia (Larsen & Olsen 2008). Epilepsy, wounds, coughs, colds, and high blood pressure are treated using their rhizome (Ghimire et al. 2005).

With the inevitable climate change, species' original habitat conditions will change, along with their distribution area, and they will progressively migrate to new environments that are better suited to their own growth and reproduction (Zhong et al. 2023). The species within the alpine zone of the sanctuary faces increasing pressure due to livestock grazing, climate change, and land use changes. Despite its global significance, there is a little knowledge on the potential distribution, and the severity of threat it faces in the region. A combination of factors play a huge role in depletion of such endangered species from the wild. Hence, identifying potential areas of high suitability can guide conservation efforts, ensuring the conservation, and prioritization of crucial current, and future potential habitats of *N. jatamansi* in the sanctuary.

Species distribution modelling (SDM), a widely adopted method in ecological research (Peterson et al. 2015; Razak et al. 2024) has become increasingly important in the context of accelerating climate change, and anthropogenic impacts on the biosphere (Novoseltseva 2024). Maximum entropy (MaxEnt) is one of the machine learning methods, (Elith & Leathwick 2009) widely used in predicting habitat suitability of species using presence only data. Maxent's ability to reduce the possibilities of overfitting makes it one of the best methods for species distribution modelling (Valavi et al. 2022). An accurate model prediction is important for guiding effective management and adaptation efforts to help protect the species. Hence, the main aim of the paper is to determine: (i) the potential distribution of *N. jatamansi* within Sakteng Wildlife Sanctuary (SWS), (ii) associated species and indicator species in the *N. jatamansi* growing area, and (iii) existing threats to the population.

METHODS

Study Area

The study was conducted in two gewogs (block) within SWS: Merak and Sakteng. Sakteng WS is one of the protected areas in Bhutan which represents the eastern temperate ecosystem (27.150°–27.468° N & 91.7844°–92.1172° E). It is adjacent to the Indian state of Arunachal Pradesh with an area of 742.46 km^2 covering two gewogs, Merak and Sakteng, under Trashigang Dzongkhag (district). The sanctuary experiences four distinct seasons (winter, spring, summer, autumn) and is characterized by five major forest types such as dry alpine scrub, rhododendron scrub, fir, hemlock, and cool broadleaved.

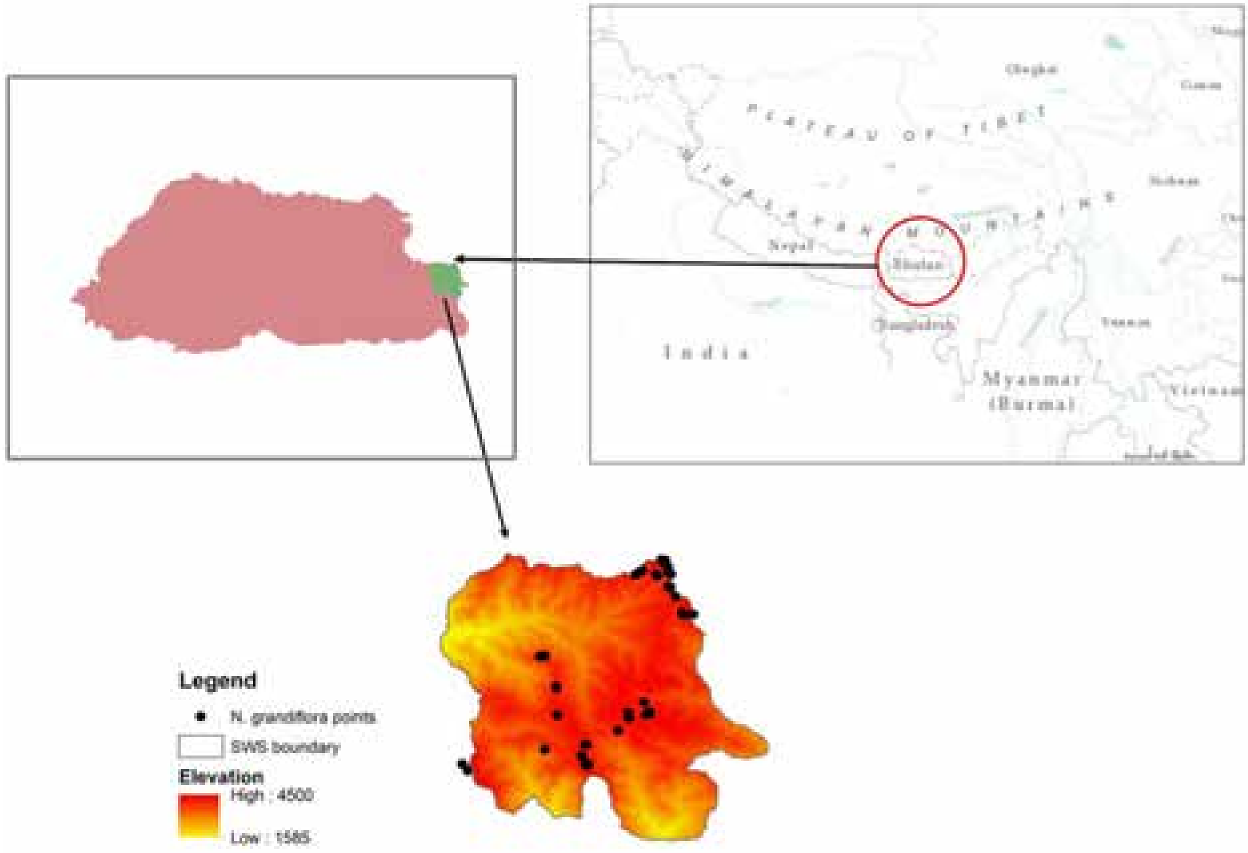

Image 1. *Nardostachys jatamansi* locations under Sakteng Wildlife Sanctuary.

Sakteng WS is also an origin of rivers such as Jomori, Nyera ama chhu, and Gamri chhu, which have the potential for hydro power generation. It connects Jomotsangkha WS to the south through a biological corridor 6 (BC 6) and Bumdeling WS through BC 9. The elevation ranges from 1,500 m in warm broadleaved forest to 4,500 m in alpine scrub. The park's rich biodiversity includes over 858 species of plants with 141 families under 35 orders, 39 mammals, 283 species of birds, 63 species of butterflies, five species of reptiles, and three species of amphibians. The sanctuary is home to 5,000 people across 13 villages with 772 households (SWS 2019). The wide range of elevation gradient provides suitable growing conditions for many important medicinal plants including the highly threatened *Nardostachys jatamansi*.

Data collection and analysis

In August 2021, preliminary listing and mapping of the *N. jatamansi* growing sites were determined through participatory mapping approach with the involvement of local communities. For plot layout, 8 m flexible electric wire and thread was used for every area of occupancy (AOO) plots measuring (2m x 2m) to enumerate the data. Thirty-two AOOs with an area of 20.93 ha within SWS were taken. Vegetation plot size of 2m x 2m quadrate plot was established for data collection. Height of the tallest species was measured using the 5 m fibre glass tape. Eterex global positioning system (GPS), compass, clinometer, measuring tape were some of the tools used during the survey. The details, including height, cover percentage, volume, and relative density of herbs, shrubs, and graminoids were recorded. Slope, aspect, barren area cover, and organic layer depth were also recorded. A total of 95 plots (48 plots in Merak and 47 plots in Sakteng Gewog) were enumerated (Image 1). Data collected from the field was compiled and processed using PivotTable of the Microsoft Excel 2016. PC-ORD version 5.1.0 was used for cluster analysis to determine the cluster solution using distance measure of Sorensen (Bray-Curtis) and group linkage methods using Ward's to determine the floristic species classification in *N. jatamansi* growing areas. Species area curve was generated through PC-ORD 5.1.0. Rank abundance curve for the species in each plot were produced using Excel 2016.

Habitat preference

A logistic regression generalized linear model (GLM) and general additive model (GAM) was performed for habitat preference for *N. jatamansi* using presence-absence data in R studio. Habitat variables such as temperature, precipitation, aspect, slope, and elevation were used. To determine the best fit model, multi-model inferences were conducted, selecting the model with lower Akaike information criterion (AIC). AIC is a mathematical method for evaluating how well a model fits the data it was generated from. Subsequently, GAM outperformed GLM.

Species Distribution Modelling (SDM)

Of the 95 geographic points of *N. jatamansi,* eight points falling outside the sanctuary boundary were clipped and the remaining 87 points that fell inside the boundary were used for species distribution modelling. Nineteen bioclimatic variables with a spatial resolution of 30 arc-second (~1 km at the equator) were downloaded from Worldclim (Fick et al. 2017) website (www.worldclim.org), and slope & aspect (30 m resolution) were extracted from digital elevation model (DEM). Accordingly, multicollinearity test was done using statistical software R v.4.4.1 (R Core Team, 2023) using the package 'usdm' (Naimi et al. 2014) and 'raster' (Hijmans 2024). Those bioclimatic variables with VIF ≥ 10 were considered as highly correlated and subsequently removed from further analysis (Zuur et al. 2009; Montgomery et al. 2012; Yoon & Lee 2021) and only four bioclimatic variables out of the total 19 variables were retained. Variables such as bio3 (isothermality (bio2/bio7) (×100)), bio5 (max temperature of warmest month), bio7 (temperature annual range (bio5–bio6)), bio14 (precipitation of driest month), aspect, slope and elevation were used. Maximum entropy modelling, MaxEnt (Phillips et al. 2025) executable jar file was used for generating species distribution modelling using presence only data with 10,000 background points. Seventy-five percentage of the occurring data were used as training data and the remaining 25% as test data. The ASC file generated by MaxEnt was further reclassified using ArcGIS v 10.8.

For future potential distribution of *N. jatamansi*, general circulation model (GCM) BCC-CSM2-MR was selected as it is broadly recognised as one of the most effective climate models for predicting the impacts of past and future climate change on plant distributions in eastern Asia, and the Himalayan region (Xin et al. 2013; Abdelaal et al. 2019; Rana et al. 2020). Among the four shared socio-economic pathway (ssp 126, ssp 245, ssp 370, and ssp 585), ssp 245, which shows an intermediate development scenario, was used in the future distribution for year 2041–2060 and 2061–2080. The SSPs are a set of reference pathways that describe alternative patterns in the evolution of society and ecosystems over a century, assuming no change in climate trends or climate policies (O'Neill et al. 2014).

RESULTS

The largest number of individuals were counted in plot 78 with organic layer depth of 3 cm, 55^{o} slope, and 280^{o} aspect. The highest relative density (RD) of *N. jatamansi* recorded was in plot 39 with RD 99.72% and least in plot 49 with RD 2.07% with slope gradient ranging 10–55 ^{o}. Likewise, the highest coverage of *N. jatamansi* was recorded in plot 34 with 94%, and least in plot 30 with 2%. The survey recorded 7,497 counts of species in 95 plots under the sanctuary.

Vegetative Composition

A total of 159 species comprising 40 families were recorded from 95 plots covering 18 sites at Merak and Sakteng gewog. From the 40 families, Compositae family was observed the highest with 27 species followed by Saxifragaceae and Polygonaceae with 14 and 11 species respectively. Fifteen families, including Valerianaceae, have recorded the lowest species count, with only one species per family (Figure 1).

The likelihood of encountering new species decreases with increased sample efforts. However, this species list is not exhaustive based on the species accumulation curve that did not flatten (Figure 2). The *N. jatamansi* growing area were composed of herbs, shrubs and graminoids (Figure 5). From the rank abundance curve, *N. jatamansi* was found to be the most abundant (Figure 6). This could be attributed to the opportunistic survey method practised, whereby plots were laid out only in *N. jatamansi* presence areas.

Habitat Preferences

Among the variables, slope has a significant effect on the distribution of *N. jatamansi* (edf = 1.0, Ref.df = 1.0, Chi sq. = 19.996, p-value = 8.15e-06), whereas aspect (edf = 1.0, Ref.df = 1.00, Chi sq. = 2.699, p-value = 0.100) does not have a significant effect on the species. There is a linear effect indicating a direct relationship between slope and the plant's presence. This supports the plant's preference for rocky and mountainous areas.

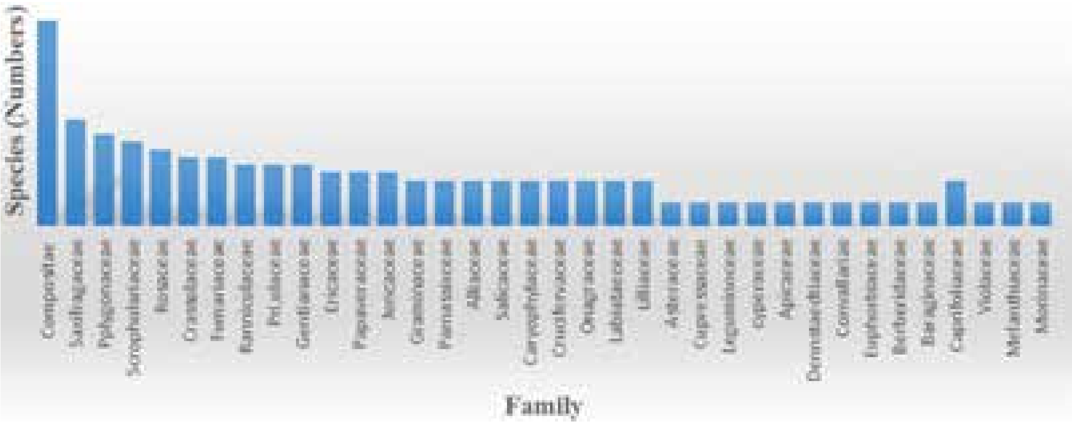

Figure 1. Families with number of species encountered.

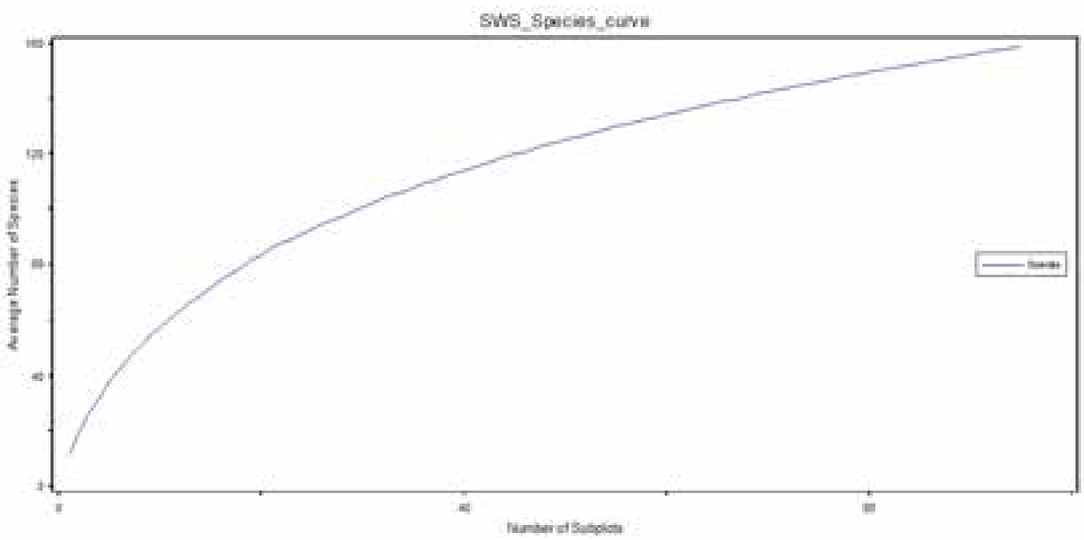

Figure 2. Species distribution curve indicating the likelihood of occurrence of additional species.

Species Distribution Modelling

The result generated by MaxEnt showed 16.64 km^2 of sanctuary area as highly suitable, 33.17 km^2 as moderately suitable, and 691.93 km^2 as unsuitable (Figure 8). Further, it showed elevation and aspect as the most important variables contributing to maxent modelling with a contribution of 73.3% and 9.8%, respectively (Table 1), and the jackknife test showed bio5 and elevation as the most important factors in in determining the distribution (Figure 3). The percent contribution of each variable is shown in Table 1. A jackknife analysis was used to calculate the importance of each environment variable in the model and the results are shown in the Figure 3. The training and test data which was set at 75% and 25% respectively provided a reliable accuracy for the model (Figure 4). The distribution modeling under the future climate scenario using global climate model BCC-CSM2-MR under scenario ssp 245 for year 2061–80 showed an increase in 1,063 ha of habitat from current unsuitable area and decrease of 937 ha from current suitable area while year 2041–2060 showed increase of 1,027 ha of suitable area from current unsuitable area, and decrease of 901.5 ha from current suitable area (Figure 9). The model predicted an overall increase in area of 125.5 ha for year 2041–2060 and 126 ha for year 2061–2080.

The similarity cluster analysis was carried out for species (n = 159) with adjusted relative abundance from the total composition. Monte Carlo test of indicator species was calculated following Dufrêne & Legendre (1997) method for the proportional abundance of a particular species in a particular group relative to the abundance of that species in all groups. The similarity index of 44% was performed using the distance measure of Sorensen (Bray-Curtis) and group linkage method

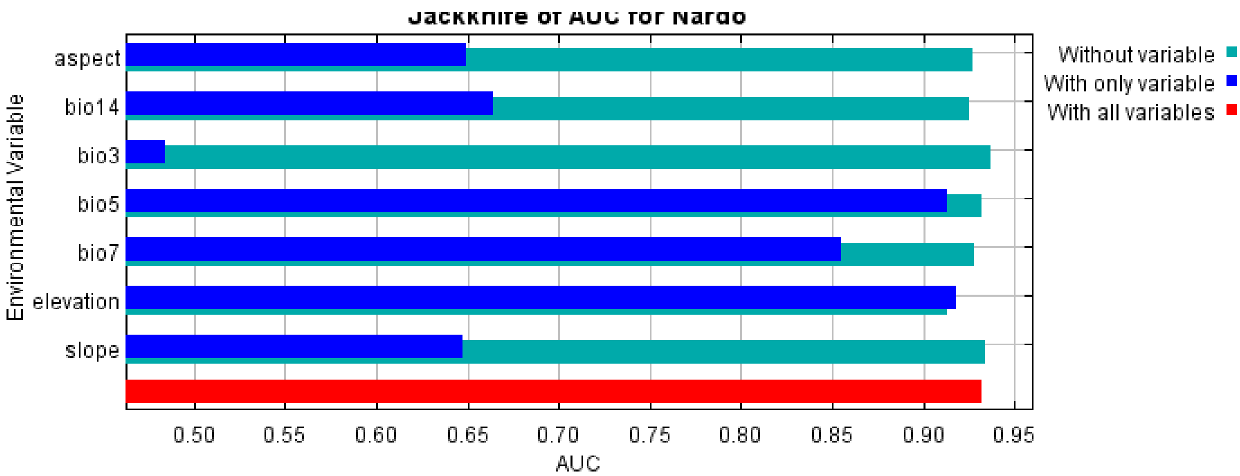

Figure 3. Jackknife test of variable importance using Area Under Curve on test data.

Table 1. Relative contributions of the environmental variables to the MaxEnt model.

Variable	Percent contribution	Permutation importance
elevation	73.3	85.8
aspect	9.8	2.2
bio14	5.1	0.5
slope	3.8	1.4
bio3	3.2	0.7
bio7	2.4	0.5
bio5	2.4	8.9

using Ward's to determine the composition of species in *N. jatamansi* growing habitat. The indicator species was *Acanthocalyx nepalensis* (IV = 27.1 | Mean = 30.0 | SD = 4.65 | p* = 0.6707) in cluster I, *Carex* species (IV = 80.9 | Mean = 25.1 | SD = 4.13 | p* = 0.0002) in cluster II, *Rhododendron setosum* (IV = 24.2 | Mean = 28.1 | SD = 4.06 | p* = 0.843) in cluster III and *Nardostachys jatamansi* (IV = 73.3 | Mean = 53.3 | SD = 2.62 | p* = 0.0002) in cluster IV representing 36 plots from 95 survey sites (Figure 7). The result highlights *Carex* sp. as one of the main indicator species in *N. jatamansi* growing area ($p < 0.05$).

DISCUSSION

The survey found *Nardostachy jatamansi* distributed within the elevation range of 3,730–4,394 m in the sanctuary as they are better acclimatized to harsh climatic conditions with the majority of species distributed in rocky outcrops (31.23%) (Ghimire et al. 2005).

Although higher growth rates and faster recovery in meadow populations appear to be due to higher recruitment and faster vegetative growth, slow growth, and low fecundity are observed in outcrops due to slow recovery after harvesting (Ghimire et al. 2007). *Nardostachys jatamansi* favoured southwestern slope as per our study, while Sharma et al. (2021) and Ugyen & Dorji (2021) observed a contrasting result with species favouring west facing slope and south-east facing slope, respectively, demonstrating aspect as not an important variable in distribution of the species. Our study shows density of *N. jatamansi* at 19.72 /m^2 across the sanctuary. Airi et al. (2000) and Nautiyal et al. (2003) also reported population density, which ranged from 8.52–25.58 individuals /m^2 in Kumau and 19.0–32.2 individuals /m^2 in Garhwal, India. In comparison, Lakey & Dorji (2016) estimated *N. jatamansi* density in Jigme Dorji Wangchuk National Park, Bhutan at 8.9 individuals /m^2. In alpine regions of Sikkim Himalaya, Sherpa et al. (2023) reported 2.64–6.49 individuals /m^2. The comparatively higher density within the sanctuary could be ascribed to the opportunistic survey conducted in *N. jatamansi* growing area. In habitat composition, Asteraceae family had the highest representation with 27 species similar to the findings of Ugyen & Dorji (2021). The survey presented that the *N. jatamansi* growing area was dominated by high altitude shrubs. Comparable studies carried out by Sharma et al. (2021) and Ugyen & Dorji (2021), yielded similar findings, but however contradicts with the findings of Tashi & Dorji (2021).

Ascertaining the current and future potential distribution of species is critical in setting up management strategies for the habitat conservation and sustainability of species (Sinclair et al. 2010; Profirio

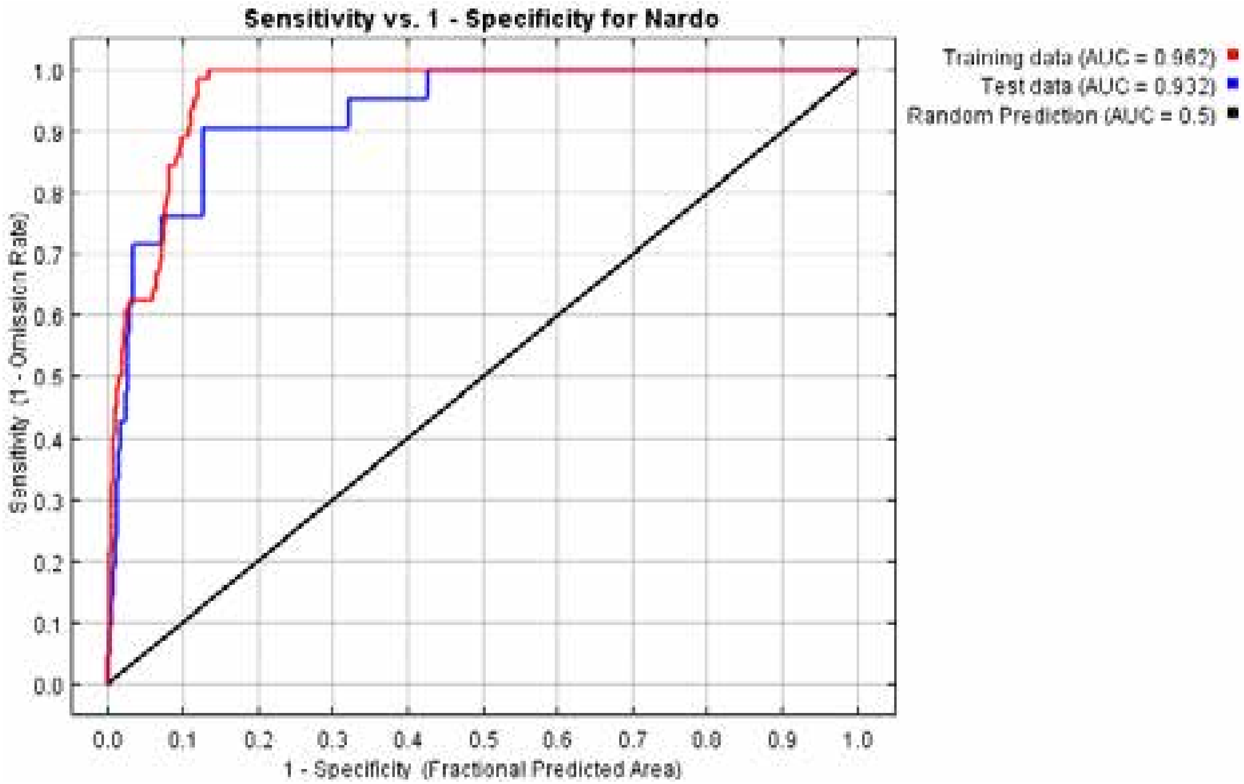

Figure 4. Receiver Operating Curve (ROC) graph showing sensitivity and specificity for *Nardostachys jatamansi* distribution model.

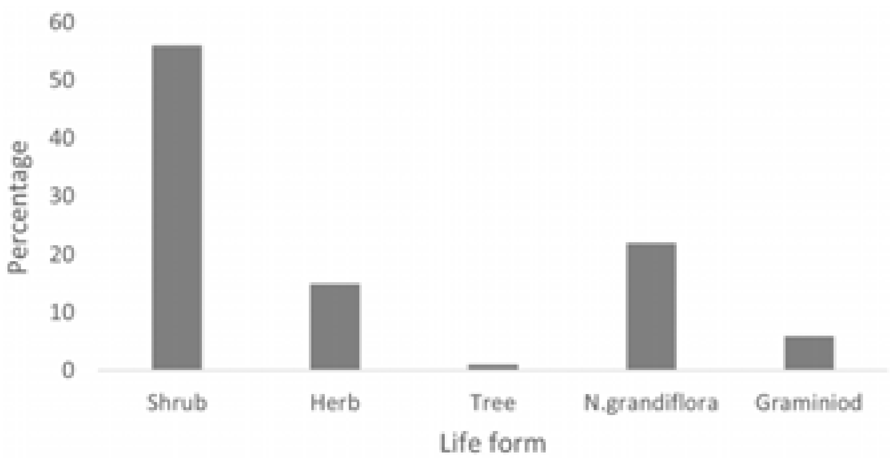

Figure 5. Life forms in *Nardostachys jatamansi* growing area.

et al. 2014). This plays a useful role in conservation management due to the interrelationship between the size of species geographic range and species extinction risk (Purvis et al. 2000; Cardillo et al. 2008). Therefore, SDM is one of the vital tools for defining species' niches (Lozier et al. 2009) and the modelling algorithms such as MaxEnt perform well with a limited number of presence-only data to produce distribution ranges (Ranjitkar et al. 2014). Further, studies carried out by Pearson & Dawson (2003), Rana et al. (2020), and Koç et al. (2024) considered climate as the most important variable in determining the species occurrence. The area under the receiving operator curve (AUC) is a performance measure applicable for any species modelling method. A random ranking on an average AUC is 0.5 and the perfect ranking achieves best possible AUC 1.0. Models

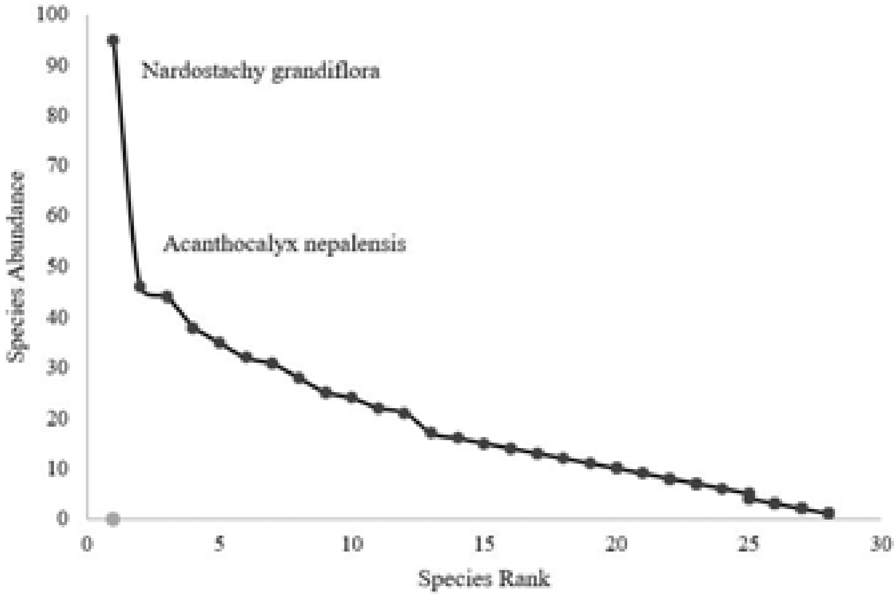

Figure 6. Rank Abundance Curve in *Nardostachys jatamansi* growing area.

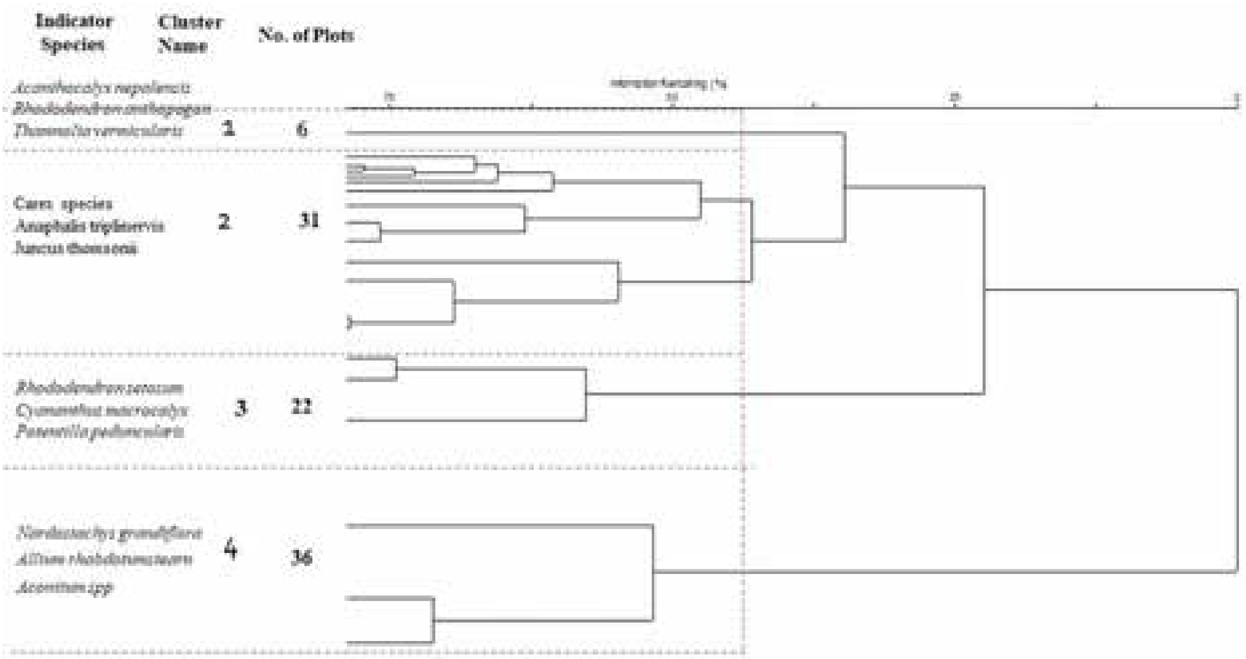

Figure 7. Similarity cluster analysis using 44% similarity index.

with values above 0.75 are considered potentially useful (Elith 2002; Phillips & Dudik 2008). The current modelling generated mean AUC of 0.93 indicating reliable accuracy of the modelling. The model generated around 6.7% of the total sanctuary area as highly suitable with elevation as the most contributing factor in determining their potential distribution. Under the maxent modelling, *N. jatamansi* exhibited strong preference to increasing elevation above 4,000 m, validating its suitability for northward expansion as reported by Rana et al. (2017). Climate change results in shifting distribution of species particularly toward higher elevations (Parmesan & Yohe 2003; Lenoir et al. 2008). The result also inferred the species' preference to temperature. The species suitability increases from 12^0 C and peaks at around 13^0 C. However, a sharp decline is observed after 13^0 C

Table 2. Minimum, maximum, mean, and standard deviation of environmental variables in *Nardostachys jatamansi* growing area.

Habitat Type	Minimum	Maximum	Mean	SD
Alpine scree				
Environmental variables				
Elevation (m)	3730	4394	4190.6	148.3
Aspect (degree)	30	280	204.6	58.8
Slope (degree)	10	55	36.4	12.3
Barren Area Cover (%)	0	50	17	14.7
Juniper Scrub				
Environmental variables				
Elevation (m)	4149	4372	4226.6	83.3
Aspect (degree)	90	240	191	61.1
Slope (degree)	15	50	36.8	12.2
Barren Area Cover (%)	2	77	37.7	31.2
Meadow				
Environmental variables				
Elevation (m)	4105	4393	4233.3	87.1
Aspect (degree)	40	300	206.6	82.9
Slope (degree)	10	61	35	15.2
Barren Area Cover (%)	0	51	19.1	17.6
Rhododendron scrub				
Environmental variables				
Elevation (m)	3964	4344	4148.6	190.2
Aspect (degree)	110	280	170	95.4
Slope (degree)	20	45	29.2	13.8
Barren Area Cover (%)	0	4	2.5	2.2
Rocky Outcrop				
Environmental variables				
Elevation (m)	3900	4391	4103.7	86.7
Aspect (degree)	70	310	163.6	84
Slope (degree)	25	65	48.6	13.1
Barren Area Cover (%)	0	77.7	48.4	25.1

indicating its aversion from increasing temperature.

The suitable habitat of *N. jatamansi* varies greatly under different climate scenarios and was more influenced by climate change (Li et al. 2019). Our results are consistent with the findings that temperature-related variables rather than precipitation variables were more significant in predictive models for medicinal species (Rana et al. 2020).

Although model predicted 49.81 km^2 of the SWS as a potential suitable habitat (fundamental niche), actual habitat (realized niche) could be comparatively less since the correlative species distribution model predicts fundamental niche which is relatively larger than the realized niche (Polechová & Storch 2019). The difference in the actual habitat suitability and predicted suitability was due to the inclusion of the model that generally over predicts. The result showed increase in net change of 125.5 ha of area suitable for *N. jatamansi* under the future climate scenario for the year 2041–2060 and 126 ha for the year 2061–2080 supporting the findings of Rana et al. (2020) which inferred increase in potentially suitable habitats of *N. jatamansi* under the future climate. Further, the distribution of species can be limited by other factors such as land use, edaphic, competition, and anthropogenic disturbances (Ranjitkar et al. 2014; Rana et al. 2020). However, findings of Shrestha et al.

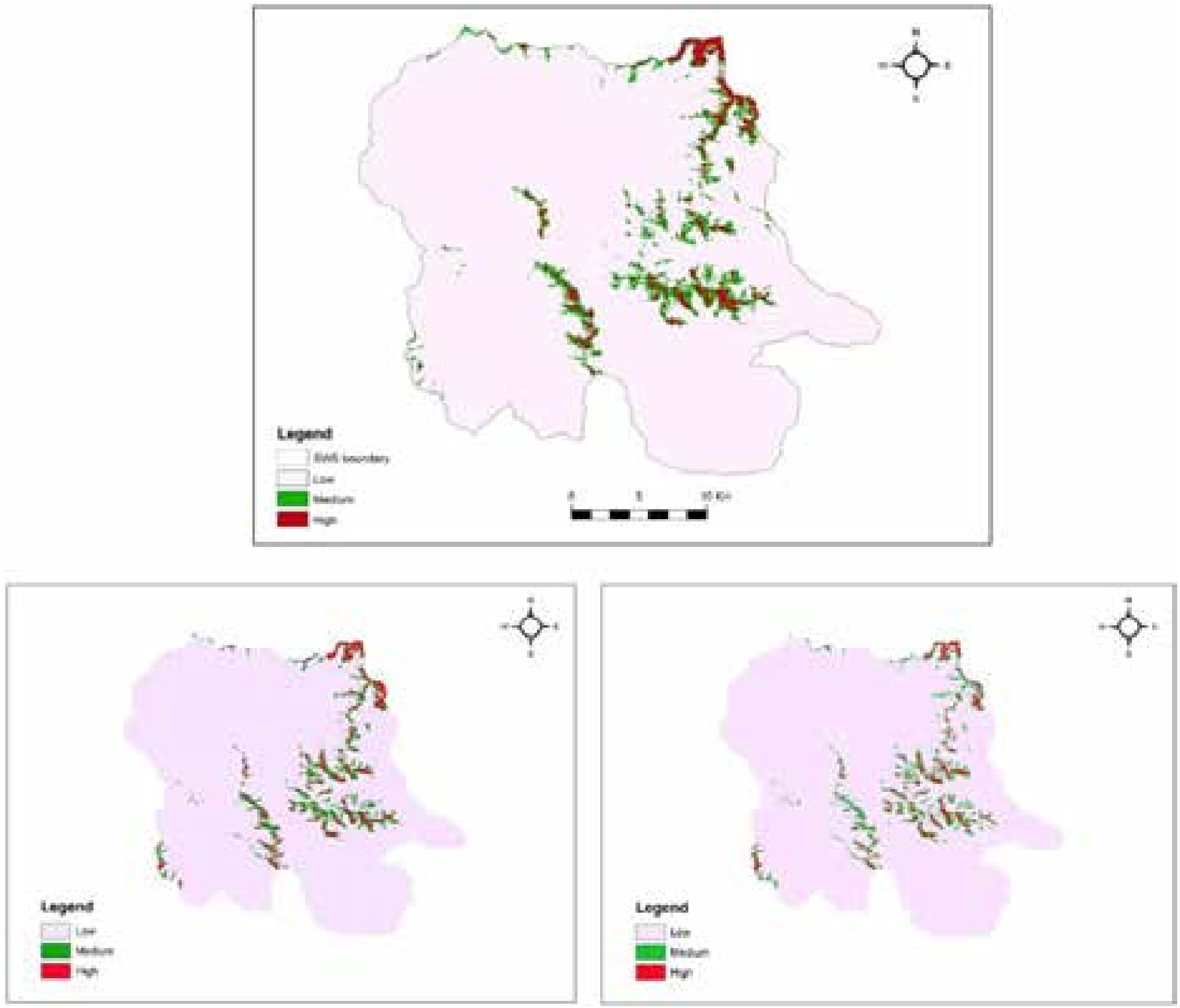

Figure 8. Distribution modelling of *Nardostachys jatamans*i in Sakteng Wildlife Sanctuary under current (top) and future climate (right 2041–2060 and left 2061–2080) under ssp 245 scenario showing its suitability.

(2022) contradict with our study through reduction in climatically suitable areas under future climate change for majority of the traded medicinal plants in Himalayan countries like Nepal. Various paper discusses the ecological status of *N. jatamansi* in the Himalayas and observed a significant decline in its density (Mulliken 2000; Nautiyal et al. 2003; Larson & Olsen 2008). Overburden on natural habitat, lack of awareness among the local people, and poor harvesting practices have pushed this species to the list of endangered (Chauhan 2021). The seasonal grazing grounds of the seminomadic herders' overlap with *N. jatamansi* growing areas as per the survey data with an estimated cattle density of 30.5 heads/km^2 (SWS 2019) making grazing as a common phenomenon. Given its unpalatable nature (Ghimire et al. 2005), *N. jatamansi* is likely to experience trampling effects from cattle movement and competition from the growth of other unpalatable species. The species slow growth in nature, poor seed setting, preference for specific habitat, low population density (Nautiyal 2003; Sherpa et al. 2023) combined with frequent disturbance by livestock trampling could be a major factor in population depletion of the species in their natural habitat. Severe overharvesting of *Nardostachys* throughout the Himalayas has jeopardized many natural populations, motivating a variety of experiments, such as enrichment planting in community forests (Aumeeruddy-Thomas et al. 2005). Local communities in Bhutan uses *N. jatamansi's* rhizome in incense and for a few other religious purposes (Gyeltshen et al. 2022) thereby limiting large quantity harvest. Domestication of such species at household level through cost sharing

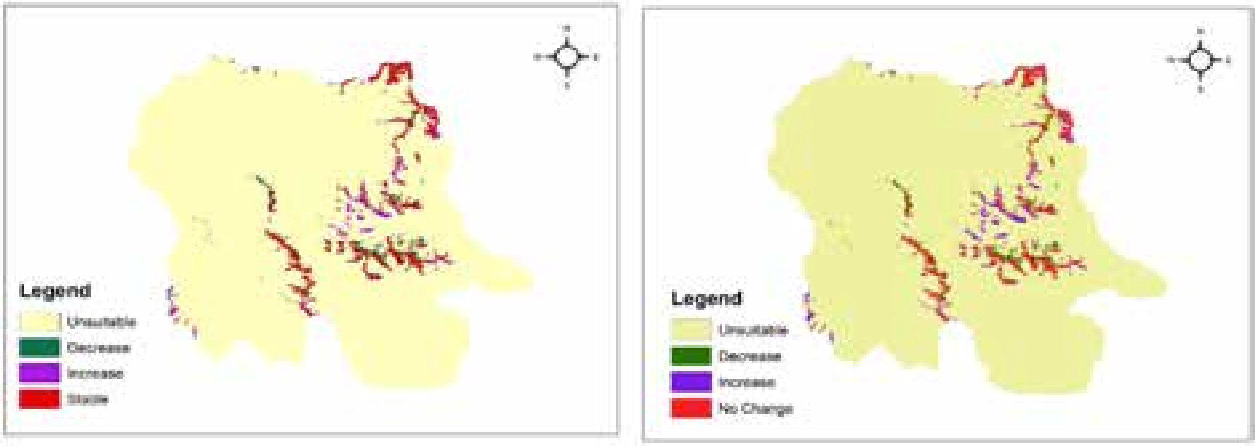

Figure 9. Gain, loss, and stable areas of *Nardostachys jatamansi* under future scenario 2041–2060 (left) and 2061–2080 (right) under ssp 245 scenario.

mechanism can save the species from extinction, while benefitting the community. Given the huge volume of rhizome harvest for its medicinal and religious purposes along with its slow recovery rate post-harvest, an illustrious method of building stewardship through establishment of management group, and conservation plans that solely manage harvest & sale of species through appropriate scientific harvesting techniques can encourage wild population distribution.

CONCLUSION

Given the global scenario of harvesting, there is a need to protect and conserve this species and address the unsustainable harvesting methods by local people through awareness. Although slope and aspect don't determine its distribution, their presence was prominent in higher altitude and shrub dominated areas. *Carex* sp. was one of the indicator species in *N. jatamansi* growing area. The sanctuary boasts 19.72 numbers of *N. jatamansi* per m^2 with 49.8 km^2 of the area as the potential suitable habitat for the species. This highlights the stringent laws & policies put in place by the country and the role sanctuary plays in conserving its wild resources. Elevation and bio5 were the most contributing factors, whereas bio3 was the least contributing factor in determining the species distribution. Under the future climate scenario, an overall net increase in suitable habitats was predicted. The findings of this study gives an insight to the park management to designate potential area under conservation for ensuring sustainability of the species for times to come. Although no rampant harvest is carried out within the sanctuary, proper awareness must be given to avoid future harvest. Besides its threat of harvest, other notable factor include slow growth rate, trampling by cattle, low population density, demand for ethnomedicine, climate change, and habitat specificity of the species. This calls for a need for prioritization of potential areas within the sanctuary.

REFERENCES

Abdelaal, M., M. Fois, G. Fenu & G. Bacchetta (2019). Using MaxEnt modeling to predict the potential distribution of the endemic plant Rosa arabica Crép. in Egypt. *Ecological Informatics* 50: 68–75.

Amatya, G. & V. Sthapit (1994). A note on *Nardostachys jatamansi*. *Journal of Herbs, Spices & Medicinal Plants* 2(2): 39–47.

Aumeeruddy-Thomas, Y., M. Karki, K. Gurung & D. Parajuli (2005). Himalayan Medicinal and Aromatic Plants, Balancing Use and Conservation. Ministry of Forests and Soil Conservation, Government of Nepal, Kathmandu.

Airi, S., R.S. Rawal, U. Dhar & A.N. Purohit (2000). Assessment of availability and habitat preference of Jatamansi: A critical endangered medicinal plant of west Himalaya. *Current Science* 79(10): 1467–1470

Cardillo, M., G.M. Mace, J.L. Gittleman, K.E. Jones, J. Bielby & A. Purvis (2008). The predictability of extinction: biological and external correlates of decline in mammals. Proceedings of the Royal Society B: *Biological Sciences* 275(1641): 1441–1448. https://doi.org/10.1098/rspb.2008.0179

Chauhan, H.K., S. Oli, A.K. Bisht, C. Meredith & D. Leaman (2021). Review of the biology, uses and conservation of the critically endangered endemic Himalayan species *Nardostachys jatamansi* (Caprifoliaceae). *Biodiversity and Conservation* 30(12): 3315–3333. https://doi.org/10.1007/s10531-021-02269-6

Chauhan, H.K. (2021). *Nardostachys jatamansi*. The IUCN Red List of Threatened Species 2021: e.T50126627A88304158. https://doi.org/10.2305/IUCN.UK.20213.RLTS.T50126627A88304158.en

CITES. 2022. Harvest and trade of Jatamansi in Nepal. https://cites.org/sites/default/files/eng/prog/Livelihoods/case_studies/2022/CITES_%26_livelihoods_fact_sheet_Jatamansi%20Nepal.pdf. Accessed on 11.ii.2025

Dufrêne, M. & P. Legendre (1997). Species assemblages and indicator species: The need for a flexible asymmetrical approach.

The Ecological Society of America 345–366. https://doi.org/10.1890/0012-9615(1997)067

Elith, J. (2002). Quantitative methods for modeling species habitat: comparative performance and an application to Australian plants. In: Ferson, S. & M. Burgman (eds.). *Quantitative Methods for Conservation Biology*. Springer, 3958 pp.

Elith, J. & J.R. Leathwick (2009). Species distribution models: Ecological explanation and prediction across space and time. *Annual Review of Ecology, Evolution, and Systematics* 40: 677–697.

Fick, S.E. & R.J. Hijmans (2017). WorldClim 2: new 1km spatial resolution climate surfaces for global land areas. *International Journal of Climatology* 37(12): 4302–4315.

Ghimire, S.K., D. McKey & Y. Aumeeruddy-Thomas (2005). Conservation of Himalayan medicinal plants: Harvesting patterns and ecology of two threatened species, *Nardostachys grandiflora* DC. and *Neopicrorhiza scrophulariiflora* (Pennell) Hong. *Biological Conservation* 124(4): 463–475.

Grierson, A.J.C. & D.G. Long (2001). *Flora of Bhutan, Volume 2, Part 3*. Royal Government of Bhutan & Royal Botanic Garden, Edinburgh.

Gyeltshen, N., N. Bidha, T. Dorji & S. Peldon (2022). Non-Detrimental findings report for *Nardostachys grandiflora* in Bhutan Himalaya, Nature Conservation Division and Social Forestry & Extension Division, Department of Forests and Park Services, Ministry of Agriculture & Forests, Thimphu, Bhutan, 40 pp.

Hijmans, R. (2024). Raster: Geographic Data Analysis and Modeling. R package version 3.6-30, https://rspatial.org/raster. https://doi.org/10.13140/RG.2.2.13303.50083

Koç, D.E., B. Ustaoğlu & D. Biltekin (2024). Effect of climate change on the habitat suitability of the relict species *Zelkova carpinifolia* Spach using ensembled species distribution modelling. *Scientific Reports* 14(1): 27967. https://doi.org/10.1038/s41598-024-78733-4

Lakey, N. & K. Dorji (2016). Ecological status of high-altitude medicinal plants and their sustainability: Lingshi, Bhutan. *BMC Ecology* 16(1): 1–14. https://doi.org/10.1186/s12898-016-0100-1

Larsen, H.O. & C.S. Olsen (2008). Towards Valid Non-Detrimental Findings for *Nardostachys grandiflora*. https://cites.org/sites/default/files/ndf_material/WG2-CS3.pdf

Lenoir, J., J.C. Gégout, P.A. Marquet, P. de Ruffray & H. Brisse (2008). A significant upward shift in plant species optimum elevation during the 20th century. *Science* 320(5884): 1768– 1771. https://doi.org/10.1126/science.1156831

Li, J., J. Wu, K. Peng, G. Fan, H. Yu, W. Wang & Y. He (2019). Simulating the effects of climate change across the geographical distribution of two medicinal plants in the genus *Nardostachys*. *PeerJ* 7: e6730. https://doi.org/10.7717/peerj.6730

Lozier, J.D., P. Aniello & M.J. Hickerson (2009). Predicting the distribution of Sasquatch in western North America: anything goes with ecological niche modelling. *Journal of Biogeography* 36(9): 1623–1627. https://doi.org/10.1111/j.1365-2699. 2009.02152.x

Montgomery, D.C., E.A. Peck & G.G. Vining (2012). Introduction to linear regression analysis, vol. 821. Wiley, Hoboken, NJ.

Mulliken, T.A. (2000). Implementing Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES) for Himalayan medicinal plants *Nardostachys grandiflora* and *Picrorhiza kurroa*. *Traffic Bulletin* 18: 63–72.

Naimi, B., N.A. Hamm, T.A., Groen, A.K. Skidmore & A.G. Toxopeus (2014). "Where is positional uncertainty a problem for species distribution modelling." *Ecography* 37: 191–203. https://doi.org/10.1111/j.1600-0587.2013.00205.x

Novoseltseva, Y. (2024). Species distribution modelling using MaxEnt: overview and prospects. *Theriologia Ukrainica* 2024(28): 102–112. https://doi.org/10.53452/tu2809

O'Neill, B.C., E. Kriegler, K. Riahi, K.L. Ebi, S. Hallegatte, T.R. Carter, R. Mathur & D.P. van Vuuren (2014). A New Scenario Framework for Climate Change Research: The Concept of Shared Socioeconomic Pathways. *Climate Change* 122: 387–400.

Parmesan, C. & G. Yohe (2003). A globally coherent fingerprint of climate change impacts across natural systems. *Nature* 421(6918): 37–42. https://doi.org/10.1038/natur e01286

Pearson, R.G. & T.P. Dawson (2003). Predicting the impacts of climate change on the distribution of species: are bioclimate envelope models useful? *Global Ecology Biogeography* 12(5): 361–371. https://doi.org/10.1046/j.1466-822X.2003.00042.x

Phillips, S.J. & M. Dudik (2008). Modeling of species distributions with MaxEnt: new extensions and a comprehensive evaluation. *Ecography* 31: 161–175. https://doi.org/10.1111/j.2007.0906-7590.05203.x

Phillips, S.J., M. Dudík & R.E. Schapire (2025). Maxent software for modeling species niches and distributions (Version 3.4.1). Available from url:http://biodiversityinformatics.amnh.org/open_source/maxent/. Accessed on 23.i.2025.

Peterson, A.T., M. Papeş & J. Soberón (2015). Mechanistic and correlative models of ecological niches. *European Journal of Ecology* 1(2): 28–38. https://doi.org/10.1515/eje-2015-0014

Polechová, J. & D. Storch (2019). Ecological Niche, pp. 72–80. In: Fath, B. (ed.). *Encyclopedia of Ecology, 2nd Edition*. Elsevier.

Purvis, A., J.L. Gittleman, G. Cowlishaw & G.M. Mace (2000). Predicting extinction risk in declining species. *Proceedings of the Royal Society B*: *Biological Sciences* 267(1456): 1947–1952. https://doi.org/10.1098/rspb.2000.1234

Rana, S.K., H.K. Rana, S.K. Ghimire, K.K. Shrestha & S. Ranjitkar (2017). Predicting the impact of climate change on the distribution of two threatened Himalayan medicinal plants of Liliaceae in Nepal. *Journal of Mountain Science* 14(3): 558–570. https://doi.org/10.1007/s11629-015-3822-1

Rana, S.K., H.K. Rana, S. Ranjitkar, S.K. Ghimire, C.M. Gurmachhan, A.R. O'Neill & H. Sun (2020). Climate-change threats to distribution, habitats, sustainability and conservation of highly traded medicinal and aromatic plants in Nepal. *Ecological Indicators* 115: 106435. https://doi.org/10.1016/j.ecolind.2020.106435

Ranjitkar, S., R. Kindt, N.M. Sujakhu, R. Hart, W. Guo, X. Yang, K.K. Shrestha, J. Xu & E. Luedeling (2014). Separation of the bioclimatic spaces of Himalayan tree rhododendron species predicted by ensemble suitability models. *Global Ecology and Conservation* 1: 2–12. https://doi.org/10.1016/j.gecco.2014.07.001

Razak, I., A.Z. Wahab, D.M. Nasir & A. Ahmad (2024). Predicting habitat suitability for tarantula in Peninsular Malaysia by using species distribution modelling (SDM). *Tropical Natural History* 24: 182–192. https://doi.org/10.58837/tnh.24.1.260221

R Core Team (2023). R: a language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. Accessed on 20.ii.2025. https://www.R-project.org/

Royal Government of Bhutan (RGoB) (2023). Forest and Nature Conservation Act of Bhutan, 2023. Thimphu, Bhutan: RGoB, 54 pp.

Sharma, K., S. Maharjan, G. Rijal & M.L. Pathak (2021). Field survey of *Nardostachys jatamansi* in Manedada, Gaurishankar Conservation Area, Ramechhap, Nepal. *Journal of Plant Resources* 19(1): 114–120.

Sherpa, P., B. Bhattarai & M. Rana (2023). Ecological Studies of *Nardostachys grandiflora*: An Endangered Medicinal Plant of Sikkim Himalaya. *Environment and Ecology* 41(4A): 2446–2451.

Shrestha, U.B., P. Lamsal, S.K. Ghimire, B.B. Shrestha, S. Dhakal, S. Shrestha & K. Atreya (2022). Climate change-induced distributional change of medicinal and aromatic plants in the Nepal Himalaya. *Ecology and Evolution* 12(8): https://doi.org/10.1002/ece3.9204

Sinclair S.J., M.D. White & G.R. Newell (2010). How useful are species distribution models for managing biodiversity under future climates? *Ecology and Society* 15(1): 8.

SWS (2019). Conservation Management Plan (2017–2027), Sakteng Wildlife Sanctuary, Department of Forests & Park Services, Royal Government of Bhutan. 7–27 pp.

Tandon, V., N.K. Bhattarai & M. Karki (eds.) (2001). Conservation Assessment and Management Prioritization Report. International Development Research Centre, New Delhi.

Tashi & K. Dorji (2021). Assessment and findings of *Nardostachys grandiflora* under Divisional Forest Office, Bumthang, Bhutan, 7 pp. https://www.academia.edu/91057999/Assessment_and_Findings_of_Nardostachys_grandiflora_under_Divisional_Forest_Office_Bumthang_Bhutan?hb-sb-sw=97719029

Ugyen, U. & G. Dorji (2021). *Nardostachys grandiflora* (Pangpoe): a status on floristic composition, distribution, Stock estimation & conservation threats of an Important Endangered Alpine medicinal plant of JKSNR. Department of Forests and Park Services of Bhutan, Haa District, 27 pp.

Valavi, R., G. Guillera-Arroita, J.J. Lahoz-Monfort & J. Elith (2022). Predictive performance of presence-only species distribution models: A benchmark study with reproducible code. *Ecological Monographs* 92(1): 1–27. https://doi.org/10.1002/ecm.1486

Weberling, F. (1975). On the systematics of *Nardostachys* (Valerianaceae). *Taxon* 24(4): 443–452.

WHO (2023). Integrating traditional medicine in health care. World Health Organization. https://www.who.int/southeastasia/news/feature-stories/detail/integrating-traditional-medicine. Accessed on 07.viii.2024.

Xin, X.G., L. Zhang, J. Zhang, T.W. Wu & Y.J. Fang (2013). Climate change projections over East Asia with BCC–CSM1.1, climate model under RCP scenarios. *Journal Meteorological Society* 91(4): 413–429. https://doi.org/10.2151/jmsj.2013-401

Yoon, S. & W.H. Lee (2021). Methodological analysis of bioclimatic variable selection in species distribution modeling with application to agricultural pests (*Metcalfa pruinosa* and *Spodoptera litura*). *Computers and Electronics in Agriculture* 190: 106430.

Zhong, X., L. Zhang, J. Zhang, L. He & R. Sun (2023). maxent modeling for predicting the potential geographical distribution of *Castanopsis carlesii* under various climate change scenarios in China. *Forests* 14(7): 1397. https://doi.org/10.3390/f14071397

Zuur, A.F., E.N. Leno, N.J. Walker, A.A. Saveliev & G.M. Smith (2009). Mixed effects models and extensions in ecology with R. Springer, New York, xxii + 574 pp.

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ARTICLE

Checklist of floristic diversity of Mahadare Conservation Reserve, Satara, Maharashtra, India

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Abstract: Conservation reserves are protected areas that serve as buffer zones, connectors, and migratory corridors, safeguarding biodiversity by protecting critical habitats, wildlife pathways, and ecosystems. The documentation of floral diversity in such habitats is an important aspect to determine conservation priorities. The present paper enumerates flowering plants along with the faunal diversity of Mahadare Conservation Reserve in Satara District of Maharashtra and represents 392 plant taxa, belonging to 293 genera, and 87 families. Amongst these, 127 taxa are listed under IUCN Red List Category, 70 endemic, and two monotypic taxa were recorded. Though the area is a conservation reserve human interference for various natural products, agriculture, and many more, along with biological invasion of alien species, are current threats to the area. The present study will help to prioritize the conservation of plant species which lead to protecting the butterflies, mammals, birds, and other fauna in the Mahadare Conservation Reserve.

Keywords: Biodiversity, butterfly larval host plants, conservation reserve, endemism, floristics, frugivores, Western Ghats, wild edible.

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INTRODUCTION

The Satara District is situated in the Sahyadri ranges of the Western Ghats. The climate ranges from rainiest western region of Mahabaleshwar to driest eastern parts of Man and Khatav Tehsils. The eastern zone comes under Sahyadri ranges with high rainfall, lateritic plateaus with peculiar plateau flora rich in endemics, and ephemerals. The basin zone in district shows average climate, presence of basalt, alluvial soil, and has tremendous diversity in vegetation from dry deciduous, scrub patches to semi-evergreen and evergreen forests. The district encompasses Koyna Wildlife Sanctuary, Sahyadri Tiger Reserve, Mahadare Conservation Reserve, Jor-Jambhali Conservation Reserve, and Mayani Conservation Reserve. Amongst this, the Mahadare Conservation Reserve (hereafter Mahadare) has rich biodiversity as it is surrounded by semi-evergreen and deciduous forests.

Mahadare lies in the valley and so is a pressure zone due to mixed biodiversity of both semi-evergreen and deciduous forest. This stream arises from the river Krishna and flows down in Mahadare and its branches are spread almost perpendicular to it. This stream and its branches are filled with water for about 5–7 months (depends upon rainfall).

Recently, Maharashtra State Government declared Dare Khurd, i.e., Mahadare as Conservation Reserve in notification WLP No./ 06.22/CR-170/F-1 dt. 10 October 2022 under Section 36-A of Wildlife (Protection) Act 1972. The area has spread over 107.6 ha under Satara District Forest Division surrounded by Sambarwadi and Yavateshwar villages.

Floristics of some wildlife sanctuaries and national parks have been explored such as Nagzira (174 species) and Nawegaon (301 species) in Bhandara District have been published by Malhotra & Rao (1980, 1981). Dhore & Joshi (1988) compiled the ‘Flora of Melghat Tiger Reserve’ comprising 648 species and ‘Tadoba National Park’ (Chandrapur Dist.) comprising 667 species by Malhotra & Moorthy (1992). Herbaceous vegetation of threatened high altitude lateritic plateau ecosystems of the Western Ghats, southwestern Maharashtra, India. (Yadav & Lekhak 2010; Bhattarai et al. 2012).

There are 242 species of legumes recorded from hilly regions of Satara and Pune districts (Tosh et al. 1988). There are 90 flowering plant species reported from Satara District which are traditionally used for their nutritional potential as wild edible (Deshpande et al. 2019a). Satara District has been explored well for the floristic diversity, viz.: Kas Plateau (Bhattarai et al. 2012; Lekhak & Yadav 2012); Mahabaleshwar (Deshpande 1993); Bharsakhale (Deshpande et al. 2019b). The diversity of herbaceous vegetation on high altitude lateritic plateaus include four floristically rich localities in Satara (Chalakewadi, Thoseghar, Kas, Panchagani Tableland) in which maximum number of endemic species (41) were reported from Kas Plateau (Lekhak & Yadav 2012).

MATERIALS & METHODS

The plants were listed on the basis of repeated seasonal observations of the study region either in the flowering or fruiting stage. The specimens collected were identified by consultation of literature (Cooke 1901–1908; Deshpande 1993; Singh et. al 2001; Yadav & Sardesai 2002), correct plant names were cited from International Plant Name Index (IPNI 2025) and synonymy followed Plants of the World Online (POWO 2025). The birds and mammals were observed by repeated visits, citing, photography, pugmarks, dropping, calls by birds, and animals. The animals observed were identified by using (Ravikanthachari et al. 2018; Abdar 2013; Fraixedas et al. 2020) and were confirmed by using Avibase (2025) and Mammal Species of the World Online.

RESULTS

The Mahadare Conservation Reserve showed great diversity in floristic components. The area harbours a variety of plants such as orchids, grasses, legumes, wild edibles, ornamentals, parasites, along with rare, endangered, and threatened species. The conservation reserve harbours 392 taxa belonging to 287 genera and 84 families, among which, 74 are dicotyledonous, and 13 are monocotyledonous. The reported plants were categorized under IUCN Red List of Threatened Species (127 plants), endemic taxa (72), plant preferred by the butterflies (72), and common taxa (168). The IUCN Red Listed plants are represented in Table 1, wherein Table 2 provides the information of endemic plants of the study region. About 72 flowering plants of the study region have been found to be the host of butterflies (Table 3). Moreover, 168 commonly occurring flowering plants have been reported from the study region (Table 4). Photographs of few of the flowering plants have been provided in Image 1 and Image 2 The investigation confirmed Fabaceae (55 spp.) as dominant family followed by Poaceae (26 spp.), Malvaceae (25 spp.),

Table 1. Plant taxa which are listed under IUCN Red List of Threatened Species, Version 2024–25.

	Species	Family	Local name	IUCN Red List status / Importance	Habit
1	*Eranthemum roseum* R.Br.	Acanthaceae	Jangali Aboli	Least Concern	H
2	*Hygrophila auriculata* (Schumach.) Heine	Acanthaceae	Talimkhana	Least Concern	H
3	*Celosia argentea* L.	Amaranthaceae	Kurdu	Least Concern	H
4	*Mangifera indica* L.	Anacardiaceae	Amba	Data Deficient	T
5	*Anacardium occidentale* L.	Anacardiaceae	Kaju	Least Concern	T
6	*Semecarpus anacardium* L.f.	Anacardiaceae	Bibba	Least Concern	T
7	*Lannea coromandelica* (Houtt.) Merr.	Anacardiaceae	Shimati	Least Concern	T
8	*Annona squamosa* L.	Annonaceae	Sitaphal	Least Concern; Edible	T
9	*Pimpinella tomentosa* Dalz.	Apiaceae	Ran Jire	Vulnerable	H
10	*Holarrhena pubescens* Wall. ex G.Don	Apocynaceae	Pandhara Kuda, Indrajav	Least Concern	T
11	*Alstonia scholaris* (L.) R.Br.	Apocynaceae	Satvin	Least Concern	T
12	*Cascabela thevetia* (L.) Lippold	Apocynaceae	Bitti	Least Concern	T
13	*Calotropis procera* (Aiton) W.T.Aiton	Apocynaceae	Kshirparna, Rui, Aditya-pushpika	Least Concern	S
14	*Plumeria rubra* L.	Apocynaceae	Chapha	Least Concern	T
15	*Ceropegia oculata* Hook.	Apocynaceae	Mor Kharchudi	Low Risk	C
16	*Cynanchum sahyadricum* (Ansari & Hemadri) Liede & Khanum	Apocynaceae	-	Vulnerable	C
17	*Caryota urens* L.	Arecaceae	Tadi Palm	Least Concern	T
18	*Chlorophytum borivilianum* Santapau & R.R.Fern.	Asparagaceae	Safed Musali	Critically Endangered	E
19	*Agave americana* L.	Asparagaceae	Ghayapat	Least Concern	H
20	*Caesulia axillaris* Roxb.	Asteraceae	Gurguza	Least Concern	H
21	*Cyathocline purpurea* (Buch.-Ham. ex D.Don) Kuntze	Asteraceae	Gangotra	Least Concern	H
22	*Eclipta prostrata* (L.) L.	Asteraceae	Maka	Least Concern	H
23	*Opuntia elatior* Mill.	Cactaceae	Nivdung	Least Concern	H
24	*Trema orientalis* (L.) Blume	Cannabaceae	Khargol	Least Concern	T
25	*Celtis tetrandra* Roxb.	Cannabaceae	Brumaj	Least Concern	T
26	*Crateva adansonii* DC.	Capparaceae	Varun	Least Concorn	T
27	*Iphigenia stellata* Blatt.	Colchicaceae	Gulabi Bhui Chakra	Endangered	E
28	*Gloriosa superba* L.	Colchicaceae	Kal Lavi	Least Concern; Medicinal	C
29	*Commelina benghalensis* L.	Commelinaceae	Kena	Least Concern	H
30	*Commelina caroliniana* Walter	Commelinaceae	Asiatic dayflower	Least Concern	H
31	*Cyanotis fasciculata* (B.Heyne ex Roth) Schult. & Schult.f.	Commelinaceae	Nilwanti	Least Concern	H
32	*Stictocardia tiliifolia* (Desr.) Hallier f.	Convolvulaceae	Garvel	Least Concern	C
33	*Rivea hypocrateriformis* (Desr.) Choisy	Convolvulaceae	Phanji	Least Concern; Wild Edible	L
34	*Cordia dichotoma* G.Forst.	Cordiaceae	Bhokar	Least Concern	T
35	*Cuscuta reflexa* Roxb.	Cuscutaceae	Amarvel	Least Concern	C
36	*Diospyros paniculata* Dalz.	Ebenaceae	Tinduka, Tembhurni	Vulnerable	T
37	*Elaeagnus conferta* Roxb.	Elaeagnaceae	Nerli	Least Concern	L
38	*Euphorbia antiquorum* L.	Euphorbiaceae	Tridhar, Vjra Kantak	Least Concern	H
39	*Euphorbia neriifolia* L.	Euphorbiaceae	Gudha	Least Concern	H
40	*Homonoia riparia* Lour.	Euphorbiaceae	Sherani	Least Concern	H
41	*Mallotus philippensis* (Lam.) Müll. Arg.	Euphorbiaceae	Kunkuphal	Least Concern	T
42	*Cassia fistula* L.	Fabaceae	Bahava	Least Concern	T

	Species	Family	Local name	IUCN Red List status / Importance	Habit
43	*Senna siamea* (Lam.) H.S.Irwin & Barneby	Fabaceae	Kashid	Least Concern	T
44	*Delonix regia* (Bojer ex Hook.) Raf.	Fabaceae	Gulmohar	Least Concern	T
45	*Sesbania sesban* (L.) Merr.	Fabaceae	Shevari	Least Concern	T
46	*Bauhinia purpurea* L.	Fabaceae	Dev Kanchan	Least Concern	T
47	*Caesalpinia decapetala* (Roth) Alston	Fabaceae	Chilar	Least Concern	S
48	*Cullen corylifolium* (L.) Medik.	Fabaceae	Bavachi	Least Concern	H
49	*Dalbergia lanceolaria* L.f.	Fabaceae	Dondus	Least Concern	T
50	*Erythrina variegata* L.	Fabaceae	Pangari	Least Concern	T
51	*Gliricidia sepium* (Jacq.) Kunth ex Walp.	Fabaceae	Undirmari	Least Concern	T
52	*Indigofera trita* L.f.	Fabaceae	Asian indigo	Least Concern	H
53	*Mimosa pudica* L.	Fabaceae	Lajaloo	Least Concern	H
54	*Pongamia pinnata* (L.) Pierre	Fabaceae	Karanj	Least Concern	T
55	*Tamarindus indica* L.	Fabaceae	Chinch	Least Concern	T
56	*Acacia auriculiformis* A.Cunn. ex Benth.	Fabaceae	Australian Acacia	Least Concern	T
57	*Acacia leucophloea* (Roxb.) Willd.	Fabaceae	Hivar, Dev babhool	Least Concern	T
58	*Vachellia nilotica* (L.) P.J.H.Hurter & Mabb.	Fabaceae	Deshi Babhool	Least Concern	T
59	*Albizia lebbeck* (L.) Benth.	Fabaceae	Shirish	Least Concern	T
60	*Albizia procera* (Roxb.) Benth.	Fabaceae	Pandhara Shirish	Least Concern	T
61	*Albizia odoratissima* (L. f.) Benth.	Fabaceae	Kala Shirish	Least Concern	T
62	*Pithecellobium dulce* (Roxb.) Benth.	Fabaceae	Vilayati Chinch	Least Concern	T
63	*Pterocarpus marsupium* Roxb.	Fabaceae	Bivala	Near Threatened	T
64	*Vigna khandalensis* (Santapau) Sundararagh. & Wadhwa	Fabaceae	Badmoog, Khandala Wild Pea	Near Threatened	C
65	*Saraca asoca* (Roxb.) De Wilde	Fabaceae	Sita Ashok	Vulnerable	T
66	*Dalbergia latifolia* Roxb.	Fabaceae	Kala Rukh	Vulnerable	T
67	*Acacia ferruginea* DC	Fabaceae	Pandhara Khair	Vulnerable	T
68	*Tectona grandis* L.f.	Lamiaceae	Sagwan	Endangered	T
69	*Colebrookea oppositifolia* Sm.	Lamiaceae	Bhaman	Least Concern	H
70	*Lavandula bipinnata* Kuntze	Lamiaceae	Ghodegui	Least Concern	H
71	*Clerodendrum chinense* (Osbeck) Mabb.	Lamiaceae	Stick bush	Least Concern	S
72	*Vitex negundo* L.	Lamiaceae	Nirgudi	Least Concern	S
73	*Gmelina arborea* Roxb. ex Sm.	Lamiaceae	Shivan	Least Concern; Medicinal	T
74	*Utricularia striatula* Sm.	Lentibulariaceae	Chire papani, Striped Bladderwort	Least Concern	H
75	*Lagerstroemia indica* L.	Lythraceae	Jarul	Least Concern	T
76	*Woodfordia fruticosa* (L.) Kurz	Lythraceae	Dhayati	Least Concern	S
77	*Hiptage benghalensis* (L.) Kurz	Malpighiaceae	Madhu Malati	Least Concern	L
78	*Bombax ceiba* L.	Malvaceae	Shalamli	Least Concern	T
79	*Firmiana simplex* (L.) W.Wight	Malvaceae	Kaushi	Least Concern	T
80	*Kydia calycina* Roxb.	Malvaceae	Warang	Least Concern	T
81	*Thespesia populnea* (L.) Sol. ex Correa	Malvaceae	Parosa Pimpal	Least Concern	T
82	*Grewia abutilifolia* Vent. ex Juss.	Malvaceae	Kirmit	Least Concern	S
83	*Grewia asiatica* L.	Malvaceae	Falasa	Least Concern	S
84	*Grewia flavescens* Juss.	Malvaceae	Donkey Berry	Least Concern	S
85	*Grewia hirsuta* Vahl.	Malvaceae	Guda Sharkara	Least Concern	S
86	*Erinocarpus nimmonii* Grah.	Malvaceae	Chira	Vulnerable	T

	Species	Family	Local name	IUCN Red List status / Importance	Habit
87	*Azadirachta indica* A. Juss.	Meliaceae	Kadunimb	Least Concern	T
88	*Cipadessa baccifera* (Roxb. ex Roth) Miq.	Meliaceae	Ranbili	Least Concern	T
89	*Melia azedarach* L.	Meliaceae	Mahaneem	Least Concern	T
90	*Ficus racemosa* L.	Moraceae	Umber	Least Concern	T
91	*Moringa oleifera* Lam.	Moringaceae	Shevaga	Least Concern	T
92	*Syzygium cumini* (L.) Skeels	Myrataeae	Jambhool	Least Concern	T
93	*Eucalyptus globulus* Labill.	Myrtaceae	Nilgiri	Least Concern	T
94	*Nyctanthes arbor-tristis* L.	Oleaceae	Prajakt	Least Concern	S
95	*Ludwigia octovalvis* (Jacq.) P.H.Raven	Onagraceae	Pan Lavang	Least Concern	H
96	*Habenaria grandifloriformis* Blatt. & McCann	Orchidaceae	Chikar kanda	Nearly Threatened	H
97	*Breynia retusa* (Dennst.) Alston	Phyllanthaceae	Dal Phodi	Least Concern	T
98	*Phyllanthus emblica* L.	Phyllanthaceae	Amala	Least Concern	T
99	*Securinega leucopyrus* (Willd.) Müll.Arg.	Phyllanthaceae	Pandharphali	Least Concern	T
100	*Bridelia stipularis* (L.) Blume	Phyllanthaceae	Phatarpodi	Least Concern	T
101	*Phyllanthus leucopyrus* (Willd.) J.Koenig ex Roxb.	Phyllanthaceae	Pandharphali	Least Concern	T
102	*Cenchrus ciliaris* L.	Poaceae	Buffel grass	Least Concern	H
103	*Echinochloa colona* (L.) Link	Poaceae	Borur	Least Concern	H
104	*Eleusine indica* (L.) Gaertn.	Poaceae	Nandimukhi	Least Concern	H
105	*Eragrostis unioloides* (Retz.) Nees	Poaceae	-	Least Concern	H
106	*Paspalum distichum* L.	Poaceae	-	Least Concern	H
107	*Chionachne gigantea* (J. Koenig) Veldkamp	Poaceae	-	Least Concern	H
108	*Maesa lanceolata* Forssk.	Primulaceae	False Assegai	Least Concern	T
109	*Grevillea robusta* A.Cunn. ex R.Br.	Proteaceae	Silver oak	Least Concern	T
110	*Putranjiva roxburghii* Wall.	Putranjivaceae	Putranjiva	Least Concern	T
111	*Ziziphus mauritiana* Lam.	Rhamnaceae	Bor	Least Concern	S
112	*Ziziphus oenopolia* (L.) Mill.	Rhamnaceae	Burgi	Least Concern	S
113	*Catunaregam spinosa* (Thunb.) Tirveng.	Rubiaceae	Gela, Madanphal	Least Concern	T
114	*Clausena anisata* (Willd.) Hook.f. ex Benth.	Rutaceae	Horse Wood	Least Concern	S
115	*Murraya koenigii* (L.) Spreng.	Rutaceae	Kadhipatta	Least Concern	T
116	*Aegle marmelos* (L.) Correa	Rutaceae	Bel	Neat Threatened	T
117	*Glycosmis mauritiana* (Lam.) Tanaka	Rutaceae	Rum Berry	Not Evaluated	S
118	*Salix tetrasperma* Roxb.	Saliaceae	Jalvetas, Walunj	Least Concern	T
119	*Santalum album* L.	Santalaceae	Chandan	Vulnerable	T
120	*Cardiospermum halicacabum* L.	Sapindaceae	Kanphuti, Kapalphodi	Least Concern	H
121	*Schleichera oleosa* (Lour.) Oken	Sapindaceae	Kusum	Least Concern	T
122	*Mimusops elengi* L.	Sapotaceae	Bakool	Least Concern	T
123	*Solanum anguivi* Lam.	Solanaceae	Dorli	Least Concern	H
124	*Gnidia glauca* (Fresen.) Gilg	Thymelaeaceae	Datpadi	Least Concern	S
125	*Typha angustifolia* L.	Typhaceae	Pan Kanis	Least Concern	H
126	*Cyphostemma auriculatum* (Roxb.) P.Singh & B.V.Shetty	Vitaceae	Jangali Kajorni	Data Deficient	C
127	*Curcuma pseudomontana* J.Graham	Zingiberaceae	Ran Halad	Vulnerable	E

S—Shrub | C—Climber | T—Tree | H—Herb | E—Epimerals | L—Lianas.

Table 2. Endemic to Indian Subcontinent.

	Species	Family	Common name	Endemism	Habit	Accesion number
1	*Carvia callosa* (Nees) Bremek.	Acanthaceae	Karvy	Endemic to WG	MS	MERI-01
2	*Eranthemum roseum* R.Br.	Acanthaceae	Jangali Aboli	Endemic to WG	H	MERI-02
3	*Barleria cuspidata* Heyne ex Nees	Acanthaceae	Kate Koranti	Endemic to India	S	MERI-03
4	*Barleria involucrata* Nees	Acanthaceae	Jambhali Koranti	Endemic to Peninsular India	S	MERI-04
5	*Barleria terminalis* Nees.	Acanthaceae	Nili Koranti	Endemic to WG	S	MERI-05
6	*Miliusa tomentosa* Finet & Gagnep.	Annonaceae	Hoom	Endemic to India	T	MERI-06
7	*Pimpinella tomentosa* Dalz.	Apiaceae	Ran Jire	Endemic to Indian subcontinent	H	MERI-07
8	*Cynanchum sahyadricum* (Ansari & Hemadri) Liede & Khanum	Apocynaceae		Endemic to the Laccadive Islands in Maharashtra	C	MERI-08
9	*Ceropegia bulbosa* Roxb. var. *bulbosa*	Apocynaceae	Kharpudi	Endemic to India	C	MERI-09
10	*Ceropegia bulbosa var. lushii* (Graham) Hook.f.	Apocynaceae	Kharpudi	Endemic to India	C	MERI-10
11	*Ceropegia hirsuta* Hochstetter ex Decaisne	Apocynaceae	Hamana	Endemic to Peninsular India	C	MERI-11
12	*Ceropegia oculata* Hook.	Apocynaceae	Mor Kharchudi	Endemic to India	C	MERI-12
13	*Hemidesmus indicus* (L.) R.Br. ex Schult.	Apocynaceae	Anantmool	Endemic to SWG	C	MERI-13
14	*Arisaema murrayi* (J.Graham) Hook.	Araceae	Pandhara Sapkanda	Endemic to WG	E	MERI-14
15	*Scilla hyacinthina* (Roth) J.F.Macbr.	Asparagaceae	Khajkanda	Endemic to WG	H	MERI-15
16	*Chlorophytum borivilianum* Santapau & R.R.Fern.	Asparagaceae	Safed Musali	Endemic to NWG	E	MERI-16
17	*Tricholepis amplexicaulis* C.B.Clarke	Asteraceae	Dahan	Endemic to NWG	H	MERI-17
18	*Cyathocline purpurea* (Buch.-Ham. ex D.Don) O.Ktze. var. *bicolor* Santapau	Asteraceae	Gangotra	Endemic to NWG	H	MERI-18
19	*Pentanema indicum* (L.) Y.Ling	Asteraceae	Sonakadi	Endemic to Peninsular India	H	MERI-19
20	*Senecio bombayensis* N. P.Balakr.	Asteraceae	Sonaki	Endemic to India	H	MERI-20
21	*Tricholepis radicans* (Roxb.) Wight	Asteraceae	Mundagoose	Endemic to Western Peninsular India	H	MERI-21
22	*Dolichandrone falcata* Seem.	Bignoniaceae	Medhshingi	Endemic to India	T	MERI-22
23	*Heterophragma quadriloculare* (Roxb.) K.Schum.	Bignoniaceae	Waras	Endemic to Central & Peninsular India	T	MERI-23
24	*Radermachera xylocarpa* (Roxb.) Roxb. ex K.Schum.	Bignoniaceae	Khadshingi	Endemic to India	T	MERI-24
25	*Boswellia serrata* Roxb.	Burseraceae	Salai	Endemic to India	T	MERI-25
26	*Maytenus rothiana* (Walp.) Ramamoorthy	Celastraceae	Makar Khana	Endemic to Peninsular India	S	MERI-26
27	*Iphigenia stellata* Blatt.	Colchicaceae	Gulabi Bhui Chakra	Endemic to NWG	E	MERI-27
28	*Iphigenia magnifica* Ansari & R.S.Rao	Colchicaceae	Magnificent Grass Lily	Endemic to NWG	E	MERI-28
29	*Cyanotis fasciculata* (B.Heyne ex Roth) Schult. & Schult.f.	Commelinaceae	Nilwanti	Endemic to WG	H	MERI-29
30	*Commelina caroliniana* Walter	Commelinaceae	Asiatic dayflower	Restricted to India and North America'	H	MERI-30
31	*Argyreia boseana* Santapau & V.Patel	Convolvulaceae	Maralmathangi	Endemic to NWG	C	MERI-31
32	*Argyreia sericea* Dalz.	Convolvulaceae	Kesal Garvel	Endemic to Western Peninsula	C	MERI-32
33	*Argyreia cuneata* (Willd.) Ker Gawl.	Convolvulaceae	Mhalungi	Endemic to WG	S	MERI-33
34	*Cordia wallichii* G.Don	Cordiaceae	Bhokar	Endemic to South Western India	T	MERI-34

	Species	Family	Common name	Endemism	Habit	Accesion number
35	*Diospyros melanoxylon* Roxb.	Ebenaceae	Tendu, Temru	Endemic to Indian Subcontinent	T	MERI-35
36	*Diospyros paniculata* Dalz.	Ebenaceae	Tinduka, Tembhurni	Endemic to WG	T	MERI-36
37	*Crotalaria calycina* Schrank	Fabaceae	Silky Haired Rattlepod	Endemic to Indian subcontinent	H	MERI-37
38	*Paracalyx scariosus* (Roxb.) Ali	Fabaceae	Ran Ghevada	Endemic to Indian subcontinent	L	MERI-38
39	*Smithia setulosa* Dalz.	Fabaceae	Motha Kawala	Endemic to Indian subcontinent	H	MERI-39
40	*Galactia striata* (Jacq.) Urb.	Fabaceae	Slender Flowered Milkpea	Endemic to NWG	H	MERI-40
41	*Sphenostylis bracteata* (Baker) J.B.Gillett	Fabaceae	Ran Pavata	Endemic to NWG	C	MERI-41
42	*Alysicarpus pubescens* Y.W.Law	Fabaceae	Durangi Shevara	Endemic to Peninsular India	H	MERI-42
43	*Saraca asoca* (Roxb.) De Wilde	Fabaceae	Sita Ashok	Endemic to WG	T	MERI-43
44	*Vigna khandalensis* (Santapau) Sundararagh. & Wadhwa	Fabaceae	Badmoog, Khandala Wild Pea	Endemic to WG	H	MERI-44
45	*Moullava spicata* (Dalz.) Nicolson	Fabaceae	Wagati	Endemic to WG	S	MERI-45
46	*Pterocarpus marsupium* Roxb.	Fabaceae	Bivala	Endemic to Peninsular India	T	MERI-46
47	*Flacourtia latifolia* (Hook.f. & Thomson) T.Cooke	Flacourtiaceae	Tambat	Endemic to SWG	T	MERI-47
48	*Canscora diffusa* (Vahl) R.Br. ex Roem. & Schult.	Gentianaceae	Kilwar, Titawi	Endemic to peninsular NWG	H	MERI-48
49	*Leucas ciliata* Benth.	Lamiaceae	Burumbi	Endemic to India	H	MERI-49
50	*Pogostemon deccanensis* (Panigrahi) Press	Lamiaceae	Jambhali Manjiri	Endemic to WG	H	MERI-50
51	*Taxillus cuneatus* (B.Heyne ex Roth) Danser	Loranthaceae		Endemic to WG	H	MERI-51
52	*Erinocarpus nimmonii* Grah.	Malvaceae	Chira	Endemic to NWG	T	MERI-52
53	*Cipadessa baccifera* (Roxb. ex Roth) Miq.	Meliaceae	Ranbili	Endemic to WG	S	MERI-53
54	*Moringa oleifera* Lam.	Moringaceae	Shevaga	Endemic to India	T	MERI-54
55	*Jasminum malabaricum* Wight.	Oleaceae	Kusar	Endemic to WG	S	MERI-55
56	*Habenaria longicorniculata* J.Graham	Orchidaceae	Gudhi	Endemic	H	MERI-56
57	*Aerides maculosum* Lindl.	Orchidaceae	Draupadi Pushp	Endemic to WG	Ep	MERI-57
58	*Habenaria grandifloriformis* Blatt. & McCann	Orchidaceae	Chikar kanda	Endemic to Peninsular India	H	MERI-58
59	*Glochidion ellipticum* Wight	Phyllanthaceae	Bhoma	Endemic to WG	T	MERI-59
60	*Bridelia stipularis* (L.) Blume	Phyllanthaceae	Phatarpodi	Endemic to Peninsular India	T	MERI-60
61	*Phyllanthus emblica* L.	Phyllanthaceae	Amala	Endemic to WG	T	MERI-62
62	*Arundinella ciliata* Nees ex Miq.	Poaceae		Endemic to Peninsular India	H	MERI-62
63	*Putranjiva roxburghii* Wall.	Putranjivaceae	Putranjiva	Endemic to WG	T	MERI-63
64	*Delphinium malabaricum* (Huth) Munz	Ranunculaceae	Nilambari	Endemic to NWG	H	MERI-64
65	*Clematis gouriana* Roxb. ex DC.	Ranunculaceae	Morvel	Endemic to WG	C	MERI-65
66	*Ixora brachiata* Roxb.	Rubiaceae	Kurati	Endemic to WG	S	MERI-66
67	*Pavetta crassicaulis* Bremek.	Rubiaceae	Kathachampa	Endemic to WG	S	MERI-67
68	*Atalantia racemosa* Wight & Arn.	Rutaceae	Makad Limbu	Endemic to WG	T	MERI-68
69	*Clausena anisata* (Willd.) Hook.f. ex Benth.	Rutaceae	Horse Wood	Endemic to SWG	S	MERI-69
70	*Curcuma pseudomontana* J.Graham	Zingiberaceae	Ran Halad	Endemic to Eastern and Western Ghats	H	MERI-70

MS—Medium shrub | S—Shrub | C—Climber | T—Tree | H—Herb | Ep—Epiphyte | E—Epimerals.

Table 3. Plants preferred by butterflies (Larval host plants).

	Name of the plant species	Family
1	*Eranthemum roseum* R.Br.	Acanthacae
2	*Barleria prionitis* L.	Acanthaceae
3	*Strobilanthes callosus* Nees	Acanthaceae
4	*Hygrophila auriculata* (Schumach.) Heine	Acanthaceae
5	*Justicia adhatoda* L.	Acanthaceae
6	*Strobilanthes ixiocephala* Benth.	Acanthaceae
7	*Achyranthes aspera* L.	Amaranthaceae
8	*Amaranthus viridis* L.	Amaranthaceae
9	*Mangifera indica* L.	Anacardiaceae
10	*Annona squamosa* L.	Annonaceae
11	*Miliusa tomentosa* Finet & Gagnep.	Annonaceae
12	*Monoon longifolium* (Sonn.) B.Xue & R.M.K.Saunders	Annonaceae
13	*Ceropegia hirsuta* Wight & Arn.	Apocynaceae
14	*Ceropegia oculata* Hook.	Apocynaceae
15	*Tylophora indica* (Burm.f.) Merr.	Apocynaceae
16	*Wattakaka volubilis* (L.f.) Stapf	Apocynaceae
17	*Caryota urens* L.	Arecaceae
18	*Cocos nucifera* L.	Arecaceae
19	*Phoenix acaulis* Roxb.	Arecaceae
20	*Asclepias curassavica* L.	Asclepiadaceae
21	*Calotropis gigantea* (L.) W.T.Aiton	Asclepiadaceae
22	*Calotropis procera* (Aiton) W.T.Aiton	Asclepiadaceae
23	*Capparis zeylanica* L.	Capparidaceae
24	*Terminalia catappa* L.	Combretaceae
25	*Bryophyllum pinnatum* (Lam.) Oken	Crassulaceae
26	*Dioscorea alata* L.	Dioscoreaceae
27	*Dioscorea wallichii* Hook.f.	Dioscoreaceae
28	*Diospyros melanoxylon* Roxb.	Ebenaceae
29	*Bridelia stipularis* (L.) Blume	Euphorbiaceae
30	*Mallotus philippensis* (Lam.) Müll. Arg.	Euphorbiaceae
31	*Ricinus communis* L.	Euphorbiaceae
32	*Desmodium triflorum* (L.) DC.	Fabacaee
33	*Acacia catechu* (L.f.) Willd.	Fabaceae
34	*Acacia concinna* (Willd.) DC.	Fabaceae
35	*Acacia nilotica* (L.) Willd. ex Delile	Fabaceae
36	*Acacia torta* (Roxb.) Craib	Fabaceae
37	*Cassia fistula* L.	Fabaceae
38	*Crotalaria hebecarpa* (DC.) Rudd	Fabaceae
39	*Dalbergia lanceolaria* L.f.	Fabaceae
40	*Derris indica* (Lam.) Bennet	Fabaceae
41	*Mucuna pruriens* (L.) DC.	Fabaceae
42	*Senna obtusifolia* (L.) H.S.Irwin & Barneby	Fabaceae
43	*Sesbania bispinosa* (Jacq.) W.Wight	Fabaceae
44	*Tamarindus indica* L.	Fabaceae
45	*Zornia gibbosa* Span.	Fabaceae
46	*Flacourtia indica* (Burm.f.) Merr.	Flacourtiaceae
47	*Dendrophthoe falcata* (L.f.) Ettingsh.	Loranthaceae
48	*Loranthus longiflorus* Desr.	Lorathaceae
49	*Magnolia champaca* (L.) Baill. ex Pierre	Magnoliaceae
50	*Hiptage benghalensis* (L.) Kurz	Malphighiaceae
51	*Abutilon pannosum* (G.Forst.) Schltdl.	Malvaceae
52	*Hibiscus tiliaceus* L.	Malvaceae
53	*Sida rhombifolia* L.	Malvaceae
54	*Triumfetta rhomboidea* Jacq.	Malvaceae
55	*Ficus benghalensis* L.	Moraceae
56	*Ficus racemosa* L.	Moraceae
57	*Aerides maculosum* Lindl.	Orchidaceae
58	*Oxalis corniculata* L.	Oxalidaceae
59	*Argemone mexicana* L.	Papaveraceae
60	*Plumbago zeylanica* L.	Plumbaginaceae
61	*Bambusa vulgaris* Schrad. ex J.C. Wendl. var. *vulgaris*	Poaceae
62	*Oryza sativa* L.	Poaceae
63	*Maesa lanceolata* Forssk.	Primulaceae
64	*Punica granatum* L.	Punicaceae
65	*Ziziphus jujuba* Mill.	Rhamnaceae
66	*Ziziphus rugosa* Lam.	Rhamnaceae
67	*Catunaregam spinosa* (Thunb.) Tirveng.	Rubiaceae
68	*Ixora coccinea* L.	Rubiaceae
69	*Atalantia racemosa* Wight & Arn.	Rutaceae
70	*Grewia tiliifolia* Vahl	Tiliaceae
71	*Curcuma pseudomontana* J.Graham	Zingiberaceae
72	*Zingiber neesanum* (J.Graham) Ramamoorthy	Zingiberaceae

Asteraceae (22 spp.), and Acanthaceae (21 spp.). *Grewia* (6 spp.) *Barleria, Crotalaria, Ipomoea*, (5 spp. each), *Acacia, Argyreia, Albizzia, Ceropegia, Iphigenia, Solanum* (4 spp. each), *Abutilon, Commelina, Datura, Diospyros, Euphorbia, Haplanthodes, Indigofera, Phyllanthus, Sida, Vigna, Ziziphus* (3 spp. each) are among the most diverse genera reported from study region. Moreover, 27 genera are represented by two species while 233 genera have single taxa in the study region. The diversified vegetation with respect to habits such as annual, perennial, herbs, shrubs, trees, climbers, liana, monocarpic ephemeral, epiphytic, and parasites have been reported. About 12 mammals and 32 bird species have been recorded from the study region (Tables 5 & 6).

Table 4. Enumeration of common plant taxa in the study area.

	Species	Family	Common name	Status / Importance	Habit
1	*Andrographis paniculata* (Burm.f.) Wall.	Acanthaceae	Chirayat	Medicinal	H
2	*Asystasia violacea* Dalz.	Acanthaceae	Neelkantha	Weed	H
3	*Barleria cristata* L.	Acanthaceae	Pandhari Koranti	Wild Ornamental	S
4	*Dicliptera foetida* Blatt.	Acanthaceae	Jivani		H
5	*Haplanthodes neilgherryensis* R.B.Majumdar	Acanthaceae	Kateri Jakara		H
6	*Haplanthodes plumosa* Panigrahi & G.C.Das	Acanthaceae	Jakara		H
7	*Haplanthodes verticillatus* R.B.Majumdar	Acanthaceae	Kale Kirayat		H
8	*Justicia betonica* L.	Acanthaceae	Gulabi Adulasa		H
9	*Lepidagathis cristata* Willd.	Acanthaceae	Bhui Gend		H
10	*Lepidagathis cuspidata* Nees	Acanthaceae	Kate adulasa		H
11	*Neuracanthus sphaerostachyus* Dalz.	Acanthaceae	Golgonda		H
12	*Peristrophe paniculata* (Forssk.) Brummitt	Acanthaceae	Rankirayat, Pittapapada		H
13	*Thunbergia fragrans* Roxb.	Acanthaceae	Chimine	Wild Ornamental	C
14	*Alternanthera philoxeroides* (Mart.) Griseb.*	Amaranthaceae	Bech Kusal	Weed	H
15	*Crinum latifolium* L.	Amaryllidaceae	Sudarshana	Ornamental	E
16	*Spondias pinnata* (L.f.) Kurz	Anacardiaceae	Ambada	Wild edible	T
17	*Anona reticulata* L.*	Annonaceae	Ramphal	Edible	T
18	*Carissa carandas* L.	Apocynaceae	Karvand	Wild edible	S
19	*Cryptolepis buchananii* R.Br. ex Roem. & Schult	Apocynaceae	Kavali, Krishna Sariva	Weed	C
20	*Wrightia tinctoria* (Roxb.) R.Br.	Apocynaceae	Kala Kuda	Medicinal	T
21	*Phoenix sylvestris* (L.) Roxb.	Arecaceae	Shindi		T
22	*Protasparagus racemosus* Oberm.	Asparagaceae	Shatawari	Medicinal	C
23	*Adenostemma lavenia* (L.) Kuntze	Asteraceae	Jangali Jeera		H
24	*Artemisia nilagirica* (C.B.Clarke) Pamp.	Asteraceae	Dhor Davana		H
25	*Bidens biternata* (Lour.) Merr. & Sherff	Asteraceae	Chirchitta		H
26	*Blumea axillaris* (Lam.) DC.	Asteraceae	Kukundar		H
27	*Conyza stricta* Willd.	Asteraceae	Bat Davana	Weed	H
28	*Echinops echinatus* Roxb.	Asteraceae	Kate Chendu, Brahma Dandi		H
29	*Gynura bicolor* (Roxb. ex Willd.) DC.	Asteraceae	Kusumbi		H
30	*Gynura nitida* DC	Asteraceae	Kusumbi		H
31	*Kleinia grandiflora* (Wall. ex DC.) N.Rani	Asteraceae	Vandar Roti		H
32	*Launaea procumbens* (Roxb.) Ramayya & Rajagopal	Asteraceae	Pathari	Wild edible	H
33	*Pentanema cernuum* (Dalz.) Y.Ling	Asteraceae	Sonasari		H
34	*Siegesbeckia orientalis* L.	Asteraceae	Katampu		H
35	*Sonchus oleraceus* L.	Asteraceae	Dudhi		H
36	*Tridax procumbens* L.	Asteraceae	Ekdandi	Medicinal	H
37	*Vernonia divergens* (DC.) Edgew.	Asteraceae		Weed	H
38	*Impatiens walleriana* Hook.f.	Balsaminaceae	Sultan's Balsam		H
39	*Trichodesma indicum* (L.) Lehm.	Boraginaceae	Adhapuspi		H
40	*Cassine glauca* (Rottb.) Kuntze	Celastraceae	Motha Bhutya		T
41	*Cleome gynandra* L.	Cleomaceae	Pandhari Tilwan		H
42	*Iphigenia indica* (L.) A.Gray ex Kunth	Colchicaceae	Jambhale bhui chakra		E
43	*Iphigenia pallida* Baker	Colchicaceae	Bhui chakra		E
44	*Combretum albidum* G.Don	Combretaceae	Piluki		L
45	*Combretum indicum* (L.) DeFilipps	Combretaceae	Lal Chameli		L
46	*Terminalia arjuna* (Roxb. ex DC.) Wight & Arn.	Combretaceae	Arjun	Medicinal	T

	Species	Family	Common name	Status / Importance	Habit
47	*Terminalia chebula* Retz.	Combretaceae	Hirada	Medicinal	T
48	*Commelina forskaolii* Vahl.	Commelinaceae	Kanpet		H
49	*Cyanotis tuberosa* (Roxb.) Schult. & Schult.f.	Commelinaceae	Aabhali		H
50	*Tonningia axillaris* (L.) Raf.	Commelinaceae	Bechaka		H
51	*Argyreia elliptica* (Roth) Choisy	Convolvulaceae	Kedari		C
52	*Camonea umbellata* (L.) A.R.Simões & Staples	Convolvulaceae	Motiya		C
53	*Evolvulus alsinoides* (L.) L. *	Convolvulaceae	Shankhapushpi		H
54	*Ipomoea capillacea* (Kunth) G.Don*	Convolvulaceae	Water spinach		C
55	*Ipomoea carnea* Jacq. *	Convolvulaceae	Besharam		S
56	*Ipomoea hederifolia* L. *	Convolvulaceae	Lal Pungali, Ganesh vel		C
57	*Ipomoea muricata* (L.) Jacq.*	Convolvulaceae	Bhingari		C
58	*Ipomoea nil* (L.) Roth. *	Convolvulaceae	Neelpushpi, Kalanjani		C
59	*Ipomoea obscura* (L.) Ker Gawl.*	Convolvulaceae	Vachagandha, Pivali Bhowari		C
60	*Porana malabarica* C.B.Clarke*	Convolvulaceae	Bhovari		C
61	*Rivea ornata* (Roxb.) Choisy	Convolvulaceae	Sanjvel, Kalmi Lata		L
62	*Kalanchoe pinnata* (Lam.) Pers.	Crassulaceae	Panphuti	Medicinal	H
63	*Coccinia grandis* (L.) Voigt*	Cucurbitaceae	Tondali	Medicinal; Wild edible	C
64	*Diplocyclos palmatus* (L.) C.Jeffrey	Cucurbitaceae	Shivlingi	Medicinal	C
65	*Momordica dioica* Roxb. ex Willd.	Cucurbitaceae	Kartooli	Wild edible	C
66	*Solena amplexicaulis* (Lam.) Gandhi	Cucurbitaceae	Gometi		C
67	*Trichosanthes tricuspidata* Lour.	Cucurbitaceae	Kavandal		C
68	*Kyllinga triceps* var. *ciliata* Boeckeler	Cyperaceae	Shwetnirvisha		H
69	*Dioscorea dodecaneura* Vell.	Dioscoreaceae	Kadu karanda	Wild edible	C
70	*Diospyros nigrescens* (Dalz.) C.J.Saldanha*	Ebenaceae	Rakta roda		T
71	*Euphorbia hirta* L. *	Euphorbiaceae	Dudhani	Weed	H
72	*Jatropha gossypifolia* L.*	Euphorbiaceae	Ratanjyoti	Ornamental	S
73	*Abrus precatorius* L.*	Fabaceae	Gunja	Medicinal	C
74	*Alysicarpus tetragonolobus* Edgew.	Fabaceae	Lal Shevara		H
75	*Bauhinia vahlii* Wight & Arn.	Fabaceae	Aapta		T
76	*Clitoria ternatea* L. var. *pilosula* Wall. ex Baker	Fabaceae	Pandhari Gokarna	Endemic; Ornamental	C
77	*Clitoria ternatea* L. var. *ternatea**	Fabaceae	Nili Gokarna	Medicinal; Ornamental	C
78	*Crotalaria juncea* L.	Fabaceae	Sun Hemp		H
79	*Crotalaria pallida* Aiton	Fabaceae	Jangali Tag		H
80	*Crotalaria spectabilis* Roth	Fabaceae	Dingala		H
81	*Derris trifoliata* Lour.	Fabaceae	Karanjvel		L
82	*Desmodium gangeticum* (L.) DC.	Fabaceae	Salvan, Ranganjya		H
83	*Entada rheedei* Spreng.	Fabaceae	Garambi	Medicinal	L
84	*Erythrina suberosa* Roxb.	Fabaceae	Pangari	Wild Ornamental	T
85	*Grona triflora* (L.) H.Ohashi & K.Ohashi	Fabaceae	Ran Methi		H
86	*Hultholia mimosoides* (Lam.) Gagnon & G.P.Lewis	Fabaceae	Vishakhmantha		T
87	*Indigofera cassioides* Rottler ex DC.	Fabaceae	Unhali		H
88	*Indigofera cordifolia* B.Heyne ex Roth	Fabaceae	Godhadi		H
89	*Vigna sublobata* (Roxb.) Bairig., Panda, B.P.Choudhury & Patnaik	Fabaceae	Jangali Udid, Vel Moong	Wild edible	C
90	*Vigna vexillata* (L.) A.Rich.	Fabaceae	Halunda, Jangali Moong	Wild edible	C
91	*Heliotropium indicum* L.	Heliotropiaceae	Bhurundi		H

	Species	Family	Common name	Status / Importance	Habit
92	*Curculigo orchioides* Gaertn.	Hypoxidaceae	Kali Musali		E
93	*Hypoxis aurea* Lour.	Hypoxidaceae	Son tara		E
94	*Anisomeles indica* (L.) Kuntze	Lamiaceae	Gopali		H
95	*Anisomeles malabarica* (L.) R.Br. ex Sims	Lamiaceae	Mahadron		H
96	*Callicarpa tomentosa* Lam.	Lamiaceae	Priyangu, Hesur		T
97	*Coleus strobilifer* (Roxb.) A.J.Paton	Lamiaceae	Panmanjiri, Karpurvallii		H
98	*Hyptis suaveolens* (L.) Poit.	Lamiaceae	Darp tulas	Weed	H
99	*Lavandula lawii* Wight*	Lamiaceae	Nivali		H
100	*Leonotis nepetifolia* (L.) R.Br.	Lamiaceae	Deepmaal, Granthiparni		H
101	*Orthosiphon pallidus* Royle ex Benth.	Lamiaceae	Jyoti, Shwet Kutheraka		H
102	*Rotheca serrata* (L.) Steane & Mabb.	Lamiaceae	Bharangi	Wild edible	H
103	*Salvia plebeia* R.Br.	Lamiaceae	Samudraphala shati		H
104	*Vitex trifolia* L.	Lamiaceae	Nirgundi	Medicinal	S
105	*Cinnamomum verum* J.Presl.*	Lauraceae	Dalchini	Medicinal	T
106	*Macrosolen capitellatus* (Wight & Arn.) Danser	Loranthaceae	Lahan Bandgul	Parasite	H
107	*Abutilon indicum* (L.) Sweet	Malvaceae	Bala	Medicinal	S
108	*Abutilon persicum* (Burm.f.) Merr.	Malvaceae	Ran Petari		S
109	*Corchorus olitorius* L.	Malvaceae	Banpaat		H
110	*Grewia multiflora* Juss.	Malvaceae	Kawari		S
111	*Helicteres isora* L.	Malvaceae	Muradsheng	Medicinal	S
112	*Hibiscus tetraphyllus* Roxb. ex Hornem.	Malvaceae	Native Rosella		S
113	*Malvastrum coromandelianum* (L.) Garcke	Malvaceae	False Mallow		S
114	*Sida acuta* Burm.f.*	Malvaceae	Bala, Chikana	Medicinal	H
115	*Sida cordifolia* L.*	Malvaceae	Bala, Chikana	Medicinal	H
116	*Sterculia urens* Roxb.	Malvaceae	Bhutya	Medicinal	T
117	*Thespesia lampas* (Cav.) Dalz. & A.Gibson	Malvaceae	Gulbhendi, Ran bhendi	Ornamental	T
118	*Urena sinuata* L.*	Malvaceae	Rankapashi, Nagbala		H
119	*Commicarpus chinensis* (L.) Heimerl	Nyctaginaceae	Punarnava		H
120	*Buchnera hispida* Buch.-Ham. ex D.Don	Orbanchaceae	Karanjee	Parasite	H
121	*Rhamphicarpa longiflora* Wight ex Benth.	Orbanchaceae	Tutari		H
122	*Sopubia delphinifolia* D.Don	Orbanchaceae	Dudhali		H
123	*Striga densiflora* (Benth.) Benth.	Orbanchaceae	Agya	Parasite	H
124	*Biophytum umbraculum* Welw.	Oxalidaceae	Lajwanti, Jalpushpa		H
125	*Passiflora foetida* L.	Passifloraceae	Vel Ghani	Ornamental	C
126	*Sesamum orientale* L.*	Pedaliaceae	Safed Til		H
127	*Glochidion velutinum* Wight	Phyllanthaceae			T
128	*Phyllanthus amarus* Schumach. & Thonn.	Phyllanthaceae	Bhui Awali, Bhumyaamalaki		T
129	*Apluda mutica* L.*	Poaceae			H
130	*Chloris barbata* Sw.	Poaceae	Gondvel		H
131	*Chloris virgata* Sw.*	Poaceae	Feather fingergrass		H
132	*Chrysopogon fulvus* (Spreng.) Chiov.*	Poaceae			H
133	*Coix lacryma-jobi* L.	Poaceae	Ran Jondhala	Ornamental	H
134	*Cynodon dactylon* (L.) Pers.*	Poaceae	Harali	Medicinal	H
135	*Dactyloctenium aegyptium* (L.) Willd.	Poaceae	Duck Grass		H
136	*Dendrocalamus strictus* (Roxb.) Nees*	Poaceae	Kalak		T
137	*Dichanthium annulatum* (Forssk.) Stapf	Poaceae	Shed grass		H
138	*Digitaria ciliaris* (Retz.) Koeler*	Poaceae	Bamboo grass		H

	Species	Family	Common name	Status / Importance	Habit
139	*Dimeria connivens* Hack.	Poaceae			H
140	*Dinebra retroflexa* (Vahl) Panz.	Poaceae	Kangar		H
141	*Eragrostis pilosa* (L.) P.Beauv.	Poaceae			H
142	*Heteropogon contortus* (L.) P. Beauv. ex Roem. & Schult.*	Poaceae			H
143	*Panicum maximum* Jacq.	Poaceae			H
144	*Pseudanthistiria heteroclita* (Roxb.) Hook.f.	Poaceae			H
145	*Sorghum bicolor* (L.) Moench	Poaceae			H
146	*Sporobolus diandrus* (Retz.) P.Beauv.*	Poaceae			H
147	*Themeda triandra* Forssk.	Poaceae			H
148	*Polygala persicariifolia* DC	Polygalaceae			H
149	*Polygonum auriculatum* Meisn.	Polygonaceae			H
150	*Maesa lanceolata* Forssk.	Primulaceae	False Assegai	Least Concern	T
151	*Ziziphus caracutta* Roxb.*	Rhamnaceae	Ghat bor	Wild edible	S
152	*Meyna laxiflora* Robyns	Rubiaceae	Myna	Wild edible	T
153	*Mitragyna parvifolia* (Roxb.) Korth.	Rubiaceae	Kadamb	Ornamental	T
154	*Viscum monoicum* Roxb. ex DC.	Santalaceae		Parasite	H
155	*Madhuca longifolia* (J.Koenig ex L.) J.F.Macbr.	Sapotaceae	Moha	Endemic; Medicinal	T
156	*Verbascum chinense* (L.) Santapau	Scrophulariaceae	Kutaki, Bhootkeshi		H
157	*Smilax ovalifolia* Roxb.	Smilacaceae	Ghotwel		T
158	*Datura ferox* L.	Solanaceae	Kala Dhotra	Medicinal	H
159	*Datura innoxia* Mill.*	Solanaceae	Pandhara Dhotra	Medicinal	H
160	*Datura quercifolia* Kunth *	Solanaceae	Chinese thorn apple		H
161	*Nicandra physalodes* (L.) Gaertn.*	Solanaceae	Shoo fly plant		H
162	*Solanum nigrum* L. *	Solanaceae	Black nightshade		H
163	*Solanum torvum* Sw.*	Solanaceae	Turkey Berry		S
164	*Solanum virginianum* L.*	Solanaceae	Kantakee		H
165	*Withania somnifera* (L.) Dunal	Solanaceae	Ashwagandha	Medicinal	H
166	*Holoptelea integrifolia* Planch.	Ulmaceae	Papadi	Wild edible; Ornamental	T
167	*Lantana camara* L.	Verbenaceae	Ghaneri		H
168	*Ampelocissus latifolia* (Roxb.) Planch.	Vitaceae	Wild Grape		H

S—Shrub | C—Climber | T—Tree | H—Herb | E—Epimerals | L—Liana | *—non-native plant to the study area.

DISCUSSION

The Mahadare accounts for total 392 plant species, of which, 127 taxa are categorised under IUCN Red List of Threatened Species, and 70 are endemic to Western Ghats, Indian Peninsula, and Sri Lanka. Amongst these 72 plant species serve as larval host plants (LHP). Because of availability of LHP Mahadare is home for many endemic butterfly species which makes it the first butterfly conservation reserve in India (Dhale et al. 2024). The flora supports frugivorous mammals (12 species) and birds (32 species). There are 168 commonly occurring taxa which comprises plants of medicinal importance, edible value, and ornamental potential. Along with this the area is invaded by some weeds which may become threat to native flora and fauna. Before the study region has been declared as the conservation reserve, many anthropogenic activities such as overgrazing, farming activities, fires, picnic or tours, sewage disposal by hotels caused considerable threat to the flora and fauna. Since declaration of the conservation reserve, there is ban on any man-made activities as well as collection of the plantlets from the Mahadare.

The area supports variety of wild edible and wild ornamental species which can be domesticated and utilised to provide the economic stability to the local people. The wild relatives of cultivated legumes such as *Vigna khandalensis* have been reported from the study region. Such legumes need to be assessed for its nutritional, phytochemical, and biological properties

Table 5. List of frugivorous mammals in study area

	Scientific name	Family	Common name
1	*Bos gaurus*	Bovidae	Indian Gaur
2	*Tetracerus quadricornis*	Bovidae	Four-horned Antelope / Chousingha / Malsada
3	*Semnopithecus entellus*	Cercopithecidae	Hanuman Langur
4	*Macaca mulatta*	Cercopithecidae	Rhesus Macaque
5	*Muntiacus muntjac*	Cervidae	Barking Deer / Indian Muntjac
6	*Hystrix indica*	Hystricidae	Indian Crested Porcupine
7	*Lepus nigricollis*	Leporidae	Indian Hare
8	*Bandicota indica*	Muridae	Bandicoot Rat
9	*Cynoteropus brachyotis*	Pteropodidae	Short-nosed Fruit Bat
10	*Funambulus palmarum*	Sciuridae	Three-striped Palm Squirrel
11	*Ratufa indica*	Sciuridae	Indian Giant Squirrel
12	*Sus scorfa*	Suidae	Indian Wild Boar

and subsequently domestication practices need to be implicated. Lack of awareness about the unique diversity, threats, and deficit planning for prioritization the conservation endemic species especially supporting the butterflies are the major risk factors in near future. Presently efforts were made by Mahadare Ecological Research Institute for creating awareness among the local people and visitors, enlisting the butterfly, spiders, and birds in the region as well as collaboration with the forest department regarding the developmental activities and planning for conservation of plant species. Preparing checklist of flowering plants of any particular region supports the designing the conservation management of that region.

The habitat is ecotone hence it is rich in floral and faunal diversity. The flowering plant population express multi-storeyed habitat which provides favourable conditions for survival of wide range of animals including butterflies, birds, insects, mammals, moths, spiders, amphibians, and fishes. The animals and plants exhibit complex food web as well as notable prey-predator relationship. The Mahadare accounts for total 393 plant species of which 127 taxa are categorised under IUCN Red List of Threatened Species and 70 are endemic to Western Ghats and India. Amongst these 72 plant species serves as Larval Host Plants (LHP). The flora supports frugivorous mammals (12 species) and birds (32 species). The floristic components are vital for survival and diversification of fauna as they provide food in the form of nectar, fruits, leaves, sites for breeding, and nesting. Because of availability of LHP, Mahadare is home for many endemic butterfly species which makes it first Butterfly Conservation Reserve in India.

Though the habitat supports diversity of native floristics components, anthropogenic activities lead to invasion of exotic weeds, which leads to destruction of natural habitat for animals, allelopathy, land, and water degradation, resulting in loss of native biodiversity, and damaging the environment. Nowadays, the forest department is undertaking gradual irradiation program for exotic plants especially *Gliricidia* by replacing them with native trees.

The area supports variety of wild edible & ornamental species which can be domesticated, and utilised to provide economic stability to the local people. Lack of awareness about the unique diversity, threats, and deficit planning for prioritization of the conservation of endemic species, especially supporting the butterflies are the major risk factors in near future. Presently efforts were made by Mahadare Ecological Research Institute (MERI) for creating awareness among the local people and visitors, enlisting the butterfly, spiders, and birds in the region as well as collaboration with the forest department regarding the developmental activities and planning for conservation of plant species. The present investigation will be helpful for prioritising threatened species for the department of forests, scientific studies of ecotone habitat diversity by conservationists, biologists, anthropologists, and amateurs. The conservation reserve can also provide labour and income source by demonstrating ecotourism, education, and in situ conservation.

Table 6. List of frugivorous birds in study area.

	Scientific name	Family	Common name	IUCN Red List	Migratory status (for India)	Schedule	Feeding guild
1	*Galerida cristata*	Alaudidae	Crested Lark	LC	R	Sch II	O
2	*Ocyceros birostris*	Bucerotidae	Indian Grey Hornbill	LC	R	Sch II	F
3	*Lalage melanoptera*	Campephagidae	Black-headed Cuckooshrike	LC	RM	Sch II	O
4	*Coracias benghalensis*	Coraciidae	Indian Roller	LC	R	Sch II	O
5	*Cuculus micropterus*	Cuculidae	Indian Cuckoo	LC	RM	Sch II	O
6	*Clamator coromandus*	Cuculidae	Chestnut-winged Cuckoo	LC	R	Sch II	O
7	*Eudynamys scolopaceus*	Cuculidae	Asian Koel	LC	R	Sch II	O
8	*Centropus sinensis*	Cuculidae	Greater Coucal	LC	R	Sch II	O
9	*Dicrurus macrocercus*	Dicruridae	Black Drongo	LC	R	Sch II	O
10	*Dicrurus leucophaeus*	Dicruridae	Ashy Drongo	LC	RM	Sch II	O
11	*Dicrurus caerulescens*	Dicruridae	White-bellied Drongo	LC	R	Sch II	O
12	*Psilopogon hemacephalus*	Megalaimidae	Coppersmith Barbet	LC	R	Sch II	F
13	*Psilopogon zeylanicus*	Megalaimidae	Brown-headed Barbet	LC	R	Sch II	F
14	*Psilopogon viridis*	Megalaimidae	White-cheeked Barbet	LC	R	Sch II	F
15	*Oriolus kundoo*	Oriolidae	Indian Golden Oriole	LC	RM	Sch II	O
16	*Gymnoris xanthocollis*	Passeridae	Yellow-throated Sparrow	LC	R	Sch II	O
17	*Passer domesticus*	Passeridae	House Sparrow	LC	R	Sch II	O
18	*Psittacula krameria*	Psittaculidae	Rose-ringed Parakeet	LC	R	Sch II	F
19	*Psittacula cyanocephala*	Psittaculidae	Plum-headed Parakeet	LC	R	Sch II	F
20	*Loriculus vernalis*	Psittaculidae	Vernal Hanging Parrot	LC	R	Sch II	F
21	*Pycnonotus cafer*	Pycnonotidae	Red-vented Bulbul	LC	R	Sch II	O
22	*Pycnonotus jocosus*	Pycnonotidae	Red-whiskered Bulbul	LC	R	Sch II	O
23	*Sturnia pagodarum*	Sturnidae	Brahminy Starling	LC	R	Sch II	O
24	*Acridotheres tristis*	Sturnidae	Common Myna	LC	R	Sch II	O
25	*Acridotheres fuscus*	Sturnidae	Jungle Myna	LC	R	Sch II	O
26	*Corvus splendens*	Sturnidae	House Crow	LC	R	Sch II	O
27	*Corvus macrorhynchos*	Sturnidae	Large-billed Crow	LC	R	Sch II	O
28	*Dumetia hyperythra*	Timaliidae	Tawny-bellied Babbler	LC	R	Sch II	O
29	*Pomatorhinus horsfieldii*	Timaliidae	Indian Scimitar Babbler	LC	R	Sch II	O
30	*Argya striata*	Timaliidae	Jungle Babbler	LC	R	Sch II	O
31	*Upupa epops*	Upupidae	Eurasian Hoopoe	LC	RM	Sch II	O
32	*Tephrodornis pondicerianus*	Vangidae	Common Woodshrike	LC	R	Sch II	O

LC—Least Concern | R—Resident | RM—Resident & Migratory | Sch—Protected under Wildlife Protection Act Schedule II | F—Frugivorous | O—Omnivorous.

REFERENCES

Abdar, M.R. (2013). Diversity and richness of bird species in newly formed habitats of Chandoli National Park in Western Ghats, Maharashtra State, India. *Biodiversity Journal* 4(1): 235–242.

Avibase (2025). The World Bird Database. Denis Lepage, National Data Center, Bird Studies Canada. https://avibase.bsc-eoc.org/avibase.jsp?lang=EN

Bhattarai, U., P. Tetali & S. Kelso (2012). Contributions of vulnerable hydrogeomorphic habitats to endemic plant diversity on the Kas Plateau, Western Ghats. *Springer Plus* 1: 25. https://doi.org/10.1186/2193-1801-1-25

Cooke, T. (1901–1908). *The Flora of the Presidency of Bombay*,*Reprinted edition, 1958*, *Vol 1 & 2*. Botanical Survey of India, Kolkata, 660 pp.

Deshpande, S. (1993). *Flora of Mahabaleshwar and Adjoinings, Maharashtra*. Botanical Survey of India, 776 pp.

Deshpande, S.M. U.S. Pawar & R.R. Kumbhar (2019a). Exploration and documentation of wild food plants from Satara district, Maharashtra (India). *International Journal of Food Science and Nutrition* 4(1): 95–101.

Deshpande, S.M., U.S. Pawar, S.H. Bhoite & J.J. Chavan (2019b). Floristic study of Kalbhairavnath sacred grove, Bharsakale, Satara, Maharashtra. *Species* 20: 155–162.

Dhale, O.S., G.N. Pawar, N.N. Bendre & S.H. Bhoite (2024). Diversity of

Image 1. A—*Abutilon persicum* | B—*Acacia nilotica* | C—*Albizzia lebbeck* | D—*Anacardium occidentale* | E—*Bombax ceiba* | F—*Barleria prionitis* | G—*Ceropegia bulbosa* | H—*Colebrookia oppositifolia* | I—*Erinocarpus nimmonii* | J—*Firmiana colorata* | K—*Helicteres isora* | L—*Impatiens balsamina*. © Sunil H. Bhoite.

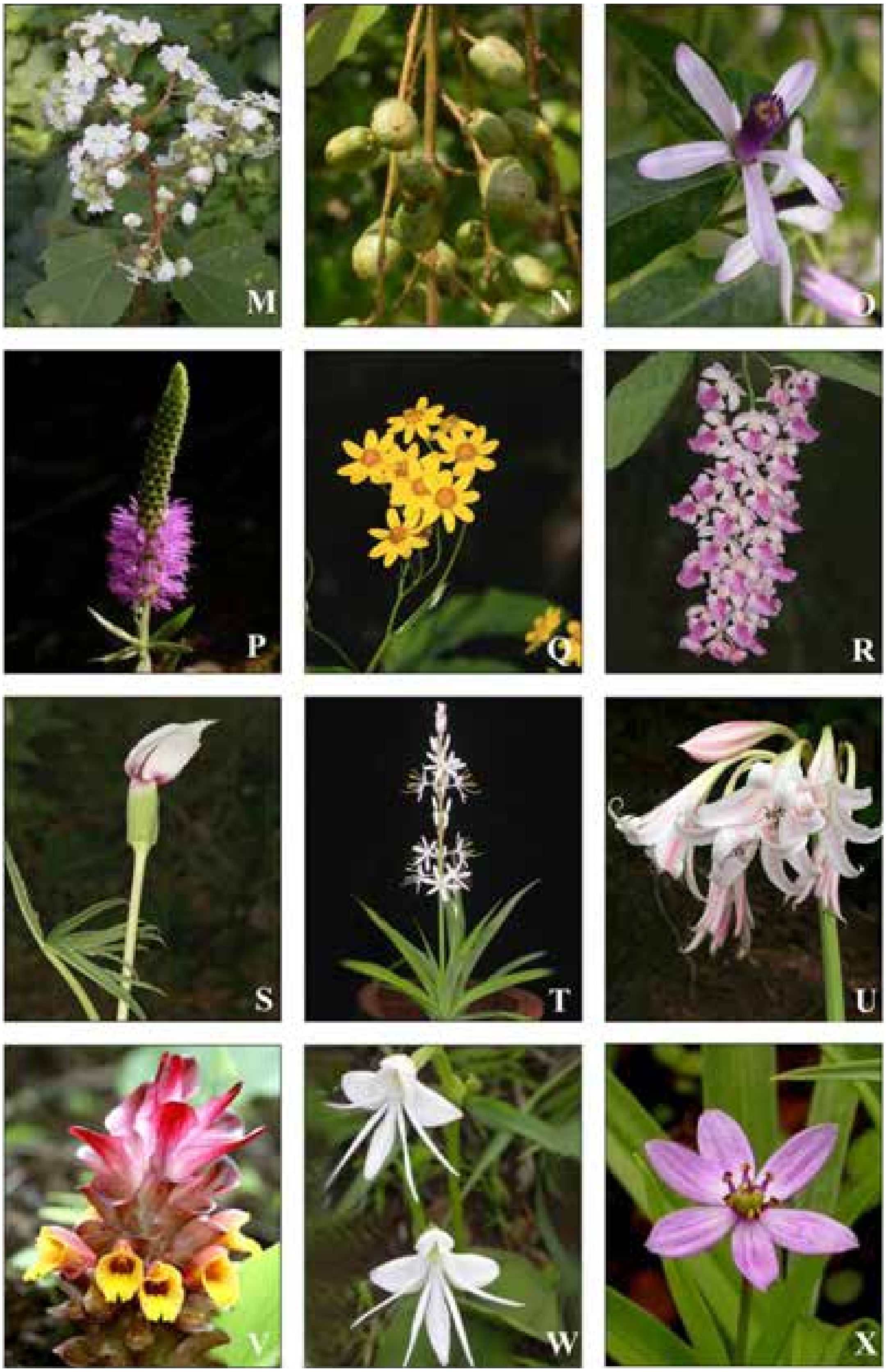

Image 2. M—*Kydia calycina* | N—*Lannea coromandeliana* | O—*Melia azadirach* | P—*Pogostemon deccanensis* | Q—*Senecio bombayensis* | R—*Arides maculosum* | S—*Arisaema murrayi* | T—*Chlorophytum borivilianum* | U—*Crinum latifolium* | V—*Curcuma pseudomontana* | W—*Habenaria grandifloriformis* | X—*Iphigenia stellata*. © Swapnaja M. Deshpande.

amphibians and reptiles in mahadare conservation reserve, Satara district (MS), Western Ghats, India. *African Journal of biological Sciences* 6(9): 4896–4801.

Dhore, M.A. & P.A. Joshi (1988). *Flora of Melghat Tiger Reserve*. Directorate, Project Tiger Melghat Parat wada, Dist. Amravati Maharashtra.

Fraixedas, S., A. Linden, M. Piha, M. Cabeza, R. Gregory & A. Lehikoinen (2020). A state of the art review on birds as indicators of Biodiversity: Advances, Challenges and Future directions. *Ecological Indicators* 118(1): 106728. https://doi.org/10.1016/j.ecolind.2020.106728

IPNI (2025). International Plant Names Index. The Royal Botanic Gardens, Kew, Harvard University Herbaria & Libraries, and Australian National Herbarium. http://www.ipni.org .

Lekhak, M.M. & S.R. Yadav (2012). Herbaceous vegetation of threatened high altitude lateritic plateau ecosystems of Western Ghats, southwestern Maharashtra, India. *Rheedea* 22(1): 39–61. https://doi.org/10.22244/rheedea.2012.22.01

Malhotra, S.K. & K.M. Rao (1981). The vegetation of Nagzira Wildlife Sanctuary, India and its Environs Maharashtra State. *Journal of the Bombay Natural History Society* 78(3): 475–486.

Malhotra, S.K. & S. Moorthy (1992). *A Floristic Account of Taroba National Park and its Environs, Chandrapur District, Maharashtra State*. Botanical Survey of India, Calcutta.

POWO (2025). Plants of the World Online. The Royal Botanic Gardens, Kew. https://powo.science.kew.org/ Accessed on 27.i.2025.

Ravikanthachari, N., V.C. Balakrishnan, V.C. Paresh, S. Kalesh, S. Prakash & K. Kunte (2018). Larval host plants of the butterflies of the Western Ghats, India. *Journal of Threatened Taxa* 10(4): 11495–11550. https://doi.org/10.11609/jott.3104.10.4.11495-11550

Singh, N.P., P. Lakshminarasimhan, S. Karthikeyan & P.V. Prasanna (2001). *Flora of Maharashtra State, Dicotyledones, Vol. II*. BSI, Calcutta.

Tosh, J., V.D. Vartak & M.S. Kumbhojkar (1988). Floristic and ecological studies on legumes from hilly regions of Pune and Satara districts of Maharashtra state India. *Journal of The Bombay Natural History Society* 85(3): 585–591.

Wilson, D.E. & D.M. Reeder (eds.) (2005). Mammal Species of the World. *A Taxonomic and Geographic Reference* (3rd ed). Johns Hopkins University Press, 2,142 pp. https://www.departments.bucknell.edu/biology/resources/msw3/

Yadav, S.R. & M. Lekhak (2010). Plateaus in northern Western Ghats - paradise of flowers. *ENVIS Newsletter* 14(1): 2–3.

Yadav S.R. & M.M. Sardesai (2002). *Flora of Kolhapur District*. Shivaji University Press, 679 pp.

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COMMUNICATION

Assessing fish diversity in the Ujani reservoir: an updated overview after one decade

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Abstract: The freshwater fish diversity of Ujani Reservoir, Pune District, Maharashtra, India, was assessed from April 2021–March 2023. A total of 56 freshwater fish species belonging to 39 genera and 18 families were documented. Comparative analysis with previous literature suggests a historical record of approximately 60 species in the reservoir. Of the 56 species recorded, 41 are endemic to the Oriental zoogeographical realm, while eight are endemic to the Krishna River system. Notably, two species, *Parambassis lala*, native to the Ganga, and Brahmaputra river basins, and *Nandus nandus* the Gangetic Leaffish, were recorded for the first time in Ujani Reservoir. The ichthyofauna of the reservoir faces significant threats from invasive alien species, industrial, and agricultural pollution, expanding human settlements, and overfishing. Given the presence of eight endemic and six threatened species, conservation measures are imperative to mitigate anthropogenic pressures, and preserve biodiversity. This study provides an updated account of fish diversity and distribution in Ujani Reservoir, serving as a crucial baseline for future conservation, and management initiatives.

Keywords: Anthropogenic impacts, conservation status, freshwater fish fauna, invasive alien species, species distribution, threats, Ujani reservoir.

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INTRODUCTION

The Western Ghats of India is a global biodiversity hotspot (Myers et al. 2000), known for its high level of endemism among taxonomic groups such as amphibians and freshwater fish. Around 320 fish species belonging to 11 orders, 35 families, and 112 genera are known from this region with more than 60% being endemic (Dahanukar & Raghavan 2013), and this number is certain to increase given the high number of species being discovered each year. The threat status of fishes in the Western Ghats shows that nearly 41% are threatened, being classified either as Vulnerable, Endangered or Critically Endangered. Conservation measures for protection of the fish fauna are thus essential (Dahanukar et al. 2004). Despite numerous studies on the freshwater fish fauna of the Western Ghats, many upstream tributaries of major river systems remain underexplored. One such underexplored region is the Bhima River, a major tributary of the Krishna River, which originates from the Bhimashankar hill region of the Western Ghats. Flowing through the states of Maharashtra, Karnataka, and Telangana, the Bhima River supports diverse aquatic life, although it is increasingly subjected to anthropogenic pressures (Das & Panchal 2018). Several dams have been constructed on the Bhima River, with the Ujani being the terminal dam. The Ujani Reservoir, characterized by its extensive shallow-water habitat, is recognized as one of the most productive freshwater fisheries in the region. Shortly after its construction, Ujani became the largest freshwater fishing cooperative dam in Maharashtra (Karmakar et al. 2012).

Following its construction, the Ujani Reservoir has become a hub for freshwater fisheries, with the first comprehensive ichthyological survey conducted in the 1990s documenting 42 species of fish (Yazdani & Singh 1990). This list was later updated in 2002, with a total of 54 species (Yazdani & Singh 2002). A further study by Sarwade & Khillare in 2010 recorded 60 species across six orders, 15 families, and 36 genera. Despite these valuable contributions, research on the fish fauna of Ujani has been scarce in recent years, with no updated studies published since 2010. In addition to the lack of recent studies, the Ujani Reservoir has undergone substantial changes in the last decade, driven by growing tourism, industrialization, and recreational activities. These alterations, coupled with the increasing human footprint on the landscape, have the potential to affect the delicate balance of the aquatic ecosystems, including fish populations. Given the paucity of information on fish diversity in the Ujani Reservoir, especially in the face of increasing anthropogenic pressures, it is imperative to revisit, and reassess the ichthyofauna of this critical waterbody.

This study aims to provide a comprehensive overview of the current diversity and distribution of fish species in the Ujani Reservoir, more than a decade after the last substantial survey. Documenting the present status of fish fauna provides baseline data that will aid in identifying key threats to fish populations and informing conservation efforts in the region.

METHODS

The study was conducted to assess the fish diversity of the Ujani Reservoir over the period of two years from April 2021–March 2023. Fish specimens were collected from Bhigwan (18.295° N, 74.773° E), Kumbhargaon (18.273° N, 74.796° E), Palasdeo (18.221° N, 74.869° E), Aagoti No.2 (18.233° N, 74.973° E), Rajewadi (18.166° N, 74.980° E), Shaha (18.114° N, 75.097° E), and Taratgaon (18.094° N, 75.129° E) (Figure 1), with the help of local fishers using different mesh-sized gill nets, and cast nets. Alternatively, fish samples were also procured from local fish markets in Bhigwan and Indapur.

Collected fish were stored in ice-containing thermos boxes and transported to the laboratory. Small-sized fish were preserved in 4% aqueous formalin solution, while larger fish were preserved in 10% aqueous formalin solution. The specimens were stored in airtight plastic bottles to ensure proper preservation. In the laboratory, fish specimens were identified using standard taxonomic literature, including Jayaram (1981) and Talwar & Jhingran (1991). Recent taxonomic literature was also consulted for accurate identification. The online database 'FishBase' was utilized for verification and authentication of scientific names(Froese & Pauly 2024). Collected fish specimens were deposited at the Museum of the Zoological Survey of India, Freshwater Biology Regional Centre Hyderabad (F.No.56.pt/Tech./2022-23/41). Assuming that the fishing effort for a given type of net (gill net or drag net) was constant, the relative abundance of the fish was grossly categorized (for each type of net separately) into four categories, namely: abundant (76–100% of the total catch), common (51–75% of the total catch), moderate (26–50 % of the total catch), and rare (1–25% of the total catch). Representative photographs were provided (Images 1–7).

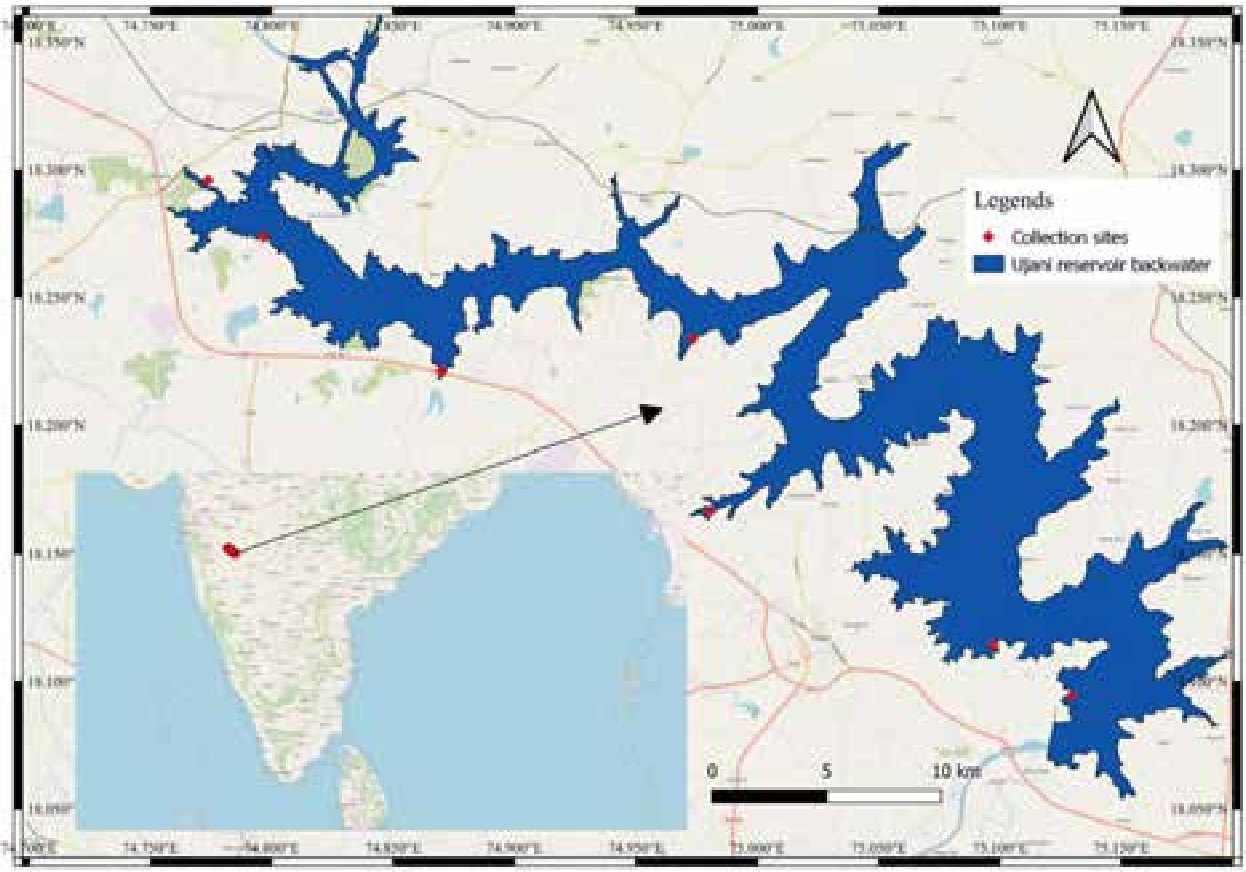


Figure 1. Map of the Ujani Reservoir, showing the study area, location of the collection sites.

RESULTS

A total of 56 fish species belonging to 39 genera, 18 families and 12 orders were reported during the study. The availability status as per catch frequency and IUCN status of species was listed in Table 1, and availability of fishes found in catch in percentage was shown in Figure 2. Of these total species, eight species endemic to the Krishna River system, seven introduced, and one exotic species were recorded during the study. Cypriniformes, with 27 species (48.21%) was found to be the most dominant order. Among 27 species, 24 were native, and three were introduced in the reservoir.

Cypriniformes was followed by Siluriformes, with 10 species (17.85%); belonging to five families. Among them, one introduced species, *Clarias gariepinus* from the family clariidae, was reported. The exotic aquarium fish *Pterygoplichthys pardalis* (family Loricariidae) was commonly encountered in the present catches. This species, first reported from the reservoir by More et al. (2020), was found in considerable abundance during the present study, indicating its successful establishment in the system. The order Anabantiformes was represented by five species, of which four belonged to the family Channidae, and one to Nandidae, within Perciformes, only the family Ambassidae was recorded, comprising three species. The orders Beloniformes, Osteoglossiformes, and Synbranchiformes each contributed two species. Meanwhile, the orders Characiformes, Cichliformes, Gobiiformes, and Mugiliformes were each represented by a single species. The family Cyprinidae was the most dominant family, with 27 species (48.21%) of all reported species, followed by Channidae and Bagridae, each with four species (7.14%). Family ambassidae had three species; notably *Parambassis lala* was first reported from the reservoir. The families Claridae, Mastacembelidae, Notopteridae, and Siluridae had two species each. Families Anguilidae, Belonidae, Cichlidae, Gobiidae, Hemiramphidae, Heteropneustidae, Loricariidae, Mugilidae, Nandidae, and Serrasalmidae each had one species to their account. This study revealed the occurrence of *Heteropneustes fossilis* and *Nandus nandus*, belonging to Heteropneustidae, and Nandidae respectively, in the reservoir.

Table 1. Inventory of fish species in the Ujani Reservoir.

Order	Family	Scientific name	Common name	Status as per catch frequency	Threat status (As per IUCN 2017)
Cypriniformes	Cyprinidae	*Amblypharyngodon mola*	Mola Carplet	A	LC
		Cirrhinus mrigala	Mrigal	C	LC
		Cirrhinus reba	Reba Carp	A	LC
		Ctenopharyngodon idella	Grass Carp	C	LC
		Cyprinus carpio	Common Carp	C	VU
		Devario aequipinnatus	Giant Danio	L	LC
		Garra mullya	Sucker Fish	C	LC
		Gymnostomus ariza	Reba Carp	C	LC
		Gymnostomus fulungee	Deccan White Carp	C	LC
		Hypophthalmichthys molitrix	Silver Carp	L	NT
		Hypselobarbus kolus	Kolus	R	VU
		Labeo boggut	Boggutlabeo	L	LC
		Labeo calbasu	Orangefinlabeo	C	LC
		Labeo catla	Catla	A	LC
		Labeo rohita	Rohu	C	LC
		Osteobrama peninsularis	Peninsular Osteobrama	R	DD
		Osteobrama vigorsii	Bheema Osteobrama	VR	LC
		Pethia ticto	Ticto Barb	A	LC
		Puntius chola	Swamp Barb	A	LC
		Puntius sophore	Pool Barb	C	LC
		Puntius vittatus	Greenstripe Barb	C	LC
		Rasbora daniconius	Slender Rasbora	L	LC
		Salmostoma bacaila	Large Razorbelly Minnow	C	LC
		Salmostoma boopis	Boopis Razorbelly Minnow	A	LC
		Salmostoma phulo	Finescalerazorbelly Minnow	C	LC
		Schismatorhynchos nukta	Nukta	VR	EN
		Systomus sarana	Olive Barb	L	LC
Siluriformes	Bagridae	*Mystus cavasius*	Gangetic Mystus	C	LC
		Mystus malabaricus	Jerdon'smystus	L	NT
		Mystus vittatus	Striped Dwarf Catfish	C	LC
		Sperata seenghala	Giant River-Catfish	L	LC
	Clariidae	*Clarias batrachus*	Philippine Catfish	C	LC
		Clarias gariepinus	North African Catfish	C	LC
	Heteropneustidae	*Heteropneustes fossilis*	Stinging Catfish	C	LC
	Loricariidae	*Pterygoplichthys pardalis*	Amazon Sailfin Catfish	C	NE
	Siluridae	*Ompok bimaculatus*	Butter Catfish	L	NT
		Wallago attu	Wallago	L	VU
Anabantiformes	Channidae	*Channa gachua*	Dwarf Snakehead	L	LC
		Channa marulius	Great Snakehead	L	LC
		Channa punctata	Spotted Snakehead	C	LC
		Channa striata	Striped Snakehead	C	LC
	Nandidae	*Nandus nandus*	Gangetic Leaffish	L	LC

Order	Family	Scientific name	Common name	Status as per catch freque-ncy	Threat status (As per IUCN 2017)
Perciformes	Ambassidae	*Chanda nama*	Elongate Glass-perchlet	A	LC
		Parambassis lala	Highfin Glassy Perchlet	L	NT
		Parambassis ranga	Indian Glassy Fish	A	LC
Beloniformes	Hemiramphidae	*Hyporhamphus limbatus*	Congaturi Halfbeak	L	LC
	Belonidae	*Xenentodon cancila*	Freshwater Garfish	L	LC
Osteoglossiformes	Notopteridae	*Chitala chitala*	Clown Knifefish	L	NT
		Notopterus synurus	Bronze Featherback	C	LC
Synbranchiformes	Mastacembelidae	*Macrognathus pancalus*	Barred Spiny Eel	C	LC
		Mastacembelus armatus	Zig-zag Eel	C	LC
Anguilliformes	Anguillidae	*Anguilla bengalensis*	Indian Mottled Eel	VR	NT
Characiformes	Serrasalmidae	*Piaractus brachypomus*	Pirapitinga	L	NE
Cichliformes	Cichlidae	*Oreochromis mossambicus*	Mozambique Tilapia	A	VU
Gobiiformes	Gobiidae	*Glossogobius giuris*	Tank Goby	A	LC
Mugiliformes	Mugilidae	*Rhinomugil corsula*	Corsula	L	LC

A—abundant | C—common | L—low | R—rare | VR—very rare | LC—Least Concern | VU—Vulnerable | NT—Near threatened | EN—Endangered | DD—Data Deficient | NE—Not Evaluated.

DISCUSSION

The Ujani Reservoir, a significant fishery station in Maharashtra, has been the focus of multiple ichthyofaunal studies over the past few decades. The initial assessments by Yazdani & Singh in 1990 documented 42 species from 14 families, which was later expanded to 54 species from 15 families in 2002 (Yazdani & Singh 2002). Their findings highlighted the dominance of the family Cyprinidae, with 34 species, and the abundant presence of Osteobrama, Channa, Wallago, Mystus, and major carp species. Additionally, they identified four introduced species—*Gambusia affinis, Oreochromis mossambicus, Cyprinus carpio,* and *Ctenopharyngodon idella*—which were historically introduced into Indian River systems (Yazdani & Singh 2002). Subsequent investigations were further refined by Sarwade & Khillare (2010) conducted an extensive study from January 2008 to December 2009, recording 60 species across 15 families and six orders, reaffirming the dominance of *Cypriniformes* with 40 species, including 37 from Cyprinidae. Among the most abundant taxa in their study were *Labeo catla, Cirrhinus mrigala, Cyprinus carpio, Labeo rohita,* and *Oreochromis mossambicus*.

The present study recorded 56 species, of which 42 species are classified as Least Concern (LC) by the IUCN Red List of Threatened Species, while six species fall under the Near Threatened (NT) category. Notably, 41 species are endemic to the Oriental zoogeographical realm, and eight species are restricted to the Krishna River system. This finding aligns with Dahanukar et al. (2012), who reported 57 species from the Indrayani River, with 12 species endemic to the Western Ghats and five endemic to the Krishna River system. Similarly, Kumar et al. (2017) documented 57 species from the Hiranyakeshi River in the northern Western Ghats, including 22 species endemic to the Western Ghats, and nine species specific to the Krishna River system.

In terms of conservation significance, the study confirms the presence of *Hypeselobarbus kolus, Osteobrama peninsularis, Osteobrama vigorsii*, and *Schismatorhynchos nukta*, all endemic to India. Notably, *Schismatorhynchos nukta*, and *Tor khudree* are categorized as Endangered (EN), while *Mystus malabaricus* and *Ompok bimaculatus* are Near Threatened (NT) (IUCN, 2011). Furthermore, the study identifies *Piaractus brachypomus* (Serrasalmidae) as an introduced species, found in low numbers throughout the sampling period. *Oreochromis mossambicus* (Cichliformes) emerged as the most abundant species. Its widespread presence aligns with previous reports suggesting its intentional introduction to enhance aquaculture and fill ecological niches in underutilized water bodies (Singh et al. 2014). Another significant finding is the first documentation of *Pterygoplichthys pardalis*, an exotic aquarium species, from the Ujani Reservoir (More et al. 2020). Its likely introduction through the aquarium trade raises ecological concerns, as non-native species can alter

Table 2. Comparative account of fish diversity among different studies from Ujani Reservoir.

Species name	Yazdani & Singh 2002	Sarwade & Khillare 2010	Present study
Labeo catla (Hamilton, 1822)	+	+	+
Gymnostomus fulungee (Sykes, 1839)	+	+	+
Cirrhinus mrigala (Hamilton, 1822)	+	+	+
Notopterus synurus (Pallas, 1769)	+	+	+
Cirrhinus reba (Hamilton, 1822)	+	+	+
Cyprinus carpio (Linnaeus, 1758)	+	+	+
Ctenopharyngodon idella (Valenciennes, 1844)	+	+	+
Hypselobarbus curmuca (Hamilton, 1807)	+	+	-
Labeo boggut (Sykes, 1839)	+	+	+
Labeo calbasu (Hamilton, 1822)	+	+	+
Labeo fimbriatus (Bloch, 1795)	+	+	-
Labeo kawrus (Sykes, 1839)	+	+	-
Labeo potail (Sykes, 1839)	+	+	-
Labeo rohita (Hamilton, 1822)	+	+	+
Osteobrama bakeri (Day, 1873)	+	+	-
Osteobrama bhimensis (Singh & Yazdani, 1992)	+	+	-
Osteobrama cotio cunma (Day, 1888)	+	+	-
Osteobrama vigorsii (Sykes, 1839)	+	+	+
Osteobrama neilli (Day, 1873)	+	+	-
Puntius conchonius (Hamilton, 1822)	+	+	-
*Systomus sarana (*Hamilton, 1822)	+	+	+
Puntius sophore (Hamlton, 1822)	+	+	+
Pethia ticto (Hamilton, 1822)	+	+	+
Schismatorhynchus nukta (Sykes, 1839)	+	+	+
Tor khudree (Sykes, 1839)	+	+	-
Chela cachius (Hamilton, 1822)	+	+	-
Salmostoma bacaila (Hamilton, 1822)	+	+	+
Salmostoma boopis (Day, 1874)	+	+	+
Salmostoma untrahi (Day, 1869)	+	+	-
Osparius bakeri (Day, 1865)	+	+	-
Osparius bendelisis (Hamilton, 1807)	+	+	-
Barilius evezardi (Day, 1872)	+	+	-
Devario aequipinnatus (McClelland, 1839)	+	+	+
Rasbora daniconius (Hamilton, 1822)	+	+	+
Garra mullya (Sykes, 1839)	+	+	+
Schistura denisonii (Day, 1867)	+	+	-
Lepidocephalichthys guntea (Hamilton, 1822)	+	+	-
Acanthocobitis botia (Hamilton, 1822)	+	+	-
Sperata aor (Hamilton, 1822)	+	+	-
Sperata seenghala (Sykes, 1839)	+	+	+
Mystus bleekeri (Day, 1877)	+	+	-
Mystus malabaricus (Jerdon, 1849)	+	+	+
Ompok bimaculatus (Bloch, 1794)	+	+	+
Wallago attu (Bloch & Schneider, 1801)	+	+	+
Xenentodon cancila (Hamilton, 1822)	+	+	+
Aplocheilus lineatus (Val.)	+	+	-

Species name	Yazdani & Singh 2002	Sarwade & Khillare 2010	Present study
Gambusia affinis (Baird & Girard, 1853)	+	+	-
Chanda nama (Hamilton, 1822)	+	+	+
Oreochromis mossambicus (Peters, 1852)	+	+	+
Rhinomugil corsula (Hamilton, 1822)	+	+	+
Glossogobius giuris (Hamilton, 1822)	+	+	+
Mastacembelus armatus (Lacepede, 1800)	+	+	+
Channa marulius (Hamilton, 1822)	+	+	+
Channa orientalis (Bloch & Schneider, 1801)	+	+	-
Salmostoma novacula (Valenciennes, 1840)	-	+	-
Rhynchorhamphus georgii (Valenciennes, 1847)	-	+	-
Amblypharyngodon mola (Hamilton, 1822)	-	+	+
Hyporhamphus limbatus (Valenciennes, 1847)	-	+	+
Chitala chitala (Hamilton, 1822)	-	+	+
Parambassis ranga (Hamilton, 1822)	-	+	+
Channa punctata (Bloch, 1793)	-	-	+
Hypophthalmichthys molitrix (Valenciennes, 1844)	-	-	+
Mystus cavasius (Hamilton, 1822)	-	-	+
Ptreygoplichthys pardalis (Castelnau, 1855)	-	-	+
Nandus nandus (Hamilton, 1822)	-	-	+
Anguilla bengalensis (Gray, 1831)	-	-	+
Clarias batrachus (Linnaeus, 1758)	-	-	+
Clarias gariepinus (Burchell, 1822)	-	-	+
Heteropneustes fossilis (Bloch, 1794)	-	-	+
Puntius chola (Hamilton, 1822)	-	-	+
Parambassis lala (Hamilton, 1822)	-	-	+
Macrognathus pancalus (Hamilton, 1822)	-	-	+
Channa gachua (Hamilton, 1822)	-	-	+
Channa striata (Bloch, 1793)	-	-	+
Gymnostomus ariza (Hamilton, 1807)	-	-	+
Hypselobarbus kolus (Sykes, 1839)	-	-	+
Osteobrama peninsularis (Silas, 1952)	-	-	+
Puntius vittatus (Day, 1865)	-	-	+
Salmostoma phulo (Hamilton, 1822)	-	-	+
Mystus vittatus (Bloch, 1794)	-	-	+
Piaractus brachypomus (Cuvier, 1818)	-	-	+

aquatic ecosystems through predation, competition, and habitat modification. The establishment of *P. paradalis* necessitates further studies to develop management and eradication strategies.

Notably, several loach species (*Nemacheilus denisonii, Lepidocephalus guntea, Nemacheilus botia*) and hill stream fishes (*Barilius bakeri, Barilius bendelisis, Barilius evezardi*), previously recorded in Ujani (Sarwade & Khillare 2010), were absent in this study. Their disappearance may be attributed to anthropogenic activities, including deforestation, siltation, tourism, sand mining, and recreational disturbances, which degrade the specialized habitats required by species from Balitoridae, and Cobitidae families. This study also reports the presence of *Hypophthalmichthys molitrix, Pterygoplichthys paradalis, Nandus nandus, Parambassis lala, Heteropneustes fossilis, Clarias batrachus,* and *Clarias gariepinus* (Table 2), which were absent from the records of (Yazdani & Singh 1990, 2002; Sarwade & Khillare 2010).

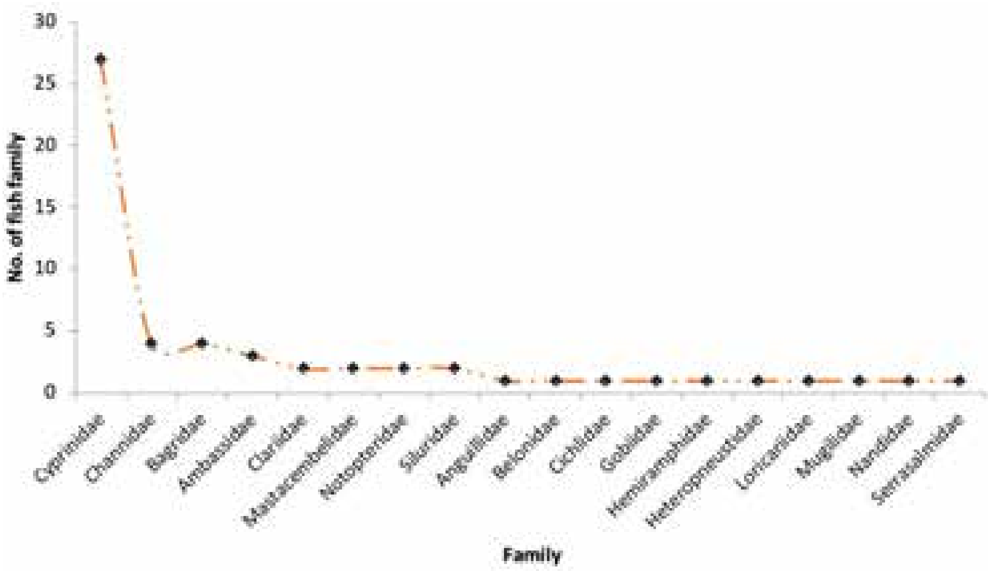


Figure 2. Number of species by family in the Ujani Reservoir, India.

CONCLUSION

The present study underscores the diverse ichthyofaunal assemblage of the Ujani Reservoir, with a total of 56 recorded species, including several endemic and threatened taxa. The dominance of Cyprinidae and the increasing presence of non-native species highlight significant ecological shifts in the reservoir's fish community. The introduction of exotic species such as *Oreochromis mossambicus, Piaractus brachypomus, Pterygoplichthys paradalis,* and *Clarias gariepinus* poses potential threats to native biodiversity through competition, predation, and habitat alteration. The absence of previously reported loach and hill stream fish species further indicates possible habitat degradation due to anthropogenic pressures, including sand mining, deforestation, and pollution. The findings emphasize the urgent need for sustainable fisheries management and conservation strategies to mitigate the impacts of invasive species, and habitat destruction. Future studies should focus on long-term monitoring of fish diversity, population dynamics of threatened species, and ecological impacts of introduced taxa. Regulatory measures should be implemented to prevent further introductions of exotic species, and community-driven conservation efforts should be promoted to safeguard the rich aquatic biodiversity of the Ujani Reservoir.

REFERENCES

Dahanukar, N. & R. Raghavan (2013). Freshwater fishes of Western Ghats: checklist v 1.0 August 2013. MIN 1: 6–16.

Dahanukar, N., M. Paingankar, R. Raut & S. Kharat (2012). CEPF Western Ghats Special Series: Fish fauna of Indrayani River, northern Western Ghats, India. *Journal of Threatened Taxa* 14(1): 2310–2317. https://doi.org/10.11609/JoTT.o2771.2310-7

Dahanukar, N., R. Raut & A. Bhat (2004). Distribution, endemism and threat status of freshwater fishes in the Western Ghats of India. *Journal of Biogeography* 31(1): 123–136. https://doi.org/10.1046/j.0305-0270.2003.01016.x

Das, A. & M. Panchal (2018). Krishna River basin. The Indian Rivers: scientific and socio-economic aspects. *Springer*, Singapore.

Froese, R. & Pauly (2024). Fish Base. World Wide Web electronic publication. www.fishbase.org. Accessed on 20.xi.2024.

Jayaram, K.C. (1981). *Freshwater fishes of India, Pakistan, Bangladesh, Burma and Sri Lanka*. Zoological Survey of India, Calcutta, 475 pp.

Karmakar, A.K., B.E. Yadav, N. Bairagi, A. Das, P.K. Banerjee & S.S. Jadhav (2012). Freshwater fishes. *Fauna of Maharashtra State Fauna Series* 20: 247–367.

Kumkar, P., S.S. Kharat, N.S. Sawant, U. Katwate & N. Dahanukar (2017). Freshwater fish fauna of Hiranyakeshi river, the northern Western Ghats, India. *Journal of Threatened Taxa* 9(5): 10178–10186. https://doi.org/10.11609/jott.3126.9.5.10178-10186

More, R.M., J.P. Sarwade & S.K. Karna (2020). *Pterygoplichthys pardalis* (castelnau, 1855) (siluriformes: loricariidae) from ujani reservoir, Maharashtra, India. *Bioinfolet* 17(4A): 587–588.

Myers, N., R.A. Mittermeier, C.G. Mittermeier, G.A. Da Fonseca & J. Kent (2000). Biodiversity hotspots for conservation priorities. *Nature* 403(6772): 853–858.

Sarwade, J.P. & Y.K. Khillare (2010). Fish diversity of Ujani wetland, Maharashtra, India. *The Bioscan* 1: 173–179.

Singh, A. K., P. Verma, S. Srivastava, & M. Tripathi (2014). Invasion, biology and impact of feral population of Nile Tilapia (*Oreochromis niloticus* Linnaeus, 1757) in the Ganga River (India). *Asia Pacific Journal of Research* I(XIV): 151–162.

Talwar, P.K. & A.G. Jhingran (1991). *Inland fishes of India and adjacent countries Vol. 2*. CRC Press, 1158 pp.

Yazdani, G.M. & D.F. Singh (1990). On the fish resources of Ujani wetland, Pune, Maharashtra. *Journal of Bombay Natural History Society* 87.

Yazdani, G.M. & D. F. Singh (2002). Wetland Ecosystem Series No. 3, Fauna of Ujani (Maharashtra). *Zoological Survey of India Kolkata*, India, 143–156 pp.

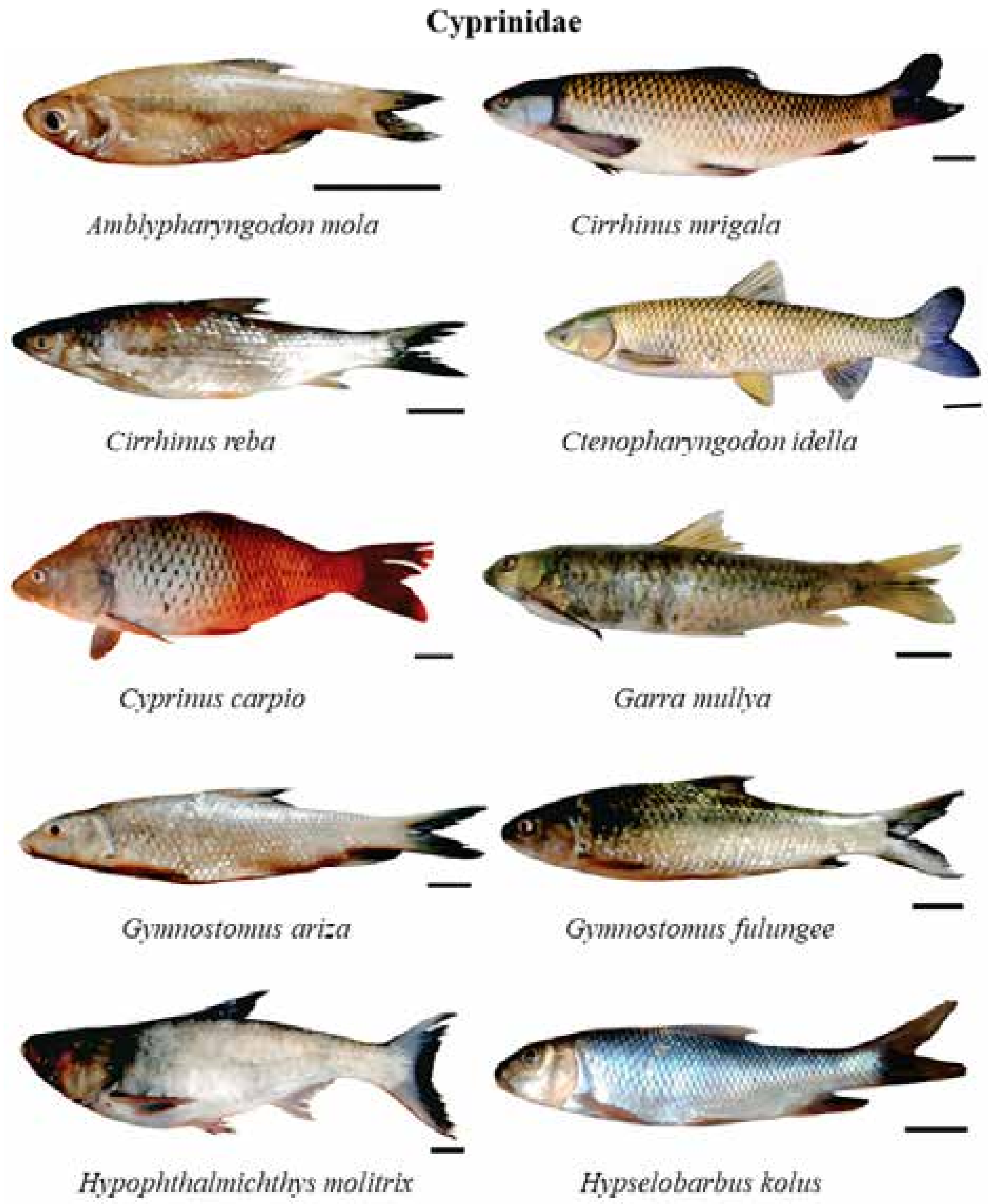
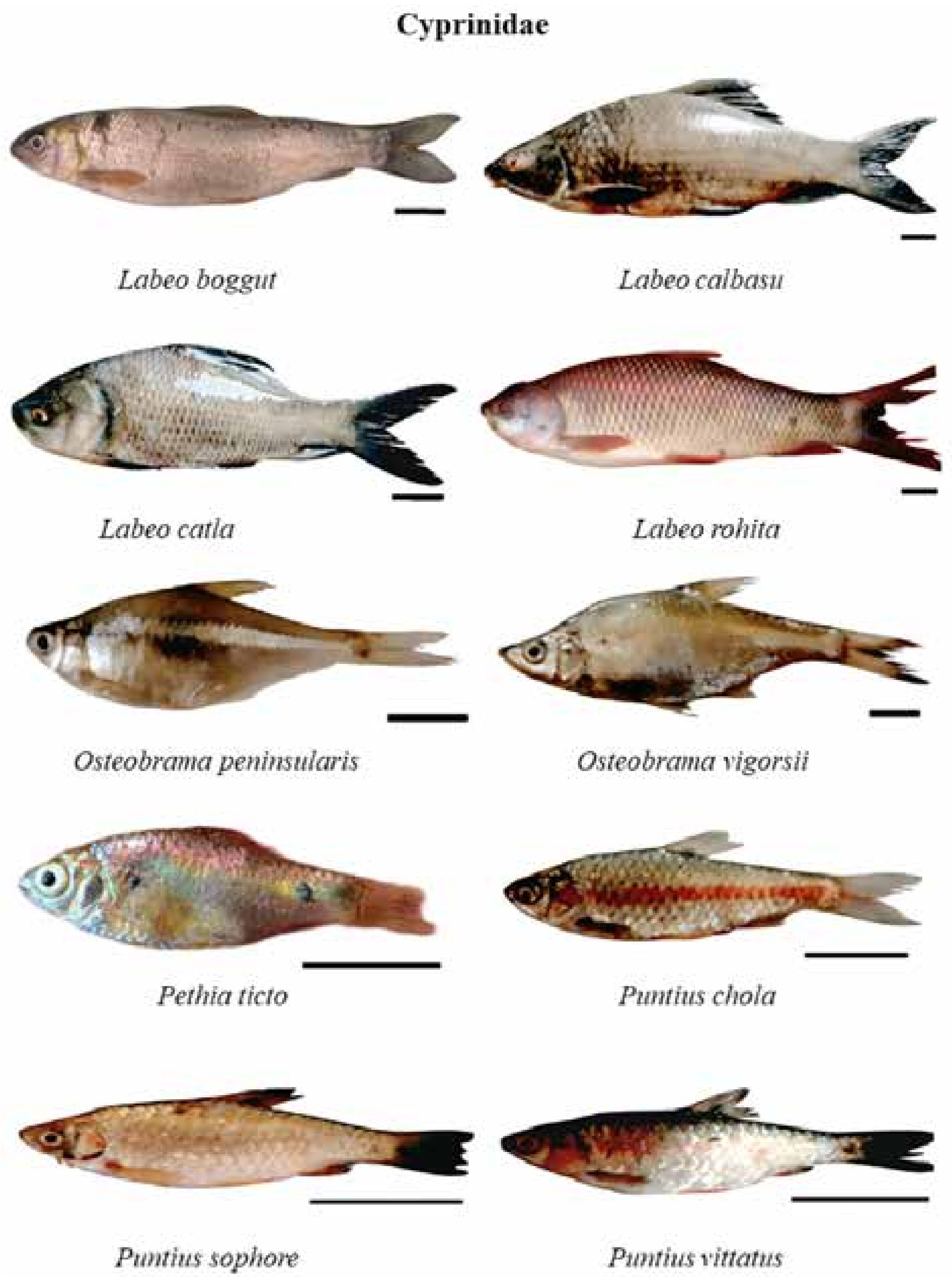


Image 1. Fish species in the Ujani Reservoir, scale bar represent 1 cm. © Ganesh Markad, Ranjit More & Sachin Shelake.



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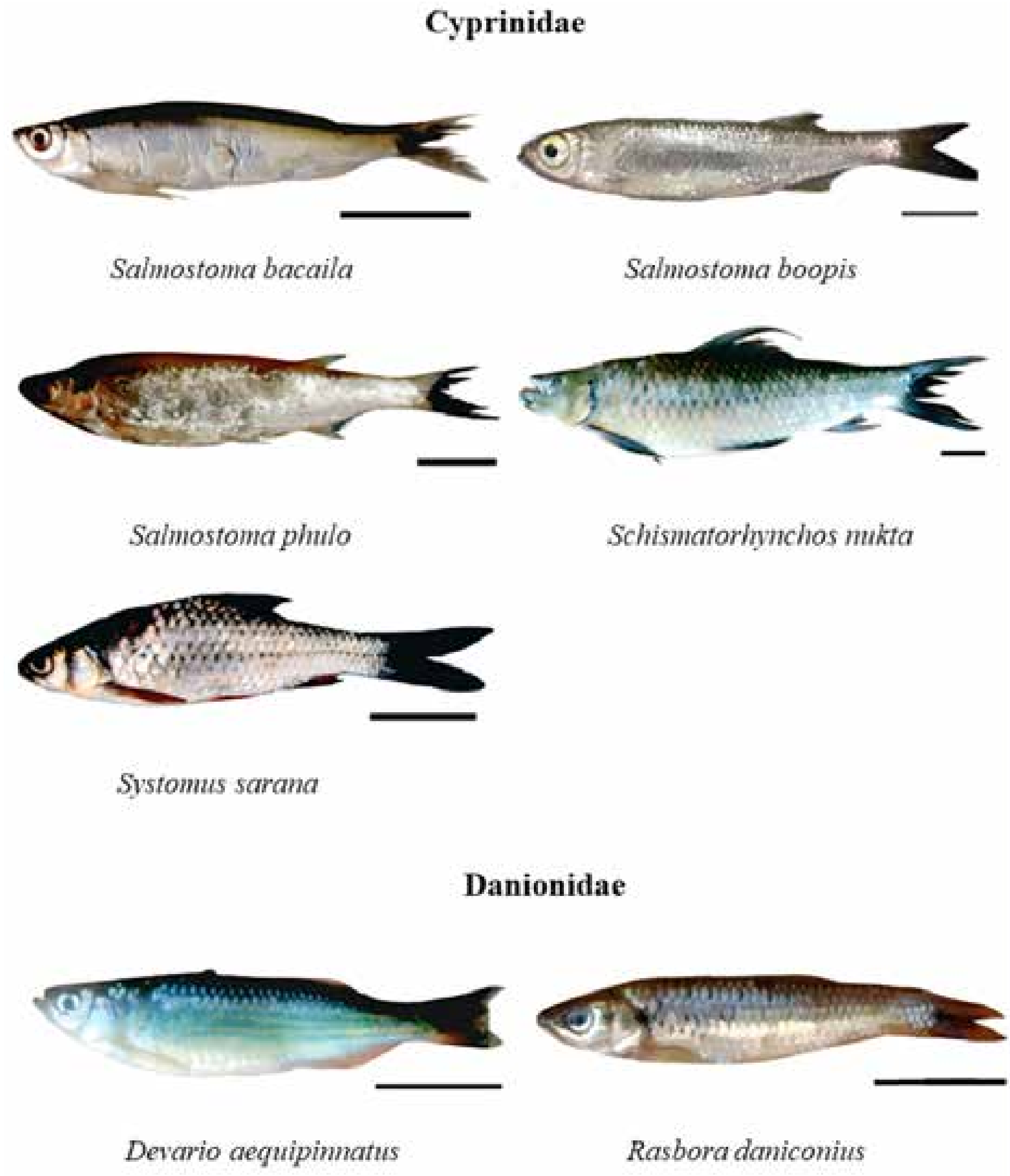

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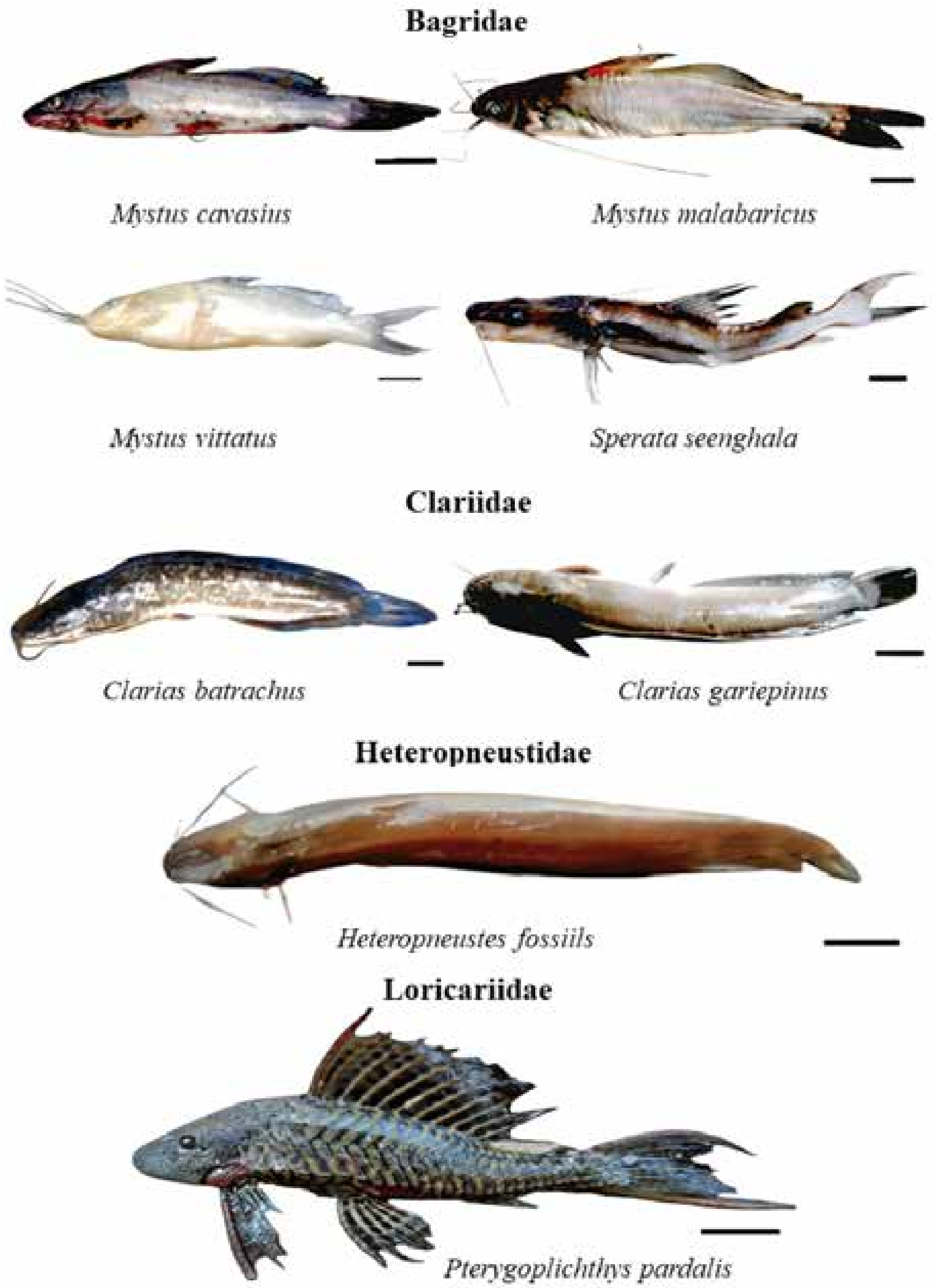

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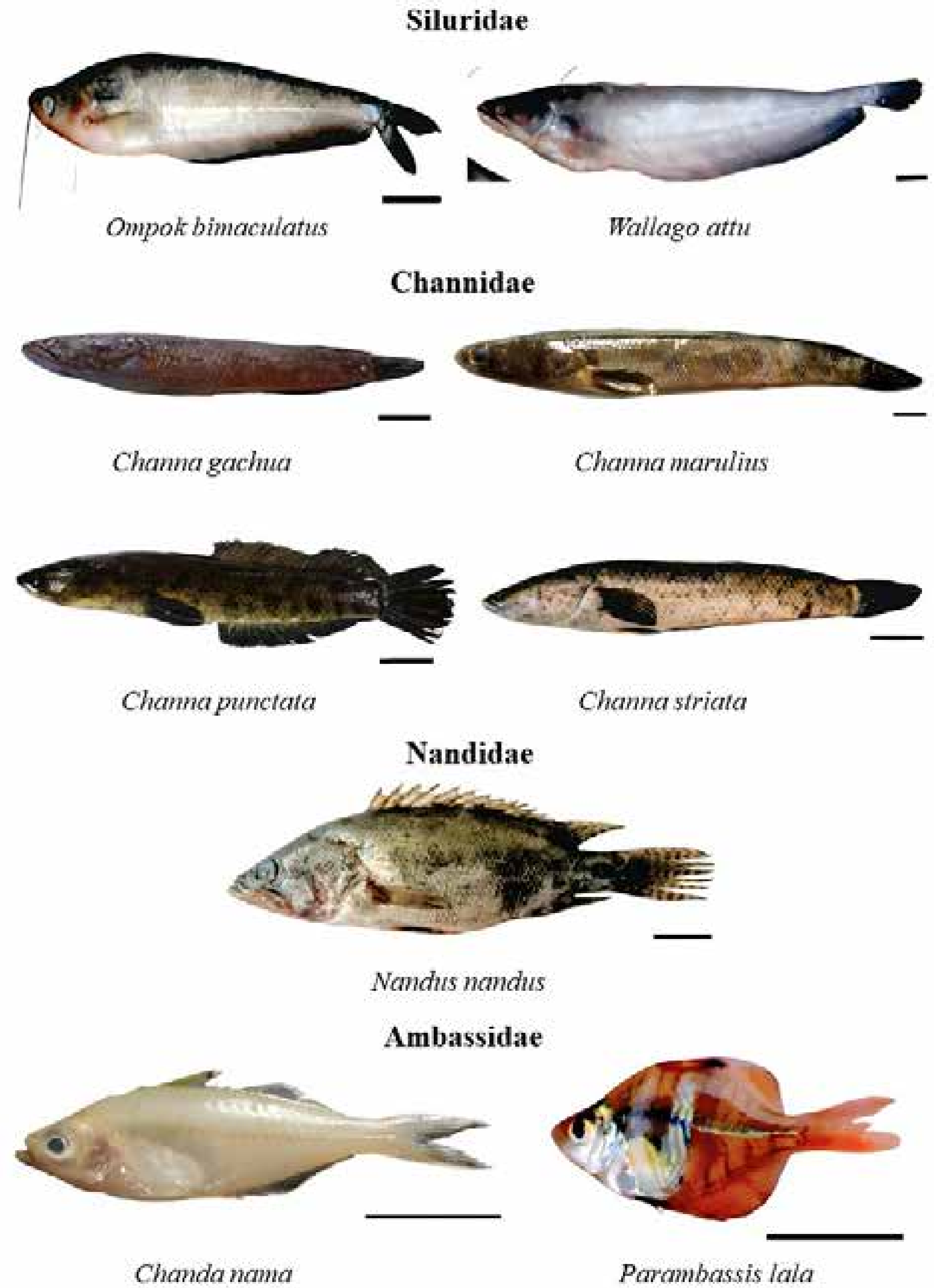

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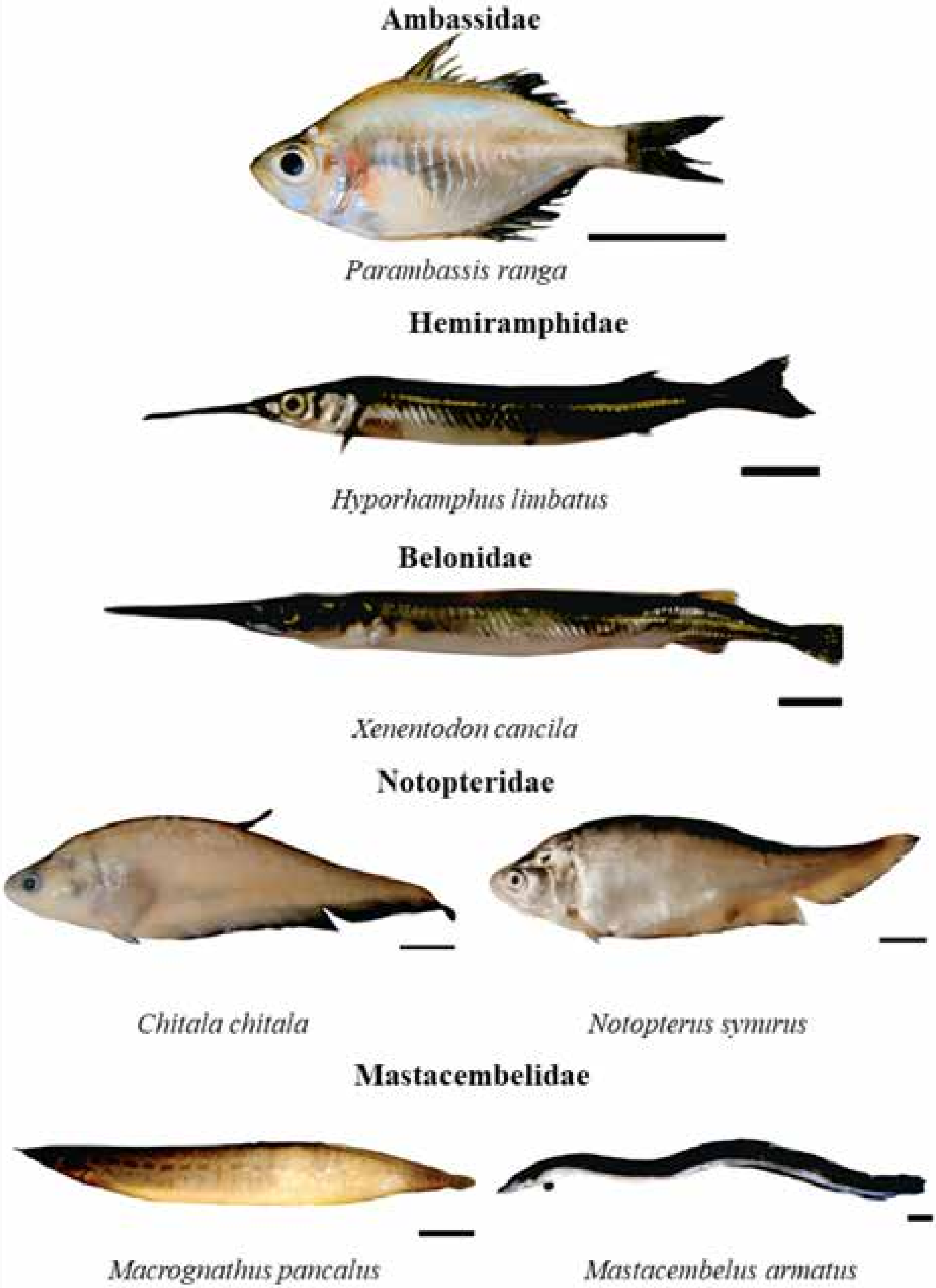

Image 6. Fish species in the Ujani Reservoir, scale bar represent 1 cm. © Ganesh Markad, Ranjit More & Sachin Shelake.

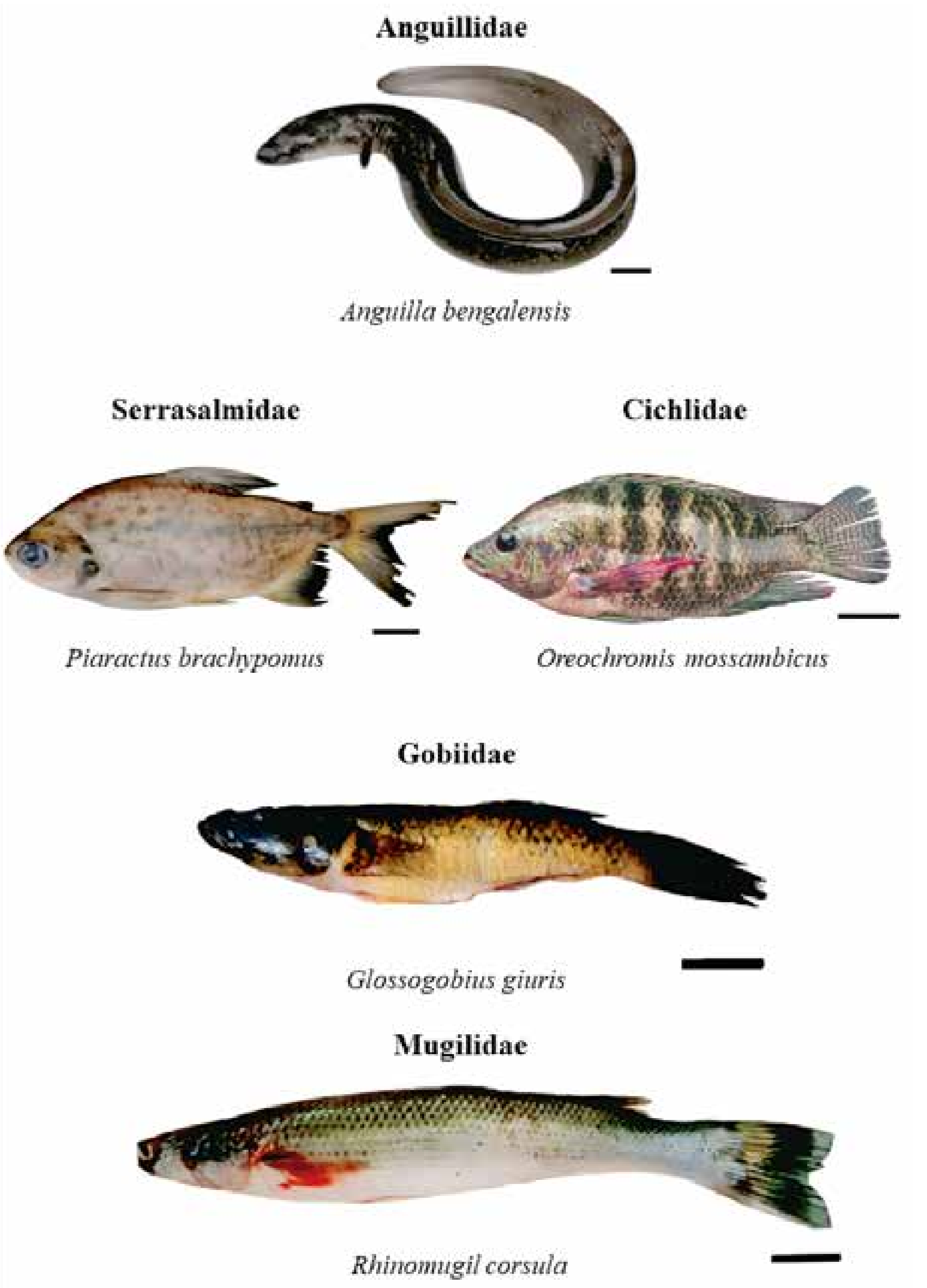

Image 7. Fish species in the Ujani Reservoir, scale bar represent 1 cm. © Ganesh Markad, Ranjit More & Sachin Shelake.

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REVIEW

A review of 21st century studies on lizards (Reptilia: Squamata: Sauria) in northeastern India with an updated regional checklist

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Abstract: The current study reviews saurian research undertaken in the 21st century in northeastern India. The scope of this review encompasses new species descriptions, range extensions, diversity assessments, systematic revisions, and species rediscoveries. In addition, it incorporates miscellaneous contributions, particularly those addressing myths, ecological aspects, conservation threats, and human-wildlife interactions documented from different states of the region. Based on published works from northeastern India, an updated checklist of the region's lizard fauna is presented. The checklist comprises 84 species representing six families and 19 genera, with their conservation status assessed according to the International Union for Conservation of Nature (IUCN) Red List of Threatened Species.

Keywords: Diversity, ecology, myths, range extension, rediscovery, saurian research, species description, systematics.

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Author contributions: MB drafted the manuscript, compiled data from various sources, and prepared the checklist of lizards with their regional distribution, accompanied by a map illustrating the study localities. MJK conceptualized the manuscript and contributed to the study's design. NS enhanced the manuscript's fluency and supervised its preparation. ARB assisted in designing the study.

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INTRODUCTION

Lizards are a diverse group of ectothermic reptiles belonging to the order Squamata and are primarily confined to tropical regions. Globally, around 12,500 reptile species have been described, of which 929 occur in India (Uetz et al. 2025). Despite lizards contributing a considerable number to these figures (nearly 446 from India; Uetz et al. 2025), they have received comparatively less attention, as snakes represent a more prominent and culturally familiar group, whereas lizards remain relatively less recognized among the general public.

Foundational contributions towards establishing baseline data on Indian lizards were made by several authors, including Günther (1864), Boulenger (1885, 1890), and Smith (1935), which laid the groundwork for future studies in the country. Eight states of India, namely, Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura, and Sikkim, collectively form northeastern India, a region that lies within the Himalaya and Indo-Burma biodiversity hotspots and harbours exceptionally high levels of species richness and endemism.

During the British colonial period, significant contributions from northeastern India included several new species descriptions of the order Sauria, notably by Gray (1845, 1846, 1853), Blyth (1854), Jerdon (1870), and Daudin (1802), and later by Annandale (1905, 1908, 1912, 1913) and Boulenger (1885, 1887, 1917).

The recent integration of molecular techniques in lizard taxonomy has greatly aided in identifying and resolving cryptic species complexes that were once considered conspecific. Studies in the 21st century have primarily focused on describing new species from various complex groups, as well as taxonomic revalidations, and revisions of earlier-described species using molecular phylogenetics. This surge in new species descriptions underscores the region's historical underestimation in terms of saurian diversity, largely due to limited sampling efforts (Purkayastha et al. 2020c).

With respect to genetic markers, most studies have relied exclusively on mitochondrial genes, while relatively few have employed both mitochondrial, and nuclear markers (Giri et al. 2019; Gowande et al. 2021; Mirza et al. 2022a), which are considered more robust for species delimitation. In the past eight years (2018–2025), 34 new species of lizards were described from northeastern India. The majority of these belong to the genus *Cyrtodactylus* Gray, 1827, which is recognized as the third largest vertebrate genus in the world (Agarwal et al. 2018a,b; Giri et al. 2019; Purkayastha et al. 2020a, 2021, 2022; Kamei & Mahony 2021; Mirza et al. 2021, 2022a,b; Bohra et al. 2022; Lalremsanga et al. 2022b, 2023a; Mahony & Kamei 2022; Boruah et al. 2024; Bharali et al. in press; Sayyed et al. 2025).

The current study reviews saurian research undertaken in northeastern India during the 21st century and presents an updated checklist of the region's lizard fauna.

MATERIALS AND METHODS

Relevant literature was obtained from the Reptile Database, Web of Science, and Google Scholar with additional references sourced by cross-checking citations within reviewed articles. The study was conducted between May 2023 and September 2025. The checklist was compiled from all peer-reviewed publications on lizards from northeastern India available up to September 2025, supplemented with data from Uetz et al. (2025). The conservation status of each species was verified using the International Union for Conservation of Nature (IUCN) Red List of Threatened Species. In total, 73 publications were reviewed, and classified into six subcategories: new species discoveries, range extensions, diversity assessments, systematic revisions, rediscoveries, and miscellaneous contributions.

RESULTS

New species discovery

In recent years, northeastern India has witnessed a surge in new species discoveries and descriptions. Since the beginning of the 21st century, there has been a marked increase in taxonomic efforts employing integrative approaches that combine morphological assessments with molecular phylogenetic analyses, mostly involving mitochondrial genes, particularly in geckos.

Following the restriction of *Cyrtodactylus khasiensis* Jerdon, 1870, to the Khasi Hills of Meghalaya by Agarwal et al. (2018a), at least 27 new species of the genus have since been described from northeastern India, including records from Tripura (Agarwal et al. 2018a), Assam (Agarwal et al. 2018b; Purkayastha et al. 2020a; Bharali et al. in press), Meghalaya (Agarwal et al. 2018b; Purkayastha et al. 2021, 2022; Kamei & Mahony 2021), Mizoram (Purkayastha et al. 2021, 2022; Lalremsanga et al. 2022b, 2023a; Bohra et al. 2022; Boruah et al. 2024), Nagaland (Agarwal et al. 2018b; Boruah et al. 2024), Manipur (Mahony & Kamei 2022; Boruah et al. 2024), and

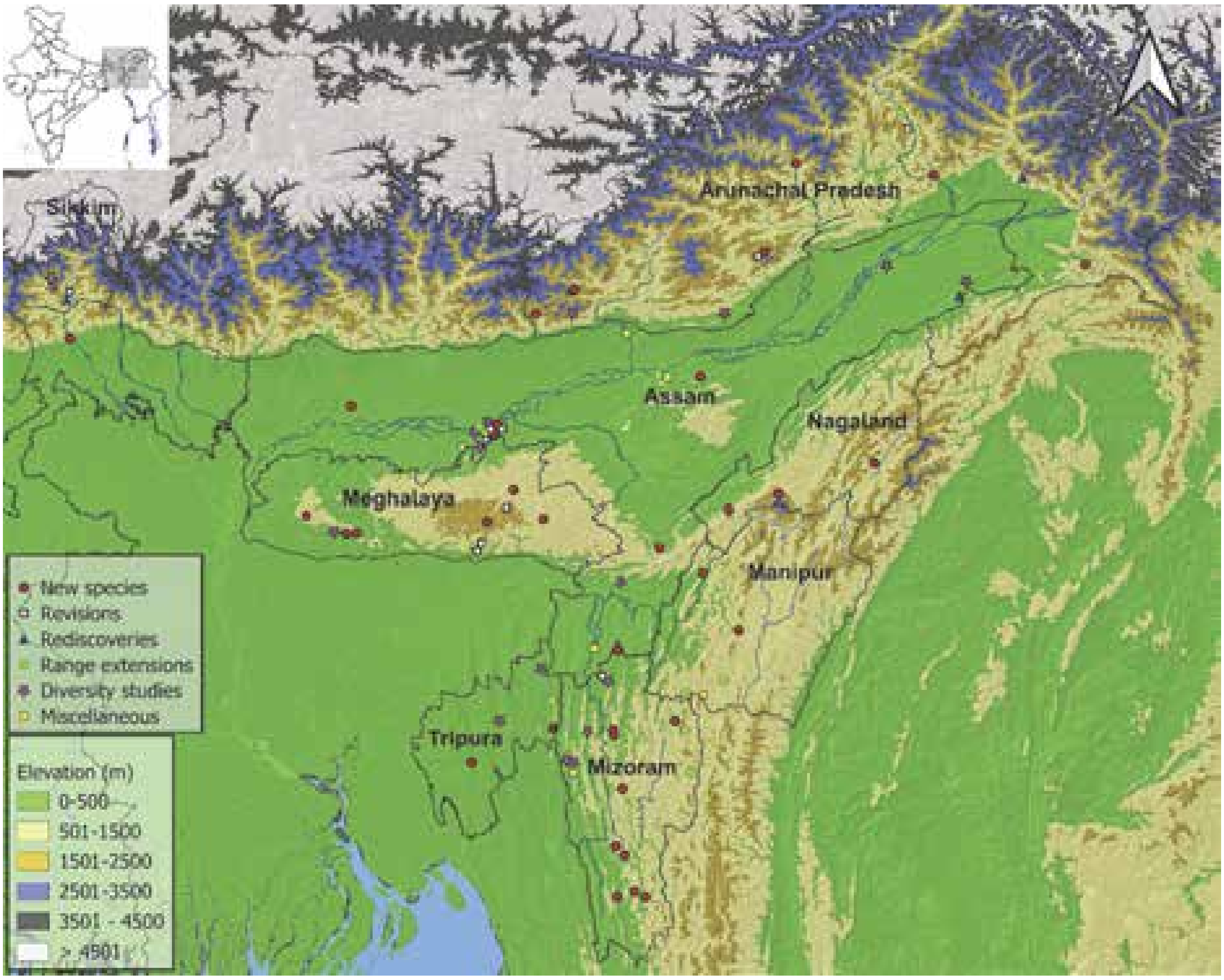

Figure 1. Map of northeastern India showing the patterns of saurian research conducted in 21st century (inset: map of India showing the area of interest).

Arunachal Pradesh (Mirza et al. 2022b; Boruah et al. 2024). Outside of *Cyrtodactylus*, several additional discoveries have contributed to the region's saurian diversity. Mahony (2009) described *Cristidorsa otai* (formerly *Japalura otai*) solely based on external morphology from Mizoram and simultaneously designated a lectotype for *Japalura sagittifera* from Upper Burma (present-day Myanmar) to stabilize its taxonomy. Datta-Roy et al. (2013) described *Sphenomorphus apalpebratus*, a spectacled lygosomatine skink from the sacred forests of Mawphlang, Meghalaya, which is distinguished from congeners by the presence of a permanent spectacle (brille) covering the eyes permanently. Giri et al. (2019) revised the genus *Oriocalotes* using morphological evidence in conjunction with nuclear and mitochondrial genomic data, placing it as a junior synonym of *Calotes*, thereby reassigning *O. paulus* to *Calotes paulus,* and also described *Calotes zolaiking* from Aizawl District, Mizoram, supported by morphological, phylogenetic, and osteological analyses. Wagner et al. (2021) revised the *Calotes mystaceus* complex using mitochondrial genes (12S rRNA and COI) and described *Calotes geissleri*, which had long been misidentified as *C. mystaceus* in northeastern India, while restricting *C. mystaceus* sensu stricto to the Irrawaddy Delta of southern Myanmar. Mirza et al. (2022a) established the genus *Protoblepharus* through the revision of *Ablepharus*, *Asymblepharus*, and *Himalblepharus*, and described *Protoblepharus apatani* from Talle Valley, Arunachal Pradesh, based on morphology, molecular data, and micro-CT scans of the skull. Lalremsanga et al. (2023b) described *Gekko mizoramensis*, a parachute gecko from Mizoram formerly considered conspecific with *Gekko lionotum* Annandale, 1905. Based on morphology and mitochondrial ND2 data, the species was recovered as a sister taxon to *G. popaense* within the *lionotum* group. Mirza et al.

Table 1. Distribution of lizards across northeastern India.
State abbreviations: AS—Assam | AR—Arunachal Pradesh | MI—Mizoram | ML—Meghalaya | TR—Tripura | SI—Sikkim | MA—Manipur | NA—Nagaland. IUCN Red List categories: EN—Endangered | VU—Vulnerable | NT—Near Threatened | LC—Least Concern | DD—Data Deficient | NE—Not Evaluated.

	Family	Scientific name	Common name	IUCN Red List status	Distribution in northeastern India	Citations
1	Varanidae	*Varanus bengalensis* (Daudin, 1802)	Bengal Monitor	NT	AR, AS, MI, SI, TR	Sinha et al. (2021), Das et al. (2009), Purkayastha et al. (2020c), Purkayastha et al. (2011), Sengupta et al. (2019), Islam & Saikia (2013), Purkayastha (2018), Mahananda et al. (2023), Lalrinchhana & Solanki (2015), Jha & Thapa (2002), Chettri et al. (2009), Purkayastha et al. (2020b), Ahmed et al. (2009), Choudhary & Choudhary (2019), Purkayastha (2013)
2	Varanidae	*Varanus flavescens* (Hardwicke & Gray, 1827)	Yellow Monitor	EN	AS	Purkayastha et al. (2020c), Islam & Saikia (2013), Purkayastha (2018), Mahananda et al. (2023), Ahmed et al. (2009), Purkayastha (2013)
3	Varanidae	*Varanus salvator* (Laurenti, 1768)	Asian Water Monitor	LC	AS, MI, NA, TR	Islam & Saikia (2013), Malsawmdawngliana et al. (2022), Lalrinchhana & Solanki (2015), Majumder et al. (2012), Ahmed et al. (2009), Choudhary & Choudhary (2019), Purkayastha (2013)
4	Gekkonidae	*Cnemaspis assamensis* Das & Sengupta, 2000	Assam Day Gecko	VU	AS	Purkayastha et al. (2020c), Purkayastha et al. (2011), Purkayastha (2018), Chandramouli et al. (2021), Mahananda et al. (2023), Ahmed et al. (2009), Das & Ahmed (2007), Sengupta et al. (2021), Purkayastha (2013)
5	Gekkonidae	*Cnemaspis brahmaputra* Sayyed, Das, Amarasinghe, Bhattacharjee & Purkayastha, 2025	Brahmaputra Day Gecko	NE	AS	Sayyed et al. (2025)
6	Gekkonidae	*Cyrtodactylus aaronbaueri* Purkayastha, Lalremsanga, Bohra, Biakzuala, Decemson, Muansanga, Vabeiryureilai & Rathee, 2021	Aaron Bauer's Bent-toed Gecko	NE	MI	Purkayastha et al. (2021)
7	Gekkonidae	*Cyrtodactylus agarwali* Purkayastha, Lalremsanga, Bohra, Biakzuala, Decemson, Muansanga, Vabeiryureilai & Rathee, 2021	Agarwal's Bent-toed Gecko	NE	ML	Purkayastha et al. (2021), Chandramouli et al. (2021)
8	Gekkonidae	*Cyrtodactylus bapme* Kamei & Mahony, 2021	Garo Hills Bent-toed Gecko	NE	ML	Kamei & Mahony (2021)
9	Gekkonidae	*Cyrtodactylus barailensis* Boruah, Narayanan, Deepak & Das, 2024	Barail Hills Bent-toed Gecko	NE	NA	Boruah et al. (2024)
10	Gekkonidae	*Cyrtodactylus bengkhuaiai* Purkayastha, Lalremsanga, Bohra, Biakzuala, Decemson, Muansanga, Vabeiryureilai & Rathee, 2021	Bengkhuaiai's Bent-toed Gecko	NE	MI	Purkayastha et al. (2021)
11	Gekkonidae	*Cyrtodactylus cayuensis* Li, 2007	Cayu Bent-toed Gecko	LC	AR	Boruah et al. (2024)
12	Gekkonidae	*Cyrtodactylus exercitus* Purkayastha, Lalremsanga, Litho, Rathee, Bohra, Mathipi, Biakzuala & Muansanga, 2022	Indian Army's Bent-toed Gecko	NE	ML	Purkayastha et al. (2022)
13	Gekkonidae	*Cyrtodactylus gubernatoris* (Annandale, 1913)	Sikkimese Bent-toed Gecko	DD	SI	Agarwal et al. (2018a)
14	Gekkonidae	*Cyrtodactylus guwahatiensis* Agarwal, Mahony, Giri, Chaitanya & Bauer, 2018	Guwahati Hill's Bent-toed Gecko	DD	AS	Mahananda et al. (2023), Agarwal et al. (2018b)
15	Gekkonidae	*Cyrtodactylus jaintiaensis* Agarwal, Mahony, Giri, Chaitanya & Bauer, 2018	Jaintia Hills Bent-toed Gecko	DD	ML	Agarwal et al. (2018b)
16	Gekkonidae	*Cyrtodactylus kamengensis* Mirza, Bhosale, Thackeray, Phansalkar, Sawant, Gowande & Patel, 2022	Kameng Hills Bent-toed Gecko	NE	AR	Mirza et al. (2022b)

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17	Gekkonidae	*Cyrtodactylus karsticola* Purkayastha, Lalremsanga, Bohra, Biakzuala, Decemson, Muansanga, Vabeiryureilai & Rathee, 2021	Karst Dwelling Bent-toed Gecko	NE	ML	Purkayastha et al. (2021)
18	Gekkonidae	*Cyrtodactylus kazirangaensis* Agarwal, Mahony, Giri, Chaitanya & Bauer, 2018	Kaziranga Bent-toed Gecko	DD	AS	Agarwal et al. (2018b)
19	Gekkonidae	*Cyrtodactylus khasiensis* (Jerdon, 1870)	Khasi Hills Bent-toed Gecko	DD	ML	Ahmed et al. (2009), Agarwal et al. (2018a)
20	Gekkonidae	*Cyrtodactylus kiphire* Boruah, Narayanan, Deepak & Das, 2024	Kiphire Bent-toed Gecko	NE	NA	Boruah et al. (2024)
21	Gekkonidae	*Cyrtodactylus lungleiensis* Lalremsanga, Chinliansiama, Chandra Bohra, Biakzuala, Vabeiryureilai, Muansanga, Malsawmdawngliana, Hmar, Decemson, Siammawii, Das, & Purkayastha, 2022	Lunglei Bent-toed Gecko	NE	MI	Lalremsanga et al. (2022b)
22	Gekkonidae	*Cyrtodactylus manipurensis* Boruah, Narayanan, Deepak & Das, 2024	Manipur Bent-toed Gecko	NE	MA	Boruah et al. (2024)
23	Gekkonidae	*Cyrtodactylus montanus* Agarwal, Mahony, Giri, Chaitanya & Bauer, 2018	Montane Bent-toed Gecko	CR	TR, MI	Agarwal et al. (2018b), Muansanga et al. (2020), Malsawmdawngliana et al. (2022)
24	Gekkonidae	*Cyrtodactylus nagalandensis* Agarwal, Mahony, Giri, Chaitanya & Bauer, 2018	Nagaland Bent-toed Gecko	DD	NA	Agarwal et al. (2018b)
25	Gekkonidae	*Cyrtodactylus namdaphaensis* Boruah, Narayanan, Deepak & Das, 2024	Namdapha Bent-toed Gecko	NE	AR	Boruah et al. (2024)
26	Gekkonidae	*Cyrtodactylus namtiram* Mahony & Kamei, 2022	Namtiram Bent-toed Gecko	NE	MA	Mahony & Kamei (2022)
27	Gekkonidae	*Cyrtodactylus ngengpuiensis* Boruah, Narayanan, Lalronunga, Deepak & Das, 2024	Ngengpui Bent-toed Gecko	NE	MI	Boruah et al. (2024)
28	Gekkonidae	*Cyrtodactylus ngopensis* Bohra, Zonunsanga, Das, Purkayastha, Biakzuala & Lalremsanga, 2022	Ngopa Hills Bent-toed Gecko	NE	MI	Bohra et al. (2022)
29	Gekkonidae	*Cyrtodactylus septentrionalis* Agarwal, Mahony, Giri, Chaitanya & Bauer, 2018	Northern Bent-toed Gecko	DD	AS	Agarwal et al. (2018b)
30	Gekkonidae	*Cyrtodactylus siahaensis* Purkayastha, Lalremsanga, Litho, Rathee, Bohra, Mathipi, Biakzuala & Muansanga, 2022	Siaha Bent-toed Gecko	NE	MI	Purkayastha et al. (2022)
31	Gekkonidae	*Cyrtodactylus siangensis* Boruah, Narayanan, Aravind, Deepak & Das, 2024	Siang Valley Bent-toed Gecko	NE	AR	Boruah et al. (2024)
32	Gekkonidae	*Cyrtodactylus tripuraensis* Agarwal, Mahony, Giri, Chaitanya & Bauer, 2018	Tripura Bent-toed Gecko	LC	TR	Agarwal et al. (2018a), Purkayastha et al. (2020b)
33	Gekkonidae	*Cyrtodactylus urbanus* Purkayastha, Das, Bohra, Bauer & Agarwal, 2020	Urban Bent-toed Gecko	NE	AS, ML	Purkayastha et al. (2020a), Mahananda et al. (2023), Purkayastha et al. (2020d)
34	Gekkonidae	*Cyrtodactylus vairengtensis* Lalremsanga, Colney, Vabeiryureilai, Malsawmdawngliana, Bohra, Biakzuala, Muansanga, Das & Purkayastha, 2023	Vairengte Bent-toed Gecko	NE	MI	Lalremsanga et al. (2023a)
35	Gekkonidae	*Cyrtodactylus vanarakshaka* Bharali, Thaosen, Vabeiryureilai, Lalremsanga, Purkayastha, Bhattacharjee, Das, Bohra & Hazarika (in press)	Vanarakshaka Bent-toed Gecko	NE	AS	Bharali et al. in press

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36	Gekkonidae	*Gekko gecko* (Linnaeus, 1758)	Tokay Gecko	LC	AR, AS, ML, MI, TR	Sinha et al. (2021), Das et al. (2009), Purkayastha et al. (2020c), Purkayastha et al. (2011), Sengupta et al. (2019), Islam & Saikia (2013), Purkayastha (2018), Chandramouli et al. (2021), Mahananda et al. (2023), Malsawmdawngliana et al. (2022), Lalrinchhana & Solanki (2015), Purkayastha et al. (2020b), Majumder et al. (2012), Ahmed et al. (2009), Das et al. (2007), Ulman & Singh (2021), Purkayastha (2013)
37	Gekkonidae	*Gekko mizoramensis* Lalremsanga, Muansanga, Vabeiryureilai & Mirza, 2023	Mizoram Gliding Gecko	NE	MI	Ahmed et al. (2009), Lalremsanga et al. (2023b)
38	Gekkonidae	*Hemidactylus aquilonius* Mcmahan & Zug, 2007	Northern Smooth Scaled Gecko	LC	AS, SI, TR	Purkayastha et al. (2020c), Purkayastha et al. (2011), Purkayastha (2018), Mahananda et al. (2023), Jha & Thapa (2002), Chettri et al. (2009), Purkayastha et al. (2020b), Ahmed et al. (2009), Purkayastha et al. (2010), Ranade & Purkayastha (2020), Das et al. (2011b), Purkayastha (2013)
39	Gekkonidae	*Hemidactylus* cf. *malcolmsmithi* (Constable, 1949)	Malcolm's Bow-fingered gecko	DD	AR, AS, MI, TR	Sinha et al. (2021), Purkayastha et al. (2020c), Purkayastha et al. (2011), Sengupta et al. (2019), Islam & Saikia (2013), Purkayastha (2018), Mahananda et al. (2023), Lalrinchhana & Solanki (2015), Purkayastha et al. (2020b), Ahmed et al. (2009), Purkayastha (2013), Manmath Bharali pers. obs. unpublished data.
40	Gekkonidae	*Hemidactylus flaviviridis* Rüppell, 1835	Northern House Gecko	LC	AS, SI	Purkayastha et al. (2011), Sengupta et al. (2019), Purkayastha (2018), Jha & Thapa (2002), Ahmed et al. (2009), Purkayastha (2013)
41	Gekkonidae	*Hemidactylus frenatus* Duméril & Bibron, 1836	Common House Gecko	LC	AR, AS, ML, MI, SI, TR	Agarwal et al. (2010), Sinha et al. (2021), Das et al. (2009), Purkayastha et al. (2020c), Purkayastha et al. (2011), Sengupta et al. (2019), Islam & Saikia (2013), Purkayastha (2018), Chandramouli et al. (2021), Mahananda et al. (2023), Malsawmdawngliana et al. (2022), Lalrinchhana & Solanki (2015), Chettri et al. (2009), Purkayastha et al. (2020b), Ahmed et al. (2009), Das et al. (2011b), Purkayastha (2013)
42	Gekkonidae	*Hemidactylus garnotii* Duméril & Bibron, 1836	Garnot's House Gecko	LC	AS, MI, NA, SI	Purkayastha et al. (2011), Islam & Saikia (2013), Purkayastha (2018), Mahananda et al. (2023), Lalrinchhana & Solanki (2015), Jha & Thapa (2002), Chettri et al. (2009), Ahmed et al. (2009), Purkayastha (2013)
43	Gekkonidae	*Hemidactylus platyurus* (Schneider, 1797)	Flat-tailed House Gecko	LC	AR, AS, ML, MI, SI, TR	Agarwal et al. (2010), Das et al. (2009), Purkayastha et al. (2020c), Purkayastha et al. (2011), Purkayastha (2018), Chandramouli et al. (2021), Mahananda et al. (2023), Malsawmdawngliana et al. (2022), Lalrinchhana & Solanki (2015), Jha & Thapa (2002), Chettri et al. (2009), Purkayastha et al. (2020b), Ahmed et al. (2009), Das et al. (2007)
44	Gekkonidae	*Hemiphyllodactylus* sp.	Slender Gecko	NE	AR	Deepak et al. (2022)
45	Agamidae	*Calotes* cf. *vultuosus* (Harlan, 1829)	Oriental Garden Lizard	LC	AR, AS, MI, NA, SI, TR	Agarwal et al. (2010), Sinha et al. (2021), Das et al. (2009), Purkayastha et al. (2020c), Purkayastha (2013), Purkayastha et al. (2011), Sengupta et al. (2019), Islam & Saikia (2013), Purkayastha (2018), Mahananda et al. (2023), Lalrinchhana & Solanki (2015), Jha & Thapa (2002), Chettri et al. (2009), Purkayastha et al. (2020b), Majumder et al. (2012), Ahmed et al. (2009), Das et al. (2007), Harit (2018)

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46	Agamidae	*Calotes emma* Gray, 1845	Emma Grey's Forest Lizard	LC	AS, ML, MI, NA, TR	Das et al. (2009), Purkayastha (2013), Chandramouli et al. (2021), Malsawmdawngliana et al. (2022), Lalrinchhana & Solanki (2015), Ahmed et al. (2009), Majumder & Agarwala (2015)
47	Agamidae	*Calotes geissleri* Wagner, Ihlow, Hartmann, Flecks, Schmitz & Böhme, 2021	Geissler's Forest Lizard	NE	NA, MI, MA	Ahmed et al. (2009), Lalremsanga et al. (2010), Wagner et al. (2021), Decemson et al. (2021)
48	Agamidae	*Calotes irawadi* Zug, Brown, Schulte & Vindum, 2006	Irawaddy Crested Lizard	LC	AS, ML, MI, MA	Das et al. (2009), Chandramouli et al. (2021), Malsawmdawngliana et al. (2022), Lalrinchhana & Solanki (2015), Tariang et al. (2022), Decemson et al. (2023)
49	Agamidae	*Calotes jerdoni* Günther, 1870	Jerdon's Forest Lizard	LC	AR, AS, NA, SI, MI	Sinha et al. (2021), Purkayastha (2013), Das et al. (2009), Sengupta et al. (2019), Jha & Thapa (2002), Chettri et al. (2009), Ahmed et al. (2009), Harit (2018)
50	Agamidae	*Calotes maria* Gray, 1845	Khasi Hills Forest Lizard	LC	ML, AS, NA, MI	Chandramouli et al. (2021), Mahananda et al. (2023), Ahmed et al. (2009), Lalremsanga et al. (2010), Purkayastha (2013)
51	Agamidae	*Calotes medogensis* Zhao & Li, 1984	Medog Bloodsucker	LC	AR	Boruah et al. (2022)
52	Agamidae	*Calotes paulus* Smith, 1935	Small Forest Lizard	EN	ML	Ahmed et al. (2009), Giri et al. (2019),
53	Agamidae	*Calotes sinyik* Patel, Thackerey, Sheth, Khandekar & Agarwal, 2024	Subansiri Dragon Lizard	NE	AR	Patel et al. (2024)
54	Agamidae	*Calotes zolaiking* Giri, Chaitanya, Mahony, Lalronunga, Lalrinchhana, Das, Sarkar, Karanth & Deepak, 2019	Mizoram Montane Forest Lizard	DD	MI, ML	Giri et al. (2019), Bohra et al. (2025)
55	Agamidae	*Cristidorsa otai* (Mahony, 2009)	Ota's Mountain Lizard	DD	MI	Mahony (2009)
56	Agamidae	*Cristidorsa planidorsata* (Jerdon, 1870)	Smooth Scaled Mountain Lizard	LC	AS, ML, MI, TR	Das et al. (2009), Sengupta et al. (2019), Chandramouli et al. (2021), Mahananda et al. (2023), Malsawmdawngliana et al. (2022), Lalrinchhana & Solanki (2015), Purkayastha et al. (2020b), Ahmed et al. (2009), Purkayastha (2013)
57	Agamidae	*Draco blanfordii* Boulenger, 1885	Blanford's Flying Lizard	LC	MI	Lalrinchhana & Solanki (2015), Jha & Thapa (2002), Ahmed et al. (2009)
58	Agamidae	*Draco maculatus* (Gray, 1845)	Spotted Flying Dragon	LC	AS	Mahananda et al. (2023), Lalrinchhana & Solanki (2015), Ahmed et al. (2009), Purkayastha (2013)
59	Agamidae	*Draco norvillii* Alcock, 1895	Norvill's Flying Lizard	NT	AS	Islam & Saikia (2013), Purkayastha (2013)
60	Agamidae	*Japalura andersoniana* Annandale, 1905	Anderson's Mountain Lizard	LC	AR	Agarwal et al. (2010), Ahmed et al. (2009)
61	Agamidae	*Japalura austeniana* (Annandale, 1908)	Abor Hills Agama	LC	AR	Agarwal et al. (2010), Ahmed et al. (2009), Mirza et al. (2024), Gowande et al. (2021), Das & Das (2007)
62	Agamidae	*Japalura mictophola* Mirza, Gowande, Thackeray, Bhosale, Sawant, Phansalkar & Patel, 2024	Mix-scaled Mountain Lizard	NE	AR	Mirza et al. (2024)
63	Agamidae	*Japalura sagittifera* Smith, 1940	Burmese Japalura	DD	AR	Kunte & Manthey (2009)
64	Agamidae	*Japalura tricarinata* (Blyth, 1853)	Three-keeled Mountain Lizard	LC	SI	Jha & Thapa (2002), Chettri et al. (2009)
65	Agamidae	*Japalura variegata* Gray, 1853	Variegated Mountain Lizard	LC	AR	Agarwal et al. (2010), Jha & Thapa (2002), Chettri et al. (2009), Ahmed et al. (2009)
66	Agamidae	*Ptyctolaemus gularis* Peters, 1864	Green Fan-throated Lizard	LC	AS, ML, MI, NA, TR	Purkayastha et al. (2020b), Purkayastha et al. (2011), Islam & Saikia (2013), Purkayastha (2018), Chandramouli et al. (2021), Mahananda et al. (2023), Malsawmdawngliana et al. (2022), Lalrinchhana & Solanki (2015), Purkayastha et al. (2020b), Ahmed et al. (2009), Harit (2018), Purkayastha (2013)

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67	Lacertidae	*Takydromus haughtonianus* Jerdon, 1870	Goalpara Grass Lizard	DD	AS	Ahmed et al. (2009), Purkayastha (2013)
68	Lacertidae	*Takydromus khasiensis* Boulenger, 1917	Java Grass Lizard	LC	AS, ML	Das et al. (2009), Islam & Saikia (2013), Chandramouli et al. (2021), Mahananda et al. (2023), Ahmed et al. (2009), Purkayastha (2013)
69	Lacertidae	*Takydromus sexlineatus* Daudin, 1802	Asian Grass Lizard	LC	MI, SI	Lalrinchhana & Solanki (2015), Chettri et al. (2009), Ahmed et al. (2009)
70	Lacertidae	*Takydromus sikkimensis* Günther, 1888	Sikkim Grass Lizard	EN	SI	Bhupathy et al. (2009)
71	Scincidae	*Ablepharus sikimmensis* (Blyth, 1854)	Sikkim Ground Skink	LC	AR, SI	Agarwal et al. (2010), Jha & Thapa (2002), Chettri et al. (2009), Ahmed et al. (2009)
72	Scincidae	*Eutropis carinata* (Schneider, 1801)	Keeled Indian Mabuya	LC	SI, AS	Jha & Thapa (2002), Ahmed et al. (2009), Purkayastha (2013)
73	Scincidae	*Eutropis cf. trivitta* (Hardwicke & Gray, 1827)	Striped Grass Skink	LC	AR	Agarwal et al. (2010), Ahmed et al. (2009)
74	Scincidae	*Eutropis macularia* (Blyth, 1853)	Bronze Grass Skink	LC	AS, ML, MI, NA, TR	Das et al. (2009), Purkayastha et al. (2020c), Purkayastha et al. (2011), Sengupta et al. (2019), Islam & Saikia (2013), Purkayastha (2018), Chandramouli et al. (2021), Mahananda et al. (2023), Lalrinchhana & Solanki (2015), Purkayastha et al. (2020b), Majumder et al. (2012), Ahmed et al. (2009), Purkayastha (2013)
75	Scincidae	*Eutropis multifasciata* (Kuhl, 1820)	Many-lined Sun Skink	LC	AR, AS, ML, MI, TR	Sinha et al. (2021), Das et al. (2009), Purkayastha et al. (2020b), Purkayastha et al. (2011), Sengupta et al. (2019), Islam & Saikia (2013), Purkayastha (2018), Chandramouli et al. (2021), Mahananda et al. (2023), Lalrinchhana & Solanki (2015), Purkayastha et al. (2020b), Majumder et al. (2012), Ahmed et al. (2009), Das et al. (2007), Purkayastha (2013)
76	Scincidae	*Eutropis quadricarinata* (Boulenger, 1887)	Beautiful Mabuya	LC	AS	Das et al. (2009), Ahmed et al. (2009), Purkayastha (2013)
77	Scincidae	*Protoblepharus apatani* Mirza, Bragin, Bhosale, Gowande, Patel & Poyarkov, 2022	East-Himalayan Skink	NE	AR	Mirza et al. (2022a)
78	Scincidae	*Riopa albopunctata* Gray, 1846	White-spotted Supple Skink	LC	AS, TR	Purkayastha et al. (2020c), Purkayastha et al. (2011), Islam & Saikia (2013), Purkayastha (2018), Mahananda et al. (2023), Purkayastha et al. (2020b), Ahmed et al. (2009), Purkayastha (2013)
79	Scincidae	*Sphenomorphus apalpebratus* Datta-Roy, Das, Bauer, Lyngdoh-Tron & Karanth, 2013	Spectacled Forest Skink	NT	ML	Datta-Roy et al. (2013)
80	Scincidae	*Sphenomorphus courcyanus* (Annandale, 1912)	Medog Skink	LC	AR	Ahmed et al. (2009), Uetz et al. 2025
81	Scincidae	*Sphenomorphus indicus* (Gray, 1853)	Indian Forest Skink	LC	AR, ML, SI, MI, AS	Agarwal et al. (2010), Islam & Saikia (2013), Chandramouli et al. (2021), Lalrinchhana & Solanki (2015), Jha & Thapa (2002), Chettri et al. (2009), Ahmed et al. (2009), Harit (2018), Purkayastha (2013)
82	Scincidae	*Sphenomorphus maculatus* (Blyth, 1853)	Spotted Forest Skink	LC	AR, ML, MI, SI, TR, AS	Das et al. (2009), Purkayastha et al. (2011), Sengupta et al. (2019), Islam & Saikia (2013), Purkayastha (2018), Chandramouli et al. (2021), Mahananda et al. (2023), Malsawmdawngliana et al. (2022), Lalrinchhana & Solanki (2015), Jha & Thapa (2002), Chettri et al. (2009), Purkayastha et al. (2020b), Majumder et al. (2012), Ahmed et al. (2009), Harit (2018), Purkayastha (2013)
83	Scincidae	*Tropidophorus assamensis* Annandale, 1912	Northeastern Water Skink	VU	AS, MI	Das et al. (2009), Lalrinchhana & Solanki (2015), Ahmed et al. (2009), Lalremsanga et al. (2022a), Purkayastha (2013)
84	Anguidae	*Dopasia gracilis* (Gray, 1845)	Assam Glass Lizard	LC	NA, SI, MI	Jha & Thapa (2002), Ahmed et al. (2009), Lalremsanga et al. (2010), Purkayastha (2013)

(2024) described *Japalura mictophola*, a montane-dwelling agamid from Arunachal Pradesh. Patel et al. (2024) described *Calotes sinyik* from the Subansiri River basin of Arunachal Pradesh, based on morphology and mitochondrial ND2 gene. Sayyed et al. (2025) described *Cnemaspis brahmaputra* from the northern bank of the Brahmaputra River, based on morphology and ND2 gene analysis. The species was recovered as the sister taxon to *C. assamensis* and together they were designated as the *C. assamensis* group within the *podihuna* clade.

Range extensions

Most studies on range extensions were based solely on classical taxonomy. Das & Ahmed (2007) reported *Cnemaspis assamensis* from the Ghorakhati Range of Kaziranga National Park, Assam thereby extending its known distribution about 200 km east of the type locality in Mayeng Reserve Forest, Kamrup District, Assam. As new state records, Das et al. (2009) documented *Tropidophorus assamensis* from the Barail Wildlife Sanctuary, Assam. Lalremsanga et al. (2010) recorded three species of lizards from Mizoram, namely, *Calotes maria* from Lengteng Wildlife Sanctuary, Champhai District; *Calotes mystaceus* (now regarded as a misidentification of *Calotes geissleri*) from Zotlang, Lunglei District; and *Ophisaurus gracilis* (now *Dopasia gracilis*) from Aizawl city. Das et al. (2011a) reported the occurrence of an invasive species of gecko, namely *Hemidactylus flaviviridis*, from Guwahati City of Assam, with remarks on its urbanized distribution. Majumder & Agarwala (2015) reported the agamid lizard *Calotes emma* from Tripura. Deepak et al. (2022) documented a specimen of *Hemiphyllodactylus* (Bleeker, 1860) from Namdapha Tiger Reserve, Changlang District, Arunachal Pradesh, representing the first record of the genus from eastern Himalaya and the Indian Himalayan region, but refrained from designating any species-specific identity to the specimen. Mirza et al. (2021) described *Cyrtodactylus arunachalensis* from Arunachal Pradesh, which was later synonymized with *C. cayuensis* by Boruah et al. (2024), thereby extending the species' range, previously known only from Xizang, China.

Only a limited number of studies have integrated molecular approaches with classical taxonomy to assess lizard distributions. Muansanga et al. (2020) recorded *Cyrtodactylus montanus* from Dampa Tiger Reserve, Mizoram. Purkayastha et al. (2020d) confirmed the occurrence of *Cyrtodactylus urbanus* from Meghalaya. Decemson et al. (2021) reported *Calotes geissleri* from the Chandel District, Manipur, which was formerly regarded as *Calotes mystaceus* but has since been restricted to Myanmar (Wagner et al. 2021). Tariang et al. (2022) confirmed the presence of *Calotes irawadi* in Mizoram, which had earlier been misidentified as *Calotes versicolor.* Boruah et al. (2022) documented *Calotes medogensis* from Arunachal Pradesh, a species long confused with *Calotes jerdoni* due to the absence of clear morphological and molecular diagnostic data. Decemson et al. (2023) confirmed the occurrence of *Calotes irawadi* from Churachandpur District, Manipur, using both morphological and molecular evidence. More recently, Bohra et al. (2025) reported *Calotes zolaiking* from Cherrapunji, Meghalaya, marking the first record of this species outside its type locality at Durtlang, Aizawl District, Mizoram.

Diversity studies

Several studies on lizard diversity have been carried out in northeastern India over the past two decades. Books such as Jha & Thapa (2002), Ahmed et al. (2009), and Purkayastha (2013) provided comprehensive accounts of the saurian fauna of Sikkim, northeastern India, and Assam respectively. Additional diversity assessments have been conducted across different states of the region, including Assam (Das et al. 2009; Purkayastha et al. 2011; Islam & Saikia 2013; Purkayastha 2018, 2020c; Sengupta et al. 2019; Mahananda et al. 2023), Sikkim (Chettri et al. 2009), Arunachal Pradesh (Agarwal et al. 2010; Sinha et al. 2021), Tripura (Majumder et al. 2012; Purkayastha et al. 2020b), Mizoram (Lalrinchhana & Solanki 2015; Malsawmdawngliana et al. 2022; Gouda et al. 2024; Solanki & Parida 2024), and Meghalaya (Chandramouli et al. 2021).

Revisions

Several important taxonomic revisions have been conducted across different states of northeastern India. Purkayastha et al. (2010) reported *Hemidactylus aquilonius* from Assam, a member of the *H. bowringii* complex, and recommended replacing *H. bowringii* sensu stricto with *H. aquilonius* for the Indian subcontinent. They also restricted the distribution of *H. bowringii* sensu stricto to southern China and its adjacent regions. From Arunachal Pradesh, Gowande et al. (2021) conducted a detailed revision of *Pseudocalotes austeniana*, using molecular phylogenetic data derived from mitochondrial and nuclear genes. Their analysis revealed that the genus *Pseudocalotes* is polyphyletic and comprises two distinct clades. *Pseudocalotes austeniana* was not nested within either clade but instead formed a sister lineage to the genus *Japalura* sensu stricto. Accordingly, the species was transferred to *Japalura austeniana*.

Sengupta et al. (2021) re-diagnosed *Cnemaspis assamensis* based on the original type series and newly collected specimens from Guwahati, Assam. They also provided the first molecular data for the species and confirmed the presence of precloaco-femoral pores, which had been reported as absent in the original description. Boruah et al. (2022) designated a lectotype for *Calotes jerdoni* to ensure taxonomic stability and presented an expanded morphological description of the species. Lalremsanga et al. (2022a) published a comprehensive study on *Tropidophorus assamensis* from Mizoram, updating its morphological data, adding distributional notes, and providing molecular data for the first time, thereby clarifying the phylogenetic position of *T. assamensis* among its congeners.

Rediscoveries

Several notable rediscoveries have been made in northeastern India in recent decades. Das & Das (2007) reported *Japalura austeniana* from West Kameng District, Arunachal Pradesh, nearly a century after its original description by Annandale (1908) from the type locality. Bhupathy et al. (2009) rediscovered *Takydromus sikkimensis* from the lower Teesta Valley, Sikkim, and designated a neotype to resolve uncertainties regarding the identity and existence of the species. Kunte & Manthey (2009) reported *Japalura sagittifera* from the tropical forests of Mehao Wildlife Sanctuary, Arunachal Pradesh, nearly 68 years after its last documented record. Originally described from northern Myanmar, this finding confirmed a significant range extension for the species into India. Islam & Saikia (2013) rediscovered *Draco norvillii* in Jeypore Reserve Forest, Assam, more than a century after its last known record from the state.

Miscellaneous

Das et al. (2007) reported reptilian mortality along the highway bordering the southern boundary of Kaziranga National Park, Assam. Das et al. (2011b) investigated the oral microflora of *Hemidactylus frenatus* and *H. aquilonius* from Guwahati, Assam, and documented the presence of Gram-positive *Staphylococcus* strains known to cause skin infections in mammals, although not fatal. Harit (2018) provided a preliminary report on reptile road mortality in Champhai District, Mizoram, and along the Indo-Myanmar border caused by vehicular traffic. Choudhary & Choudhary (2019) documented the persecution of monitor lizards in Barak Valley, Assam. Ranade & Purkayastha (2020) reported cannibalistic behaviour in *Hemidactylus aquilonius* based on observations from Rani, Assam. Ulman & Singh (2021) surveyed the population density, habitat preferences, and public perception of *Gekko gecko* in Nameri Tiger Reserve, Assam. Rai et al. (2023) provided insights into the sexual dimorphism and reproductive biology of *Takydromus sikkimensis*, highlighting female-biased size differences, seasonal male coloration, and a single annual breeding cycle with small clutch sizes. Thaosen et al. (2024) reported functional males in *Hemidactylus garnotii* from Mizoram, based on histological, and gonadal examinations, in a species previously considered to be entirely parthenogenetic.

DISCUSSION

Although northeastern India has witnessed a recent surge in saurian studies, research efforts remain unevenly distributed across the states. In contrast to states like Assam and Mizoram, where substantial work has been undertaken, states such as Nagaland and Manipur remain largely unexplored. These regions likely harbour undocumented taxa that may be revealed through systematic field surveys, thereby contributing to improved taxonomy, and conservation of regional herpetofauna.

Instances of misidentification were also noted among the reviewed literature. A prominent example concerns *Cyrtodactylus khasiensis,* the distribution of which was restricted to the Khasi Hills of Meghalaya by Agarwal et al. (2018a). This necessitates taxonomic revalidation of *C. khasiensis* records from Arunachal Pradesh (Agarwal et al. 2010), Nagaland (Bhupathy et al. 2013), Sikkim (Chettri et al. 2009), Tripura (Majumder et al. 2012), and Assam (Das et al. 2009; Agarwal et al. 2010; Purkayastha et al. 2011, 2020c; Islam & Saikia 2013). Similarly, Lalrinchhana & Solanki (2015) reported *Hemidactylus brookii* and *Sphenomorphus maculatus* from Dampa Tiger Reserve, Mizoram (see Figures 12 & 17 in Lalrinchhana & Solanki 2015), which appear to be conspecific with *Hemidactylus frenatus* and *Eutropis* sp., respectively. Furthermore, several checklists of saurian diversity from northeastern India such as Jha & Thapa (2002), Chettri et al. (2009), Ahmed et al. (2009), Agarwal et al. (2010), Majumder et al. (2012), and Purkayastha (2013), require updating as a number of the saurian species listed therein have since undergone taxonomic revisions. To address this, the present study provides an updated checklist of lizards from northeastern India (Table 1).

In conclusion, northeastern India holds immense potential for the discovery of many new cryptic lizard species that remain undocumented. This potential can be realized through extensive field surveys across poorly explored regions, supported by advanced statistical approaches for ecological, and morphological analyses. Furthermore, the integration of both mitochondrial, and nuclear markers in phylogenetic frameworks will be essential for resolving species complexes, and accurately documenting the region's true saurian diversity.

REFERENCES

Agarwal, I., S. Biswas, A.M. Bauer, E. Greenbaum, T.R. Jackman, A.D. Silva & S. Batuwita (2017). Cryptic species, taxonomic inflation, or a bit of both? New species phenomenon in Sri Lanka as suggested by a phylogeny of dwarf geckos (Reptilia, Squamata, Gekkonidae, *Cnemaspis*). *Systematics and Biodiversity* 15(5): 427–439. https://doi.org/10.1080/14772000.2017.1282553

Agarwal, I., S. Mahony, V.B. Giri, R. Chaitanya & A.M. Bauer (2018a). Two new species of bent-toed geckos, *Cyrtodactylus* Gray, 1827 (Squamata: Gekkonidae) from northeastern India with comments on name-bearing types from the region. *Zootaxa* 4420(3): 334–356. https://doi.org/10.11646/zootaxa.4420.3.2

Agarwal, I., S. Mahony, V.B. Giri, R. Chaitanya & A.M. Bauer (2018b). Six new *Cyrtodactylus* (Squamata: Gekkonidae) from northeastern India. *Zootaxa* 4524(5): 501–535. https://doi.org/10.11646/zootaxa.4524.5.1

Agarwal, I., V.K. Mistry & R. Athreya (2010). A preliminary checklist of the reptiles of Eaglenest Wildlife Sanctuary, West Kameng District, Arunachal Pradesh, India. *Russian Journal of Herpetology* 17(2): 81–93.

Ahmed, M.F., A. Das & S.K. Dutta (2009). *Amphibians and Reptiles of Northeastern India: A Photographic Guide.* Aaranyak, Guwahati, Assam, India, 169 pp.

Alcock, A. (1895). On a new species of flying lizard from Assam. *The Journal of the Asiatic Society of Bengal* 64(1): 14–15.

Annandale, N. (1905). Notes on some Oriental geckos in the Indian Museum, Calcutta, with descriptions of new forms. *The Annals and Magazine of Natural History, including Zoology, Botany and Geology* 7(15): 26–32.

Annandale, N. (1908). Description of a new species of lizard of the genus *Salea* from Assam. *Records of the Zoological Survey of India* 2(1): 37–38. https://doi.org/10.26515/rzsi/v2/i1/1908/163304

Annandale, N. (1912). Zoological results of the Abor Expedition, 1911–1912. *Records of the Indian Museum* 8(1): 7–59 [Reptilia: 37–59]. Supplement: *Records of the Indian Museum* 8(4): 357–358 (1914).

Annandale, N. (1913). The Indian geckos of the genus *Gymnodactylus*. *Records of the Zoological Survey of India* 9(4): 99–109. https://doi.org/10.26515/rzsi/v9/i4/1913/163665

Bharali, M., K. Thaosen, M. Vabeiryureilai, H.T. Lalremsanga, J. Purkayastha, R. Bhattacharjee, M. Das, S.C. Bohra, A.K. Hazarika (in press). A new species of *Cyrtodactylus* Gray, 1827 (Reptilia: Squamata: Gekkonidae) from the montane forests of Dima Hasao District, Assam, India. *Journal of Asia-Pacific Biodiversity.* Available online 18 July 2025. https://doi.org/10.1016/j.japb.2025.06.008

Bhupathy, S., B. Chettri & A.M. Bauer (2009). Rediscovery and revalidation of *Takydromus sikkimensis* (Günther, 1888) (Squamata: Lacertidae) from Sikkim, India. *Journal of Herpetology* 43(2): 267–274. https://doi.org/10.1670/08-136R1.1

Bleeker, P. (1860). Reptilien van Agam. *Natuurkundig Tijdschrift voor Nederlandsch Indie* 20: 325–329.

Blyth, E. (1854). Notices and descriptions of various reptiles, new or little known. *The Journal of the Asiatic Society of Bengal* 22: 639–655.

Bohra, S.C., H.T. Zonunsanga, M. Das, J. Purkayastha, L. Biakzuala & H.T. Lalremsanga (2022). Morphological and molecular phylogenetic data reveal another new species of bent-toed gecko (*Cyrtodactylus* Gray: Squamata: Gekkonidae) from Mizoram, India. *Journal of Natural History* 56(41–44): 1585–1608. https://doi.org/10.1080/00222933.2022.2119178

Bohra, S.C., C. Ranglong, G. Thongni, B. Wankhar, C.M. Umlong, M. Das, H. Warjri & J. Purkayastha (2025). Leaping from Mizoram to Meghalaya: first documentation of *Calotes zolaiking* Giri, Chaitanya, Mahony, Lalronunga, Lalrinchhana, Das, Sarkar, Karanth & Deepak, 2019 (Sauria: Agamidae) outside its type locality in Mizoram, India. *Zootaxa* 5642(4): 395–400. https://doi.org/10.11646/zootaxa.5642.4.7

Boruah, B., S. Narayanan, N.A. Aravind, S. Lalronunga, V. Deepak & A. Das (2024). Description of six new species of *Cyrtodactylus* Gray (Squamata: Gekkonidae) from northeastern India. *Vertebrate Zoology* 74: 453–486. https://doi.org/10.3897/vz.74.e124752

Boruah, B., S. Narayanan, V. Deepak & A. Das (2022). Morphological and molecular differences in two closely related *Calotes* Cuvier, 1817 (Squamata: Agamidae: Draconinae) with the first record of *Calotes medogensis* Zhao & Li, 1984 from India. *Zootaxa* 5219(5): 433–455. https://doi.org/10.11646/zootaxa.5219.5.3

Boulenger, G.A. (1885). *Catalogue of the Lizards in the British Museum (Natural History).* Printed by order of the Trustees, London, 428 pp.

Boulenger, G.A. (1887). An account of the scincoid lizards collected in Burma, for the Genoa Civic Museum, by Messrs. G.B. Comotto & L. Fea. *Annali del Museo Civico di Storia Naturale di Genova* 4(2): 618–624.

Boulenger, G.A. (1890). *The Fauna of British India, Including Ceylon and Burma. Reptilia and Batrachia.* Taylor & Francis, London, 541 pp.

Boulenger, G.A. (1903). Descriptions of new lizards in the collection of the British Museum. *Annals and Magazine of Natural History* 12(7): 429–435.

Boulenger, G.A. (1917). A revision of the lizards of the genus *Tachydromus*. *Journal of the Asiatic Society of Bengal* 13(4): 207–235.

Chandramouli, S.R., R.S. Naveen, S. Sureshmarimuthu, S. Babu, P.V. Karunakaran & H.N. Kumara (2021). Catalogue of herpetological specimens from Meghalaya, India at the Sálim Ali Centre for Ornithology and Natural History. *Journal of Threatened Taxa* 13(11): 19603–19610. https://doi.org/10.11609/jott.7318.13.11.19603-19610

Che, J., K. Jiang, F. Yan & Y. Zhang (2020). *Amphibians and Reptiles in Tibet—Diversity and Evolution*. Chinese Academy of Sciences, Beijing, 803 pp.

Chettri, B., S. Bhupathy & B.K. Acharya (2009). Distribution pattern of reptiles along an eastern Himalayan elevation gradient, India. *Acta Oecologica* 36(1): 16–22. https://doi.org/10.1016/j.actao.2009.09.004

Choudhury, A.S. & P. Choudhury (2019). Cruelty to *Varanus* species of the Barak Valley, Assam, India. *Biawak* 13(1): 50–53.

Das, A. & I. Das (2007). Rediscovery of *Mictopholis austeniana* (Annandale, 1908) (Squamata: Agamidae). *Current Herpetology* 26(1): 45–47.

Das, A. & M.F. Ahmed (2007). Range extension of Assamese Day Gekko *Cnemaspis assamensis* Das and Sengupta (Sauria: Gekkonidae). *Zoos' Print Journal* 22(6): 2720. https://doi.org/10.11609/JoTT.ZPJ.1513a.2720

Das, A., M.F. Ahmed, B.P. Lahkar & P. Sharma (2007). A preliminary report of reptilian mortality on road due to vehicular movement near Kaziranga National Park, Assam, India. *Zoos' Print Journal* 22(7): 2742–2744. https://doi.org/10.11609/JoTT.ZPJ.1541.2742-4

Das, A., U. Saikia, B.H.C.K. Murthy, S. Dey & S.K. Dutta (2009). A herpetofaunal inventory of Barail Wildlife Sanctuary and adjacent regions, Assam, north-eastern India. *Hamadryad* 34(1): 117–134.

Das, I. & S. Sengupta (2000). A new species of *Cnemaspis* (Sauria: Gekkonidae) from Assam, northeastern India. *Journal of South Asian Natural History* 5(1): 17–24.

Das, M., J. Purkayastha, A.M. Bauer & S. Sengupta (2011a).

Hemidactylus flaviviridis Rüppell, 1835 (Sauria: Gekkonidae), an invasive gecko in Assam. *North-Western Journal of Zoology* 7(1): 98–104.

Das, M., R.K. Brahma & J. Purkayastha (2011b). More in our mind than in their mouth? A preliminary inspection inside the oral cavity of two house geckos: *Hemidactylus frenatus* Schlegel, 1836 and *Hemidactylus aquilonius* McMahan & Zug, 2007. *Herpetology Notes* 4: 303–306.

Datta-Roy, A., I. Das, A.M. Bauer, R.K.L. Tron & P. Karanth (2013). Lizard wears shades. A spectacled *Sphenomorphus* (Squamata: Scincidae) from the sacred forests of Mawphlang, Meghalaya, northeastern India. *Zootaxa* 3701(2): 257–276. https://doi.org/10.11646/zootaxa.3701.2.7

Daudin, F.M. (1802). *Histoire naturelle, générale et particulière des reptiles, ouvrage faisant suite à l'histoire naturelle, générale et particulière composée par Leclerc de Buffon, et rédigée par C.S. Sonnini*, Vol. 1. F. Dufart, Paris, 452 pp.

Decemson, H., R.R. Sinate, L. Biakzuala, V. Mathipi, P. Lalnuntluanga, J. Malsawma & H.T. Lalremsanga (2023). Confirmation of Irawadi Forest Lizard, *Calotes irawadi* Zug, Brown, Schulte and Vindum 2006 (Squamata: Agamidae), from Manipur, northeastern India. *Reptiles & Amphibians* 30(1): e17043. https://doi.org/10.17161/randa.v30i1.17043

Decemson, H.T., M. Vabeiryureilai, L. Lalbiakzuala & H.T. Lalremsanga (2021). Confirmation on the occurrence of *Calotes geissleri* Wagner, Ihlow, Hartman, Flecks, Schmitz and Böhme, 2021 (Sauria: Agamidae) in Chandel, Manipur, India with comments on its phylogenetic position. *Journal of Animal Diversity* 3(4): 14–19. http://doi.org/10.52547/JAD.2021.3.4.2

Deepak, C.K., D. Kaushik & C. Kailash (2022). First record of *Hemiphyllodactylus* Bleeker, 1860 (Squamata: Sauria: Gekkonidae) from the Eastern Himalayas. *Russian Journal of Herpetology* 29(6): 367–372. https://doi.org/10.30906/1026-2296-2022-29-6-367-372

Duméril, A.M.C. & G. Bibron (1836). *Erpétologie Générale ou Histoire Naturelle Complète des Reptiles*. Vol. 3. Librairie Encyclopédique Roret, Paris, 528 pp.

Duméril, A.M.C. & G. Bibron (1837). *Erpétologie Générale ou Histoire Naturelle Complète des Reptiles*. Vol. 4. Librairie Encyclopédique Roret, Paris, 570 pp.

Giri, V.B., R. Chaitanya, S. Mahony, S. Lalrounga, C. Lalrinchhana, A. Das, V. Sarkar, P. Karanth & V. Deepak (2019). On the systematic status of the genus *Oriocalotes* Günther, 1864 (Squamata: Agamidae: Draconinae) with the description of a new species from Mizoram State, northeastern India. *Zootaxa* 4638(4): 451–484. https://doi.org/10.11646/zootaxa.4638.4.1

Gouda, S., H. Decemson, F. Malsawmdawngliana, L. Biakzuala & H.T. Lalremsanga (2023). Threat assessment and conservation challenges for the herpetofaunal diversity of Dampa Tiger Reserve, Mizoram, India. *Journal of Threatened Taxa* 15(10): 24016–24031. https://doi.org/10.11609/jott.8590.15.10.24016-24031

Gowande, G.G., H.S. Bhosale, P.U. Phansalkar, M. Sawant & Z.A. Mirza (2021). On the systematics and the phylogenetic position of the poorly known, montane dragon-lizard species *Pseudocalotes austeniana* (Annandale, 1908) (Squamata: Agamidae: Draconinae). *Evolutionary Systematics* 5(1): 141–150. https://doi.org/10.3897/evolsyst.5.67137

Gray, J.E. (1827). A synopsis of the genera of saurian reptiles in which some new genera are indicated, and the others reviewed by actual examination. *Philosophical Magazine, London* 2(2): 54–58.

Gray, J.E. (1845). *Catalogue of the specimens of lizards in the collection of the British Museum*. Trustees of the British Museum/Edward Newman, London, xxvii + 289 pp.

Gray, J.E. (1846). Descriptions of some new species of Indian Lizards. *Annals and Magazine of Natural History* 18(1): 429–430.

Gray, J.E. (1853). Descriptions of some undescribed species of reptiles collected by Dr. Joseph Hooker in the Khassia Mountains, east Bengal, and Sikkim Himalaya. *Annals and Magazine of Natural History* 12(2): 386–392.

Grismer, L.L., P.L. Wood Jr., N.A. Poyarkov, M.D. Le, F. Kraus, I. Agarwal, P.M. Oliver, S.N. Nguyen, T.Q. Nguyen, S. Karunarathna, L.J. Welton, B.L. Stuart, V.Q. Luu, A.M. Bauer, K.A. O'Connell, E.S.H. Quah, K.O. Chan, T. Ziegler, H. Ngo, R.A. Nazarov, A. Aowphol, S. Chomdej, C. Suwannapoom, C.D. Siler, S. Anuar, N.V. Tri & J.L. Grismer (2021). Phylogenetic partitioning of the third-largest vertebrate genus in the world, *Cyrtodactylus* Gray, 1827 (Reptilia; Squamata; Gekkonidae) and its relevance to taxonomy and conservation. *Vertebrate Zoology* 71: 101–154. https://doi.org/10.3897/vz.71.e59307

Grismer, L.L., M.K. Thura, M.S. Grismer, R.M. Brown & B.L. Stuart (2018). Geographically structured genetic variation in *Ptychozoon lionotum* (Squamata: Gekkonidae) and a new species from an isolated volcano in Myanmar. *Zootaxa* 4514(2): 202–214. https://doi.org/10.11646/zootaxa.4514.2.4

Günther, A. (1864). *The Reptiles of British India*. Ray Society, London, xxvii + 452 pp.

Günther, A. (1870). Descriptions of a new Indian lizard of the genus *Calotes*. *Proceedings of the Zoological Society of London* 1870: 778–779.

Günther, A. (1888). On a collection of reptiles from China. *Journal of Natural History* 1(3): 165–172.

Harit, D.N. (2018). Report on reptile mortality due to vehicular traffic on Indo-Myanmar border at Champhai District of Mizoram, north east India. *Environment Conservation Journal* 19(3): 133–138.

Islam, M. & P.K. Saikia (2013). Inventory and natural history of lizards in Jeypore Reserve Forest, Assam. *Reptile Rap* 16(1): 17–26.

Jerdon, T.C. (1870). Notes on Indian herpetology. *Proceedings of the Asiatic Society of Bengal* 1870: 66–85.

Jha, A. & K. Thapa (2002). *Reptiles and Amphibians of Sikkim.* Mrs. Shila Jha, Chhattisgarh, 100 pp.

Kamei, R.G. & S. Mahony (2021). A new species of Bent-toed Gecko (Squamata: Gekkonidae: *Cyrtodactylus* Gray, 1827) from the Garo Hills, Meghalaya State, north-east India, and discussion of morphological variation for *C. urbanus*. *Herpetological Journal* 31(3): 177–196. https://doi.org/10.33256/31.3.177196

Kunte, K. & U. Manthey (2009). Wiederentdeckung von *Japalura sagittifera* (Sauria: Agamidae) in Arunachal Pradesh, Ost-Himalaya: Ein Erstnachweis für die indische Herpetofauna. *Sauria* 31: 49–55.

Lalremsanga, H.T., Z. Colney, M. Vabeiryureilai, F. Malsawmdawngliana, S.C. Bohra, L. Biakzuala, L. Muansanga, M. Das & J. Purkayastha (2023a). It's all in the name: Another new *Cyrtodactylus* Gray (Squamata: Gekkonidae) from northern Mizoram, north-east India. *Zootaxa* 5369(4): 553–575. https://doi.org/10.11646/zootaxa.5369.4.5

Lalremsanga, H.T., H. Chinliansiama, S.C. Bohra, L. Biakzuala, M. Vabeiryureilai, L. Muansanga, F. Malsawmdawngliana, G.Z. Hmar, H.T. Decemson, V. Siammawii, M. Das & J. Purkayastha (2022b). A new bent-toed gecko (*Cyrtodactylus* Gray: Squamata: Gekkonidae) from the state of Mizoram, India. *Zootaxa* 5093(4): 465–482. https://doi.org/10.11646/zootaxa.5093.4.5

Lalremsanga, H.T., H. Decemson, M. Vabeiryureilai, F. Malsawmdawngliana, V. Lalhlimpuia, L. Muansanga & L. Biakzuala (2022a). Phylogenetic position of *Tropidophorus assamensis* Annandale, 1912 with updated morphological data and distributional records. *Herpetological Journal* 32(1): 1–4. https://doi.org/10.33256/32.1.14

Lalremsanga, H.T., L. Khawlhring & Lalrotluanga (2010). Three additional lizard (Squamata: Sauria) records for Mizoram, India. *Journal of Threatened Taxa* 2(2): 718–720. https://doi.org/10.11609/JoTT.o2246.718-20

Lalremsanga, H.T., L. Muansanga, M. Vabeiryureilai & Z.A. Mirza (2023b). A new species of Parachute Gecko of the subgenus *Ptychozoon* (Sauria: Gekkonidae: Gekko) from the Indo-Burma region. *Salamandra* 59(2): 125–135.

Lalrinchhana, C. & G.S. Solanki (2015). Lizard (Reptilia: Sauria) diversity of Dampa Tiger Reserve, Mizoram, India. *Science Vision* 15(1): 19–28.

Laurenti, J.N. (1768). *Specimen medicum, exhibens synopsin reptilium emendatam cum experimentis circa venena et antidota reptilium austracorum, quod authoritate et consensus.* Joan. Thomae, Vienna, 217 pp.

Linnaeus, C. (1758). *Systema naturae, per regna tria naturae: secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis. Tomus I. Editio decima, reformata.* Laurentii Salvii, Holmiæ, 824 pp.

Mahananda, P., S.N. Jelil, S.C. Bohra, N. Mahanta, R.B. Saikia & J. Purkayastha (2023). Terrestrial vertebrate and butterfly diversity of Garbhanga Landscape, Assam, India. *Journal of Threatened Taxa* 15(4): 23029–23046. https://doi.org/10.11609/jott.8334.15.4.23029-23046

Mahony, S. & R.G. Kamei (2022). A new species of *Cyrtodactylus* Gray (Squamata: Gekkonidae) from Manipur State, northeastern India, with a critical review highlighting extensive errors in literature covering bent-toed geckos of the Indo-Burma region. *Journal of Natural History* 55(39–40): 2445–2480. https://doi.org/10.1080/00222933.2021.1994667

Mahony, S. (2009). A new species of *Japalura* (Reptilia: Agamidae) from northeastern Indiawith a discussion of the similar species *Japalura sagittifera* Smith, 1940 and *Japalura planidorsata* Jerdon, 1870. *Zootaxa* 2212(1): 41–61. https://doi.org/10.11646/zootaxa.2212.1.2

Majumder, J. & B.K. Agarwala (2015). *Calotes emma* Gray, 1845 (Squamata: Agamidae): range extension and new addition to the reptilian fauna of Tripura, northeastern India. *Check List* 11(2): 1562. https://doi.org/10.15560/11.2.1562

Majumder, J., P.P. Bhattacharjee, K. Majumdar, C. Debnath & B.K. Agarwala (2012). Documentation of herpetofaunal species richness in Tripura, northeastern India. *NeBio: An International Journal of Environment and Biodiversity* 3(1): 60–70.

Malsawmdawngliana, B. Boruah, N.G. Patel, S. Lalronunga, I. Zosangliana, K. Lalhmangaiha & A. Das (2022). An updated checklist of reptiles from Dampa Tiger Reserve, Mizoram, India, with sixteen new distribution records. *Journal of Threatened Taxa* 14(10): 21946–21960. https://doi.org/10.11609/jott.8004.14.10.21946-21960

Mathew, R. (1995). State Fauna Series 4: *Fauna of Meghalaya*, Part 1. *Zoological Survey of India*, Kolkata: 379–454.

McMahan, C.D. & G.R. Zug (2007). Burmese *Hemidactylus* (Reptilia: Squamata: Gekkonidae): geographic variation in the morphology of *Hemidactylus bowringii* in Myanmar and Yunnan. *Proceedings of the California Academy of Sciences* 58(23–30): 485–509.

Mirza, Z.A., A.M. Bragin, H. Bhosale, G.G. Gowande, H. Patel & N.A. Poyarkov (2022a). A new ancient lineage of ablepharine skinks (Sauria: Scincidae) from eastern Himalayas with notes on origin and systematics of the group. *PeerJ* 10(1): e12800. https://doi.org/10.7717/peerj.12800

Mirza, Z.A., H. Bhosale, F. Ansari, P. Phansalkar, M. Sawant, G. Gowande & H. Patel (2021). A new species of geckos of the genus *Cyrtodactylus* Gray, 1827 from Arunachal Pradesh, India. *Evolutionary Systematics* 5(1): 13–23. https://doi.org/10.3897/evolsyst.5.61667

Mirza, Z.A., H.S. Bhosale, T. Thackeray, P. Phansalkar, M. Sawant, G.G. Gowande & H. Patel (2022b). A new species of bent-toed geckos of the genus *Cyrtodactylus* Gray, 1827 from western Arunachal Pradesh, India. *Herpetozoa* 35(1): 65–76. https://doi.org/10.3897/herpetozoa.35.e80610

Mirza, Z.A., G. Gowande, T. Thackeray, H. Bhosale, M. Sawant, P. Phansalkar & H. Patel (2024). A new montane-dwelling species of *Japalura* Gray, 1853 (Squamata: Agamidae) from Arunachal Pradesh, India. *Taprobanica* 13(1): 1–8. https://doi.org/10.47605/tapro.v13i1.317

Muansanga, L., H. Decemson, L. Biakzuala, G.Z. Hmar, H.T. Lalremsanga, M. Das & J. Purkayastha (2020). First record of the Jampui Bent-toed Gecko, *Cyrtodactylus montanus* Agarwal, Mahony, Giri, Chaitanya & Bauer, 2018 (Squamata: Gekkonidae), from Mizoram, India. *Reptiles & Amphibians* 27(2): 267–268. https://doi.org/10.17161/randa.v27i2.14325

Patel, H., T. Thackeray, C. Sheth, A. Khandekar & I. Agarwal (2024). A new small-sized *Calotes* Cuvier (Squamata: Agamidae: Draconinae) from the Subansiri River Basin, Arunachal Pradesh, India. *Zootaxa* 5523(2): 151–170. https://doi.org/10.11646/zootaxa.5523.2.1

Pawar, S.S., G.S. Rawat & B.C. Choudhury (2004). Recovery of frog and lizard communities following primary habitat alteration in Mizoram, northeastern India. *BMC Ecology* 4(1): 1–18. https://doi.org/10.1186/1472-6785-4-10

Purkayastha, J. (2013). *An Amateur's Guide to Reptiles of Assam.* Eastern Book House Publishers (India), Guwahati, 144 pp.

Purkayastha, J. (2018). Urban biodiversity: an insight into the terrestrial vertebrate diversity of Guwahati, India. *Journal of Threatened Taxa* 10(10): 12299–12316. https://doi.org/10.11609/jott.3721.10.10.12299-12316

Purkayastha, J., S.C. Bohra & M. Das (2020d). First record of the Urban Bent-toed Gecko, *Cyrtodactylus urbanus* Purkayastha, Das, Bohra, Bauer, and Agarwal, 2018 (Squamata: Gekkonidae), from Meghalaya, India. *Reptiles & Amphibians* 27(3): 512–513. https://doi.org/10.17161/randa.v27i3.14901

Purkayastha, J., H.T. Lalremsanga, B. Litho, Y.S. Rathee, S.C. Bohra, M. Vabeiryureilai, L. Biakzuala & L. Muansanga (2022). Two new *Cyrtodactylus* (Squamata: Gekkonidae) from northeastern India. *European Journal of Taxonomy* 794: 111–139. https://doi.org/10.5852/ejt.2022.794.1659

Purkayastha, J., H.T. Lalremsanga, S.C. Bohra, L. Biakzuala, H.T. Decemson, L. Muansanga, M. Vabeiryureilai, S. Chauhan & Y.S. Rathee (2021). Four new Bent-toed Geckos *Cyrtodactylus* Gray, 1827 (Squamata: Gekkonidae) from northeastern India. *Zootaxa* 4980(3): 451–489. https://doi.org/10.11646/zootaxa.4980.3.2

Purkayastha, J., M. Das & S. Sengupta (2011). Urban herpetofauna: a case study in Guwahati City of Assam, India. *Herpetology Notes* 4(1): 195–202.

Purkayastha, J., M. Das, A.M. Bauer, S. Sengupta & S.K. Dutta (2010). Notes on the *Hemidactylus bowringii* complex (Reptilia: Gekkonidae) in India, and a change to the national herpetofaunal list. *Hamadryad* 35(1): 20–27.

Purkayastha, J., M. Das, S.C. Bohra, A.M. Bauer & I. Agarwal (2020a). Another new *Cyrtodactylus* (Squamata: Gekkonidae) from Guwahati, Assam, India. *Zootaxa* 4732(3): 375–392. https://doi.org/10.11646/zootaxa.4732.3.2

Purkayastha, J., N. Khan & S. Roychoudhury (2020b). A preliminary checklist of herpetofauna occurring in Rowa Wildlife Sanctuary, Tripura, India, pp. 225–233. In: Förstner, U. & W.H. Rulkens (eds.). *Environmental Science and Engineering*. Springer International Publishing. https://doi.org/10.1007/978-3-030-32463-6_10

Purkayastha, J., S. Roychoudhury, B.B. Biswa, M. Das & S. Sengupta (2020c). Herpetofaunal Diversity and conservation status in Amchang Wildlife Sanctuary of Assam, India, pp. 217–223. In: Roy, N., S. Roychoudhury, S. Nautiyal, S. Agarwal & S. Baksi (eds.). *Socio-economic and Ecobiological Dimensions in Resource Use and Conservation: Strategies for Sustainability*. Springer, Cham.

Rai, A., R. Mothey & B. Chettri (2023). Sexual dimorphism and reproductive biology of a Sikkim Endemic Grass Lizard *Takydromus sikkimensis* (Squamata: Lacertidae) in the eastern Himalaya, India. *Herpetological Conservation and Biology* 18: 508–519.

Ranade, S. & J. Purkayastha (2020). Cannibalism in the Kachin Smooth Gecko, *Hemidactylus aquilonius* Zug & McMahan, 2007 (Squamata: Gekkonidae), from Assam, India. *Reptiles & Amphibians* 27(3): 514. https://doi.org/10.17161/randa.v27i3.14902

Rüppell, E. (1835). *Neue Wirbelthiere zu der Fauna von Abyssinien gehörig, entdeckt und beschrieben. Amphibien.* S. Schmerber, Frankfurt am Main, 18 pp.

Sauvage, H.E. (1879). Notice sur quelques reptiles nouveaux ou peu connus de la Nouvelle-Guinée. *Bulletin des Sciences par la Société Philomatique de Paris*, Série 7(3): 47–61.

Sayyed, A., M. Das, A.A.T. Amarasinghe, R. Bhattacharjee & J. Purkayastha (2025). A new day gecko of the *Cnemaspis podihuna* (Reptilia: Gekkonidae) clade from northeastern India. *Taprobanica* 14(2): 107–120. https://doi.org/10.47605/tapro.v14i2.363

Schneider, J.G. (1797). *Amphibiorum Physiologiae Specimen Alterum Historiam et Species Generis Stellionum seu Geckonum Sistens*.

Frankfurt (Oder): C.L.F. Aitzi, 54 pp.

Sengupta, D., C.G. Borah & J. Phukon (2019). Assessment of the reptilian fauna in the Brahmaputra Plains of two districts in Assam, India. *Reptiles & Amphibians* 26(1): 65–67. https://doi.org/10.17161/randa.v26i1.14346

Sengupta, S., J. Purakayasta, N. Anandan, M. Das, K.O. Chan & C. Murthy (2021). The odd one in: re-diagnosis and phylogenetic placement of the Assam Day Gecko, *Cnemaspis assamensis* Das & Sengupta, 2000 (Squamata: Gekkonidae). *Zootaxa* 5048(4): 581–593. https://doi.org/10.11646/zootaxa.5048.4.7

Sinha, B., K.P. Nath & S.D. Gurumayum (2021). Herpetofaunal diversity of Zoological Survey of India campus, Itanagar, Arunachal Pradesh, India. *Records of the Zoological Survey of India* 121(3): 411–418. https://doi.org/10.26515/rzsi/v121/i3/2021/156654

Smith, M.A. (1935). *The Fauna of British India, including Ceylon and Burma. Reptilia and Amphibia. Volume II. Sauria.* Taylor and Francis, London, 185 pp.

Solanki, G.S. & A. Parida (2024). Study on re-establishment of herpetofauna in jhum fallow areas in Mizoram. In: *Proceedings of the Zoological Society*, Springer India, New Delhi: 1–9. https://doi.org/10.1007/s12595-024-00551-3

Tariang, A.D., F. Malsawmdawngliana, L. Biakzuala, H. Decemson, L. Muansanga, L. Rinsanga, M. Vabeiryureilai & H.T. Lalremsanga (2022). Confirmation on the occurrence of *Calotes irawadi* Zug, Brown, Schulte & Vindum, 2006 (Squamata: Agamidae) in Mizoram, northeastern India. *Hamadryad* 39(1 & 2): 88–94.

Thaosen, K., J. Purkayastha, M. Vabeiryureilai & H.T. Lalremsanga (2024). Sexual males in the parthenogenetic *Hemidactylus* cf. *garnotii* (Squamata: Gekkonidae) in Mizoram, India. *Taprobanica* 13: 124–131. https://doi.org/10.47605/tapro.v13i2.337

Uetz, P., P. Freed, R. Aguilar, F. Reyes & J. Hošek (eds.) (2025). The Reptile Database. http://www.reptile-database.org. Accessed on 20.vii.2025.

Wagner, P., F. Ihlow, T. Hartmann, M. Flecks, A. Schmitz & W. Böhme (2021). Integrative approach to resolve the *Calotes mystaceus* Duméril & Bibron, 1837 species complex (Squamata: Agamidae). *Bonn Zoological Bulletin* 70(1): 141–171. https://doi.org/10.20363/BZB-2021.70.1.141

Wall, F. (1908). Remarks on Agamid lizard (*Ptyctolaemus gularis*). *Journal of the Bombay Natural History Society* 18: 505.

Web of Science (2025). https://www.webofscience.com. Accessed on 20.vii.2025.

Ulman, Y. & M. Singh (2021). Density, habitat associations and conservation status of *Gekko gecko* (Tokay gecko) in human-dominated landscapes around Nameri Tiger Reserve, Assam, India. *Acta Ecologica Sinica* 42(3): 188–197. https://doi.org/10.1016/j.chnaes.2021.03.004

Zhao, E. & S. Li (1984). A new species of *Calotes* (Lacertilia: Agamidae) from Xizang (Tibet) [in Chinese]. *Acta Herpetologica Sinica* 3(4): 77–78.

Zug, G.R., H.H.K. Brown, J.A. Schulte II & J.V. Vindum (2006). Systematics of the Garden Lizards, *Calotes versicolor* Group (Reptilia: Squamata: Agamidae), in Myanmar: central dry zone populations. *Proceedings of the California Academy of Sciences* 57(2): 35–68.

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REVIEW

Understanding the ethnozoological drivers and socioeconomic patterns of bird hunting in the Indian subcontinent

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Abstract: Bird hunting and trade pose major threats to avifauna in the Indian subcontinent. Although prohibited under the Indian Wildlife Protection Act of 1972, bird poaching has continued, driven primarily by demand from the pet trade, traditional medicine, and cultural beliefs. This study systematically reviewed literature on the socioeconomic and ethnozoological drivers of bird hunting, and trade across India, Pakistan, Nepal, Bhutan, Bangladesh, and Sri Lanka. Around 124 publications were analysed to examine bird use, socioeconomic drivers, and poaching trends. Keywords including "zootherapy," "ethnozoology," "traditional uses", and "bird trade" were used to identify relevant studies on bird hunting with Google Search, Scopus, and Web of Science. A linear regression analysis revealed a significant negative correlation between the sub-national human development index and the number of species hunted at the state level, while, factors like indigenous population size, and state gross production per capita did not significantly impact hunting prevalence. A chi-square test for independence revealed that subsistence hunting in India was less than expected, with cultural, and commercial factors being more significant drivers of hunting. The pet trade was a key driver of poaching in India and Bangladesh, while traditional falconry in Pakistan severely affected raptor populations. A strong positive correlation was found between the number of studies per state and reported hunting prevalence, highlighting geographical, and temporal biases in research. A more comprehensive analysis is needed to fully understand bird hunting patterns, integrating government seizure records, NGO rescue data, CITES trade data, and online media sources.

Keywords: Bird conservation, bird poaching, ethnoornithology, ethnozoology, exotic bird trade, indigenous hunting, illegal wildlife trade, subsistence hunting, wildlife crime, wildlife hunting.

Hindi: भारतीय उपमहाद्वीप में पक्षी शकिार और व्यापार पक्षी-जीवों के लिए बड़े खतरे हैं। यद्यपि भारतीय वन्यजीव संरक्षण अधनियिम, 1972 के तहत यह प्रतबिंधति है, फरि भी पक्षी शकिार जारी है, जो मुख्य रूप से पालतू व्यापार, पारंपरकि चकित्सिा और सांस्कृतकि मान्यताओं की मांग से प्रेरति है। इस अध्ययन ने भारत, पाकस्तिान, नेपाल, भूटान, बांग्लादेश और श्रीलंका में पक्षी शकिार और व्यापार के सामाजकि-आर्थकि और नृजातीय-प्राणी-वैज्ञानकि कारकों पर साहत्यि की व्यवस्थति समीक्षा की। पक्षयिों के उपयोग, सामाजकि-आर्थकि कारकों और अवैध शकिार के रुझानों की जाँच के लिए लगभग 124 प्रकाशनों का वश्लिेषण कयिा गया। Google सर्च, स्कोपस और वेब ऑफ साइंस के साथ पक्षी शकिार पर प्रासंगकि अध्ययनों की पहचान करने के लिए "प्राणी-चकित्सिा", "नृजातीय-प्राणी-वज्ञिान", "पारंपरकि उपयोग" और "पक्षी व्यापार" जैसे कीवर्ड का उपयोग कयिा गया। एक रेखीय समाश्रयण वश्लिेषण से उप-राष्ट्रीय मानव वकिास सूचकांक और राज्य स्तर पर शकिार की जाने वाली प्रजातयिों की संख्या के बीच एक महत्वपूर्ण नकारात्मक सहसंबंध का पता चला, जबकि स्वदेशी जनसंख्या के आकार और राज्य के प्रतव्यिक्ति सकल उत्पादन जैसे कारकों ने शकिार की व्यापकता को महत्वपूर्ण रूप से प्रभावति नहीं कयिा। स्वतंत्रता के लिए एक चस्क्विायर. परीक्षण से पता चला कि भारत में नर्विाह हेतु शकिार अपेक्षा से कम था, और सांस्कृतकि एवं व्यावसायकि कारक. शकिार के अधकि महत्वपूर्ण चालक थे। भारत और बांग्लादेश में पालतू जानवरों का व्यापार अवैध शकिार का एक प्रमुख कारण था, जबकि पाकस्तिान में पारंपरकि बाज़ शकिार ने शकिारी पक्षयिों की आबादी को गंभीर रूप से प्रभावति कयिा। प्रतिराज्य अध्ययनों की संख्या और. शकिार की व्यापकता की रपिोर्ट के बीच एक मजबूत सकारात्मक सहसंबंध पाया गया, जसिसे शोध में भौगोलकि और लौककि पूर्वाग्रहों पर प्रकाश डाला गया। पक्षयिों के शकिार के पैटर्न को पूरी तरह से समझने के लिए, सरकारी ज़ब्ती रकिॉर्ड, एनजीओ बचाव डेटा, सीआईटीईएस व्यापार डेटा और ऑनलाइन मीडयिा स्रोतों को एकीकृत करते हुए, एक अधकि व्यापक वश्लिेषण की आवश्यकता है।

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THINK WILDLIFE FOUNDATION

INTRODUCTION

Bird hunting and trade pose a significant threat to avifauna across the Indian subcontinent, driven by a range of cultural, economic, and commercial factors (Bhupathy et al. 2013; Roy et al. 2024) . Despite the existence of legislation such as the Wild Life (Protection) Act that prohibits the poaching and trade of wildlife, a study analyzing 182 media reports documented the seizure of 25,850 birds across 109 incidents (Poonia et al. 2022). The illegal bird trade persists due to demand from the pet market, traditional medicine (zootherapy), cultural beliefs (Solavan et al. 2004; Yesodharam et al. 2011; Velho & Laurance 2013; Vijaykumar et al. 2015), subsistence hunting, and sport hunting (Selvan et al. 2013; Das et al. 2017; Ahmed et al. 2021).

The use of birds in traditional medicine is widespread across the Indian subcontinent, reflecting broader global trends. The World Health Organization (WHO) estimates that 80% of the global population relies on traditional medicine, including zootherapy (WHO 2022). In northeastern India, 24 bird species have been documented as being used by 17 ethnic groups to treat 37 diseases (Das et al. 2017). Similarly, in Bhutan, five bird species are commonly used in Sowa Rigpa Medicine (Yeshi et al. 2021). Bird use in ethnopharmacology is prevalent across Nepal and Pakistan as well (Lalramnghinglova 1999; Negi & Palyal 2007; Lohani 2010, 2012; Lokwani 2011; Tynson et al. 2012; Paudyal 2014; Paudyal & Singh 2014; Kushwah 2017; Shoukat et al. 2020; Adhikari et al. 2020, 2023; Ahmad et al. 2021; Kunwar 2024). Beyond medicinal use, superstitious rituals and religious practices also drive the poaching of certain species. For example, the Mottled Wood Owl *Strix ocellata*, and Brown Fish Owl *Bubo zeylonensis* are frequently targeted for illegal trade in India during the Diwali festival, where they are used in black magic practices (Ahmed 2010).

Hunting for sport and captive breeding further exacerbates the decline of several bird species. In Pakistan, the hunting of the Houbara Bustard *Chlamydotis undulata* has surged as its populations have declined in the Middle East and northern Africa, making the country a key destination for Arab falconers (Tourenq et al. 2005). The live capture of raptors, including the Laggar Falcon *Falco jugger*, and White-eyed Buzzard *Butastur teesa*, has also increased due to high mortality rates in falconry, further driving illegal poaching in Pakistan (Mohan & Athreya 2011). Meanwhile, in both Nepal and Bangladesh, there have been numerous records of bird and wildlife poaching for ethnozoological purposes (Poudel & Singh 2016; Barkat et al. 2021).

In India, subsistence hunting remains a significant driver of bird poaching in some regions. For instance, in Pangti Village, Wokha District of Nagaland, the massacre of Amur falcons *Falco amurensis* was driven for local consumption, and for sale in a nearby market (Mero & Mishra 2022). Despite the prevalence of bird hunting across the Indian subcontinent, limited efforts have been made to synthesize available data at a national scale. Research on bird poaching is often localized within a specific state or district or included as part of broader wildlife trade analyses (Niraj et al. 2012; Poonia et al. 2022; Singh 2023).

This literature review aims to consolidate and analyse the socioeconomic and ethnozoological drivers of bird hunting and trade in the Indian subcontinent, covering India, Bhutan, Nepal, Pakistan, and Bangladesh. Maldives, though a part of the Indian subcontinent, is not included in the study due to a lack of publications on the topic. Specifically, the review aims at identifying the ethnozoological uses of birds, including traditional medicine, and cultural practices. Additionally, it investigates the correlation between income levels, the subnational human development index (SHDI), and bird hunting prevalence at a subnational level. SHDI is a more comprehensive socioeconomic factor than household income, which incorporates factors like education, standard of living, and health. Lastly, the review identifies patterns in bird trade, including available data on species hunted, trade quantities, pricing, trade routes, and involvement of tribal communities.

Furthermore, this review seeks to identify critical knowledge gaps and data limitations in existing literature. By incorporating insights from both peer-reviewed studies and technical reports (e.g., TRAFFIC, WWF), this study aims to provide a comprehensive assessment of bird poaching trends, and their implications for conservation efforts in the region.

METHODS

Literature search

The preliminary literature search was conducted using the search terms “bird trade” and “bird hunting” on Google Search, Scopus, and Web of Science databases. The initial search was limited to articles covering bird hunting and trade in India, as this was the initial scope of the project. Only 11 articles were found in India for these specific keywords. Therefore, the geographic scope of the search was expanded to all countries in the Indian subcontinent, including Pakistan, Bhutan, Nepal, Bangladesh, and Sri Lanka. This resulted in an additional 14 articles on the topic of bird hunting and trade, bringing the total to 25 publications.

Snowballing techniques were used to identify other potential primary keywords related to bird hunting in the region from references cited in the preliminary papers on "bird hunting" and "bird trade". From these papers, a recurring theme of literature cited was the traditional use of birds by indigenous communities. Phrases such as "zootherapy", "ethnozoology", "traditional uses", and "ethnopharmacology" were identified as key search terms. Literature with these themes was in the scope of this literature review, which aimed to identify the drivers, uses, and patterns of bird trade and hunting in the region. While these keywords did produce studies solely focused on the traditional uses of birds, many papers were more generic and included wildlife as a whole. Additionally, numerous papers on the generic themes of "bird conservation", "illegal wildlife trade", and "wildlife hunting" were also identified. From the search results, any article within the geographical scope that contained the trade, hunting, or ethnozoological use of at least one species of wild bird was utilized for the study (Mirin & Klinck 2021). Publications without explicit reference to the trade, hunting, or use of a single avian species were not utilized for the literature review. The distribution of literature across keywords is illustrated in Table 1.

The literature review was not limited only to peer-reviewed publications. Technical reports from organizations, such as TRAFFIC and WWF, were also utilized for this publication. Preprint repositories such as bioRxiv and ResearchSquare were also searched, using all the mentioned keywords. The literature review also aimed to identify temporal patterns in bird hunting and trade in the region. Therefore, there was no criterion regarding the timeframe within which a study was published. The earliest study included was published in 1986 (Mian 1986). All relevant studies published until November 2024, was included in this study.

Zotero has a built-in duplicate detection feature that was utilized to prevent the duplication of publications in the literature review. Additionally, a manual review of the citation was also conducted to remove duplicate publications (Mirin & Klinck 2021). In total 124 publications were used for the literature review, that includes 120 peer-reviewed publications, two preprints, and two technical reports.

Table 1. Number of Publications Retrieved by Keyword: Various keywords were applied in Google Scholar, Web of Science and Scopus to compile information on the drivers of bird hunting and trade in the Indian subcontinent.

Keyword	Number of results
Bird Trade	13
Bird Hunting	12
Bird Conservation	10
Ethnopharmacology	22
Ethnozoology	24
Illegal Wildlife Trade	8
Wildlife Traditional Uses	12
Wildlife Hunting	9
Zootherapy	14

Literature review data collection

A wide array of information was extracted from each source, including metadata of the study, such as study location, data collection methods, year of publication, and, where relevant, the ethnic groups interviewed.

The studies were further categorized by geographical scale, ranging from local to international levels. Local-level studies were confined to a single jurisdiction below the district level, such as a forest division, city, village, or market. District and state-level studies encompassed multiple locations within a district or state, respectively. Regional studies spanned two or more states within a single country, while national-level studies examined wildlife trade across an entire country. International-level studies included research conducted across multiple countries.

This literature review incorporated studies employing both primary and secondary data collection methods. Primary methods included local interviews and market surveys, whereas secondary methods relied on government seizure records, crime data, and news reports. Additionally, species-specific data were compiled from each source, covering bird species involved in trade, hunting, or seizures. The scientific names of the recorded species were obtained from HBW-BirdLife Version 5.0 (December 2020), while their conservation status was determined using the IUCN Red List (2024). Additional details, such as the number of seizures, the individual birds involved, trade or hunting purposes, pricing information, the ethnic groups engaged, the body parts used, and any associated ethnozoological beliefs linked to the species.

Socioeconomic data collection

The trends in bird species were compared to various socioeconomic parameters. The first amongst these was the sub-national human development index provided by the global data index (Global Data Lab 2022).

Another socioeconomic factor utilized in this study was the net state domestic product (NSDP) per capita for each Indian state. This was chosen to identify whether income levels affected the likelihood of hunting birds. The state-wise data were retrieved using the data provided from the Press Information Bureau under the Ministry of Statistics and Program Implementation (Press Information Bureau 2023). Different conversion rates were used because the per capita NSDP values for each state are reported for different fiscal years. Exchange rates fluctuate annually, so applying a single rate for all years would introduce inaccuracies. To ensure a more precise conversion, 2020–21 data was converted using the average exchange rate of ₹74.00 per USD for that year while the 2021–22 data was converted using ₹74.50 per USD (average for that period). Finally, the 2022–23 data was converted using ₹82.00 per USD, reflecting the depreciation of the Indian rupee in that timeframe. Unfortunately, similar state-wise data was not found for the provinces and states of Bangladesh, Pakistan, and Nepal.

As this study aimed at identifying any ethnozoological patterns of bird hunting in the region, the population of scheduled tribes (ST) in each Indian state were also retrieved from the 2011 national census (Ministry of Tribal Affairs 2013). Like NSDP, the state-wise population of indigenous and tribal communities in Bangladesh, Pakistan, and Nepal was not found.

Simple linear regression analysis was conducted to understand how factors such as SHDI, NSDP per capita, and ST population influenced the number of species hunted, and the number of bird hunting records per state. Additionally, a linear regression was conducted to determine the influence of the number of publications on the number of species hunted.

RESULTS

Geographical distribution of literature

India contributed the highest proportion of studies, representing 61% (n = 76), followed by Pakistan with 20% (n = 25), Nepal with 15% (n = 19), and Bangladesh with 4% (n = 5). Bhutan had only one publication, which did not include a recorded list of hunted species. At a subnational level, Arunachal Pradesh had the highest number of publications (n = 12). In fact, there was a disproportionate number of publications from the northeast Indian States, with 23 studies being published from the states of Arunachal Pradesh, Assam, Manipur, Mizoram, Meghalaya, and Sikkim.

In terms of geographical scale, most studies (n = 51) were conducted at the district level. This was followed by state-level (n = 26) and local-level (n = 25) studies. Fewer studies were conducted at broader scales, with nine at the regional level and 12 at the national level. Only one study was conducted at an international level, incorporating data from Bangladesh, Nepal, Pakistan, and India. The geographical distribution of literature is depicted in Figure 1.

Temporal distribution of literature

The earliest study on bird hunting, trade, and poaching dates back to 1986. A significant increase in publications occurred after 2010, with 81% of all studies (n = 106) published in this period, including 76 studies released after 2015. The peak year for publications was 2020, with 13 studies, followed by 2015 with 12. The temporal distribution of these studies is illustrated in Figure 2.

Overview of species hunted

A total of 1,578 records of hunting from 613 bird species were derived from the 124 published articles. The Rock Pigeon *Columba livia* was the most frequently cited species in studies on bird hunting, with 55 citations. It was followed by the House Sparrow *Passer domesticus* and the Indian Peafowl *Pavo cristatus*, each with 38 citations, and the Red Junglefowl *Gallus gallus* with 27 citations. Table 2 presents the 10 most commonly cited species in publications on bird hunting in the region.
Around 64.3% of the hunted species were classified as 'Least Concern' by the IUCN Red List of 2022 (n = 529). This was followed by 35 species classified as 'Near Threatened' and 26 as 'Vulnerable'. Figure 3 represents the distribution of recorded species across the IUCN Red List.

Spatial distribution of hunted species

India had the highest number of hunted species recorded with 490 species, followed by Pakistan, Nepal, and Bangladesh as depicted in Figure 4. The one publication from Bhutan did not provide specific species. The hunted species list often overlapped across countries.

At a sub-national level, the state of Arunachal Pradesh in northeastern India had the highest prevalence of hunting, with 141 hunting records from 110 species. This was followed by Tamil Nadu with 68 species, and Jammu & Kashmir with 33 species.

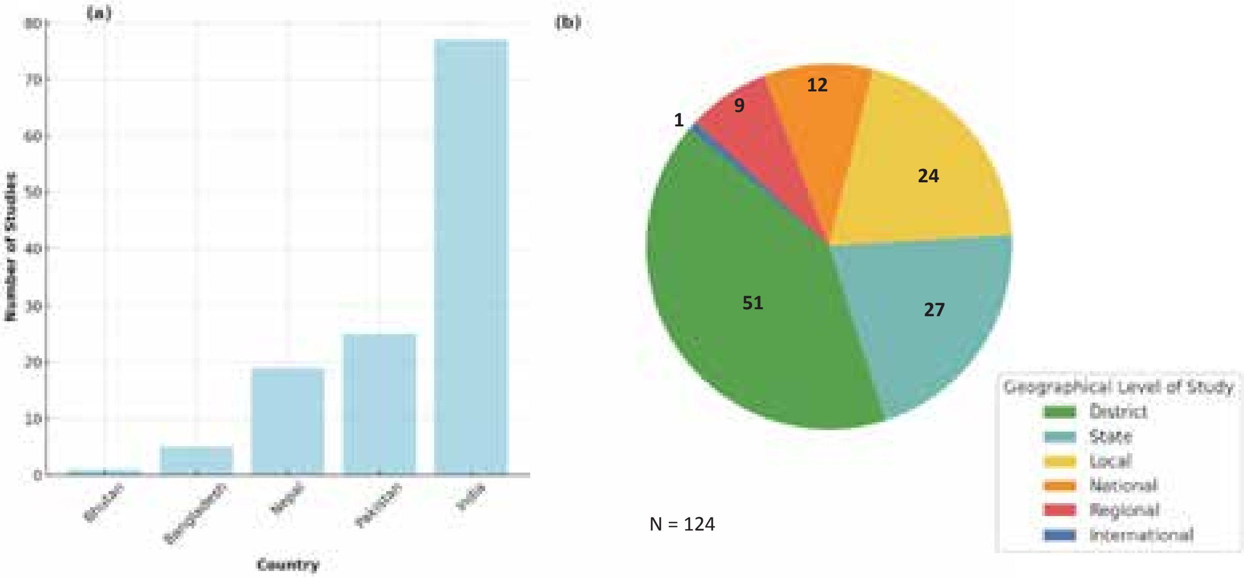

Figure 1. Geographic distribution of published studies on bird hunting, trade and poaching: India had the highest number of publications with 76 studies, followed by Pakistan at a distant second with 24: a—within countries, 51 studies were conducted a district level followed by a state and local with 26 and |b—25 studies.

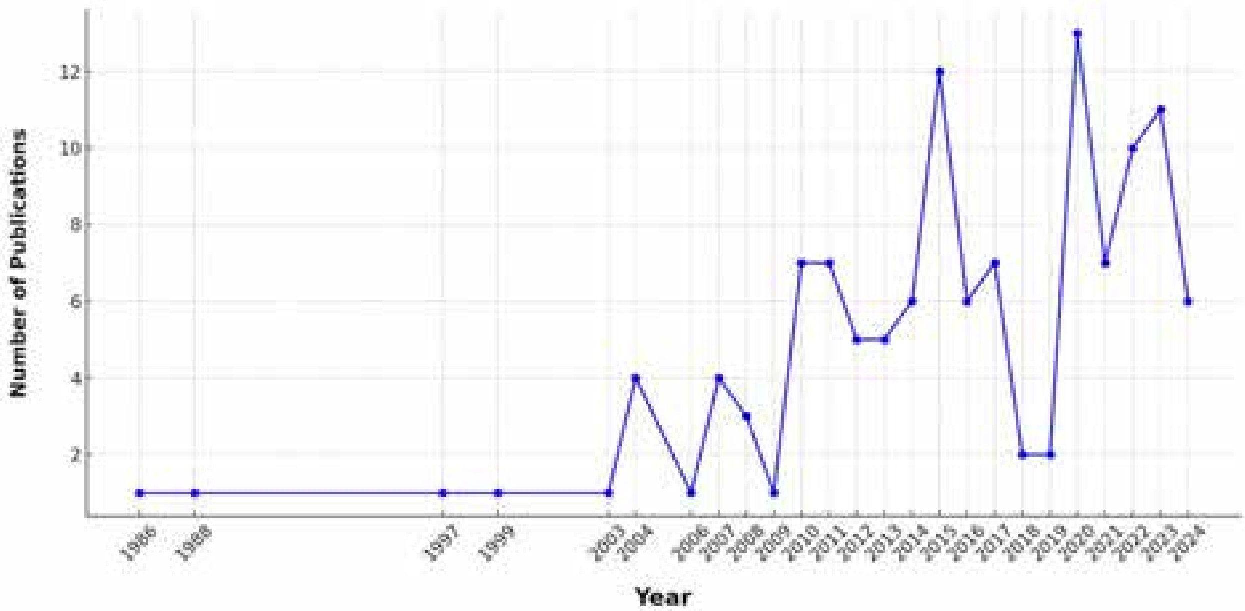

Figure 2. No. of publication on bird hunting, trade, and poaching per year: the highest number of studies were published in 2020 (n = 13), followed closely by 2015 (n = 12).

Correlation between number of studies and species hunted per state

A simple linear regression was conducted to examine the relationship between the number of publication and number of hunted species recorded in each state. A significant positive correlation was recorded between the number of hunted species recorded in a state and the number of studies. Specifically, for each additional study conducted within a state, the number of hunted species recorded in the state increased by 9.06 species (F-statistic = 39.47, df = (1,44), $p < 0.01$). The model explains 47% of the variation. This relationship is illustrated by Figure 5.

Relationship between sub-national human development index and bird hunting

A simple linear regression analysis was performed to assess the relationship between the SHDI and the number of hunted species recorded in each state. The results indicated a significant negative correlation, with the number of hunted species decreasing as SHDI increased (F-statistic = 4.77, df = (1,44), $p < 0.05$). The model accounted for 10% of the variation in the number of hunted species. Figure 6 represents the relationship between SHDI and the number of hunted species.

Relationship between net state domestic production per capita and bird hunting

A linear regression analysis was conducted to estimate the correlation between number of species hunted with the net state domestic product per capita (USD) across each Indian state. A negligible insignificant negative relationship was detected as NSDP per capita only determined 0.3% of the variation in number of species hunted in each state (F-statistic = 0.08, df = (1,44), p-value = 0.769). Similarly, no significant correlation was detected between NSDP per capita and number of bird

Table 2. Ten most frequently cited species for hunting in published literature from the region. The number of citations refer to the number of studies that identified the hunting of the species.

Common name	Scientific name	Order	IUCN Red List status	Number of citations
Rock Pigeon	*Columbia livia*	Columbiformes	Least Concern	55
House Sparrow	*Passer domesticus*	Passeriformes	Least Concern	38
Indian Peafowl	*Pavo cristatus*	Galliformes	Least Concern	38
Red Junglefowl	*Gallus gallus*	Galliformes	Least Concern	27
House Crow	*Corvus splendens*	Passeriformes	Least Concern	21
Great Hornbill	*Buceros bicornis*	Bucerotiformes	Vulnerable	17
Common Mynah	*Acridotheres tristis*	Passeriformes	Least Concern	17
Common Quail	*Coturnix coturnix*	Galliformes	Least Concern	16
Spotted Dove	*Spilopelia chinensis*	Columbiformes	Least Concern	15
Large-billed Crow	*Corvus macrorhynchos*	Passeriformes	Least Concern	14

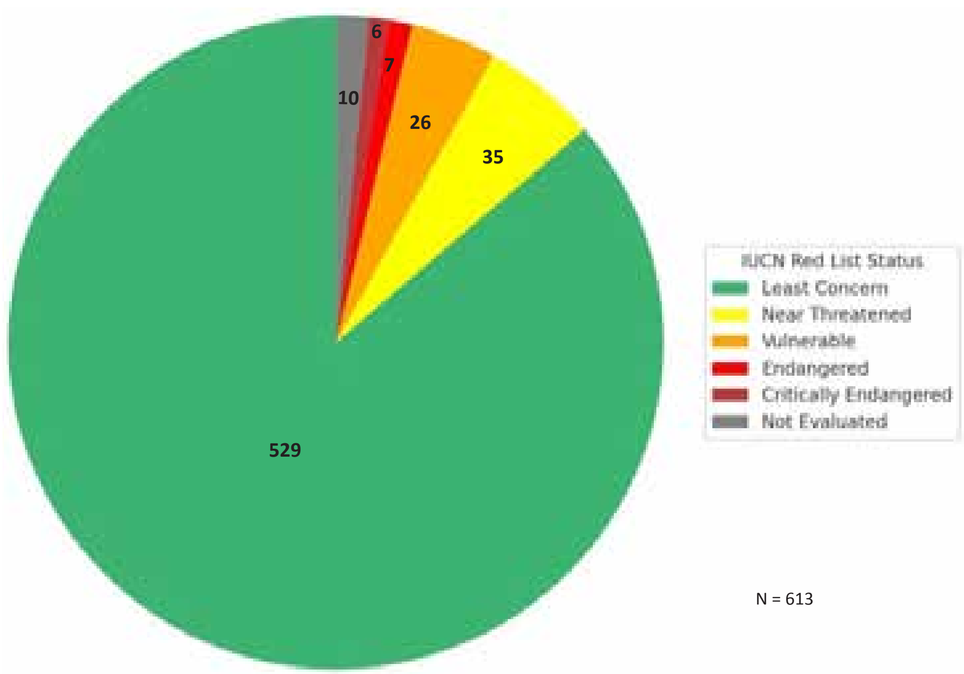

Figure 3. Distribution of recorded species across the IUCN Red List: 529 species were classified as "Least Concern", followed by 35 as "Near Threatened", 26 as "Vulnerable", seven as "Endangered" and six as "Critically Endangered". Around 10 species were classified as "Not Evaluated.

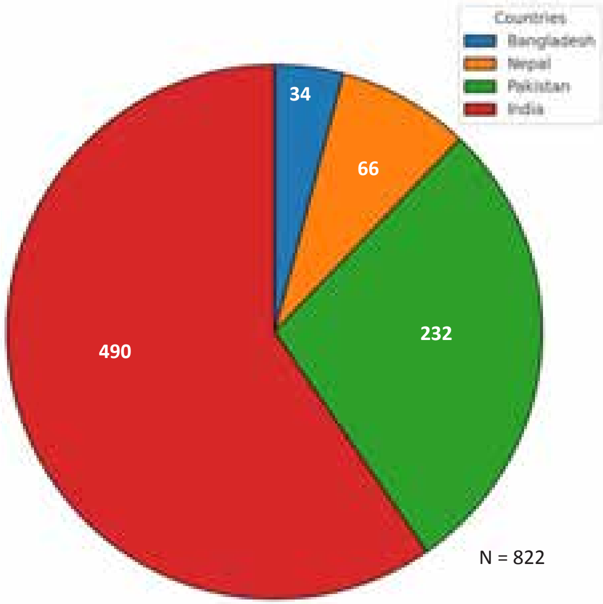

Figure 4. No of hunted birds reported from each country: India recorded the highest number of hunted species (n = 490), followed by Pakistan (n = 232), Nepal (n = 66), Bangladesh (n = 34).

hunting records in each state (F-statistic = 0.07, df = (1,44), p-value = 0.797).

Relationship between state-wise schedule tribe population and bird hunting

A total of 92 tribal communities were recorded to be involved in the trade, hunting, and poaching of birds across the region. The Mughal, Sayed, Sheik, and Malik communities of Pakistan were recorded with the highest number of species hunted (117 each).

A simple linear regression analysis was conducted to examine the relationship between the population of tribals and the number of species hunted in each state. The analysis was limited to the ST population in each Indian state as the state-wise population of indigenous and tribal communities of Pakistan, Nepal, and Bangladesh were not found. Results show a very weak and insignificant negative relationship between the number of species hunted and the ST population (F-statistic = 0.1289, df = (1,44), p-value = 0.722), with the model explaining only 0.4% of the variation in species count.

Similarly, a separate linear regression was performed to analyse the relationship between the ST population and the number of bird hunting records in each state. The findings indicated that the ST population accounted for only 0.2% of the variation in hunting records, again showing an insignificant negative relationship (F-statistic = 0.06, df = (1,44), p-value = 0.808).

Drivers of bird hunting across countries

A chi-squared test of independence was conducted to examine whether the distribution of the bird use categories varied significantly across India, Pakistan, Bangladesh, and Nepal. The test revealed a highly significant difference ($\chi^2 = 415.47$, df = 18, $p < 0.0001$), indicating that the differential utilization of species differed significantly across countries.

The observed and expected frequencies revealed significant deviations across specific use categories. Pakistan recorded 190 instances of birds being used for cultural purposes, markedly exceeding the expected count of 92.3. Similarly, India showed a disproportionately high number of records in the pet trade (observed = 267, expected = 198.0), and zoo trade (observed = 22, expected = 12.6). In contrast, Bangladesh had significantly fewer records than expected across most categories, with zero recorded instances for medicine and food, compared to the expected 8.9 and 2.7, respectively. Lastly, Nepal demonstrated a greater-than-expected reliance on species for medicinal (observed = 63, expected = 35.1), and food purposes (observed = 33, expected = 10.6). Categorization of bird uses for different purposes across countries is illustrated in Figure 7.

DISCUSSION

This literature review aimed to identify the ethnozoological and socioeconomic drivers of bird hunting and trade. Surprisingly, no correlation was found between net state domestic production per capita and the prevalence of bird hunting across different states. This contradicts previous studies that have linked poverty with wildlife poaching and crime in regions such as the Serengeti (Harrison et al. 2015), the Amazon, and the Congo Basin (Choudhury & Talukdar 2023), where bushmeat serves as both a source of protein, and livelihood (Harrison et al. 2015; Choudhury & Talukdar 2023). Notably, in Uganda, poverty alleviation has been an effective tool for mitigating wildlife crime, and poaching (Rane & Datta 2015).

While this review did not establish a direct correlation between income and hunting prevalence, findings indicate that hunting activity decreases with an increasing SHDI. This aligns with previous research conducted in Brazil (El Bizri et al. 2024), Europe (Harrison et al. 2015), and central & western Africa (Nasi et al. 2011). Moreover, this literature review found that subsistence was not a primary driver of bird hunting in

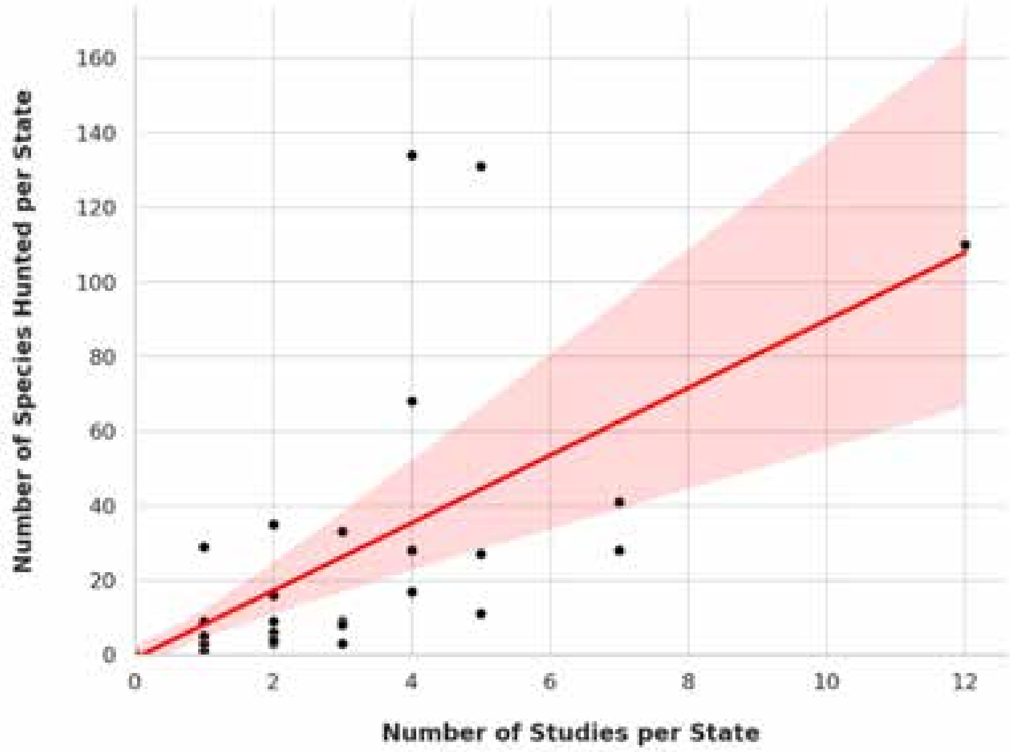

Figure 5. Relationship between the number of publications and the number of hunted species recorded in each state: a significant positive correlation was recorded between the number of hunted species recorded in a state and the number of studies ($p < 0.01$).

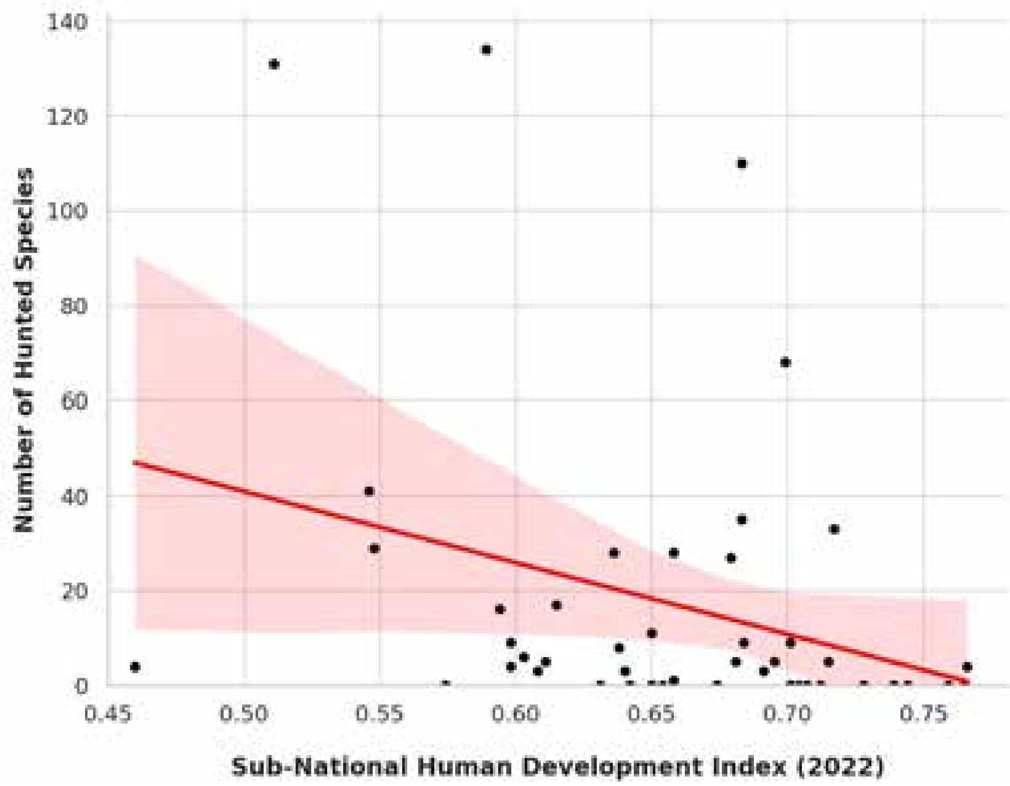

Figure 6. Relation between sub-national human development index at a state level and the number of hunted species recorded: a significant positive correlation was recorded between the number of hunted species recorded in a state and the number of studies ($p < 0.01$).

South Asia, suggesting that poverty alleviation alone may be insufficient to curb hunting, and that broader improvements in overall socioeconomic wellbeing are likely more effective. This study found that factors like cultural traditions and commercial wildlife trade were bigger drivers of bird hunting in the region.

For instance, this study found that cultural practices was a major driver for bird hunting in Pakistan, where traditional falconry, and sport hunting has severely impacted endangered bird populations (Ali & Khan 2019; Kumar & Kant 2021; Muhammad et al. 2021; Sadam 2022). Meanwhile, the pet trade was identified as a major driver of bird poaching in India and Bangladesh, surpassing its prevalence in neighbouring countries. This aligns with the growing concern over the commercialization of the domestic wildlife trade and the rising exotic pet market in the region (Ahmed 1997; Singh et al. 2011; Paudel et al. 2020; Poonia et al. 2020; Choudhury & Talukdar 2023; Hinsley et al. 2024; Uddin 2024). The demand for birds as traditional medicine, while existent in South Asia, was not identified as a major driver of bird hunting in this literature review (Mahawar & Jaroli 2006; Mahaway & Jaroli 2007; Mahawar 2008; Quave et al. 2010; Rai & Singh 2015; Negi & Kandari 2017; Ataf et al. 2018; Mughal et al. 2020; Mussarat et al. 2021; Mandal & Rahaman 2022; Shrestha & Bajracharya 2023; Bashir et al. 2023).

Interestingly, in India, bird poaching for cultural purposes was not a major driver of bird hunting, despite its prevalence in Arunachal Pradesh. This possibly could be attributed to India has strict legislation, such as the Wild Life (Protection) Act (1972), and Forest Rights Act (2008), which strictly prohibits traditional hunting (Robinson et al. 2018). Additionally, no significant correlation was found between the population of scheduled tribes and hunting prevalence at the state level in India. Contrastingly, in regions, such as the Peruvian Amazon (Aiyadurai et al. 2010), Indonesia (Francesconi et al. 2018), Malaysia (Tukuboya et al. 2024), traditional hunting practices have contributed to drastic wildlife declines. Similar trends have been recorded in northeastern India as well (Solanki & Chutia 2009; Solanki et al. 2004; Solanki & Chutia 2004; Aiyadurai et al. 2010; Aiyadurai 2012; Singh 2023).

A possible explanation for this unexpected finding is the geographical bias in the reviewed publications. This represents a limitation of the literature review, as a strong positive correlation has been observed between the number of studies conducted and the reported hunting prevalence across states. Notably, around 23% of the analysed studies focused on northeastern India (Lalramnghingloa 1999; Kumar & Riba 2005; Chakravoty et al. 2011; Chinlampianga et al. 2013; Chaudhury et al. 2016; Chowdhury et al. 2017; Betlu 2022).

While traditional hunting has historically posed a significant threat to wildlife in this region, community-led conservation initiatives have achieved remarkable success (Dasgupta 2012; Shepherd et al. 2023). For instance, the Pakke Paga Hornbill festival in Arunachal Pradesh and the Amur Falcon conservation efforts in Nagaland have not only significantly reduced the hunting of these species but also encouraged widespread community engagement in conservation programs (Rane & Datta 2015; Smith & Lee 2024). Similarly, southern India (Dixit 2010; Chellappandian et al. 2014; Gubbi & Linkie 2015; Holennavar 2015; Vijaykumar et al. 2015; Ramachandran et al. 2017; Sinha et al. 2023), and the province of Azad Jammu & Kashmir in Pakistan occupied Kashmir were regions with a substantial number of studies (Hakeem et al. 2017; Faize et al. 2022; Hassan et al. 2022; Faiz & Altaf 2024).

In contrast, only nine studies focused on bird hunting from central and eastern Indian states, including Andhra Pradesh, Bihar, Chhattisgarh, Madhya Pradesh, Odisha, Jharkhand, West Bengal, Telangana, and Maharashtra (Choubey 2021). Although wildlife hunting is prevalent in central India and the Eastern Ghats, there is limited scientific documentation in the region (Benarjee et al. 2010; Rao et al. 2010; Bagde & Jain 2013; Misar & Subhas 2014; Mishra et al. 2020; Gajendra & Tirkey 2020; Samal et al. 2020; Chakraborty & Mondal 2021; Sethi 2022; Patil 2022; Veena & Krishna 2023; Pandey 2024). Provided that these states are among the poorest in India and host significant tribal populations, bird hunting by tribal communities in India is likely to be understated (George et al. 2014).

Additionally, a significant temporal bias was noted in the publications. A majority (61.3%) of the studies were published within the last 10 years, while 85.5% were published within the last 15 years. This temporal limitation restricts the ability to analyse long-term trends in bird hunting. Moreover, it prevents an assessment of whether critical legislative measures, such as the Forest Rights Act and the Wildlife Conservation (Protection) Amendment Act, have had any tangible impact on bird hunting.

While this review provides a broad overview of trends in bird poaching, hunting, and trade, more comprehensive studies incorporating diverse data sources are required. For instance, data from forest departments, the Wildlife Crime Control Bureau, and wildlife rescue centres would offer valuable insights into

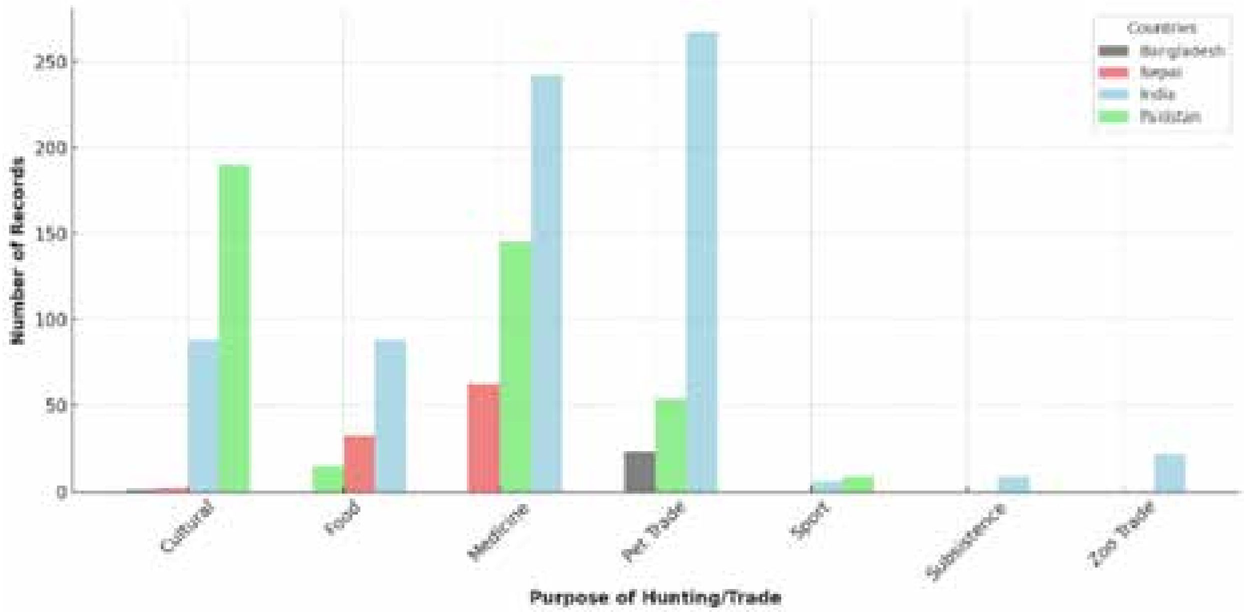

Figure 7. Categorization of bird uses for different purposes across countries. The Chi-Squared test of Independence revealed a highly significant difference amongst use categories.

bird poaching, and seizures at the local level.

Other potential sources include the CITES database, which records the legal international trade of birds, as well as online platforms such as social media, e-commerce websites, and news media reports (Datta 2021), which are increasingly relevant given the rising use of the internet for the exotic pet trade (Massocato et al. 2024). Incorporating seizure and poaching data from these sources will be critical in developing a more holistic understanding of the bird trade in the region. This would be particularly useful, as through the literature review, there was negligible data extracted on the quantity, prices, and trade routes of specimens traded for each species. Lastly, an analysis on specific habitats, such as wetlands, and taxa, such as cranes & parakeets, might provide useful insights, due to the prevalence of habitat, and taxa-specific poaching (Pandit 1988; Tariq 2015; Gosai et al. 2016; Umar et al. 2018; Rehman et al. 2022; Pandey et al. 2024).

REFERENCES

Adhikari, A., K. Timilsina, S. Koirala & R. Bhandar (in press). Illegal wildlife trade in a protected area of western Himalayas, Nepal. 11 September 2023 PREPRINT Version 1 available at Research Square https://doi.org/10.21203/rs.3.rs-3326827/v1

Adhikari, J., B. Bhattarai, M. Rokaya & T. Thapa (2020). Ethno-medicinal uses of vertebrates in the Chitwan-Annapurna landscape, central Nepal. *PLOS ONE* 15(10): e0240555. https://doi.org/10.1371/journal.pone.0240555

Ahmad, S., M. Akram, M. Riaz, N. Munir, I. M. Tahir, H. Anwar, R. Zahid, M. Daniyal, F. Jabeen, E. Ashraf, G. Sarwar, G. Rasool & S.A. Shah (2021). Zootherapy as traditional therapeutic strategy in the Cholistan desert of Bahawalpur, Pakistan. *Veterinary Medicine and Science* 9(4): 1861–1868. https://doi.org/10.1002/vms3.491

Ahmed, A. (1997). *Live Bird Trade in Northern India*. TRAFFIC India, New Delhi, 104 pp. https://portals.iucn.org/library/sites/library/files/documents/Traf-082.pdf

Ahmed, A. (2010). *Imperilled Custodians of the Night: A Study of Illegal Trade, Trapping and Utilization of Owls in India*. TRAFFIC India, New Delhi, 78 pp. https://www.traffic.org/site/assets/files/3160/imperilled-custodians-of-the-night-1.pdf

Ahmed, T., F. Rehman, G. Saba, N. Munawar, T. Mahmood, F. Akram & A. Baig (2021). Hunting pressure on two migratory species, Common Crane *Grus grus* and Demoiselle Crane *Anthropoides virgo* in Khyber Pakhtunkhwa Province, Pakistan. *International Journal of Biosciences* 19(4): 76–83. https://doi.org/10.12692/ijb/19.4.76-83

Aiyadurai, A. (2012). Bird hunting in Mishmi Hills of Arunachal Pradesh, north-eastern India. *Indian Birds* 7(5): 134–137.

Aiyadurai, A., N.J. Singh & E.J. Milner-Gulland (2010). Wildlife hunting by indigenous tribes: a case study from Arunachal Pradesh, north-east India. *Oryx* 44(4): 564–572. https://doi.org/10.1017/S0030605309990937

Ali, A. & A. Khan (2019). Trapping techniques and lure (bait) used in capturing of falcons in Punjab, Pakistan. *Pakistan Journal of Zoology* 52(1): eSC4. https://doi.org/10.17582/journal.pjz/2020.52.1.sc4

Altaf, M., M. Umair, A. Abbasi, N. Muhammad & A. Abbasi (2018). Ethnomedicinal applications of animal species by the local communities of Punjab, Pakistan. *Journal of Ethnobiology and Ethnomedicine* 14(1): e55. https://doi.org/10.1186/s13002-018-0253-4

Arshad, M., M. Ahmad, E. Ahmed, A. Saboor, A. Abbas & S. Sadiq (2014). An ethnobiological study in Kala Chitta hills of Pothwar region, Pakistan: multinomial logit specification. *Journal of Ethnobiology and Ethnomedicine* 10(1): e13. https://doi.org/10.1186/1746-4269-10-13

Badola, S. (2020). Indian Wildlife Amidst the COVID-19 crisis: An Analysis of Status of Poaching and Illegal Wildlife Trade. TRAFFIC & WWF, New Delhi, India, 35 pp. https://wwfin.awsassets.panda.org/

downloads/indian_wildlife_amidst_the_covid_19_crisis.pdf

Bagde, N. & S. Jain (2013). An ethnozoological study and medicinal values of vertebrate origin in the adjoining areas of Pench National Park of Chhindwara district of Madhya Pradesh, India. *International Journal of Life Sciences* 1(4): 278–283.

Baral, H. (2010). Protected birds of Nepal: a review of their status, distribution and habitat. *The Initiation* 3: 66–80. https://doi.org/10.3126/init.v3i0.2429

Barkat, A., F. Liza, S. Akter, A. Shome & M. Rabbe (2021). Wildlife hunting practices of the Santal and Oraon communities in Rajshahi, Bangladesh. *Journal of Threatened Taxa* 13(11): 19484–19491. https://doi.org/10.11609/jott.7260.13.11.19484-19491

Bashir, S.M., M. Altaf, T. Hussain, M. Umair, M. Majeed, W.M. Mangrio, et al. (2023). Vernacular taxonomy, cultural and ethnopharmacological applications of avian and mammalian species in the vicinity of Ayubia National Park, Himalayan Region. *Biology* 12(4): e609. https://doi.org/10.3390/biology12040609

Benarjee, G., R. Gundu, K. Srikanth & N. Ramulu (2010). Ethnozoological study in a tropical wildlife sanctuary of Eturunagaram in the Warangal district, Andhra Pradesh. *Indian Journal of Traditional Knowledge* 9(4): 701–704.

Betlu, A. (2022). Indigenous knowledge of zootherapeutic use amongst Biate tribe of Dima Hasao district, Assam, Northeast India. *Journal of Ethnobiology and Ethnomedicine* 9(56): e2013. https://doi.org/10.1186/1746-4269-9-56

Bhupathy, S., S. Kumar, P. Thirumalainathan, J. Paramanandham & C. Lemba (2013). Wildlife exploitation: a market survey in Nagaland, north-eastern India. *Tropical Conservation Science* 6(2): 241–253. https://doi.org/10.1177/194008291300600206

BirdLife International (n.d.). Taxonomy. *BirdLife Data Zone*. https://datazone.birdlife.org/about-our-science/taxonomy. Accessed on?

Chakraborty, S. & M. Mondal (2021). Wildlife hunting by indigenous tribes: a case analysis from Susunia hills, West Bengal, India. *International Journal of Conservation Science* 12(3): 935–944. https://doi.org/10.21786/bbrc/13.3/87

Chakravorty, J., V. Meyer-Rochow & S. Ghosh (2011). Vertebrates used for medicinal purposes by members of the Nyishi and Galo tribes in Arunachal Pradesh (north-east India). *Journal of Ethnobiology and Ethnomedicine* 7(1): e13. https://doi.org/10.1186/1746-4269-7-13

Chaudhury, S., H.R. Chowdhury & H. Singh (2016). Some ethnozoological uses of Birhor tribe of West Bengal, India. *Journal of Traditional and Folk Practices* 2(3–4): 33–42. https://doi.org/10.25173/jtfp.38

Chellappandian, M., P. Pandikumar, S. Mutheeswaran, M. Gabriel Paulraj, S. Prabakaran, V. Duraipandiyan, S. Ignacimuthu & N. Al-Dhabi (2014). Documentation and quantitative analysis of local ethnozoological knowledge among traditional healers of Theni district, Tamil Nadu, India. *Journal of Ethnopharmacology* 154(1): 116–130. https://doi.org/10.1016/j.jep.2014.03.028

Chinlampianga, M., R. Singh & A. Shukla (2013). Ethnozoological diversity of northeast India: empirical learning with traditional knowledge holders of Mizoram and Arunachal Pradesh. *Indian Journal of Traditional Knowledge* 12(1): 18–30.

Choubey, K.N. (2021). Categorisation in forest areas: a study of the 'OTFDs' in the Forest Rights Act. *Indian Journal of Public Administration* 67(4): 537–551. https://doi.org/10.1177/00195561211051518

Choudhury, P. & N.R. Talukdar (2023). Illegal trade of exotic wildlife along the porous borders of northeastern Indian states. *Zoo's Print* 38(6): 1–4.

Chowdhury, M., M. Halim, M. Miah, N. Muhammed & M. Koike (2007). Biodiversity use through harvesting faunal resources from forests by the Mro tribe in the Chittagong Hill Tracts, Bangladesh. *International Journal of Biodiversity Science & Management* 3(1): 56–62. https://doi.org/10.1080/17451590709618162

Das, K., S. Choudhury, K. Chanreila & L. Nonglait (2017). Zootherapy among the ethnic groups of north eastern region of India: a critical review. *Journal of Critical Reviews* 4(2): 1–9. https://doi.org/10.22159/jcr.2017v4i2.14698

Dasgupta, S. (2012). Differential effects of hunting on populations of hornbills and imperial pigeons in the rainforests of the eastern Indian Himalaya. *Indian Forester* 138(10): 902–909.

Datta, A. (2021). Status of illegal bird hunting in Bangladesh: online news portal as the source. *Human Dimensions of Wildlife* 27(2): 183–192. https://doi.org/10.1080/10871209.2021.1895380

Dhakal, P., B. Chettri, S. Lepcha & B. Acharya (2020). Rich yet undocumented ethnozoological practices of socio-culturally diverse indigenous communities of Sikkim Himalaya, India. *Journal of Ethnopharmacology* 249: 112386. https://doi.org/10.1016/j.jep.2019.112386

Dixit, A., K. Kadavul, S. Rajalakshmi & M. Shekhawat (2010). Ethno-medico-biological studies of south India. *Indian Journal of Traditional Knowledge* 9(1): 116–118.

Faiz, M. & M. Altaf (2024). Study of avian-human interaction: uses of avian species in ethnopharmacological practices in Haveli, Azad Jammu and Kashmir, Pakistan. *Journal of Wildlife and Ecology* 8(2): 154–178.

Faiz, M., M. Altaf, M. Umair, K. Almarry, Y. Elbadawi & A. Abbasi (2022). Traditional uses of animals in the Himalayan region of Azad Jammu and Kashmir. *Frontiers in Pharmacology* 13: 807831. https://doi.org/10.3389/fphar.2022.807831

Francesconi, W., V. Bax, G. Blundo-Canto, S. Willcock, S. Cuadros, M. Vanegas, M. Quintero & C.A. Torres-Vitolas (2018). Hunters and hunting across indigenous and colonist communities at the forest-agriculture interface: an ethnozoological study from the Peruvian Amazon. *Journal of Ethnobiology and Ethnomedicine* 14(1): 54. https://doi.org/10.1186/s13002-018-0247-2

Gajendra, R. & S. Tirkey (2020). Ethnozoological remedial practices by the Madia tribe and indigenous inhabitants of Dantewada District, Chhattisgarh, India. *National Journal of Life Sciences* 17(1): 57–62.

George, V., P. Sreedevi & T. Iljinu (2014). Ethnozoological knowledge of Indian scheduled tribe, scheduled caste and rural communities. *Indian Journal of Traditional Knowledge* 13(4): 735–741.

Global Data Lab (2022). Subnational Human Development Index (SHDI) Table for Bangladesh, Pakistan, India, and Nepal. *Global Data Lab*. https://globaldatalab.org/shdi/table/2022/shdi+lifexp+lgnic+pop/BGD+PAK+IND+NEP/?levels=1+4&interpolation=0&extrapolation=0. Accessed on ?

Gosai, K., T. Shrestha, S. Hill, S. Shrestha, B. Gyawali, D. Gautam & A. Aryal (2016). Population structure, behavior, and current threats to the Sarus Crane *Grus antigone antigone* in Nepal. *Journal of Asia-Pacific Biodiversity* 9(3): 301–305. https://doi.org/10.1016/j.japb.2016.06.008

Gubbi, S. & M. Linkie (2012). Wildlife hunting patterns, techniques, and profile of hunters in and around Periyar Tiger Reserve. *Journal of the Bombay Natural History Society* 109(3): 165–172.

Hakeem, F., M. Altaf, S. Manzoor, K. Rauf, B. Mumtaz, M. Bashir, R. Haider, S.I. Farooq, L. Safdar & M. Altaf (2017). Assessment of behavioral study, human activities, impacts, and interaction with Streak Laughing Thrush *Trochalopteron lineatum* in district Bagh, Azad Jammu and Kashmir, Pakistan. *Journal of Wildlife and Ecology* 1(3): 1–7.

Haq, S., E. Calixto, U. Yaqoob, R. Ahmed, A. Mahmoud, R. Bussmann, O. Mohammed, K. Ahmad & A. Abbasi (2020). Traditional usage of wild fauna among the local inhabitants of Ladakh, Trans-Himalayan Region. *Animals* 10(12): 2317. https://doi.org/10.3390/ani10122317

Haq, S.M., M. Waheed & R.W. Bussmann (in press). "Traditional" use in a global world: Unsustainable harvesting drives species to extinction. *Research Square* PREPRINT Version 1. https://doi.org/10.21203/rs.3.rs-3259535/v1. Accessed on 01.xii.2024.

Harrison, M., D. Roe, J. Baker, G. Mwedde, H. Travers, A. Plumptre, A. Rwetsiba & E.J. Milner-Gulland (2015). Wildlife crime: a review of the evidence on drivers and impacts in Uganda. IIED Research Report, 142 pp.

Hassan, M., S. Haq, R. Ahmad, M. Majeed, H. Sahito, M. Shirani, I. Mubeen, M. Aziz, A. Pieroni, R. Bussmann, A. Alataway, A. Dewidar, M. Al-Yafrsi, H. Elansary & K. Yessoufou (2022). Traditional use of wild and domestic fauna among different ethnic groups in the western Himalayas: a cross cultural analysis. *Animals* 12(17): 2276. https://doi.org/10.3390/ani12172276

Hinsley, A., D.W.S. Challender, S. Masters, D.W. Macdonald, E.J. Milner-Gulland, J. Fraser & J. Wright (2024). Early warning of trends in commercial wildlife trade through novel machine-learning analysis of patent filing. *Nature Communications* 15: 6379. https://doi.org/10.1038/s41467-024-49688-x

Holennavar, P. (2015). Use of animal and animal derived products as medicines by the inhabitants of villages in Athani Taluka of Belagavi District (Karnataka). *International Journal of Applied Science* 1(12): 437–440.

IUCN (2024). The IUCN Red List of Threatened Species. Version 2024-2. https://www.iucnredlist.org. Accessed on 19.xii.2024.

Jameel, M., M. Khan, M. Awan, M. Nadeem, S. Aslam, S. Mehmood, D. Ahmad, R. Wali, Q. Rehman, M. Khan & T. Mahmood (2022). Population and risk assessment of sympatric pheasant species in Palas Valley, Pakistan. *Brazilian Journal of Biology* 84: e259582. https://doi.org/10.1590/1519-6984.259582

Jaroli, D., M. Mahawar & N. Vyas (2010). An ethnozoological study in the adjoining areas of Mount Abu Wildlife Sanctuary, India. *Journal of Ethnobiology and Ethnomedicine* 6(1): e6. https://doi.org/10.1186/1746-4269-6-6

Jugli, S., J. Chakravorty & V. Meyer-Rochow (2020). Tangsa and Wancho of north-east India use animals not only as food and medicine but also as additional cultural attributes. *Foods* 9(4): 528. https://doi.org/10.3390/foods9040528

Kalra, S., A. Davies, R.O. Martin & A. Poonia (2024). Insights from the media into the bird trade in India: an analysis of reported seizures. *Oryx* 58(1): 69–77. https://doi.org/10.1017/S0030605322001594

Kanagavel, A., S. Parvathy, P. Nameer & R. Raghavan (2016). Conservation implications of wildlife utilization by indigenous communities in the southern Western Ghats of India. *Journal of Asia-Pacific Biodiversity* 9(3): 271–279. https://doi.org/10.11609/jott.8948.16.5.25147-25156

Katuwal, H.B., H.P. Sharma, R.K. Thakur, P. Rokka, D.N. Mandal, H.S. Baral & R.C. Quan (2023). Illegal trapping and local trade of farmland birds in Madhesh Province, Nepal. *Global Ecology and Conservation* 42: e02391. https://doi.org/10.1016/j.gecco.2023.e02391

Kaul, R., Hilaluddin, J. Jandrotia & P. McGowan (2004). Hunting of large mammals and pheasants in the Indian western Himalaya. *Oryx* 38(4): 426–431. https://doi.org/10.1017/S0030605304000808

Khan, A. & I. Khaliq (2008). Status, threats and conservation of Great Indian Bustard *Ardeotis nigriceps* in Pakistan. *Current Science* 95(8): 1079–1082.

Khan, A.M., M. Altaf, T. Hussain, M.H. Hamed, U. Safdar, A. Ayub, Z. Memon, A. Hafiz, S. Ashraf, M.S. Amjad, M. Majeed, M. Hassan, R.W. Bussmann, A.M. Abbasi, M. Al-Yafrsi, H.O. Elansary & E.A. Mahmoud (2024). Ethnopharmacological uses of fauna among the people of central Punjab, Pakistan. *Frontiers in Veterinary Science* 11: 1351693. https://doi.org/10.3389/fvets.2024.1351693

Krishna, C., K. Sarma & A. Kumar (2012). Rapid assessment of wreathed hornbill (*Aceros undulatus*) (Aves: Bucerotidae) populations and conservation issues in fragmented lowland tropical forests of Arunachal Pradesh, India. *Journal of Threatened Taxa* 4(14): 3342–3348. https://doi.org/10.11609/JoTT.o2969.3342-8

Kumar, A. & B. Riba (2025). Assessment of effectiveness of conservation action adopted for hornbill species in Arunachal Pradesh, India: the Great Indian Hornbill *Buceros bicornis*. *International Journal of Conservation Science* 6(1): 125–134.

Kumar, A. & S. Kant (2021). Economic valuation of forest ecosystem services: a review of methods and applications. *Forest Ecosystems* 8(1): 47. https://doi.org/10.11648/j.eco.20150405.11

Kunwar, A., D. Rai, R. Pandey, R.B. Adhikari & T.R. Ghimire (2024). Ethnozoological study of the Tamang people in Konjyosom Rural Municipality, Lalitpur, Nepal. *Nepalese Journal of Zoology* 8(1): 7–15. https://doi.org/10.3126/njz.v8i1.67107

Kushwah, V., R. Sisodia & C. Bhatnagar (2017). Magico-religious and social belief of tribals of district Udaipur, Rajasthan. *Journal of Ethnobiology and Ethnomedicine* 13(1): 19. https://doi.org/10.1186/s13002-017-0195-2

Lalramnghinglova, H. (1999). Ethnobiology in Mizoram State: folklore medico-zoology. *Bulletin of the Indian Institute of History of Medicine (Hyderabad)* 29(2): 123–148.

Lohani, U. (2010). Man-animal relationships in central Nepal. *Journal of Ethnobiology and Ethnomedicine* 6(1): 31. https://doi.org/10.1186/1746-4269-6-31

Lohani, U. (2012). Zootherapeutic knowledge of two ethnic populations from central Nepal. *Studies on Ethno-Medicine* 6(1): 45–53. https://doi.org/10.1080/09735070.2012.11886420

Lokwani, U. (2011). Eroding ethnozoological knowledge among Magars in central Nepal. *Indian Journal of Traditional Knowledge* 10(3): 466–473.

Mahawar, M. & D. Jaroli (2006). Animals and their products utilized as medicines by the inhabitants surrounding the Ranthambhore National Park, India. *Journal of Ethnobiology and Ethnomedicine* 2(1): 46. https://doi.org/10.1186/1746-4269-2-46

Mahawar, M. & D. Jaroli (2007). Traditional knowledge on zootherapeutic uses by the Saharia tribe of Rajasthan, India. *Journal of Ethnobiology and Ethnomedicine* 3(1): 25. https://doi.org/10.1186/1746-4269-3-25

Mahawar, M. (2008). Traditional zootherapeutic studies in India: a review. *Journal of Ethnobiology and Ethnomedicine* 4: 17. https://doi.org/10.1186/1746-4269-4-17

Manisha, K.C. & N. Singh (2020). Ethnomedicinal knowledge of Kisan community: a case study. *Himalayan Journal of Science and Technology* 3(4): 16–23. https://doi.org/10.3126/hijost.v4i0.33861

Mandal, S. & C. Rahaman (2022). Perception and application of zootherapy for the management of cattle diseases in the northern laterite region of West Bengal, India. *Asian Journal of Ethnobiology* 5(1): 12–19. https://doi.org/10.13057/asianjethnobiol/y050102

Massocato, G.F., A.L.J. Desbiez, J.V. Campos-Silva, D.Z. La Laina, J.M.B. Duarte, R.S.L. Barboza & J.A. Bogoni (2024). Exposing illegal hunting and wildlife depletion in the world's largest tropical country through social media data. *Conservation Biology* 38(5): e14334. https://doi.org/10.1111/cobi.14334

Mazumdar, K. (2014). Hunting of avifauna in proposed Tsangyang Gyatso Biosphere Reserve, western Arunachal Pradesh. *Zoo's Print* 29(4): 3–7.

Mian, A. (1986). Ecological impact of Arab falconry on houbara bustard in Baluchistan. *Environmental Conservation* 13(1): 41–46. https://doi.org/10.1017/S0376892900035852

Ministry of Tribal Affairs (2013). Statistical profile of Scheduled Tribes in India 2013. *Ministry of Tribal Affairs, Government of India*. https://tribal.nic.in/ST/Statistics8518.pdf

Mirin, B.H. & H. Klinck (2021). Bird singing contests: looking back on thirty years of research on a global conservation concern. *Global Ecology and Conservation* 30: e01812. https://doi.org/10.1016/j.gecco.2021.e01812

Misar, S. & M. Subhas (2014). Ethno-zoological practices in some tribal areas of Chandrapur district, Maharashtra, India. *The Journal of Agriculture and Natural Resources Science* 1(3): 172–179.

Mishra, N., S. Rout & T. Panda (2022). Ethno-zoological studies and medicinal values of Similipal Biosphere Reserve, Orissa, India. *African Journal of Pharmacy and Pharmacology* 5(1): 6–11.

Mughal, S., M. Pervaz, S.M. Bashir & S.S. Shamashad (2020). Assessment of diversity and ethnopharmacological uses of birds in Chakar, Hattian Bala District, Azad Jammu and Kashmir, Pakistan. *Journal of Wildlife and Ecology* 4(1): 35–44.

Muhammad, E., M. Ali, M. Imran, M. Nadeem & M. Khan (2021). Analytical study of chukar partridge farming, marketing, fighting and using it as cage bird in houses of Balochistan, Pakistan. *Gazi University Journal of Science* 34(3): 18–32.

Mussarat, S., R. Ali, S. Ali, R. Mothana, R. Ullah & M. Adnan (2021). Medicinal animals and plants as alternative and complementary medicine in southern regions of Khyber Pakhtunkhwa, Pakistan. *Frontiers in Pharmacology* 12: 649046. https://doi.org/10.3389/fphar.2021.649046

Naro, E., E. Mero, E. Naro, K. Kapfo, K. Wezah, K. Thopi, K. Rhakho,

L. Akami, L. Thopi, M. Chirhah, T. Chirhah, T. Tsuhah, T. Thopi, W. Wezah, W. Mero, W. Thopi, K. Thopi, T. Naro, W. Tsuhah, N. Dahanukar & P. Molur (2015). Project hunt: an assessment of wildlife hunting practices by local community in Chizami, Nagaland, India. *Journal of Threatened Taxa* 7(11): 7729–7743. https://doi.org/10.11609/jott.2317.7729-7743

Nasi, R., A. Taber & N. Van Vliet (2011). Empty forests, empty stomachs? Bushmeat and livelihoods in the Congo and Amazon Basins. *International Forestry Review* 13(3): 355–368. https://doi.org/10.1505/146554811798293872

Negi, C. & V. Palyal (2007). Traditional uses of animal and animal products in medicine and rituals by the Shoka tribes of District Pithoragarh, Uttaranchal, India. *Studies on Ethno-Medicine* 1(1): 47–54. https://doi.org/10.1080/09735070.2007.11886300

Negi, T. & L.S. Kandari (2017). Traditional knowledge and zootherapeutic use of different animals by Bhotiya tribe: a case study from Uttarakhand, India. *Indian Journal of Traditional Knowledge* 16(4): 638–647.

Niraj, S., P. Krausman & V. Dayal (2012). Temporal and spatial analysis of wildlife poaching in India from 1992 to 2006. *International Journal of Ecological Economics and Statistics* 24(1): 79–109.

Pandey, S., A. Samal & D. Priyadarshini (2024). Enforcement and capacity building to combat illegal trade of Alexandrine parakeets *Psittacula eupatria* (Linnaeus, 1766) in Odisha, India. *Sustainability and Biodiversity Conservation* 3(3): 1–14.

Pandit, A. (1988). Threats to Kashmir wetlands and their wildlife resources. *Environmental Conservation* 15(3): 266–268. https://doi.org/10.1017/S0376892900029142

Patil, S. (2022). Ethno-medico-zoological studies of Nandubar district of Maharashtra. *Indian Journal of Traditional Knowledge* 2(3): 297–299.

Paudel, P.K., K.P. Acharya, H.S. Baral, J.T. Heinen & S.R. Jnawali (2020). Trends, patterns, and networks of illicit wildlife trade in Nepal: a national synthesis. *Conservation Science and Practice* 2(9): e247. https://doi.org/10.1111/csp2.247

Paudyal, R. & N. Singh (2014). Ethno-medicinal uses of animals and plants among the migratory Tangbetons of Pokhara, Nepal. *Journal of Institute of Science and Technology* 19(1): 145–149.

Poonia, A., A. Ghanghas, R. Sharma & M. Jangra (2022). Trends in CITES-listed birds' trade in Indian subcontinent countries in view of evolution of Indian laws during last four decades. *International Journal of Ecological Economics and Statistics* 43(1): 1–114.

Poudel, M. & N. Singh (2016). Medical ethnobiology and indigenous knowledge system found in Darai ethnic group of Chitwan, Nepal. *Journal of Institute of Science and Technology* 21(1): 103–111. https://doi.org/10.3126/jist.v21i1.16061

Press Information Bureau (2023). State-wise data on per capita income. *Press Information Bureau, Government of India*. https://www.pib.gov.in/PressReleasePage.aspx?PRID=1942055. Accessed on 01.iii.2025.

Quave, C., U. Lohani, A. Verde, J. Fajardo, D. Rivera, C. Obón, A. Valdes & A. Pieroni (2010). A comparative assessment of zootherapeutic remedies from selected areas in Albania, Italy, Spain and Nepal. *Journal of Ethnobiology* 30(1): 92–125. https://doi.org/10.2993/0278-0771-30.1.92

Rai, R. & N. Singh (2015). Medico-ethnobiology in Rai community: a case study from Baikunthe Village Development Committee, Bhojpur, eastern Nepal. *Journal of Institute of Science and Technology* 20(1): 127–132. https://doi.org/10.3126/jist.v20i1.13935

Ramachandran, R., A. Kumar, K. Gopi Sundar & R. Bhalla (2017). Hunting or habitat? Drivers of waterbird abundance and community structure in agricultural wetlands of southern India. *Ambio* 46(5): 613–620. https://doi.org/10.1007/s13280-017-0907-9

Rane, A. & A. Datta (2015). Protecting a hornbill haven: a community-based conservation initiative in Arunachal Pradesh, northeast India. *Malayan Nature Journal* 67(2): 203–218.

Rao, M., S. Hedges & A. Johnson (2010). The "empty forests" of the northern Eastern Ghats, India: a case study of the loss of wildlife due to hunting. *Tropical Conservation Science* 3(3): 331–343.

Rehman, J., S. Alam, S. Khalil, M. Hussain, M. Iqbal, K. Khan, M. Sabir, A. Akhtar, G. Raza, A. Hussain & U. Habiba (2022). Major threats and habitat use status of Demoiselle Crane *Anthropoides virgo* in district Bannu, Pakistan. *Brazilian Journal of Biology* 82: e242636. https://doi.org/10.1590/1519-6984.242636

Robinson, E.J.Z., A.M. Kumar & H.J. Albers (2018). Protecting forests by promoting use of biomass briquettes: does gender matter? *Land Use Policy* 70: 367–375.

Roy, K., B.P. Narzary & J. Narzary (2024). Zootherapeutic and perspective among the ethnic groups of Gossaigaon sub-division in Kokrajhar, Assam, India. *Bioscene* 21(3): 708–731.

Sadam, A. (2022). Hunting and illegal trade of White-breasted Waterhen *Amaurornis phoenicurus*: evidence from district Mardan, Khyber Pakhtunkhwa, Pakistan. *Pakistan Journal of Zoology* 54: 1–10. https://doi.org/10.17582/journal.pjz/20210822070833

Samal, M., K. Sahoo, S. Pati, S. Tripathy, M. Parida & B. Das (2020). Use of animal and animal products for rheumatoid arthritis treatment: an explorative study in Odisha, India. *Frontiers in Medicine* 6: 323. https://doi.org/10.3389/fmed.2019.00323

Sarwar, M., A. Hamid & I. Hussain (2021). Hunting pressure on migratory demoiselle cranes in Pakistan. *Pakistan Journal of Zoology* 54(1): e20180625070601. https://doi.org/10.17582/journal.pjz/20180625070601

Selvan, K., G. Veeraswami, B. Habib & S. Lyngdoh (2013). Losing threatened and rare wildlife to hunting in Ziro Valley, Arunachal Pradesh, India. *Current Science* 104(11): 1492–1495.

Sethi, S. (2022). Insights into illegal wildlife hunting by forest guards of selected tiger reserves in central India. *European Journal of Wildlife Research* 68(1): 4. https://doi.org/10.1007/s10344-021-01553-8

Shepherd, C.R., L. Shepherd, D. Rathore & U. Mendiratta (2023). Recent seizures of hornbills trafficked to India. *Hornbill Natural History & Conservation* 4: 20–24.

Shoukat, A., M. Khan, G. Shah, S. Tabassam, K. Badshah & I. Ullah (2020). Indigenous knowledge of zootherapeutic use among the people of Hazara division, Khyber-Pakhtunkhwa, Pakistan. *Indian Journal of Traditional Knowledge* 19(3): 568–579.

Shrestha, N. & S. Bajracharya (2023). Utilization of fauna for therapeutic purposes by the Newar community in Bhanu Municipality, Tanahun, Nepal. *Amrit Research Journal* 4(1): 69–78. https://doi.org/10.3126/arj.v4i1.61215

Singh, O.I., K.S. Devi & K.B. Singh (2023). Rare and unexplored ethnozoological practices of the Tangkhul Naga community of Manipur: a north-eastern state of India. *Journal of Advanced Zoology* 44(3): 451–464. https://doi.org/10.53555/jaz.v44i3.711

Singh, R., J. Sethy & D. Chatrath (2023). Trends and patterns of illegal wildlife hunting and trading in Uttar Pradesh, India. *International Journal of Conservation Science* 14(1): 327–336.

Singh, R., L. Slade & O. Ilyas (2011). Trapped and traded—an insight into the field realities of the live bird trade in Uttar Pradesh, India. *BirdingAsia* 16: 45–47.

Sinha, A., P. Hazra & T.N. Khan (2023). Potential threats to the migratory waterbirds in south Bengal, India. *Research Square* PREPRINT (Version 1). https://doi.org/10.21203/rs.3.rs-3375273/v1. Accessed on 01.xii.2024.

Smith, J. & T. Lee (2024). Conservation strategies for endangered species in fragmented landscapes. *Conservation Science and Practice* 6(2): e13191. https://doi.org/10.1111/csp2.13191

Solanki, G. & P. Chutia (2004). Ethnozoological and socio-cultural aspects of Monpas of Arunachal Pradesh. *Journal of Human Ecology* 15(4): 251–254. https://doi.org/10.1080/09709274.2004.11905701

Solanki, G. & P. Chutia (2009). Studies on ethno-medicinal aspects and zoo-therapy in tribal communities in Arunachal Pradesh, India. *International Journal of Ecology and Environmental Sciences* 35(1): 67–76.

Solanki, G., P. Chutia & O. Singh (2004). Headgear – a cultural artifact and its impact on biodiversity in Arunachal Pradesh, India. *Arunachal University Research Journal* 7(1): 35–44.

Solavan, A., R. Paulmurugan, V. Wilsanand & A. Singh (2004). Traditional therapeutic uses of animals among tribal population of

Tamil Nadu. *Indian Journal of Traditional Knowledge* 3(2): 198–205.

Tariq, M. & R. Aziz (2015). Threats and hunting methods of crane species in district Karak of Khyber Pakhtunkhwa, Pakistan. *Journal of Environment and Earth Science* 5(22): 11–15.

Timilsina, S. & N. Singh (2015). Ethnobiology and indigenous knowledge about medicinal animals and plants in the Balami ethnic group in Nepal. *Journal of Institute of Science and Technology* 19(2): 79–85. https://doi.org/10.3126/jist.v19i2.13857

Tukuboya, F., K. Mizuno, H. Herdiansyah & E. Frimawaty (2024). Togutil tribe's ecological hunting calendar on Halmahera Island, Indonesia. *Global Ecology and Conservation* 55: e03244. https://doi.org/10.1016/j.gecco.2024.e03244

Tourenq, C., O. Combreau, M. Lawrence, S. B. Pole, A. Spalton, X. Xinji, M. Al Baidani & F. Launay (2005). Alarming houbara bustard population trends in Asia. *Biological Conservation* 121(1): 1–8. https://doi.org/10.1016/j.biocon.2004.03.031

Tynsong, H., B. Tiwari & M. Dkhar (2012). Bird hunting techniques practised by War Khasi community of Meghalaya, north-east India. *Indian Journal of Traditional Knowledge* 11(2): 334–341.

Uddin, N., A. Islam, T. Akhter, T. Ara, D. Hossain, C. Fullstone, S. Enoch & A. C. Hughes (2022). Exploring market-based wildlife trade dynamics in Bangladesh. *Oryx* 58(1): 56–68. https://doi.org/10.1017/S0030605322001077

Umar, M., M. Hussain, G. Murtaza, F.A. Shaheen & F. Zafar (2018). Ecological concerns of migratory birds in Pakistan: a review. *Punjab University Journal of Zoology* 33(1): 69–76. https://doi.org/10.17582/pujz/2018.33.1.69.76

Veena, P. & C. Krishna (2023). Importance, threats and conservation strategies of Telangana state bird, Palapitta. *International Journal of Researches in Biosciences, Agriculture and Technology* (XI): 12–15.

Velho, N. & W. Laurance (2013). Hunting practices of an Indo-Tibetan Buddhist tribe in Arunachal Pradesh, north-east India. *Oryx* 47(3): 389–392. https://doi.org/10.1017/S0030605313000252

Vijayakumar, S., J. Morvin Yabesh, S. Prabhu, M. Ayyanar & R. Damodaran (2015). Ethnozoological study of animals used by traditional healers in the Silent Valley of Kerala, India. *Journal of Ethnopharmacology* 162: 296–305. https://doi.org/10.1016/j.jep.2014.12.055

Vijayakumar, S., S. Prabhu, J. Morvin Yabesh & R. Pragashraj (2015). A quantitative ethnozoological study of traditionally used animals in Pachamalai hills of Tamil Nadu, India. *Journal of Ethnopharmacology* 171: 51–63. https://doi.org/10.1016/j.jep.2015.05.023

World Health Organization (2022). WHO establishes the Global Centre for Traditional Medicine in India. *World Health Organization*. https://www.who.int/news/item/25-03-2022-who-establishes-the-global-centre-for-traditional-Medicine-in-india. Accessed on 01.iv.2025.

Yeshi, K., P. Morisco & P. Wangchuk (2017). Animal-derived natural products of Sowa Rigpa medicine: their pharmacopoeial description, current utilization and zoological identification. *Journal of Ethnopharmacology* 207: 192–202. https://doi.org/10.1016/j.jep.2017.06.009

Yesodharan, K., P. Padmanabhan & N. Cini (2011). Wild food traditionally used by the indigenous people of Parambikulam Wildlife Sanctuary, Western Ghats, Kerala, India. *Journal of the Bombay Natural History Society* 108(1): 41–46.

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SHORT COMMUNICATION

Recent records of endemic bird White-faced Partridge *Arborophila orientalis* (Horsfield, 1821) in Meru Betiri National Park, Indonesia

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Abstract: The ecological records of the White-faced Partridge *Arborophila orientalis* in Meru Betiri National Park (MBNP) are extremely scant. Recently, camera trap monitoring has revealed the presence of this endemic bird in three different areas at MBNP: Malangsari (09 August 2018; 28 August 2018; 28 November 2018), Sumberpacet (17 November 2018), and Rajegwesi (18 October 2021). The White-faced Partridge was found in MBNP's highland regions, at elevations ranging 446–960 m and on slopes inclining 21.13–53.61%. Furthermore, it was located under high-density forest cover, as indicated by a normalized difference vegetation index (NDVI) ranging 0.67–0.72. It was observed solitary or in groups (four individuals per frame), participating in activities such as self-grooming and foraging on the forest floor, and crossing forest ground. We conclude that our report is remarkable in terms of the distribution and habitat characteristics of the White-faced Partridge in the MBNP, which is critical information for developing conservation strategies for this endemic species in their refuge.

Keywords: Camera trap, dense forest, distribution, forest floor, highlands, steeper terrain.

The White-faced Partridge *Arborophila orientalis* (Horsfield, 1821) is an endemic bird species to the East Java highlands, Indonesia (Fuller et al. 2000), and categorized as 'Vulnerable' (VU B1 ab(ii,iii,v)) by the International Union for Conservation of Nature (IUCN) Red List (Birdlife International 2024). It has a highly restricted range, confined to the mountains of eastern Java (van Ballen 1992; Fuller et al. 2000). Reports indicate that, White-faced Partridge resides in montane forests at elevations of 500–2,200 m (van Ballen 1992; McGowan et al. 1995), but usually above 1,000 m (Fuller et al. 2000). Currently, this partridge is recorded in three separate geographic areas, i.e., Yang Highland (van Ballen 1992; McGowan et al. 1995; Fuller et al. 2000), Ijen Mountain (van Ballen 1992; Mittermeier et al. 2014; Siddiq et al. 2023a), and Meru Betiri National Park based on old records (Seidensticker et al. 1980; van Ballen 1992).

In Meru Betiri National Park (MBNP), the ecological record of the White-faced Partridge remains poorly documented. Its last scientific report was by Seidensticker et al. (1980), which was in the tropical primary forest, though the details of this report is unclear. Their occurrence in the highland forests makes it tough to detect and monitor by MBNP staff. Additionally, MBNP features a wide range of slopes (0–283 %), predominantly in steeper categories (Siddiq

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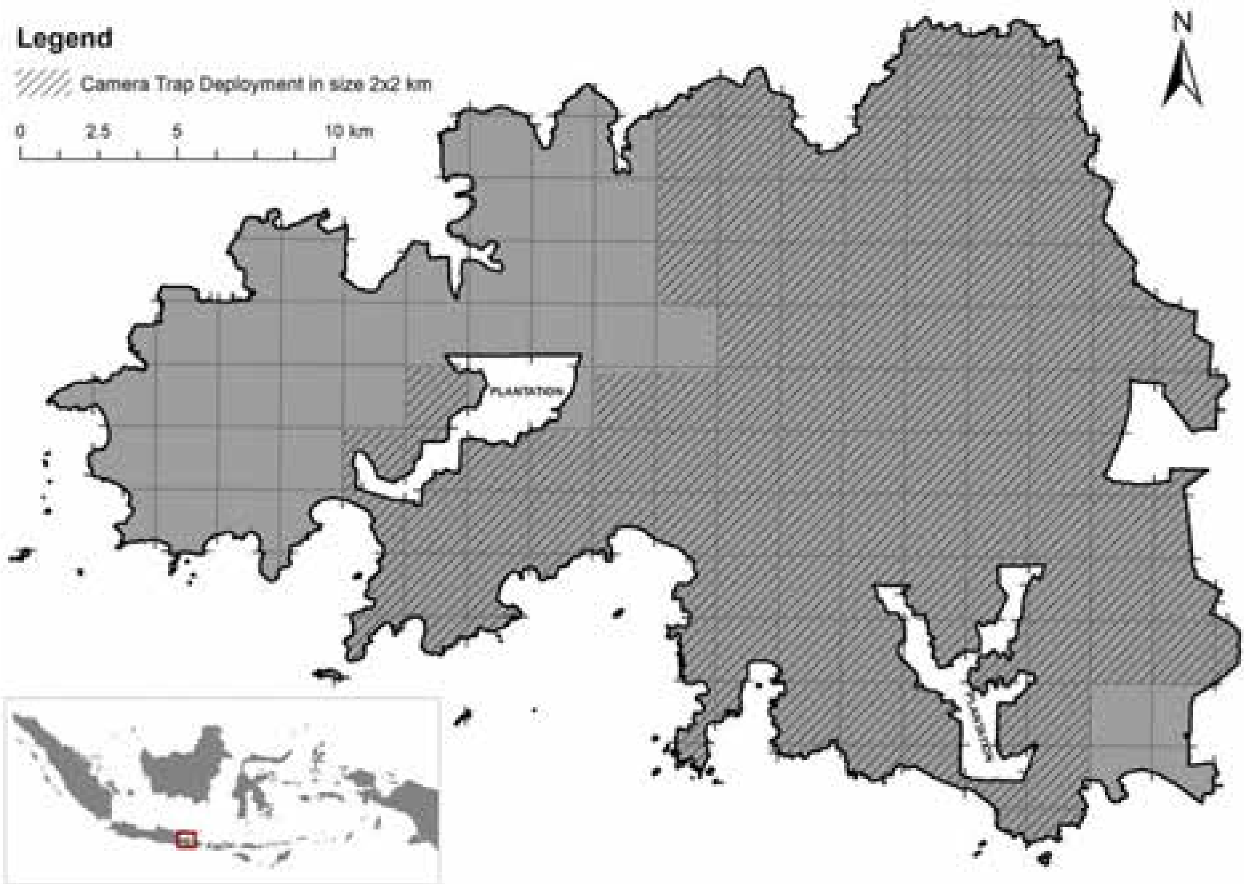

Image 1. Camera trap deployment in the Meru Betiri National Park, Indonesia.

et al. 2023b), which further complicates efforts to survey for this species. Generally, this endemic species inhabits tropical montane forests, preferring dense interior forest areas (BirdLife International 2024). As a Phasianidae species, the White-faced Partridge has limited flight capabilities, and primarily forages on the forest floor (Taufiqurrahman et al. 2022). Therefore, to effectively detect and capture this ground-dwelling species, appropriate methods, such as camera traps, are required.

Since 2017, MBNP has extensively deployed camera traps to inventory and monitor wildlife species. Camera traps, equipped with motion, and thermal sensors (Molloy 2018), are a highly effective tool for detecting ground-dwelling species (Thunhikorn et al. 2016). This camera has been proven to record several species of ground-dwelling birds, such as Green Peafowl *Pavo muticus*, and Junglefowl *Gallus* sp. in Alas Purwo National Park, Ujung Kulon National Park, and Meru Betiri National Park (Ariyanto et al. 2024). In addition, based on camera trap data from 2018 and 2021, we confirm the recent records of the endemic bird White-faced Partridge in MBNP. This confirms the existence of this endemic species in the MBNP and also reveals its local distribution.

Camera trap deployment

Meru Betiri National Park, located in the eastern expanse of Java Island, Indonesia, encompasses an area of 52,626.04 ha (Image 1). Administratively, it is stratified into three management sectors: Sarongan, comprising the Karangtambak, Rajegwesi, and Sukamade resorts; Kalibaru, comprising the Baban, Malangsari, and Sumberpacet resorts; and Ambulu, comprising the Wonoasri, Sanenrejo, Andongrejo, and Bandealit resorts. According to Syarief (2018), the park harbours five distinctive natural ecosystems, namely lowland rainforest, coastal forest, brackish forest, swamp forest, and rheophyte vegetation. Furthermore, the park exhibits diverse geological, and land cover attributes, with an altitudinal gradient ranging 0–1,185 m, slopes varying 0–283 %, and a NDVI spanning -0.36–0.81 (Siddiq et al. 2023b).

The monitoring of wildlife at MBNP utilizing camera traps was conducted from 2017–2023 across 111 grids, each measuring 2 x 2 km (Image 1). The primary objective of this surveillance was to detect the presence of the Javan Leopard and its prey species. Nevertheless, the camera traps also inadvertently documented other terrestrial species, such as the White-faced Partridge. Each camera trap was strategically deployed within the grids, positioned approximately 20–40 cm above ground level, and operated continuously for 3–4 months, capturing both photographs, and videos.

Results

The White-faced Partridge was documented in three distinct locations at MBNP: Malangsari (09 August 2018; 28 August 2018; 28 November 2018), Sumberpacet (17 November 2018), and Rajegwesi (18 October 2021) (Table 1). The species was recognized as the White-faced Partridge based on its stocky build, grey color, and short legs (Image 2). The body size is smaller and rounder than that of the Red Junglefowl *Gallus gallus*, another sympatric Phasianidae species found in the MBNP (Image 3). Another prominent feature is a white forehead, cheeks, and throat (Image 2). The encounters were during the day, including morning (065430 h and 082432 h), and afternoon (1333 h, 133844 h, 144256 h, 151034 h, and 163622 h).

The White-faced Partridge was recorded in the highland regions of MBNP, at elevations ranging 446–960 m (Image 4), and on slopes with inclinations ranging 21.13–53.61 % (Image 5). Furthermore, it was occupied in high-density forest cover, as reflected by an NDVI ranging 0.67–0.72 (Image 6). In the photographs, this endemic species was recorded solitary or in groups (four individuals per frame), engaging in activities such as self-grooming, foraging on the forest floor, and crossing forest ground (Image 2).

Discussion

This finding constitutes a noteworthy rediscovery of the White-faced Partridge in MBNP, which had its last scientific record around 40 years ago (Seidensticker et al. 1980). These recent records are essential for determining the occurrence and range of this elusive species in MBNP. First, the altitudinal range of the White-faced Partridge in MBNP, particularly at Rajegwesi (446 m), exposes a new lower elevation record. A slightly different report with prior references that noted its low elevation range of 500 m (van Ballen 1992; McGowan et al. 1995), and more recent observations reporting a minimum range of 600 m (BirdLife International 2024). According to this report, the elevation range of the White-faced Partridge is approximately 446–2,200 m.

Another notable habitat characteristic of the White-faced Partridge in MBNP is the steepness of the terrain it occupies (21.13–53.61 %). This may reveal an important predictor for analyzing this species' habitat preference, although further research is needed to support this hypothesis. Probably, steep terrains frequently provide unique microhabitats, such as colder temperatures, and certain vegetation types, which are critical for the White-faced Partridge's feeding, nesting, and sheltering requirements. Furthermore, steep slopes are usually linked with extensive forest cover, which corresponds to the high NDVI values seen in these partridge habitats (0.67–0.72). According to Jiang et al. (2006), an NDVI value more than 0.4 indicates a dense forest with a mix of plants, huge trees, and broad canopies. Furthermore, Taufiqurrahman et al. (2022), suggest that this species is frequently found in places dominated by Dipterocarpaceae trees, implying a possible biological link with specific forest compositions.

Ultimately, we encourage further research to appraise the ecology of the White-faced Partridge in MBNP, including population estimates, and habitat suitability models. The findings will support the MBNP

Table 1. The occurrence of White-faced Partridge in Meru Betiri National Park, Indonesia.

	Resort: Coordinate	Altitude (m)	Slope (%)	NDVI	Date	Time
1	Malangsari: -8.432° S, 113.852° E	960	21.13	0.68	09.viii.2018	0654 h
					28.viii.2018	1333 h
						1338 h
					28.xi.2018	1636 h
2	Rajegwesi: -8.524° S, 113.930° E	446	53.61	0.67	17.xi.2018	0824 h
3	Sumberpacet: -8.446474° S, 113.884460° E	610	40.03	0.72	18.x.2021	1442 h
						1510 h

Image 2. Photographs of the White-faced Partridge in the MBNP.

Image 3. Photographs of the Red Junglefowl in the MBNP as a sympatric Phasianidae species.

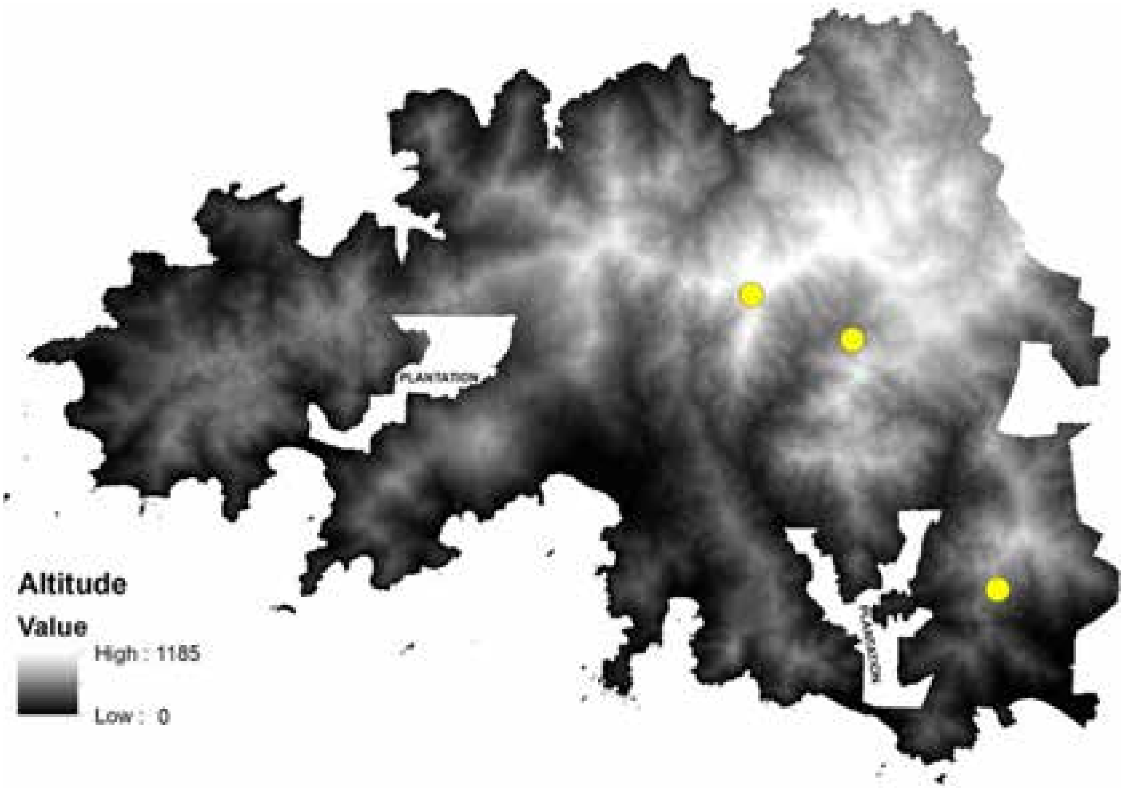

Image 4. The occurrence of White-faced Partridge (yellow dots) in the MBNP based on the altitude map.

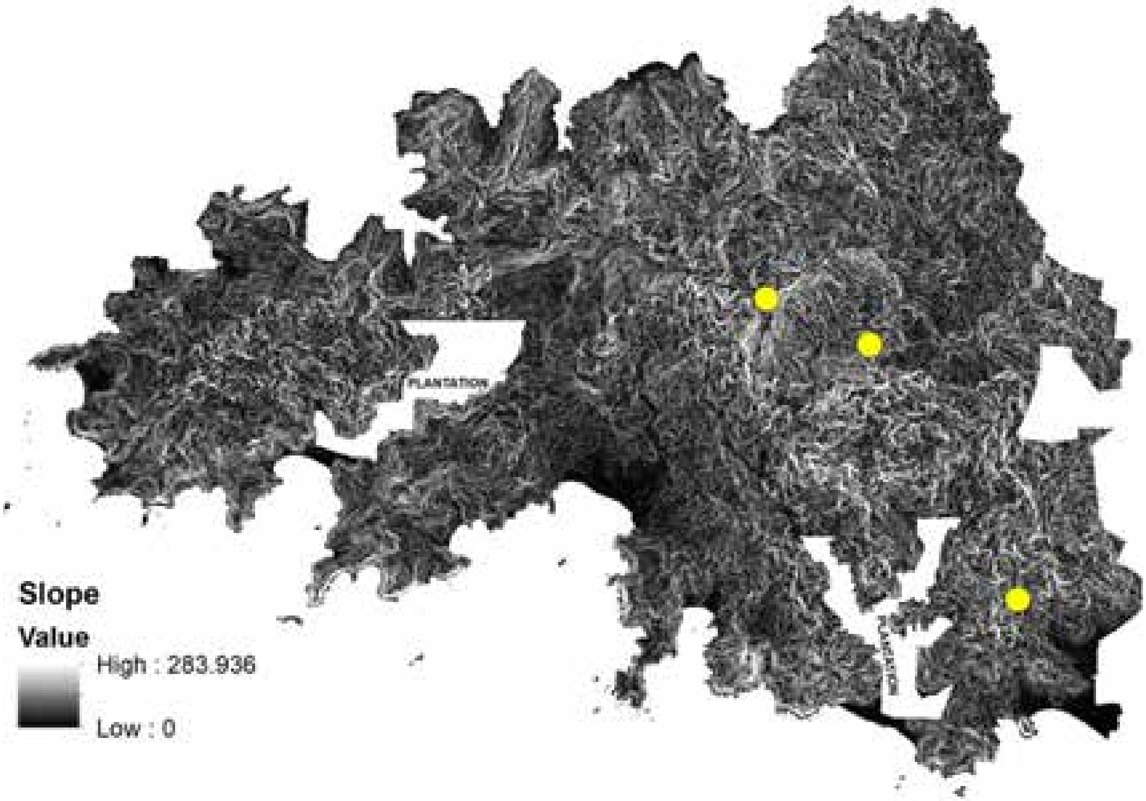

Image 5. The occurrence of White-faced Partridge (yellow dots) in the MBNP based on the slope map.

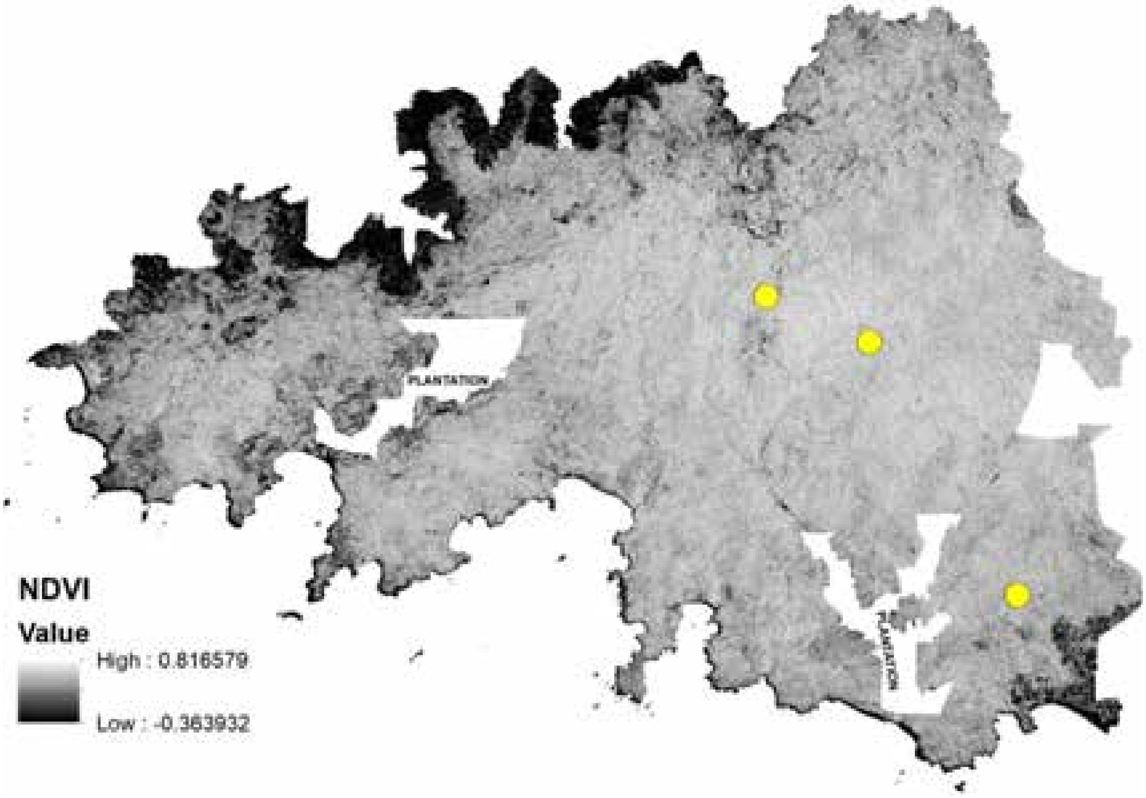

Image 6. The occurrence of White-faced Partridge (yellow dots) in the MBNP based on the NDVI map.

management as the primary conservation authority in designing and implementing appropriate conservation strategies for the White-faced Partridge. Moreover, this bird species is a potential target for poaching and trading as it has been traded in the Java-Bali bird market for 27 years (Nijman 2022). As previously stated, the White-faced Partridge is an endemic species that is restricted to the East Java highlands (Iyang Argopuro, Ijen Mountains, and Meru Betiri National Park). Thus, an ecological report on this species is critical. Our findings, in particular the occurrence of White-faced Partridge in three distinct regions at MBNP, could provide essential preliminary information.

References

Ariyanto, A.C., T. Wang, A.K. Skidmore, H.T. Wibisono, F.A. Widodo, A.Y. Firdaus, Y. Wiharisno, N. Koliq & W. Murdyatmaka (2024). Range-wide camera traps reveal potential prey species for Javan leopards. *Global Ecology and Conservation* 53(e03020): 1–15. https://doi.org/10.1016/j.gecco.2024.e03020

BirdLife International (2024). *Arborophila orientalis*. The IUCN Red List of Threatened Species 2024: e.T22679038A246271035. Accessed on 01.i.2025.

Fuller, R.A., J.P. Carroll & P.J.K. McGowan (2000). Partridges, Quails, Francolins, Snowcocks, Guineafowl, and Turkeys. Status Survei and Conservation Action Plan 2000–2004. WPA/BirdLife/SSC Partridge, Quail, and Francolin Specialist Group. IUCN, Gland, Swit-zerland and Cambridge, UK, and the World Pheasant Association, Reading, UK, vii + 63 pp.

Jiang, Z., A.R. Huete, J. Chen, Y. Chen, J. Li, G. Yan & X. Zhang (2006). Analysis of NDVI and scaled difference vegetation indeks retrievals of vegetation fraction, *Remote Sensing of Environment* 101(3): 366–378. https://doi.org/10.1016/j.rse.2006.01.003

McGowan, P.J.K., S.D. Dowell, J.P. Caroll & N.J. Aebisher (1995). Partridges, Quails, Francolins, Snow-cocks, Guineafowl, and Turkeys. Status Survey and Conservation Action Plan 1995–1999. IUCN, Gland, Switzerland, 68 pp.

Mittermeier, J., C. Oliveros, T. Haryoko, M. Irham & R. Moyle (2014). An avifaunal survey of three Javan volcanoes Gn Salak, Gn Slamet and the Ijen highlands. *BirdingASIA* 22(2014): 91–100.

Molloy, S. (2018). A Practical Guide to Using Camera Traps for Wildlife Monitoring in Natural Resource Management Projects. Australian Government's National Landcare Program, Australia, 28 pp.

Nijman, V. (2022). Analysis of trade in endemic Javan hill partridges over the last quarter of a century period. *Avian Biology Research* 15(2): 84–92. https://doi.org/10.1177/17581559221086469

Seidensticker, J., Suyono & T. Thomas (1980). *The Javan Tiger and Meru Betiri Reserve*. IUCN, Gland, Switzerland, 167 pp.

Siddiq, A.M., H. Sulistiyowati, A.S. Kurnianto, A. Aninas & S. Samsuri (2023a). The Diversity and Uniqueness of Avifauna in Erek-Erek Geoforest at Ijen Geopark, East Java, Indonesia. *Journal of Tropical Biodiversity and Biotechnology* 8(1): 1–10. https://doi.org/10.22146/jtbb.75639

Siddiq, A.M., N. Kholiq, W. Subchan & H.I. Maulahila (2023b). Habitat suitability model for Banteng (*Bos javanicus*) in Meru Betiri National Park, Indonesia. *Biodiversitas* 24(2): 1296–1302. https://doi.org/10.13057/biodiv/d240272

Syarief, N.R. (2018). *Jendela Meru Betiri*. Balai Taman Nasional Meru Betiri, Jember, Indonesia.

Taufiqurrahman, I., P.G. Akbar, A.A. Purwanto, M. Untung, Z. Assiddiqi, W.K. Wibowo, M. Iqbal, F.N. Tirtaningtyas & D.A. Triana (2022). *Panduan Lapangan Burung-Burung di Indonesia Sunda Besar Sumatera, Kalimantan, Jawa, Bali*. Birdpacker Indonesia-Interlude, Batu, Indonesia, 400 pp.

Thunhikorn, S., M.J. Grainger, P.J.K. Mcgowan & T. Savini (2016). Methods used to survey avian species and their potential for surveying ground-dwelling birds in Asia. *Forktail* 32: 5–13.

van Balen, S. (1992). Distribution, status and conservation of the forest partridges in the Greater Sundas (Indonesia) with special reference to the Chestnut-bellied Partridge (*Arborophila javanica*). *Gibier Faune Sauvage* 9: 561–569.

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SHORT COMMUNICATION

Exploring carapace phenotypic variation in female Fiddler Crab *Austruca annulipes* (H. Milne Edwards, 1837): insights into adaptive strategies and ecological significance

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Abstract: Fiddler crabs (Ocypodidae: Crustacea: Arthropoda) are globally documented but relatively understudied along the Indian coastline. *Austruca annulipes*, common across Indian mangrove habitats, remains insufficiently explored in terms of female morphology. While male fiddler crabs are recognized for their prominent chelae, females of *A. annulipes* exhibit notable polymorphism. In this short-term study conducted in the mangroves of Sauta Vaddo (Baga), Goa, we documented 14 distinct female morphs, alongside observations of male moulting. The study highlights the scope for future research into the adaptive significance of female phenotypic variation in this species.

Keywords: Alternative reproductive tactics, behaviour, carapace pattern, colour variation, mangrove, morphology, moulting, Ocypodidae, polymorphism, sexual dimorphism.

Fiddler crabs are semi aquatic crustaceans (Arthropoda: Crustacea: Ocypodidae) found in the intertidal zones. They are found in dense numbers in mangroves, mudflats, salt marshes throughout the tropics, and subtropics. They form an important part of mangrove ecosystems and are considered flagship species, and ecosystem engineers (Peer et al. 2015). The fiddler crabs widely known as 'calling crabs' display characteristics of sexual dimorphism. The females have symmetrical, small-sized chelipeds while the males have asymmetrical chelipeds one exceedingly large and another much smaller, minor cheliped (Bouchard et al. 2013). The enlarged cheliped is used in nuptial display by males to impress the females before mating and the enlargement occurs at random, resulting in a right-handed or left-handed claw in about equal proportions (Yamaguchi 1977).

More than 100 species of fiddler crabs are recognized at present, many of which are studied for their behaviour, ecology, and systematics (Silva et al. 2024). One overlooked species is *Austruca annulipes* (H. Milne Edwards, 1837), commonly called the Porcelain Fiddler Crab (Fulmali et al. 2021). The species has been included in global studies of taxonomy, population biology, feeding, and burrow characteristics, however, these studies have nearly exclusively considered the male fiddler crab only, and a very little data is available on females. An exception is a study of South African mangroves where 14 variations in female patterns are documented showing female polymorphism in *A. annulipes* (Peer et al. 2015). Fiddler crabs, like many other animals, have dynamic carapace colour and pattern changes, especially during moulting, which can be timed to tidal or lunar cycles (Brown & Webb 1949). They are known to undergo rapid colour changes in response to stress, during courtship, and as a result of thermo-regulation (Hemmi et al. 2006). The colour

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changes that result are more noticeable in females than in males of the same size (Detto et al. 2008). Hence, in this study, we examine and document the phenotypic variation in female carapace morphology of *Austruca annulipes* and whether it represents ecologically adaptive polymorphism, potentially driven by selective pressures such as predation, habitat complexity, or mate recognition.

Materials and Methods

The study was conducted in mangroves off Sauta Vaddo, Baga-Calangute, Goa (15.5661º N, 73.7581º E) (Image 1) during December 2023. The mangroves have expanded into the abandoned fields nearby creating mangrove edge ecosystems which are affected by the tidal cycle. These provide suitable habitat for fiddler crabs that have populated these areas over the past 20 years. The river Baga runs through the mangroves and the area has seen little human disturbance since the fields were abandoned (Image 2).

The variation in female carapace colour and pattern was observed in the field and photographed using Sony HX400V, and Nikon Coolpix P1000. Microscopic characters such as minor cheliped, abdomen, and walking legs were photographed using stereomicroscope Zeiss Stemi 508 with Axiocam camera. The study area map was created using Qgis 3.34. The species was identified using taxonomic keys given by White A (1847) and WORMS (World Register of Marine Species) online database (marinespecies.org). The crabs were handpicked and scooped by random sampling during low tide and collected & tagged in containers, and brought to the lab as prescribed by Darnell et al. (2019). Each specimen was assigned a unique identification code comprising the site abbreviation, date of collection (day–month–year), and an individual serial number (e.g., SV17122301–SV17122350). In total, 50 specimens were catalogued, including 25 males and 25 females. The specimens were then freeze-killed and immersed in 80% absolute ethanol (Hampton et al. 2013). This study was conducted with the Ethical permission no. GUZ/IAEC/23-24/N42. Basic morphometric analyses (Crane 2015) were performed for all specimens and the carapace length (CL), carapace breath (CB), & breadth of front (BF) was recorded for both sexes; major propodus length (MPL) & major dactyl length (MDL) for males; and

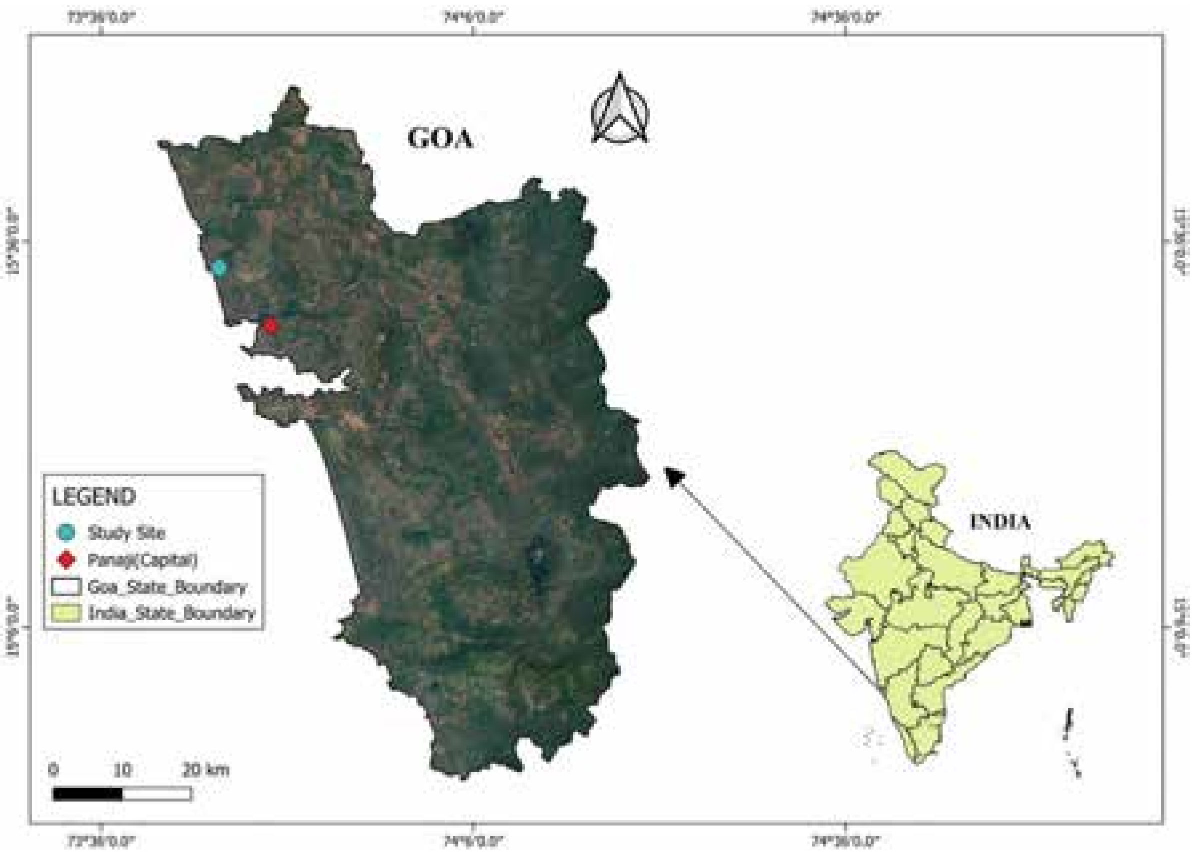

Image 1. Study area of Baga creek, Goa, India.

length of propodus (LP) & length of abdomen (LA) for females were recorded separately.

Results

The morphometric data collected (Table 1) from these crabs support that all observed morphs, belong to the same species, *Austruca annulipes*. A total of 14 female variations (Table 2), adult males and four male moults (Image 3) were recorded during the present field study. The females were slightly smaller than the males in size and illustrated more colour, and pattern variations compared to males, while the males were similar in size but showed varied patterns on carapace as they underwent periodic moulting.

Discussion

The study confirms pronounced sexual dimorphism in *A. annulipes*, with significant polymorphism observed in females. Male carapace patterns appear linked to periodic moulting, while female variation is more persistent, and diverse. The documentation of 14 female morphs in this Indian population parallels findings from South Africa (Peer et al. 2015), although with differing pattern types. Five morphs resemble male-like androchromic traits, while the remaining exhibit heterochromic features. The ecological and genetic underpinnings of such polymorphism remain unclear, warranting further investigation. Colour variation in fiddler crabs has been linked to light, stress, and social signalling (Crane 1944, 1958; Taborsky 2008; Tate & Amar 2017). While in females it is linked mostly with sexual selection and female ornamentation, indicating towards alternative reproductive tactics (Oliveira et al. 2008; Diamant et al. 2021). This study adds valuable observational data, supporting the case for more detailed ecological, and genetic research into female-specific traits in *A. annulipes*.

Conclusion

This study provides the first documentation of carapace polymorphism among female *Austruca annulipes* in the Baga mangroves of Goa, India. Observations indicate size-related variation and distinct colour morphs across individuals. Though moulting patterns might be influenced by lunar cycles, this was not a primary focus of the current study. Given their role as bioindicators and ecosystem engineers, deeper insight into the species' phenotypic diversity can contribute to broader mangrove conservation strategies. Future research should explore the genetic basis and ecological drivers of polymorphism in female *A. annulipes.*

Table 1. Morphometric data (mm) for males and females of *Austruca annulipes*.

	Morphometric character	Male (n = 25): Mean ± SD	Female (n = 25): Mean ± SD
1	Carapace length (CL)	16.42 ± 1.41	13.57 ± 1.57
2	Carapace breath (CB)	9.84 ± 0.61	8.16 ± 0.62
3	Breath of front (BF)	2.5 ± 0.19	2.21 ± 0.16
4	Major propodus length (MPL)	26.74 ± 2.30	-
5	Major dactyl length (MDL)	15.14 ± 1.62	-
6	Length of propodus (LP)	-	4.72 ± 0.515
7	Length of abdomen (LA)	-	6.13 ± 0.68

References

Bouchard, J., J. Poupin, R. Cleva, J. Dumas & V. Dinhut (2013). Land, mangrove and freshwater decapod crustaceans of Mayotte region (Crustacea Decapoda). *Atoll Research Bulletin* 592: 1–60. https://doi.org/10.5479/si.00775630.592

Brown, F.A. & H.M. Webb (1949). Studies of the Daily Rhythmicity of the Fiddler Crab, Uca. Modifications by Light. *Physiological Zoology* 22(2): 136–148. https://doi.org/10.1086/physzool.22.2.30152036

Crane, J. (1944). On the colour changes of Fiddler crabs (Genus Uca) in the field. *Zoologica Scientific Contributions of the New York Zoological Society* 29(15): 161–168. https://doi.org/10.5962/p.203572

Crane, J. (1958). Aspects of social behavior in fiddler crabs, with special reference to Uca maracoani (Latreille). *Zoologica Scientific Contributions of the New York Zoological Society* 43(10): 113–130. https://doi.org/10.5962/p.203380

Crane, J. (2015). *Fiddler Crabs of the World: Ocypodidae: Genus UCA*. Princeton University Press, 766 pp.

Darnell, M.Z., P.R. Backwell & P. Munguia (2019). Frequency and latency of autotomy of a sexually selected fiddler crab appendage. *Journal of Experimental Marine Biology and Ecology* 523: 151255. https://doi.org/10.1016/j.jembe.2019.151255

Detto, T., J.M. Hemmi & P.R.Y. Backwell (2008). Colouration and colour changes of the fiddler crab, *Uca capricornis*: a descriptive study. *PLoS ONE* 3(2): e1629. https://doi.org/10.1371/journal.pone.0001629

Diamant, E.S., J.J. Falk & D.R. Rubenstein (2021). Male-like female morphs in hummingbirds: the evolution of a widespread sex-limited plumage polymorphism. *Proceedings of the Royal Society B Biological Sciences* 288(1945): 1–10. https://doi.org/10.1098/rspb.2020.3004

Fulmali, M., S. Kumaresan, A. Saravanakumar & R. Samuthirapandian (2021). Customisation of bioturbatory structure and spatio-temporal burrow density variations and allometric growth pattern by porcelain fiddler crab (*Austruca annulipes* H. Milne Edwards, 1837) in polluted and unpolluted habitats of Vellar Estuary, India. Thesis for Master of Science in Marine Biology and Oceanography. Annamalai University.

Hampton, K., M. Hopkins, J. McNamara & C. Thurman (2013). Intraspecific variation in carapace morphology among fiddler crabs (Genus Uca) from the Atlantic coast of Brazil. *Aquatic Biology* 20(1): 53–67. https://doi.org/10.3354/ab00545

Hemmi, J.M., J. Marshall, W. Pix, M. Vorobyev & J. Zeil (2006). The variable colours of the fiddler crab*Uca vomeris*and their relation to background and predation. *Journal of Experimental Biology* 209(20): 4140–4153. https://doi.org/10.1242/jeb.02483

Oliveira, R.F., M. Taborsky & H.J. Brockmann (2008). *Alternative Reproductive Tactics: An Integrative Approach*. Cambridge University Press, 518 pp.

Peer, N., N.A. Miranda & R. Perissinotto (2015). A review of fiddler crabs (genus*Uca*Leach, 1814) in South Africa. *African Zoology* 50(3):

Image 2. ***Austruca annulipes*: A—Males surrounded by mangrove pneumatophores | B—Colony | C—Male (left) and heterochrome female morph (right) | D—Male (left) and androchrome female morph (right) on the burrow opening | E—Two males engaged in claw fight to defend its burrow | F—Colony during neap (low) tide feeding | G—Study site during neap (high) tide | H—Mangroves invaded fields occupied by fiddler crabs during neap tide. © Vaishnavi Bharti.**

Table 2. The observed morphs of female *Austruca annulipes* in the study site. © Vaishnavi Bharti.

Morph	Photographic evidence	Description
Female morph 1		White carapace with dark to bright pink stripes on both sides of postero–lateral border touching the cervical groove. The pair of front legs are bright pink and back legs are white.
Female morph 2		White carapace with a dark pink cross mark at cervical groove. First two pairs of front legs are bright red and the third pair is half pink and half white. The back legs are completely white.
Female morph 3		White carapace with dark pink stripes on both sides of the postero-lateral border. A triangular dark pink mark ends the cervical groove. Last two- three pairs of walking legs are asymmetrically white while others are bright pink in colour.
Female morph 4		Light pinkish carapace ending with a bright white band. Dark pink lines outline the postero-lateral border. Dark red front and back legs with diffused white patterns on them.
Female morph 5		Carapace is tricoloured starting with a pale pink, bright red stripe, and a thick white stripe on the posterior end. All pairs of legs are dark pink in colour.
Female morph 6		Carapace is tricoloured starting with a pale pink, bright red stripe, and a thick white stripe on the posterior end. First four pairs of walking legs are bright red followed by a white fifth pair.
Female morph 7		White–grey carapace with a bright red posterior margin. Bright red coloured front and back legs.
Female morph 8		White–grey carapace with red and white posterior margins. Both front and back legs have similar patterns. The legs are covered with alternate bands of red and white segments.

Morph	Photographic evidence	Description
Female morph 9		The carapace has three bands with brownish frontal margin with white pattern on it, followed by black band in cervical groove with white pattern, and a bright, plain white posterior margin. First two pairs of front legs are bright red, and the third pair is white. The back legs are white in colour.
Female morph 10		Black carapace with sparse white pattern on anterior end and a bright white stripe at the posterior end. Walking legs vary in colour from white to red in colour.
Female morph 11		Plain black carapace with a white stripe at posterior end. All pairs of legs are black in colour.
Female morph 12		The upper carapace is dull white–greyish. A distinct black band forms below the cervical groove followed by a bright white band ending the posterior margin. The back legs are completely white.
Female morph 13		Carapace pattern is similar to males. Upper carapace is greyish with white patterns on it, followed by black band with white pattern in it below the cervical groove, and ends with a plain white band. Front and back legs are the same greyish in colour with random white patterns on it.
Female morph 14		The carapace is black with white patterns. A black line passes below the cervical groove. The posterior margin is a plain white stripe. Front and back legs are similar, with bright black colour, with small white spots on them.

187–204. https://doi.org/10.1080/15627020.2015.1055700

Silva, D.J.A., M.F. Erickson & D.M.A. Pessoa (2024). The role of carapace colour in species recognition in a fiddler crab. *Animal Behaviour* 216: 37–44. https://doi.org/10.1016/j.anbehav.2024.07.016

Tate, G.J. & A. Amar (2017). Morph specific foraging behavior by a polymorphic raptor under variable light conditions. *Scientific Reports* 7(1): 1–12. https://doi.org/10.1038/s41598-017-07829-x

WoRMS World Register of Marine Species - *Austruca annulipes* (H. Milne Edwards, 1837). Accessed on 2.vi.2023. https://www.marinespecies.org/aphia.php?p=taxdetails&id=955178#:~:text=DecaNet%20eds.%20(2024).%20DecaNet.%20Austruca%20annulipes%20(H.%20Milne%20Edwards%2C%201837).%20Accessed%20through%3A%20World%20Register%20of%20Marine%20Species%20at%3A%20https%3A//www.marinespecies.org/aphia.php%3Fp%3Dtaxdetails%26id%3D955178%20on%202024%2D02%2D16

Yamaguchi, T. (1977). Studies on the handedness of the fiddler crab, *Uca lactea*. *Biological Bulletin* 152(3): 424–436. https://doi.org/10.2307/1540430

Image 3. *Austruca annulipes*: A–F—Observed colour morphology of males in Baga mangroves. A—Adult | B—C—Moulting | D–E—Juveniles | F—Adult. © Vaishnavi Bharti.

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SHORT COMMUNICATION

Habitat-specific distribution and density of fireflies (Coleoptera: Lampyridae): a comparative study between grassland and woodland habitats

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Abstract: Habitat plays a crucial role in the survival of insect species, with many restricted to or thriving in particular environments. This study examines the population densities and flight heights of fireflies across different habitats. Firefly density was estimated using the point count method along randomly placed 100 m transects in two distinct habitats: grassland and woodland. Results revealed that the average density of *Abscondita chinensis* and *Asymmetricata circumdata* was significantly higher in grassland than in woodland. Firefly vertical distribution also varied by flight height, with a greater density observed below 1.5 m in grassland ($z = 13.90$, $n1 = 99$, $n2 = 99$, $p < 0.05$), while in woodland, higher densities were found above 1.5 m ($z = 2.29$, $n1 = 38$, $n2 = 38$, $p < 0.05$). These findings emphasize habitat-specific preferences & behaviours, highlighting the need for targeted conservation & management strategies to preserve firefly populations, and their diverse environments.

Keywords: *Abscondita chinensis*, *Asymmetricata circumdata*, conservation, glowworms, transects, vertical distribution.

The Neotropics and the Asian south-east harbour the highest diversity of fireflies within the family Lampyridae (Lawrence & Newton 1995; Hu & Fu 2018; Lewis et al. 2021; Poukin et al. 2023). According to Lloyd (2008), the Lampyridae family is renowned for its bioluminescent courtship signalling traits. Research suggests that the flashing behaviour observed in male fireflies serves purposes such as mate choice and predation (Buck & Buck 1968; Lewis & Cratsley 2008).

Abscondita chinensis (Kiesenwetter, 1874) and *Asymmetricata circumdata* (Motschulsky, 1854) are two firefly species with distinct but overlapping distributions in Asia. *Abscondita chinensis* is primarily found across eastern and southeastern Asia, with documented occurrences in countries such as India, China, Japan, Taiwan, Vietnam, and Thailand (Wattanachaiyingcharoen et al. 2011; Ballantyne et al. 2013; Chatragadda 2020; Chaiwongsaen et al. 2024). In India, its distribution includes Assam, Uttarakhand, Doon Valley, and western Himalaya (Ballantyne et al. 2009; Ghosh et al. 2023; Rana et al. 2024). The bioluminescent behaviour of *Abscondita chinensis* fireflies is well-studied in northeastern India (Rabha et al. 2017). This species thrives in moist, lowland habitats, including rice paddies, wetlands, and forested areas (Fu et al. 2012). On the other hand, *Asymmetricata circumdata* has a broader distribution across the Oriental region, reported from southeastern Asia, including India, Sri Lanka, Myanmar, Thailand, parts of China (Lloyd et al. 1989; Ballantyne & Lambkin 2009), and in Assam India (Rabha & Barua 2016).

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Despite extensive research on firefly diversity, bioluminescence, and ecological roles, the significance of flight height in relation to their behaviour, and habitat preferences remains understudied. Most previous research has focused on flashing behaviour for mate selection, but little is known about how flight height impacts firefly behaviour, and survival across habitats. As human-induced threats such as habitat loss and light pollution increase, understanding factors like flight height, and density is essential for conservation (Shen et al. 2022). This study addresses the gap by investigating the density and flight height of two firefly species in grassland, and woodland habitats in & around Bodoland University.

Materials and Methods

We conducted the research in the Bodoland University Campus, Assam, India (26.469° N, 90.294° E, 100 m), covering an area of 49.6 acres for six consecutive months from January through June 2022 (Figure 1). We studied in two primary habitats: predominantly grassland and woodland, interspersed with perennial and deciduous plants. The closest water source, the Gaurang River, flows along the easternmost boundary of the campus. The density of fireflies was assessed by point count method, separated by 20 m distance between two successive points along stratified, randomly placed 100 m transects in both grassland, and woodland habitat. We counted fireflies within a 20 m radius during 1930–2100 h. Prior to the data collection, we had done a pilot study, and observed that during this period, the activity of the fireflies was more. We surveyed 99 points in the grassland habitat and 34 points in the woodland habitat. In comparison to the grassland habitat, in the study area, the woodland was smaller, and hence, the number of points surveyed was less, following a stratified random

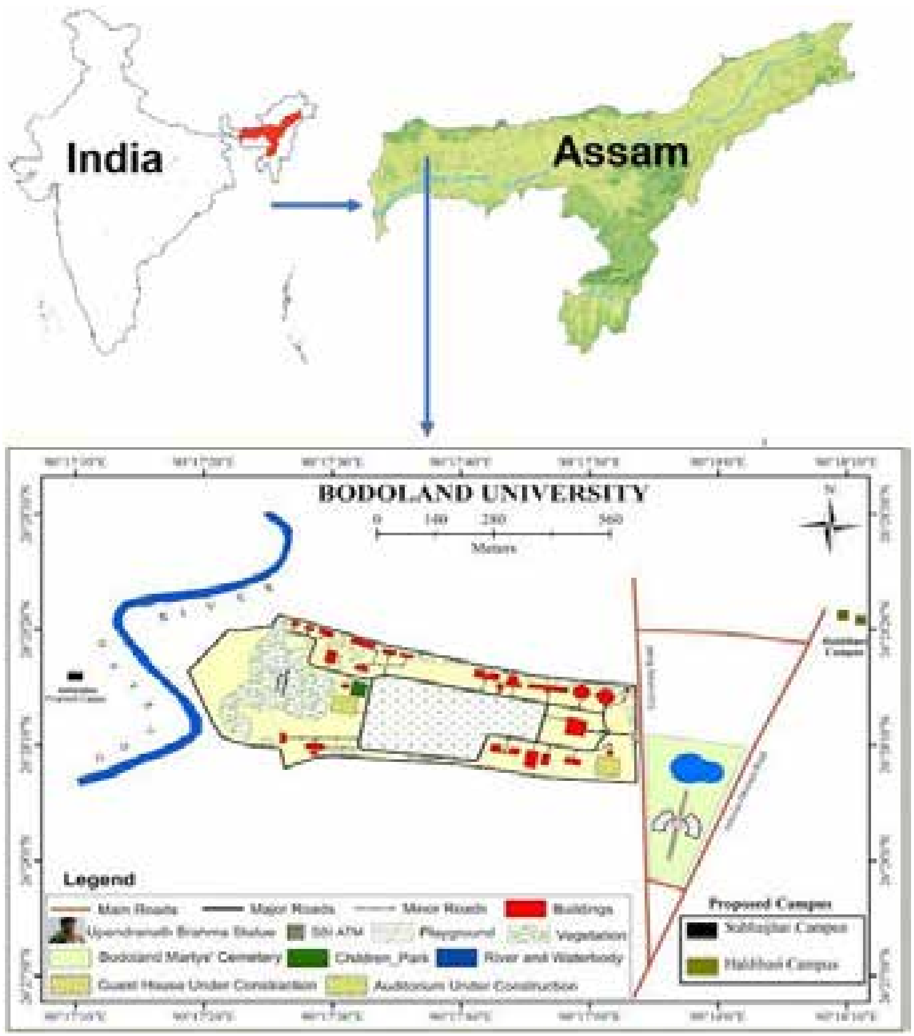

Figure 1. Study area map of Bodoland University campus, Assam, India, showing grassland and woodland habitats.

sampling. The flight height of the fireflies is categorised into two categories: up to 1.5 m from the ground and above 1.5 m, based on the height of the observer, i.e., up to eye level and above. All data were analyzed using Microsoft Excel 2007 and PAST statistical software (version 4.03). To compare firefly densities between the grassland and woodland habitats, a z-test was conducted at a significance level of 0.05.

Results

A total of 556 individuals of two species of fireflies, namely, *Abscondita chinensis* (Kiesenwetter, 1874), and *Asymmetricata circumdata* (Motschulsky, 1854) (Image 1), were recorded from the study area. The average density of fireflies was significantly higher (0.0051 ± 0.004, n = 99) in the grassland habitat than in the woodland habitat (0.0031 ± 0.0030, n = 38) (z = 3.17, n1 = 99, n2 = 38, $p < 0.05$) below mid height (BMH) and above mid height (AMH) (Figure 1). The average densities of fireflies were recorded as 0.0000041 /m^2 in the grassland and 0.0000024 /m^2 in the woodland.

The density of *Abscondita chinensis* was higher in the grassland habitat (0.0034 /m^2) than in the woodland habitat (0.0018 /m^2). In contrast, the density of *Asymmetricata circumdata* was also higher in the grassland (0.0017 /m^2) than in the woodland habitat (0.0010 /m^2).

Firefly density was notably higher below 1.5 m from the ground in the grassland habitat (z = 13.90, n1 = 99, n2 = 99, $p < 0.05$) (Figure 2), whereas in woodland habitats, it was more concentrated above 1.5 m (z = 2.29, n1 = 38, n2 = 38, $p < 0.05$) (Figure 3).

Discussion

Firefly density varies across different habitats, likely due to slight variations in environmental factors between the two habitats. Moreover, the presence of vegetation is crucial for fireflies, serving as copulation and resting sites, as documented in *Luciola cruciata* (Yuma & Hori 1990; Wattanachaiyingcharoen et al. 2016). During the night, temperatures typically remain relatively higher in open areas compared to forested areas due to the canopy coverage. Additionally, there may be greater availability of nectar plants in grasslands than in woodlands because the exposure to sunlight in the open grassland habitat results in a higher density of flowering plants compared to the woodland habitat. Another factor contributing to the low density of fireflies in woodland is the scarcity of nectar sources. Asri et al. (2020) found that firefly abundance exhibited a significant correlation with temperature and humidity. Specifically, they observed a positive relationship between firefly abundance and temperature, while noting a negative correlation with humidity. Jusoh (2015) observed that firefly species tend to inhabit a range of environments and may coexist with multiple other species. Their study particularly highlights the coexistence of *Abscondita chinensis* and *Asymmetricata circumdata* in shared habitats, a finding that aligns with our study as well.

In contrast, fireflies may exhibit a preference for higher flight altitudes in woodland habitats for several reasons. Within this habitat, despite still relying on bioluminescence for mating, flying at elevated heights enhances the visibility of their light signals amidst the dense foliage. This heightened visibility extends the range over which potential mates can detect their signals, fostering increased mating opportunities (Lloyd 2008). Furthermore, woodland often harbours intricate vegetation and various obstacles nearer to the ground, such as tree trunks, and branches. By soaring at higher heights, fireflies mitigate the risk of collisions with these obstacles, facilitating better navigation through the forest canopy (Shen 2022). Additionally, given that many

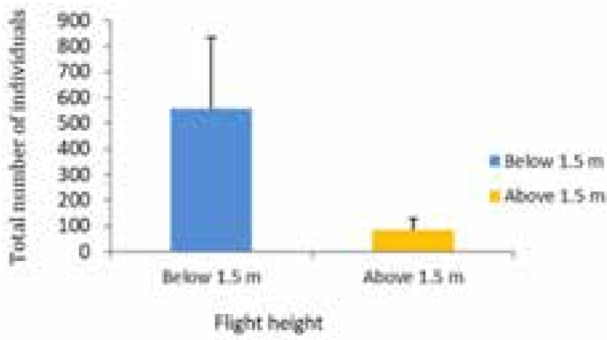

Figure 2. Firefly density distribution in grassland habitat, with significantly higher densities observed below 1.5 m.

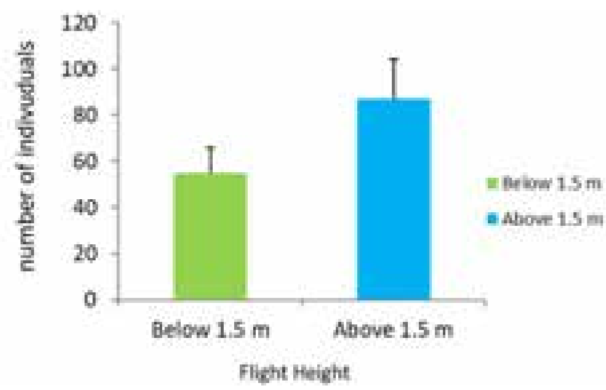

Figure 3. Firefly density distribution in woodland habitat, with significantly higher densities observed above 1.5 m.

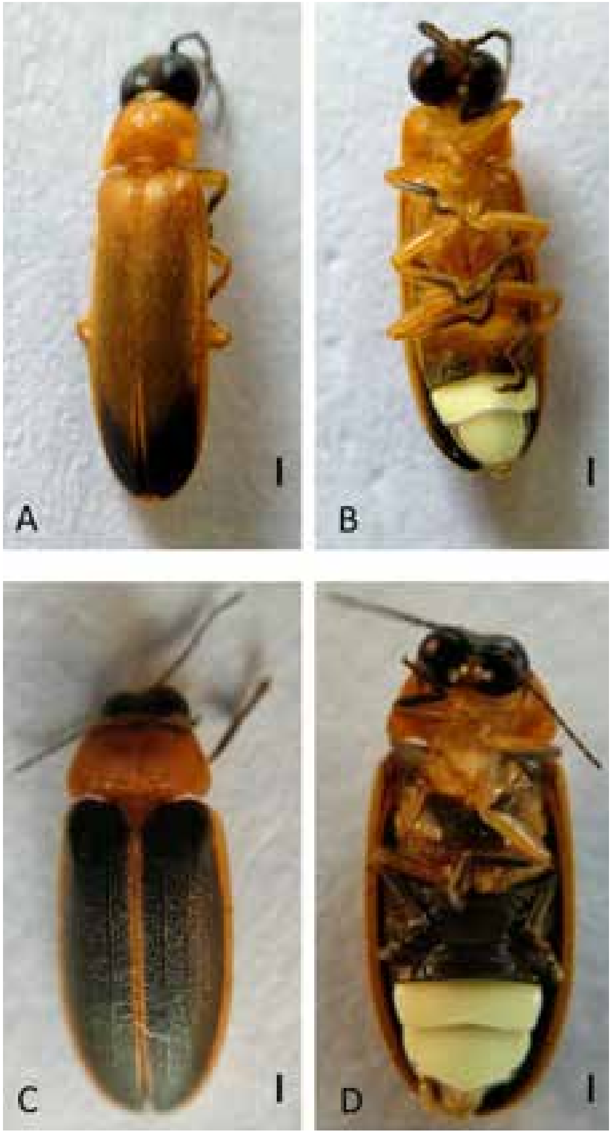

Image 1. Morphological views of two firefly species: A—dorsal view (male) | B—ventral view of *Abscondita chinensis* | C—dorsal view (male) | D—ventral view of *Asymmetricata circumdata*. (Scale in 2 mm). © Kushal Choudhury.

firefly species seek refuge and forage for sustenance in the canopy during daylight hours, elevated flight allows easier access to these critical resources, and habitats during their active periods. While this behavior may expose fireflies to aerial predators like bats, the advantage lies in the enhanced visibility of oncoming threats, enabling more effective evasion strategies compared to lower-altitude flights where ambushes by predators within dense vegetation pose a greater risk (Barbosa & Castellanos 2005). In addition, some specific features of plant leaves, for example, broader leaves, may be a crucial factor in enabling fireflies to escape the attention of predators.

Conclusion

From a conservation perspective, understanding habitat preferences and flight height is crucial for firefly survival, as these factors directly impact their ecological roles, reproductive success, and vulnerability to threats. Habitat type influences food availability, larval development, and mating behaviours, while flight height can affect how fireflies interact with their environment, find mates, and avoid predators. Fireflies that fly close to the ground may be more vulnerable to habitat disturbance, such as land-use changes or pesticide exposure, whereas, those flying at higher altitudes could be more affected by artificial lighting (Costin & Boulton 2016). Since light pollution interferes with their bioluminescent signalling (Owens et al. 2022), critical for mating, knowing flight height can inform strategies to minimize artificial light at key levels in specific habitats. The present research explicitly highlights how these objectives are addressed from both behavioural and ecological perspectives. Thus, conservation efforts must integrate both habitat protection and an understanding of species-specific flight heights to ensure effective firefly preservation amidst growing environmental threats.

References

Asri, L.N., N.A. Abdullah, A. Sulaiman, M.H.M. Asri, N. Sulaiman, E.M.F Satiman & N.D.A. Darbis (2020). Abundance and species composition of synchronous flashing firefly at Sungai Rembau, Negeri Sembilan, Malaysia. *International Journal of Tropical Insect Science* 41(2): 1095–1106. https://doi.org/10.1007/s42690-020-00295-5

Ballantyne, L.A. & C. Lambkin (2009). Systematics of Indo-Pacific fireflies with a redefinition of Australasian Atyphella Olliff, Madagascan Photuroluciola Pic, and description of seven new genera from the Luciolinae (Coleoptera: Lampyridae). *Zootaxa* 1997(1): 1–188. https://doi.org/10.11646/zootaxa.1997.1.1

Ballantyne, L.A. & C.L. Lambkin (2013) Systematics and phylogenetics of Indo-Pacific Luciolinae fireflies (Coleoptera: Lampyridae) and the description of new genera. *Zootaxa* 3653(1): 1–162. https://doi.org/10.11646/zootaxa.3653.1.1

Barbosa, P. & I. Castellanos (2005). *Ecology of Predator-Prey Interactions*. Oxford University Press, Oxford and New York, xvii + 394 pp.

Buck, J. & E. Buck (1968). Mechanism of rhythmic synchronous flashing of fireflies: fireflies of Southeast Asia may use anticipatory time-measuring in synchronizing their flashing. *Science* 159(3821): 1319–1327. https://doi.org/10.1126/science.159.3821.131

Chaiwongsaen, P., S. Pinmongkhonkul, A. Nuntakwang, B. Boonsuk, M. Titayavan, W. Boonriam & S. Nak-eiam (2024). Spatial Distribution of Fireflies (Coleoptera: Lampyridae) A Case Study of Kwan Phayao Area, Phayao Province, Thailand, pp. 1–5. In: *2024 Geoinformatics for Spatial-Infrastructure Development in Earth and Allied Sciences (GIS-IDEAS)*. IEEE. https://doi.org/10.1109/gis-ideas63212.2024.10990917

Chatragadda, R. (2020). Decline of luminous firefly Abscondita chinensis population in Barrankula, Andhra Pradesh, India. *International Journal of Tropical Insect Science* 40(2): 461–465. https://doi.org/10.1007/s42690-019-00078-7

Costin, K.J. & A.M. Boulton (2016). A field experiment on the effect of introduced light pollution on fireflies (Coleoptera: Lampyridae) in the Piedmont Region of Maryland. *The Coleopterists Bulletin* 70(1): 84–86. https://doi.org/10.1649/072.070.0110

Fu, X.H., L.A. Ballantyne & C. Lambkin (2012). *Emeia* gen. nov., a new genus of Luciolinae fireflies from China (Coleoptera: Lampyridae) with an unusual trilobite-like larva, and a redescription of the genus *Curtos* Motschulsky. *Zootaxa* 3403(1): 1–53. https://doi.org/10.11646/zootaxa.3403.1.1

Ghosh S., S.K. Sarkar & S. Chakraborty (2023). New distributional records of fireflies (Coleoptera, Lampyridae, Luciolinae) from two eastern states of India with notes on their biology and an updated Indian checklist. *Biodiversity Data Journal* 11: e98948. https://doi.org/10.3897/BDJ.11.e98948

Hu, J. & X. Fu (2018). The complete mitochondrial genome of the firefly, *Abscondita anceyi* (Olivier) (Coleoptera: Lampyridae). *Mitochondrial DNA Part B* 3(1): 442–443. https://doi.org/10.1080/23802359.2018.1456373

Jusoh, W.F.A. (2015). Taxonomy and molecular phylogenetic analysis of bent-winged fireflies (Coleoptera: Lampyridae: Pteroptyx) in Peninsular Malaysia and Sarawak. Doctoral dissertation, Universiti Putra Malaysia. Universiti Putra Malaysia Institutional Repository.

Lawrence, J.F. & A.F. Newton (1995). Families and subfamilies of Coleoptera (with selected genera, notes, references and data on family-group names), pp 779–1006. In: Pakaluk, J. & S.A. Ślipiński (eds.). *Biology, Phylogeny and Classification of Coleoptera: Papers Celebrating the 80th Birthday of Roy A. Crowson, Volume 1*. Muzeum i Institut Zologii PAN, Warszawa, 1092 pp.

Lewis, S.M., A. Thancharoen, C.H. Wong, T. López-Palafox, P.V. Santos, C. Wu & J.M. Reed (2021). Firefly tourism: Advancing a global phenomenon toward a brighter future. *Conservation Science and Practice* 3(5): e391. https://doi.org/10.1111/csp2.391

Lewis, S.M. & C.K. Cratsley (2008). Flash signal evolution, mate choice, and predation in fireflies. *Annual Review of Entomology* 53: 293–321. https://doi.org/10.1146/annurev.ento.53.103106.093346

Lloyd, J.E. (2008). Fireflies (Coleoptera: Lampyridae), pp. 1429–1452. In: Capinera, J.L. (ed.). *Encyclopedia of Entomology*. Springer, Dordrecht. https://doi.org/10.1007/978-1-4020-6359-6_3811

Lloyd, J.E., S.R. Wing & T. Hongtrakul (1989). Flash behavior and ecology of Thai *Luciola* fireflies (Coleoptera: Lampyridae). *Florida Entomologist* 72(1): 80–85.

Owens, A.C., M. van den Broeck, R. de Cock & S.M. Lewis (2022). Behavioral responses of bioluminescent fireflies to artificial light at night. *Frontiers in Ecology and Evolution* 10: 946640. https://doi.org/10.3389/fevo.2022.946640

Poukin, E., M.D. Mahadimenakbar & M. Mohamed (2023). The seasonal monsoon variations and the climatic effects on the abundance of fireflies (Coleoptera: Lampyridae) at Klias River, Beaufort, Sabah, East Malaysia. *Serangga* 28(2): 78–97.

Rabha, M.M. & A.G. Barua (2016). Bioluminescence emissions of female fireflies of the species Asymmetricata circumdata. *Asian Journal of Physics* 25(11): 1415–1420.

Rabha, M.M., U. Sharma, A. Goswami & A.G. Barua (2017). Bioluminescence emissions of female fireflies of the species Luciola praeusta. *Journal of Photochemistry and Photobiology B: Biology* 170: 134–139. https://doi.org/10.1016/j.jphotobiol.2017.03.028

Rana, N., R. Rayal, V.P. Uniyal & P. Bahuguna (2024). First record of abscondita chinensis (Linnaeus) (Lampyridae, Luciolinae) from Uttarakhand. *Indian Journal of Entomology* 87(1): 145–147. https://doi.org/10.55446/IJE.2024.1983

Shen, M., Z. Qing & S. Lin (2022). The impact of environment situation on fireflies and the contribution of fireflies on environment situation. *The 2nd International Conference on Biological Engineering and Medical Science* (*Theoretical and Natural Science*) 4: 391–396. https://doi.org/10.54254/2753-8818/4/20220604

Wattanachaiyingcharoen, W., S. Nak-eiam & A. Thancharoen (2011). Distribution and habitat of the firefly, Asymmetricata circumdata (Motsch.) (Coleoptera: Lampyridae: Luciolinae) in the North of Thailand. *NU. International Journal of Science* 8(2): 12–18.

Wattanachaiyingcharoen, W., S. Nak-eiam, W. Phanmuangma, S. Booninkiaew & N. Nimlob (2016). Species diversity of firefly (Coleoptera: Lampyridae) in the highlands of Northern Thailand. *NU International Journal of Science* 13(2): 24–32.

Yuma, M. & M. Hori (1990). Seasonal and age-related changes in the behavior of the Genji firefly, *Luciola cruciata* (Coleoptera: Lampyridae). *Japanese Journal of Entomology* 58(4): 863–870.

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SHORT COMMUNICATION

Hygrophila phlomoides Nees (Acanthaceae), a new record to the flora of northern India from Suhelwa Wildlife Sanctuary, Uttar Pradesh

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Abstract: *Hygrophila phlomoides* Nees is reported as a new distribution record to the flora of northern India from Bhagwanpur forest of Suhelwa Wildlife Sanctuary, Uttar Pradesh. In India, the distribution of this species is previously reported only from the eastern Himalaya (Assam, Arunachal Pradesh, Manipur, Meghalaya, West Bengal) and Karnataka State of Western Ghats.

Keywords: Angiosperm flora, Balrampur and Shravasti, Bhagwanpur forest, Indo-Nepal border, marshy areas, tropical and subtropical regions.

Hygrophila R.Br. (Acanthaceae: Ruellieae) is a cosmopolitan genus, commonly found in swamp areas of tropical and subtropical regions of the world (Hu & Daniel 2011). Around 77 species of the genus are reported worldwide (POWO 2025), of which, 17 taxa have been documented from India (Arisdason et al. 2020).

While working on the floristic diversity of Suhelwa Wildlife Sanctuary, the first author encountered an interesting population of a *Hygrophila* species near a water body in Bhagwanpur forest area, Tulsipur range at an elevation of 178 m. The detailed taxonomic study of the collected specimens using relevant taxonomic literature (Clarke 1884; Cook 1996; Jaseela et al. 2024) and consultation with experts, the identity of the specimen was confirmed as *Hygrophila phlomoides* Nees (Nees 1832). Based on the review of literature (Duthie 1960; Maheshwari 1963; Parker 1973; Kachroo & Sapru 1977; Bhandari 1978; Osmaston 1978; Sharma & Kachroo 1981; Chowdhery & Wadhwa 1984; Khanna et al. 2020; Kumar 2001; Singh & Prakash 2002; Mohan 2006) it revealed that, the species has not been reported from any states and union territories of northern India (Himachal Pradesh, Uttarakhand, Haryana, Punjab, Uttar Pradesh, Rajasthan, Jammu & Kashmir, Delhi, Chandigarh, Ladakh). Therefore, the present collection

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Competing interests: The authors declare no competing interests.

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AcSIR

मानव संसाधन विकास समूह
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वैज्ञानिक तथा औद्योगिक अनुसंधान परिषद्
Council of Scientific & Industrial Research

of this plant species from Uttar Pradesh reports the extended distribution to the angiosperm flora of northern India.

Material and Methods

Study area: During the present study, *H. phlomoides* has been collected from the marshy areas of Bhagwanpur forest, Suhelwa Wildlife Sanctuary, Uttar Pradesh. The Suhelwa Wildlife Sanctuary, encompassing an area of 452 sq km, is situated in the Balrampur and Shravasti districts of northern Uttar Pradesh near Indo-Nepal border. The sanctuary ranges from 27.500–27.928° N and 81.927–82.809° E at an altitude of 120–200 m (Khanna 2015).

The live specimens were collected from the Bhagwanpur forest areas of Suhelwa Wildlife Sanctuary. Micro morphological characters were examined by using Leica S8 APO stereo microscope. The nomenclatural corrections were made according to Shenzhen code (Turland et al. 2018). Abbreviated author citations were given by following authors of plant names (Brummitt & Powell 1992), and acronyms of herbaria were provided according to Index Herbariorum (Thiers 2025). The specimens of appropriate size with relevant plant parts were collected from the field and the herbarium specimens were prepared following the standard methods (De Vogel 1987; Bridson & Forman 1998). The voucher specimens were deposited in the herbarium of CSIR-National Botanical Research Institute (LWG) for future reference.

Botanical description

Hygrophila phlomoides Nees, N.Wallich, Pl. Asiat. Rar. 3: 80(1832). (Images 1, 2).

Type (Lectotype designated by Jaseela et al. 2024): Bangladesh, Sillet, G. Gomez, Wall Cat n. 2376 (GZU [GZU000250031 digital image!]; isolectotypes GZU [GZU, K, E, P, PH, G-DC, C, CAL].

Erect unarmed herb, 55–92 cm high. Stem branched, quadrangular, green, strigose; internodes swollen, 2–10 cm long, strigose. Leaves sub-sessile, obovate, elliptic, 5–10 × 2–2.8 cm, obtuse or acute at apex, margin entire,

Image 1. *Hygrophila phlomoides* Nees.: a—habitat | b—flower | c—bracts. © Pankaj Bharti.

undulate or crenate, cuneate at base, hairy on both surfaces; midrib prominent adaxially and conspicuous abaxially; lateral nerves 7–13 pairs; cystoliths present; petiole 3–7 mm long, hairy. Flowers axillary in dense villous whorls, 8–10; bracts in three series; outer bracts large, foliaceous, obovate, 18–22 × 5–6 mm, obtuse at apex, margins entire, base cuneate, green, hairy on both surfaces; middle series of bracts ovate-lanceolate, 12–14 × 4–4.5 mm, sub-acute at apex, margins entire, base cuneate, green, hairy on both surfaces; inner series of bracts oblong, 8–10 × 2–2.5 mm, sub-acute at apex, margins entire, base cuneate, green, hairy on both surfaces; bracteoles linear, 5.5–5.8 × 1.2–1.3 mm, hirsute, obtuse at apex, margin entire, cuneate at base, hairy on both surfaces. Calyx tubular, 5-lobed, 1–12 × 11–12 cm, divided halfway down reddish-brown; teeth linear, 6–6.5 mm long, dissimilar, one segment larger than others, hairy. Corolla bilabiate, 15–16 mm long, pink and dark purple streaks on the mouth, glandular hairy; tube 4.5–4.8 mm long, tube white to light pink, glabrous; upper lip 2-lobed, glandular hairy outside, glabrous inside; lower lip oblong, 3-lobed, glandular hairy outside, glabrous inside except at mouth hairy, middle lobe sub-orbicular, larger than the lateral lobes, purple-stripes at centre. Stamens didynamous, adnate at the base of the corolla tube; filaments white, glabrous on the upper part and hairy beneath; posterior filaments 3.5–3.8 mm long; anterior filaments 4.5–4.8 mm long; anther thecae elliptic, 1.8–2.2 mm long, pubescent at the base otherwise glabrous. Ovary 2-loculed, oblong, 2.5–2.8 mm long, glabrous; style filiform, 15–17 mm long, white, glandular hairy at base; stigma white, glabrous. Capsule linear-oblong, 14–16 mm long, exceeding the calyx, green, glabrous; seeds many, 18–24, ovoid, 1.7–1.9 × 1.2–1.4 mm, brownish, woolly, attached on the prominent retinacula.

Specimens examined: India: Uttar Pradesh, Balrampur District, Suhelwa Wildlife Sanctuary, Tulsipur, Bhagwanpur, elevation 178 m, 27.585° N, 82.457° E, 06.xi.2023, Pankaj Bharti 349037 (LWG).

Phenology: Flowering and fruiting was observed from October to February.

Distribution: Globally the species is distributed in India, Bangladesh, China, Cambodia, Laos, Malaya, Myanmar, Philippines, Thailand, and Vietnam (Govaerts et al. 2025). In India, the occurrence of this species is so far recorded from eastern Himalaya (Assam, Arunachal Pradesh, Manipur, Meghalaya, West Bengal), Karnataka, and Uttar Pradesh (present study). While compiling the Flora of Bihar Analysis, Singh et al. (2001) included the name *H. phlomoides* and mentioned the locality as 'Purnia'. The inclusion of this species in Bihar was not based on any collection but a cross citation from Haines (1961) publication, Botany of Bihar and Orissa. In Hayne's publication, the author is not confident about the locality, and mentioned as 'Marshes. Sikkim Tarai and Duars close to our area! Probably in Purnea'. The recent publication of Jaseela et al. (2024) also confirmed that, there are no voucher specimens available in any of the Indian herbaria from the state of Bihar. Hence the previous report of *H. phlomoides* from Bihar is without any scientific evidence and excluded during the study.

References

Arisdason, W., P. Lakshminarasimhan, K. Karthigeyan, G. Krishna, D.W. Albertson, P. Venu, D. Panja, T. Ghosh, H.S. Debnath, G. Gnanasekaran, G.V.S. Murthy & D.K. Roy (2020). Acanthaceae: pp. 270-319. In: Mao, A.A. & S.S. Dash, (eds.). *Flowering Plants of India: An Annotated Checklist (Dicotyledons),* vol. 2. Botanical Survey of India, Kolkata, 705 pp.

Bhandari, M.M. (1978). *Flora of the Indian Desert.* United Book Traders, Jodhpur, 471 pp.

Bridson, D.M. & L. Forman (1998). *Herbarium Handbook.* Royal Botanic Gardens, Kew, England, 300 pp.

Brummitt, R.K. & C.E. Powell (1992). Authors of Plant Names Standard. International Working Group on Taxonomic Databases (TDWG) http://www.tdwg.org/standards/101

Chowdhery, H.J. & B.M. Wadhwa (1984). *Flora of Himachal Pradesh* (Analysis), vol.2, Flora of India Series 2. Howrah: Botanical Survey of India, 550 pp.

Clarke, C.B. (1884). Acanthaceae: pp. 406-408 In: Hooker, J.D. (eds). *The Flora of British India*, vol.4. London: L. Reeve & Co. Ltd, 780pp.

Cook, C.D. (1996). *Aquatic and Wetland Plants of India*. A Reference Book and Identification Manual for the Vascular Plants Found in Permanent or Seasonal Fresh Water in the Subcontinent of India South of the Himalayas. Oxford University Press, 394 pp.

De Vogel, E.F. (1987). *Manual of Herbarium Taxonomy*. United Nations Educational, Scientific and Cultural Organization, 164 pp.

Duthie, J.F. (1960). *Flora of The Upper Gangetic Plain and of the adjacent Siwalik and Sub-Himalayan tracts*. vol. 2 reprint. Calcutta: Botanical Survey of India, pp. 55–57.

Govaerts, R. (2025). The World Checklist of Vascular Plants (WCVP). Royal Botanic Gardens, Kew. Checklist dataset. https://doi.org/10.15468/6h8ucr Accessed via GBIF.org on 03.x.2025.

Haines, H.H. (1961). The Botany of Bihar and Orissa, vol. 2. Botanical Survey of India, pp. 703–704.

Hu, J.Q. & T.F. Daniel (2011). Acanthaceae, pp. 430–432. In: Wu, Z.Y., P.H. Raven & D.Y. Hong, (eds.). *Flora of China*, vol. 19. Beijing: Science Press; St. Louis: Missouri Botanical Garden Press, 884 pp.

Jaseela, V.T., E.K. Sinisha & N.S. Pradeep (2024). Taxonomy, typification and distribution of Hygrophila phlomoides (Acanthaceae) in India. *Rheedea* 33(4): 382–388.

Kachroo, P. & B.L. Sapru (1977). *Flora of Ladakh. Dehra Dun*. Bishen Singh Mahendra Pal Singh, pp. 1–172.

Khanna, K.K. (2015). *Floristic diversity of Sohelwa Wildlife Sanctuary, Uttar Pradesh.* Phytotaxonomy, 15, pp. 166–191.

Khanna, K.K. (2020). *Family Acanthaceae: Uttar Pradesh*, pp. 271-310. In: Singh, K.P., A.A. Ansari, K.K. Khanna, G.P. Sinha, B.K. Shukla, Anand Kumar, U.S. Vaish, A.N. Shukla & V.K. Madhukar. *Flora of Uttar Pradesh*, vol. 2. Botanical Survey of India, Kolkata, 519 pp.

Kumar, S. (2001). *Flora of Haryana (Materials).* Dehradun: Bishen Singh Mahendra Pal Singh, 291 pp.

Maheshwari, J.K. (1963). *The Flora of Delhi. New Delhi.*Council of Scientific & Industrial Research, 447 pp.

Mohan, S. (2006*).* *Flora of Chandigarh UT. PhD Thesis.* Panjab

Image 2. Voucher specimen of *Hygrophila phlomoides* Nees deposited at LWG herbarium. © Pankaj Bharti.

University, 328pp.

Nees von Esenbeck, C.G.D. (1832). *Acanthaceae Indiae Orientalis*: pp. 70-117. In: Wallich, N. *Plantae Asiaticae Rariores,* vol. 3. London: Treuttel, Würtz & Ritter.

Osmaston, A.E. (1978). *A Forest Flora for Kumaon.* Reprinted. Dehra Dun: Bishen Singh Mahendra Pal Singh, pp. 387–403.

Parker, R.N. (1973). *A Forest Flora for the Punjab with Hazara and Delhi.* Dehra Dun: Bishen Singh Mahendra Pal Singh, pp. 381–393.

POWO (2025). Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew. Available at: http://www.plantsoftheworldonline.org/ .Accessed on 15.i. 2025.

Sharma, B.M. & P. Kachroo (1981). *Flora of Jammu and Plants of Neighbourhood*. Vol.1. Bishen Singh Mahendra Pal Singh, Dehradun, 246 pp.

Singh, K.K. & A. Prakash (2002). *Flora of Rajaji National Park Uttaranchal.* Bishen Singh Mahendra Pal Singh, Dehradun, 164 pp.

Singh, N.P., V. Mudgal, K.K. Khanna, S.C. Srivastava, A.K. Sahoo, S. Bandopadhyay, N. Aziz, M. Das, R.P. Bhattacharya & P.K. Hajra (2001). Flora of Bihar Analysis. Botanical Survey of India, pp. 386–387.

Thiers, B. (2020). *Index Herbariorum*. A Global Directory of Public Herbaria and Associated Staff. New York Botanical Garden's virtual herbarium. Available at: http://sweetgum.nybg.org/ih .Accessed on 15.i.2025.

Turland, N.J., J.H. Wiersema, F.R. Barrie, W. Greuter, D.L. Hawksworth, P.S. Herendeen S. Knapp, W.H. Kusber, W.H., Li, D.-Z., K. Marhold, T.W. May, J. McNeill, A.M. Monro, J. Prado, M.J. Price & G.F. Smith (2018). *International Code of Nomenclature for Algae, Fungi, and Plants (Shenzhen Code).* Regnum Vegetabil 159. Glashütten: Koeltz Botanical Books. https://doi.org/10.12705/Code.2018. Accessed on 15.i.2025.

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SHORT COMMUNICATION

The rediscovery of *Strobilanthes parryorum* C.E.C.Fisch., 1928 (Asterids: Lamiales: Acanthaceae) in Mizoram, India

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Abstract: *Strobilanthes parryorum* C.E.C.Fisch. was originally described in 1928 from Mizoram (erstwhile Lushai Hills), northeastern India, with a brief description of the flowers, leaves, and stem. Except for a few collections made by Parry in 1927 & 1928, there are no additional specimens recorded in India. New specimens were rediscovered after 96 years in Ailawng, a village some 200 km from Darzo, the type locality. With new herbarium specimens, live images, and scanning electron microscopy, a more detailed description is provided for better understanding of the species. Based on the rarity, sparse distribution, and limited collections of this species, and no evaluation for threat status to date, the species can be placed in the 'Data Deficient' category of IUCN Red List.

Keywords: Ailawng, description, flora, Indo-Burma hotspot, IUCN Red List, northeastern India, rare species.

The genus *Strobilanthes* Blume comprises small gregarious flowering plants and is the second-largest in the family Acanthaceae, next to *Justicia* L. (Wood & Scotland 2021). Currently, 466 valid species are recognised globally under the genus (POWO 2025a). Despite its high species richness, the genus is almost entirely restricted to tropical & subtropical Asia, and primarily thrives in the monsoon climate of hill forests (Wood et al. 2021). In India, it is represented by approximately 155 species (Albertson & Venu 2023), distributed across two major regions — the central and southern parts of peninsular India, which host about 65 species, and the Himalaya, and northeastern hills, where around 85 species are recorded (Karthikeyan et al. 2009; Thomas et al. 2020; Wood et al. 2021; Borah et al. 2025). Over 86 species are known to be endemic to India, with most of them distributed in two diversity centers, i.e., the peninsular India and northeastern India (Albertson & Venu 2023). Due to their plietesial pattern of reproduction, flowering gregariously after many years and then die, many of them are rare or already extinct, for which their comprehensive documentation is a persistent problem (Wood & Scotland 2009).

The remotest part in northeastern India, Mizoram, is the only state that is enclaved, and demarcated by two international borders, of Bangladesh and Myanmar. It is geologically part of the Arakan-Yoma mountain formation of the Indo-Myanmar range, which was formed during the tectonic collision of the Indian, and Eurasian plates (Soibam et al. 2015; Khin et al. 2022). It, thus, constitutes the main landmass connecting mainland India and southeastern Asia (Sawant et al. 2017). Its ecological

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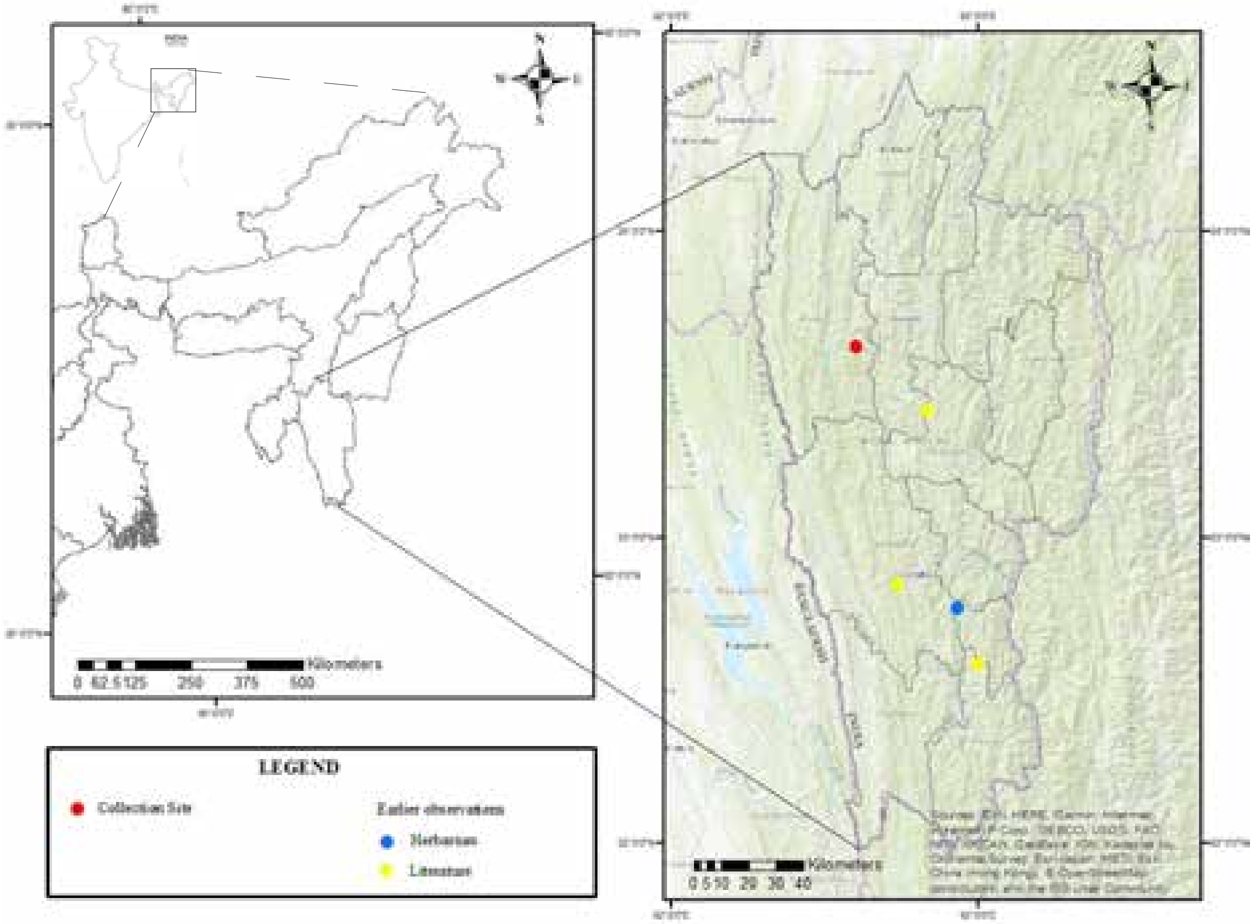

Image 1. Location map of the collection site and distribution of *Strobilanthes parryorum* in Mizoram, India.

classification is therefore variously described as within the Indo-Burma biodiversity hotspot (Rai 2012) or the eastern Himalaya (Banerjee et al. 2022).

Cecil Ernest Claude Fischer of the Indian Forest Service and later of the Royal Botanic Gardens, Kew, was the first to systematically document the flora of Mizoram (Fischer 1928a). By 1938, he was able to identify 20 taxa of *Strobilanthes* (Fischer 1938), to which the flora of the state adds only another four species (Sinha et al. 2012). In May 1928, Fischer described *Strobilanthes parryorum* C.E.C.Fisch. based on herbarium specimens collected by Mrs A.D. Parry (Fischer 1928b; POWO 2025b), who found the plants in March 1927 at Darzo (22.932° N, 92.956° E), then a tribal chieftaincy in Lushai Hills, the provincial name of Mizoram under British Colony.

During floristic explorations in Mizoram, India, in November 2024, the first author collected several plant specimens at Ailawng (23.684° N, 92.632° E), a village north of Darzo (Image 1). After identifying the different plants, some evidently of the genus *Strobilanthes*, were not easily identifiable at the level of species (Image 2). They were examined using taxonomic records, and after critical study, the specimens were identified as *S. parryorum* by comparison with the type sheets housed at Kew (catalogue numbers K000883146 and K000883147), and the recent account available in *Flora of India Volume 20* (Albertson & Venu 2023). Parry collected the initial set of specimens from the Lushai Hills during July 1927 and also in March 1928. These specimens were deposited at the Royal Botanic Garden herbarium, Kew. Later, it was collected by M.S. Khan in 1965 (Collection No. 1122) from Chittagong Hills, Bangladesh, which he deposited at the Royal Botanic Garden Herbarium, Edinburgh. In India, no additional specimens are available anywhere, including ASSAM (BSI, Eastern Regional Centre, Shillong), MH, CAL, BSD, and RHT. Photographs were taken using a Canon EOS R10 camera, a scanning electron micrograph of the pollen using Hitachi TM4000Plus II, and the location map generated with ArcGIS 10.8. Herbarium specimens were prepared, and a voucher specimen (LC 001/MCCH) was deposited in the Herbarium of the Department of Botany, Madras Christian College, Tambaram, Chennai, Tamil Nadu, India. The description of pollen morphology was based on terminologies established by Erdtman (1952) and Punt et al. (2007). This collection represents the first confirmed record of the species in 96 years, highlighting its extreme rarity in the wild. Notably, it is also the first documentation of the species near its type locality since its original discovery in 1927 (GBIF 2023).

Results And Discussion

Strobilanthes parryorum C.E.C.Fisch. Bull. Misc. Inform. Kew 1928(4): 141–147. 1928; Karthikeyan et al., Fl. Pl. India 1: 55. 2009; Albertson & Venu, Fl. India 20: 699. 2023.

Type: India, Mizoram, Darzo, alt 1,250 m, 01.iii.1927, Parry A.D. 155, K000883146, K000883147.

Description: Erect subshrub, up to 2.5 m high. Stem quadrangular, sulcate, subterete when mature, pubescent or glabrescent, base woody, young shoots green in color, brown when old, lenticellate, profusely branched; leaf scar persistent at nodes, swollen above nodes, pubescent. Leaves petiolate, opposite, and decussate, anisophyllous, elliptic to ovate, 7–28 × 2–12 cm, base attenuate, decurrent into petiole, margin serrate, apex acuminate, cystoliths numerous, hispid on the upper surface, lateral veins 6–12 pairs, impressed above, raised beneath; petiole 1–10 cm long, green, slightly bulging at the base, pubescent; inflorescence terminal or axillary, 8–29 cm long, cyme, branched at base, rachis densely covered with brown, and white glandular hairs; bracts sessile, spathulate to obtuse, 1–2.5 cm long, covered with brown, and white trichomes, pale green with pink at the apex, prominent ridge in the middle; bracteoles linear to lanceolate, 1–2 cm, apex obtuse to rounded, pale green, covered with trichomes, ridge in the middle; calyx bilabiate, five lobed, lobes linear to lanceolate, 1–2 cm long, subequal, two lower free, three upper fused in the middle, covered with brown, and white trichomes, white, pale green at the apex; corolla pale yellow, tubular, slightly swollen on one side, 4.5–5 cm long, slightly curved, tube widens from base, corolla mouth 1–1.5 cm wide, open, five lobed, subequal, 0.5–1 cm × 0.5–0.8 mm, glabrous, white; throat pale yellow, densely covered with trichomes on outer surface, and long white hairs on inner surface, brown striations present on inner surface; four stamens, didynamous, inserted, longer filament 7–8 mm, short filament 2.5–3.5 mm long, villous throughout; anther linear, 4–5 mm long, bithecate; style filiform, covered with trichomes,

Image 2. *Strobilanthes parryorum* growing wild at Ailawng, Mizoram, India. © Lucy Lalawmpuii.

Image 3. ***Strobilanthes parryorum*: A—aerial parts | B—nodes | C&D—leaves | E—lenticels | F&G—bract and bracteoles | H—bract | I—bracteoles | J—inflorescence | K—flower | L—L.S. of flower | M&N—androecium | O—g)ynoecium | P&Q—capsule | R—jaculators | S—seed | T—pollen. © Renthlei Lalnunfeli.**

3–3.6 cm long; stigma linear, simple, glabrous; ovary 4–4.5 mm long, apex pubescent, two locular with two ovules in each locule; capsule elliptic to clavate, 1.5–2 cm long, dark brown, glabrous; four seeds, suborbicular, 4–4.5 × 4–4.2 mm, hairy, dark brown, mucronate at the apex. Pollen in monads, radially symmetrical, isopolar, amb circular; P: 35–37 µm, E: 27 µm; P/E ratio: 1.16, subprolate; three colporate, colpus linear elliptic, compital membrane scabrate, endoaperture (os) elliptic and longitudinally elongated; pseudocolpi nine, linear, often coalescent at poles; sexine of 12 longitudinal ribs or bands with ladder-like reticulum, lumen perforate to micro-reticulate (Image 3A–T).

Wood & Scotland (2003) argued that, based on the available herbarium specimens, *S. parryorum* could be considered as subspecies of *S. denticulata* (Nees) T.Anderson (Anderson 1867). Notable differences from *S. denticulata* and other species were discernible, including larger bracts and the number of calyx lobes (3 in *S. denticulata*). In addition, their distribution does not coincide as *S. denticulata* is endemic to Meghalaya, and Nagaland.

Flowering and fruiting occur from October to January.

Ecology: *Strobilanthes parryorum* is associated with *Abelmoschus moschatus* Medik, *Allophylus cobbe* (L.) Raeusch., *S. glomerata* (Nees) T.Anderson, *S. capitata* (Nees) T.Anderson, *Coix lacryma-jobi* L., *Commelina* sp., *Impatiens tripetala* Roxb. ex DC., *Eupatorium cannabinum* L., *Hoya griffithii* Hook.f at the collection site.

Distribution: India — Mizoram, Darzo, Chhingchhip, Phawngpui, Serkawn, Ailawng (Figure 2); Bangladesh — Chittagong Hills.

Specimen examined: India, Mizoram, Ailawng, altitude 1,221 m, 16 November 2024, Lalawmpuii, LC 001/MCCH (Madras Christian College Herbarium).

Conservation status

There has been no evaluation to assess the conservation status of *S. parryorum*. In addition to Darzo, Parry had noted specimens from Chhingchhip, Phawngpui, and Serkawn (Wood & Scotland, 2003), all places adjacent to Darzo. Ailawng is the farthest place of the plant's distribution where fewer than 35 mature individuals were found. It is thus evident that the species is strictly endemic to the northeastern region of the Indian subcontinent. Considering the time span of the rediscovery and small extent of occurrence, based on the IUCN Red List, *S. parryorum* is best designated as 'Data Deficient' (DD).

References

Albertson, W.D. & P. Venu (2023). *Strobilanthes* Blume., pp. 568–757. In: Lakshminarasimhan, P., W. Arisdasan, K. Karthigeyan, G. Krishna & A.A. Mao (eds.) *Flora of India, Volume 20*: *Gesneriaceae-Acanthaceae*. Botanical Survey of India, Kolkata, India, 834 pp.

Anderson, T. (1867). An enumeration of the Indian species of Acanthaceae. (continued.). *Botanical Journal of the Linnean Society* 9(40): 455–526. https://doi.org/10.1111/j.1095-8339.1867.tb01309.x

Banerjee, S., R. Niyogi, M.S. Sarkar & R. John (2022). Assessing the vulnerability of protected areas in the eastern Himalayas based on their biological, anthropogenic, and environmental aspects. *Trees, Forests and People* 8: 100228. https://doi.org/10.1016/j.tfp.2022.100228

Borah, D., N. Ahmed & J.R.I. Wood (2025). *Strobilanthes sherdukpenorum* (Acanthaceae), a new species from the East Himalayas. *Gardens' Bulletin Singapore* 77(1): 141–148. https://doi.org/10.26492/gbs77(1).2025-11

Erdtman, G. (1952). *Pollen Morphology and Plant Taxonomy. Angiosperms*. Almqvist and Wiksell, Stockholm, 538 pp.

Fischer, C.E.C. (1928a). Decades Kewenses, Plantarum novarum in Herbario Horti Regii Conservatarum Decas CXIX. *Bulletin of Miscellaneous Information* (*Royal Botanic Gardens, Kew*) 1928(2): 72–78. https://doi.org/10.2307/4107649

Fischer, C.E.C. (1928b). Decades Kewenses: Plantarum Novarum in Herbario Horti Regii Conservatarum. Decas CXX. *Bulletin of Miscellaneous Information* (*Royal Botanic Gardens, Kew*) 1928(4): 141–147. https://doi.org/10.2307/4107121

Fischer, C.E.C. (1938). The flora of Lushai hills. *Records of the Botanical Survey of India* 12(2): 75–161. https://archive.org/details/dli.ministry.13059

GBIF (2023). *Strobilanthes parryorum* C.E.C.Fisch. Global Biodiversity Information Facility (GBIF) Backbone Taxonomy. https://doi.org/10.15468/39omei. Accessed on 26.viii.2025.

IUCN (2012). IUCN Red List categories and criteria, version 3.1, second edition. International Union for Conservation of Nature, Gland, Switzerland, 16–18pp. https://portals.iucn.org/library/sites/library/files/documents/RL-2001-001-2nd.pdf

Karthikeyan S., M. Sanjappa & S. Moorthy (2009). *Flowering Plants of India, Dicotyledones, Volume 1.* (*Acanthaceae – Avicenniaceae*). Botanical Survey of India, Kolkata, 365 pp.

Khin, K., A. Moe & K.P. Aung (2022). Tectono-structural framework of the Indo-Myanmar Ranges: implications for the structural development on the geology of the Rakhine Coastal Region, Myanmar. *Geosystems and Geoenvironment* 1(3): 100079. https://doi.org/10.1016/j.geogeo.2022.100079

POWO (2025a). Acanthaceae: *Strobilanthes* Blume. Plants of the World Online, the Royal Botanic Gardens, Kew. https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:327189-2. Accessed on 08.i.2025.

POWO (2025b). *Strobilanthes parryorum* C.E.C.Fisch. Plants of the World Online, the Royal Botanic Gardens, Kew. https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:55860-1. Accessed on 08.i.2025.

Punt, W., P.P. Hoen, S. Blackmore, S. Nilsson & A. Le Thomas (2007). Glossary of pollen and spore terminology. *Review of Palaeobotany and Palynology* 143(1&2): 1–81. https://doi.org/10.1016/j.revpalbo.2006.06.008

Rai, P.K. (2012). Assessment of multifaceted environmental issues and model development of an Indo-Burma hotspot region. *Environmental Monitoring and Assessment* 184: 113–131. https://doi.org/10.1007/s10661-011-1951-8

Sawant, S.S., K.V. Kumar, V. Balaram, D.S. Rao, K.S. Rao & R.P. Tiwari (2017). Geochemistry and genesis of craton-derived sediments from active continental margins: insights from the Mizoram Foreland Basin, NE India. *Chemical Geology* 470: 13–32. https://doi.org/10.1016/j.chemgeo.2017.08.020

Sinha, G.P., D.K. Singh & K.P. Singh (2012). Flora of Mizoram. Volume 2. Botanical Survey of India, Kolkata, 270 pp.

Soibam, I., M.C. Khuman & S.S. Subhamenon (2015). Ophiolitic rocks of the Indo-Myanmar Ranges, NE India: Relicts of an inverted and tectonically imbricated hyper-extended continental margin basin? Pp. 301–331. In: Gibson, G.M., F. Roure & G. Manatschal (eds.). *Sedimentary Basins and Crustal Processes at Continental Margins: From Modern Hyper-extended Margins to Deformed Ancient Analogues*. Geological Society, London, Special Publications. http://doi.org/10.1144/SP413.12

Thomas S., B. Mani, S.J. Britto & A.K. Pradeep (2020). A new species of *Strobilanthes* (Acanthaceae) from the Western Ghats, India. *Taiwania* 65(2): 167–171. https://doi.org/10.6165/tai.2020.65.167

Wood, J.R.I & R.W. Scotland (2003). The 2-lipped species of *Strobilanthes* (Acanthaceae). *Kew Bulletin* 58: 83–129. https://doi.org/10.2307/4119357

Wood, J.R.I & R.W. Scotland (2009). New and little-known species of *Strobilanthes* (Acanthaceae) from India and south east Asia. *Kew Bulletin* 64: 3–47. https://doi.org/10.1007/s12225-009-9098-2

Wood, J.R.I. & R.W. Scotland (2021). A *Strobilanthes* (Acanthaceae) miscellany. *Kew Bulletin* 76: 827–840. https://doi.org/10.1007/s12225-021-09990-z

Wood, J.R.I., D. Borah & M. Taram (2021). The rediscovery of *Strobilanthes tubiflos* (Acanthaceae) in north east India. *Kew Bulletin* 76: 333–338. https://doi.org/10.1007/s12225-021-09935-6

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SHORT COMMUNICATION

New report of *Biophytum nervifolium* Thwaites (Oxalidaceae) from Gujarat, India

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Abstract: During floristic surveys in the Saurashtra Peninsula of Gujarat, India, specimens of *Biophytum nervifolium* Thwaites were collected. After reviewing relevant literature and type specimens, it was found that this species was previously known only from Tamil Nadu, and Andhra Pradesh, in India. The present collection of *B. nervifolium*, therefore, represents a new record for Gujarat. This paper presents the taxonomy, ecology, and distribution of the species, along with colour photographs, to facilitate its identification.

Keywords: Distribution, ecology, floristic study, new record, Saurashtra Peninsula, taxonomy, western India.

The genus *Biophytum* DC. consists of 82 species (POWO 2025) distributed across the tropical regions of Africa, Madagascar, Asia, and South America (Veldkamp 1971; Lourteig 1980). In India, 24 species of *Biophytum* have been recorded by various authors (Manna 1997; Khan et al. 1998; Kumar et al. 2000, 2017; Jisha et al. 2020; Jisha 2023) and are mainly occurring in the Peninsular Indian states of Kerala, Tamil Nadu, Karnataka, and Andhra Pradesh (Manna 1997). In Gujarat, two species, *Biophytum sensitivum* (L.) DC., and *Biophytum reinwardtii* (Zucc.) Klotzsch, have been reported so far (Shah 1978; Reddy & Sharma 2015).

During the floristic studies in the Kutch and the Saurashtra Peninsula of Gujarat, specimens of *Biophytum* were collected from Bhavnagar and Rajkot districts. These specimens were initially identified as *Biophytum sensitivum* (Santapau 1968; Shah 1978). *Biophytum sensitivum* is characterized by flowers with sepals and petals more or less equal in length, whereas in the present specimens, the sepals are only about two-thirds in length to the petals. This is a notable feature that differentiates the two taxa. After a thorough review

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of relevant literature and examination of type materials housed at different herbaria, the collected specimens were identified as *Biophytum nervifolium* Thwaites, a species previously reported from southern India and Sri Lanka, with no prior records of its occurrence in Gujarat (Shah 1978; Shetty & Singh 1987; Bhandari 1990; Singh & Karthikeyan 2001). The description for *B. nervifolium* in the literature is quite inadequate. Therefore, a detailed account of the species, including morphological description, phenology, ecology, distribution map, and a coloured photoplate is provided to facilitate accurate identification of the species.

Results

Taxonomic Treatment

Biophytum nervifolium Thwaites, Enum. Pl. Zeyl.: 64. 1858; Manna in Hajra et al. (eds.), Fl. India 4: 234. 1997. *B. sensitivum* var. *nervifolium* (Thwaites) Edgew. & Hook.f. in J.D.Hooker, Fl. Brit. India 1: 437.1874.

Erect, annual herbs; stem 2–13 cm high, unbranched, herbaceous, cylindrical, red when young. Leaves 7–20 per plant, paripinnate, crowded on top of the stem; rachis hairy, 1–7 cm long; leaflets opposite, sessile, 3–12(–14) pairs, overlapping, green, and glabrous above, paler beneath, terminal leaflets are the largest, obovate, 11–13 × 3–6 mm, apex obtuse, apiculate, base sharply oblique, margins entire, lateral leaflets oblong, 2–10 × 3–5 mm, obtuse at apex, apiculate, not asymmetric at base, entire at margin, slightly hairy along margins (under dissecting microscope), lateral nerves 6–13 pairs, prominent, sub-opposite or alternate. Inflorescence shorter than or rarely exceeding the leaves, peduncles 0.8–5(–7) cm, stiff with appressed glandular hairs. Flowers 3–6 in dense, crowded umbels, yellow with purple lines; pedicels shorter than bracts, 0.5–1 mm long (fruiting pedicels around 2 mm); bracts broadly ovate, 1–2 × 0.5 mm; shortly acuminate at apex, glandular hairy; bracteoles 1–2 mm long, linear, glandular pubescent. Sepals five, linear-lanceolate, 4–5.5 × 0.5–1 mm, deeply divided to the base, sharply acuminate at apex, broader at base, glandular hairy, nerves seven, prominent, parallel, persistent. Petals five, exceeding the sepals, oblanceolate, 6–7 × 2–2.5 mm, slightly hairy on both surfaces, 3-nerved, middle nerve prominent. Stamens 10 in two whorls, 5-longer filaments 2.5–3 mm long, hairy along one side, 5-shorter filaments 1.5 mm long. Ovary ovoid, as long as broad, 0.8–1 mm, pubescent; styles five, bifid, ca. 0.5 mm long. Capsules ovoid, shorter than sepals, 3–4 × 2–2.5 mm, glabrous except the densely hairy apex, 5-valved; seeds 10, 2 per locule, arillate, strongly transversely ridged, as long as broad, reddish-brown (Image 1).

Flowering & Fruiting: August to December.

Habitat & Ecology: In the present study, the specimens were collected from two different localities in the Saurashtra Peninsula. The first is situated in the Shatrunjaya Hill ranges, characterized by undulating terrain of hills with a mix of dry deciduous and thorny scrub vegetation. Here, the individuals (nearly 50) of *Biophytum nervifolium* grow in microhabitats on rocky cliffs at an altitude of 150–170 m and at c. 300 m. The main associated species in a 5–6 m radius include *Aeschynomene* sp., *Alysicarpus* sp., *Blepharis maderaspatensis* (L.) B.Heyne ex Roth, *Cassia absus* L., *Chorchorus aestuans* L., *Crotalaria bifaria* L.f., *Crotalaria hebecarpa* (DC.) Rudd, *Dalechampia scandens* var. *cordofana* (Hochst. ex Webb) Müll.Arg., *Evolvulus alsinoides* (L.) L., *Grewia villosa* Willd., *Hibiscus lobatus* (Murray) Kuntze, *Hyptis suaveolens* (L.) Poit., *Indigofera cordifolia* B.Heyne ex Roth, *Ipomoea sindica* Stapf, *Phyllanthus maderaspatensis* L., *Phyllanthus* sp., *Polygala erioptera* DC., *Tephrosia strigosa* (Dalzell) Santapau & Maheshw., *Tridax procumbens* L., and *Urochloa ramosa* (L.) T.Q.Nguyen.

In the Rajkot location, the second recorded site, all the individuals (more than 150) are growing along the roadsides among grasses. The main associated species are *Apluda mutica* L., *Alysicarpus scariosus* (Rottler ex Spreng.) Graham, *Alysicarpus tetragonolobus* Edgew., *Atylosia scarabaeoides* (L.) Benth., *Aristida* sp., *Convolvulus* sp., *Cymbopogon* sp., *Dichanthium* sp., *Euphorbia* sp., *Merremia gangetica* (L.) Cufod., *Mimosa hamata* Willd., *Orthosiphon pallidus* Royle ex Benth., *Polygala chinensis* L., *Rhynchosia aurea* (Willd.) DC., *Sehima nervosa* (Rottler) Stapf, *Senna uniflora* (Mill.) H.S.Irwin & Barneby, *Trichodesma* sp., and *Ziziphus nummularia* (Burm.f.) Wight & Arn. (Image 2).

Distribution: Sri Lanka and India. In India, it occurs in Tamil Nadu, Andhra Pradesh, and Gujarat.

Specimen examined: INDIA, Gujarat, Bhavnagar District, Shatrunjaya Hill ranges, 150–170 m, N21.5028373 E71.8130176, 15.ix.2024, Kishan Prajapati & Siddharth Dangar, KP-036, KP-037; Shatrunjaya Hill ranges, c. 300 m, N21.5025425 E71.8119276, 22.09.2024, Kishan Prajapati, KP-038, KP-039; Rajkot District, Munjka to Ishwariya Village, c. 50 m, N22.2901183 E70.7174083, 16.x.2024 to 10.11.2024, Kishan Prajapati, KP-040,041,042,043.

Notes

Biophytum nervifolium was described by Thwaites in 1858 based on the collection by A.O. Brodie (CP 2787)

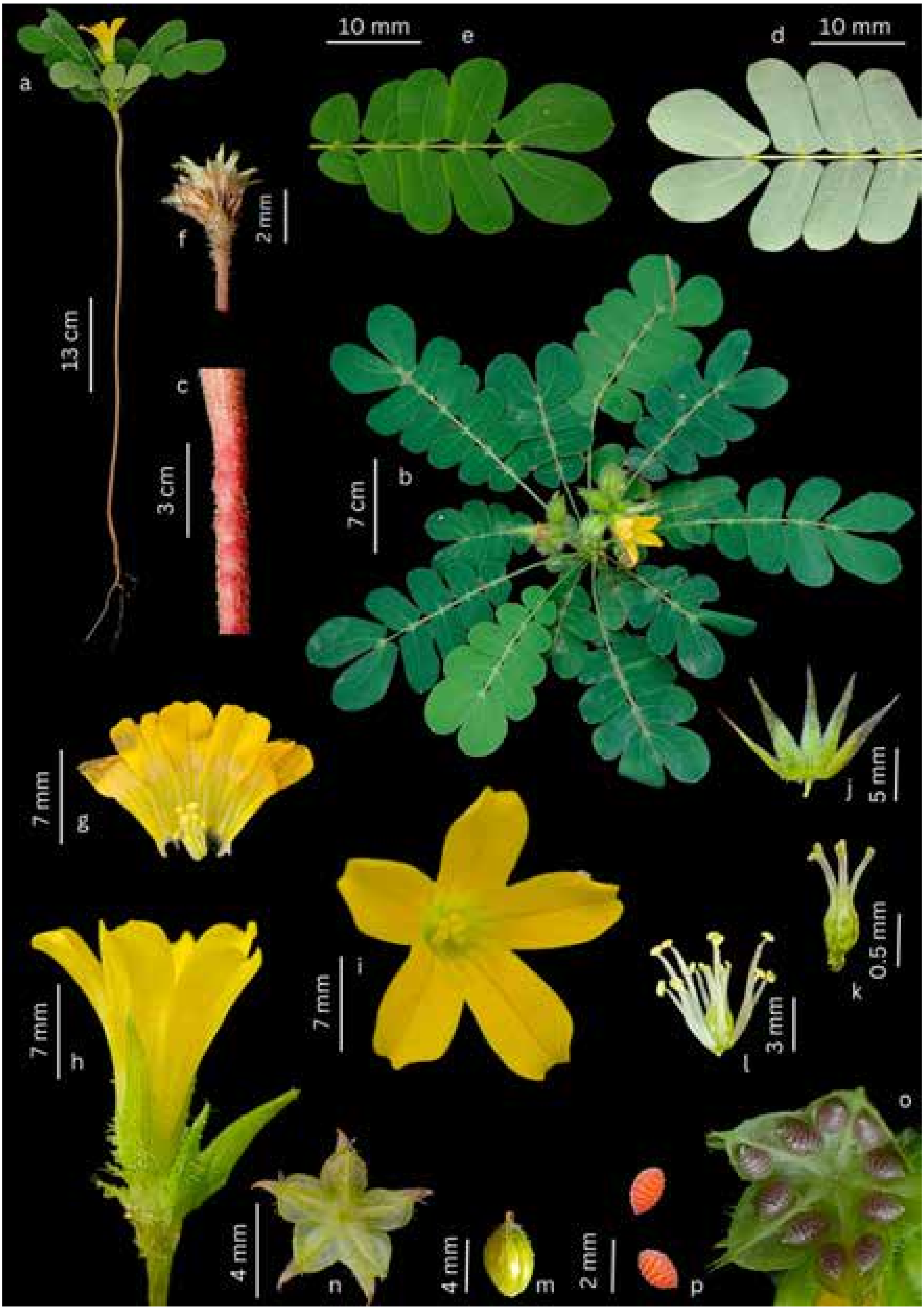

Image 1. *Biophytum nervifolium* Thwaites: a & b—habit | c—mature stem | d & e—abaxial and adaxial surface of leaflets, respectively | f—bracts | g—opened tube of corolla | h & i—side view and top view of the flower, respectively | j—sepals | k—gynoecium | l—androecium | m—capsule | n—opened capsule with persistent calyx | o—opened capsule with seeds | p—seeds. © Kishan Ishwarlal Prajapati.

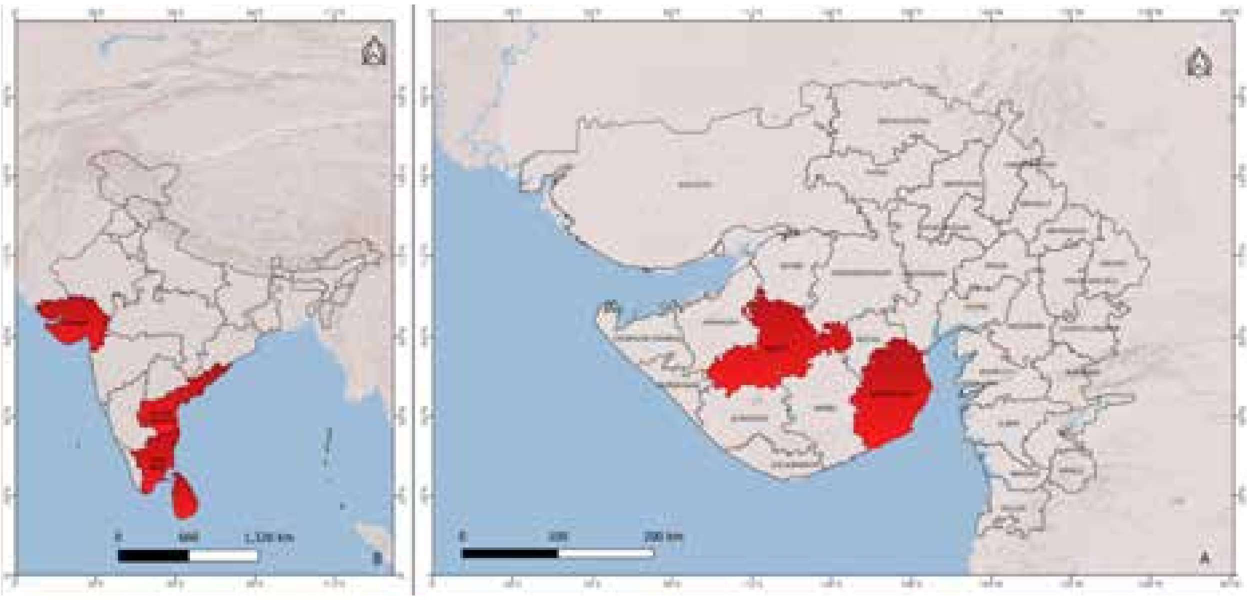

Image 2. Distribution of *Biophytum nervifolium* Thwaites. A—Gujarat map showing the occurrence of the species in the Rajkot and Bhavnagar districts | B—Distribution in within India (Tamil Nadu, Andhra Pradesh, and Gujarat). Map prepared by: V.U. Chauhan.

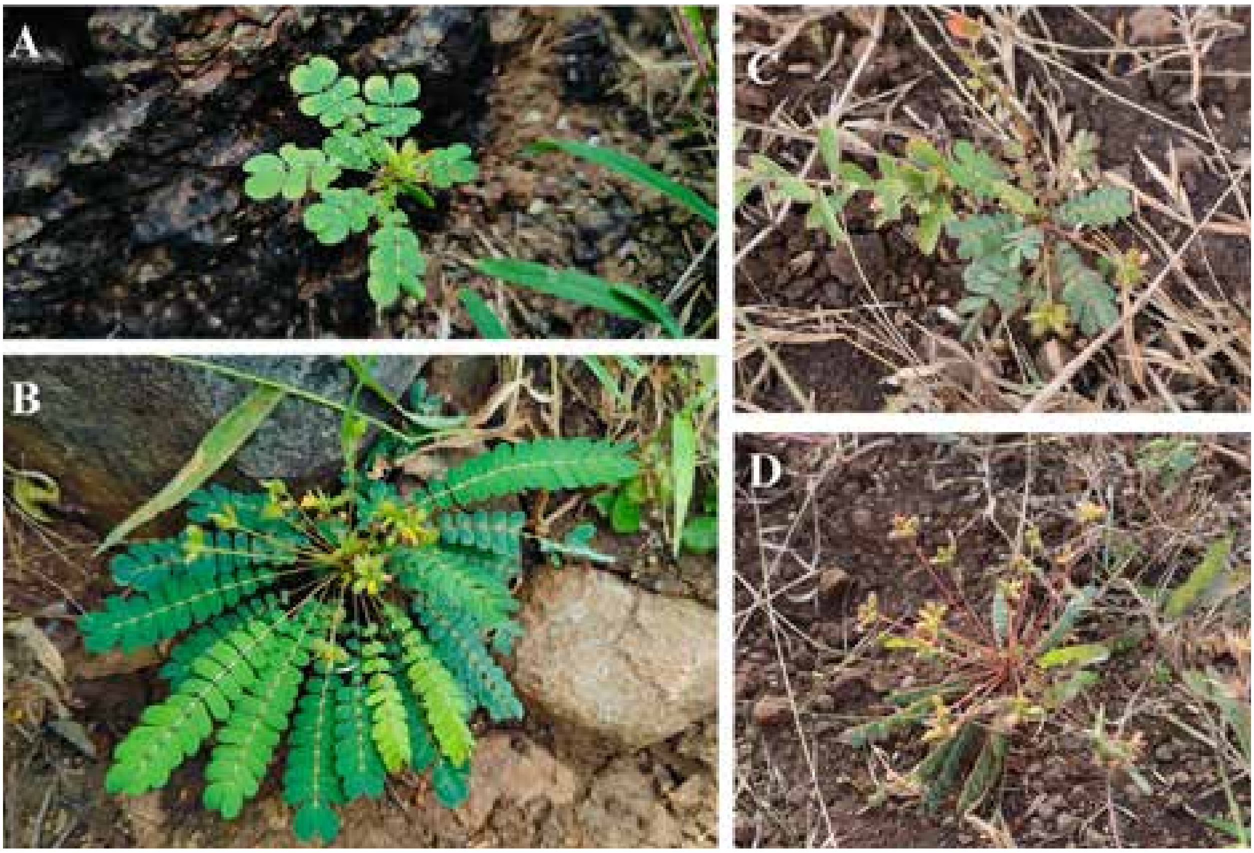

Image 3. *Biophytum nervifolium* Thwaites: Habitats in the Shatrunjaya hill range (A & B) and the Rajkot locality (C & D). © Kishan Ishwarlal Prajapati.

from Puttalum in the Puttalum District of Sri Lanka. This species is reported to be common on sandy and clayey soils of the dry zones in Jaffna, Anuradhapura, Mannar, Batticaloa, and Hambantota districts of Sri Lanka (Dassanayake 1999).

During this study, we observed that *B. nervifolium* is commonly present in Gujarat, but is often misidentified as *B. sensitivum*, including in regional floras (Santapau 1968; Shah 1978). However, these two species can be easily distinguished by their floral features. In *B. sensitivum*, the sepals are nearly as long as the petals, whereas in *B. nervifolium,* the petals are longer than the sepals. The linear glandular bracteoles are one of the striking characters in *B. nervifolium*, but the bracteoles are absent in *B. sensitivum*.

References

Bhandari, M.M. (1990). *Flora of the Indian Desert*. (MPS Reports), Jodhpur, 435 pp.

Dassanayake, M.D. (ed.) (1999). *A Revised Handbook to the Flora of Ceylon*. Vol. 13. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi & A.A. Balkema, Rotterdam, 285 pp.

eFlora Kerala (2025). eFlora Kerala: An Online Database on Plants of 2025, https://www.eflorakerala.com/. Sasidharan, N. (n.d.). *Biophytum nervifolium*. E-Flora of Kerala. Retrieved May 31, 2025 https://www.eflorakerala.com/plant_detail.php?id=Biophytum_nervifolium

Jisha, D. (2023). Studies on the Systematics and Phytogeographical affinities of the family Oxalidaceae of Kerala, India. PhD Thesis (unpublished), University of Kerala, Thiruvananthapuram, Kerala, India, 175 pp.

Jisha, D., E.S.S. Kumar, S.W. Decruse & M. Rajendraprasad (2020). A new species of *Biophytum* (Oxalidaceae) from the Western Ghats (Kerala, India). *Phytotaxa* 438(1): 49–52. https://doi.org/10.11646/phytotaxa.438.1.6

Khan, A.E.S., E.S.S. Kumar, S. Binu & P. Pushpangadan (1998). A new species of Biophytum DC. (Oxalidaceae) from Peninsular India. *Rheedea* 8: 79–81. https://doi.org/10.22244/rheedea.1998.08.01.05

Kumar, E.S.S., A.E.S. Khan, S. Binu & P. Pushpangadan (2000). A note on the occurrence and identity of *Biophytum umbraculum* Sch. (Oxalidaceae) in Kerala. *Journal of Economic and Taxonomic Botany* 24(3): 746–748.

Kumar, E.S.S., G.K. Suchithra, K. Murugesan, L.H. Namitha & J.F. Veldkamp (2017). Reinstatement and lectotypification of *Biophytum poterioides* Edgew. (Oxalidaceae)—an endemic species of the Peninsular India. *Abrahamia* 3: 16–19.

Lourteig, A. (1980). Oxalidaceae. Flora of Panama. *Annals of the Missouri Botanical Garden* 67(1): 826–834. https://doi.org/10.2307/2398968

Manna, M.K. (1997). Oxalidaceae, pp. 241–255. In: Hajra, P.K., V.J. Nair & P. Daniel (eds.). *Flora of India* 4. Botanical Survey of India, Calcutta.

POWO (2025). Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew. https://powo.science.kew.org/. Retrieved on 01.x.2025.

Reddy, A.S. & A. Sharma (2015). *Biophytum reinwardtii* (Zucc.) Klozsch. A new record for Gujarat state. *Life Sciences Leaflets* 67: 8–11.

Santapau, H. (1962). *The flora of Saurashtra Part-I. Ranunculaceae to Rubiaceae*. Saurashtra Research Society, Rajkot, 309 pp.

Shah, G.L. (1978). *Flora of Gujarat State*. Volume 1. Sardar Patel University, Vallabh Vidyanagar, 1074 pp.

Shetty, B.V. & V. Singh (1987). *Flora of Rajasthan* Vol 1, Botanical survey of India, Howrah, 447 pp.

Singh, N.P. & S. Karthikeyan (2001). *Flora of Maharashtra State (Vol. 1)*. Botanical Survey of India, Calcutta, 898 pp.

Thwaites, G.H.K. (1858). *Enumeratio plantarum Zeylaniae*. Dulau & Co., London, 483 pp. https://doi.org/10.5962/bhl.title.574

Veldkamp, J.F. (1971). Oxalidaceae, pp. 151–178. In: van Steenis, C.G.G.J. (ed.) *Flora Malesiana* 7(1). Bogor, Indonesia. https://doi.org/10.5962/bhl.title.40744

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NOTE

Water Monitor *Varanus salvator* predation on a Hog Deer *Axis porcinus* fawn at Kaziranga National Park, Assam, India

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The Water Monitor Lizard *Varanus salvator* is a large-growing, carnivorous reptile that is widespread in southern and southeastern Asia (Quah et al. 2021). It is the largest lizard found in India (Ahmed et al. 2009). It is a Schedule I species under the Wildlife (Protection) Act, 1972 in India. It is listed in Appendix II of CITES (Chatterjee & Bhattacharyya 2015), and has been categorised as 'Least Concern' in the IUCN Red List of threatened species (ver. 3.1). The water monitor is an opportunistic animal and is semi-aquatic in nature, found in a variety of natural, and human-influenced habitats (Pal & Chatterjee 2022). It is both a predator and a scavenger, which feeds on invertebrates, fishes, turtles, snakes, lizards, small mammals, birds, and their eggs (e.g., rats), as well as carrion (e.g., Das 2010; Briggs-Gonzalez et al. 2022).

Kaziranga National Park and Tiger Reserve (26.47–26.79° N; 92.59–93.69° E; 1,055 km^2) is located across Golaghat, Nagaon, and Biswanath districts of Assam (NTCA 2025). Famous for the One-horned Rhinoceros, it is a UNESCO World Heritage Site and a popular tourist destination. With diverse habitats present, Kaziranga National Park serves as an ideal home for reptiles, although it has not been extensively studied due to difficult terrains and the presence of many large mammalian species (Vignesh et al. 2023). The Water Monitor *V. salvator* and Bengal Monitor *Varanus bengalensis* lizards are among the most visible limbed reptiles of Kaziranga National Park (Pal & Chatterjee 2022).

On the evening of 5 April 2023, during a safari at the central range (Kohora) of Kaziranga National Park, a female Hog Deer *Axis porcinus* was observed exhibiting distress behaviour with continuous distress call under a tree. The deer was seen trying to chase away some other animal by forcefully beating its forelimbs on bushes and ground. Upon closer observation with binoculars and cameras, the team could see a tail. After repositioning the jeep, the team was able to identify the animal as a Water Monitor Lizard *V. salvator*, despite its head being partially obscured by vegetation. After waiting for some time, as the lizard started to move, the team observed a hog deer fawn in its mouth (Image 1). The animal could be identified as a hog deer fawn by looking at the spots on the lateral sides of the body. Kaziranga National Park doesn't fall within the natural distribution range of the superficially similar-looking Spotted Deer *Axis axis*. But the Hog Deer fawns have white spots on the sides of the body, and hence the animal could be identified as a Hog Deer fawn. The monitor lizard was feeding on the

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Image 1. Water Monitor Lizard *Varanus salvator* preying on a Hog Deer fawn *Axis porcinus* in Kaziranga, Assam, India. © Luku Ranjan Nath

fawn. The average Hog Deer *Axis porcinus* fawn weighs approximately 1–1.5 kg and measures 40–50 cm in length at birth (Vignesh et al. 2023). In contrast, adult water monitor lizard like the one observed at Kaziranga, can weigh over 10 kg and exceed 200 cm in total length, making it physically capable of preying upon such a fawn (Ahmed et al. 2009; Pal & Chatterjee 2022).

Water Monitor Lizard *V. salvator* on account of being a large-growing, predator lizard having a reasonably large distribution range, and possible anthropophilic nature, is a rather well-researched species, compared to other lizards, including other monitors in Asia (Briggs-Gonzalez et al. 2022). Closest of such vital feeding events was a report of predation on a kitten by *V. salvator* in Indonesia (Mardiastuti & Kusrini 2023). Upon consulting recent literature on the diet of the *V. salvator* complex (Mahaprom & Kulabtong 2018; Yu et al. 2021; Briggs-Gonzalez et al. 2022; Du et al. 2022; Guerrero-Sanchez et al. 2022, 2023; Zdunek & Kolenda 2022; Han 2023; Mardiastuti & Kusrini 2023; Trivalairat & Srikosamatara 2023; Zdunek et al. 2024 and references therein), it was found that this is probably the first precise record of a water monitor preying on a Hog Deer and hence worth placing on record.

References

Ahmed, F., A. Das & S.K. Dutta (2009). *Amphibians and Reptiles of Northeast India: A Photographic Guide*. Aaranyak, Guwahati, India, 75 pp.

Briggs-Gonzalez, V., P. Evans, C. Klovanish & F.J. Mazzotti (2022). A species bioprofile for the Asian water monitor (*Varanus salvator*). *Southeastern Naturalist* 21(3): 187–210. https://doi.org/10.1656/058.021.0302

Chatterjee, A. & S. Bhattacharyya (2015). Distribution and abundance of monitor lizards (*Varanus* spp.) in human habitations of south West Bengal: People's tradition of coexisting with wildlife. *African Journal of Science and Research* 3(7): 01–07.

Das, I. (2010). *Field Guide to the Reptiles of South-East Asia*. Bloomsbury Publishing, 376 pp.

Du, Y., J.Q. Chen, Q. Liu, J.C. Fu, C.X. Lin, L.H. Lin, H. Li, Y.F. Qu & X. Ji (2022). Dietary correlates of oral and gut microbiota in the water monitor lizard, *Varanus salvator* (Laurenti, 1768). *Frontiers in Microbiology* 12: 771527. https://doi.org/10.3389/fmicb.2021.771527

Guerrero-Sanchez, S., K. Majewski, P. Orozcoter-Wengel, S. Saimin & B. Goossens (2022). The effect of oil palm-dominated landscapes on the home range and distribution of a generalist species, the Asian water monitor. *Ecology and Evolution* 12(1): e8531. https://doi.org/10.1002/ece3.8531

Guerrero-Sanchez, S., L. Frias, S. Saimin, P. Orozcoter-Wengel & B. Goossens (2023). The fast-food effect: costs of being a generalist in a human-dominated landscape. *Conservation Physiology* 11(1): coad055. https://doi.org/10.1093/conphys/coad055

Han, K.K. (2023). Biodiversity Record: Malayan water monitor preying on Gerard's water snake. *Nature in Singapore* 16: e2023006. https://doi.org/10.26107/NIS-2023-0006

Mardiastuti, A. & M.D. Kusrini (2023). Kitten predation by a Water Monitor, *Varanus salvator* (Laurenti, 1758) in an urban residential area. *Herpetology Notes* 16: 653–655.

Mahaprom, R. & S. Kulabtong (2018). Observation of feeding habit of the Common Water Monitor, *Varanus salvator* (Laurenti, 1768) (Squamata Varanidae) on a Asian Toad, *Duttaphrynus melanostictus* (Schneider, 1799) (Anura Bufonidae) in Thailand. *Biodiversity Journal* 9(3): 213–216. https://doi.org/10.31396/Biodiv.Jour.2018.9.3.213.216

NTCA (2025). National Tiger Conservation Authority. https://ntca.gov.in/. Accessed on 15.i.2025.

Quah, E., K. Lwin, M. Cota, L. Grismer, T. Neang, G. Wogan, J. McGuire, L. Wang, D.Q. Rao, M. Auliya & A. Koch (2021). *Varanus salvator*. The IUCN Red List of Threatened Species 2021: e.T178214A113138439. Accessed on 02.ii.2025. https://doi.org/10.2305/IUCN.UK.2021-2.RLTS.T178214A113138439.en

Pal, A. & A. Chatterjee (2022). The Asian Water Monitor, *Varanus salvator*: An Introduction to its Non-Breeding Ethology. *Hamadryad* 39(1&2): 57–68.

Trivalairat, P. & S. Srikosamatara (2023). Daily activities of water monitors (*Varanus salvator macromaculatus* Deraniyagala, 1944) in urban wetland, Bangkok, Thailand. *Herpetozoa* 36: 189–201.

Vignesh, C.S., R. Sharma, S. Ojah & R. Basumatary (2023). *Kaziranga: The Cradle of Biodiversity*. Field Director Kaziranga National Park and Tiger Reserve, Assam, 216 pp.

Yu, X., A.B.M. Zanudin, M.U. Rusli, D.T. Booth & J. Lei (2021). Diet reflects opportunistic feeding habit of the Asian Water Monitor (*Varanus salvator*). *Animal Biology* 72(1): 27–37. https://doi.org/10.1163/15707563-bja10065

Zdunek, P. & K. Kolenda (2022). The threat of discarded food and drinks containers to monitor lizards. *The Herpetological Bulletin* 161: 28–30. https://doi.org/10.33256/hb161.2830

Zdunek, P., D.S. Karunarathna & G. Harold (2024). Additional records of intrageneric predation and cannibalism in monitor lizards (Squamata: Varanidae). *Herpetology Notes* 17: 749–755.

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BOOK REVIEW

A book review of moths from the Eastern Ghats: Moths of Agastya

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In recent years, the study of moths by amateur naturalists, and photographers has gained remarkable momentum. This surge in interest has been driven largely by the publication of accessible field guides. Dr. V. Shubhalaxmi's 'Birdwing Field Guide to Indian Moths' (2018) introduced readers to 773 species. In 2022, Unnikrishnan M.P. followed with 'A Beginner's Field Guide to Moths of Malabar', documenting over 400 species. In 2024, Titli Trust published 'Moths of India: A Field Guide', authored by me, covering 1,500 species. Adding to this growing literature is 'Moths of Agastya' by Dr. R. Bhanumati—an important, and timely contribution.

What sets 'Moths of Agastya' apart is its focus on the Eastern Ghats, a region underrepresented in recent moth literature. The book is based on an impressive four years and eight months of surveys, and documents 653 species and genera, including 369 macromoths, 231 micromoths, and 53 unidentified species.

The book opens with a brief introduction to moth morphology and ecology, along with useful sections on moth watching, tourism, and awareness. A concise guide to moth identification makes the book accessible to beginners. The main species accounts are divided into two sections—macromoths and micromoths—organized by superfamily, family, subfamily, and genus. Though tribe-level classification is generally omitted in the species descriptions, it is included in the comprehensive checklist at the end. Short notes on moth families and subfamilies provide helpful context.

The photographs are of consistently high quality, with some examples showing dorsal, and lateral views, posture variations, and sexual dimorphism. The absence of scale bars is a minor limitation, but the images remain highly effective for identification.

The design is simple yet effective, and the print quality is excellent. Most significantly, the identifications are robust, and carefully considered. Dr. Bhanumati takes

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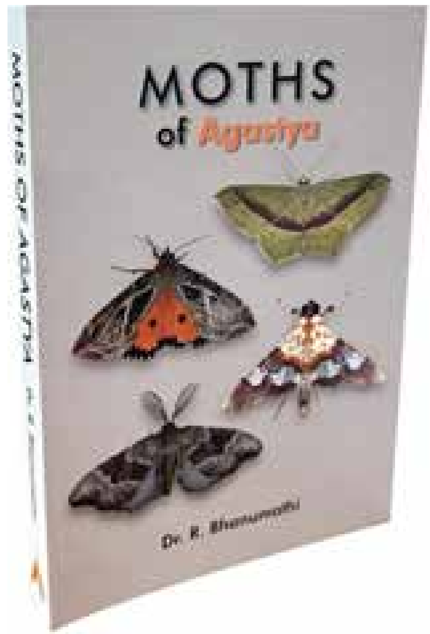

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a commendably cautious approach, recording taxa at the genus or subfamily level where necessary, and using the "cf." designation when image-based identification was inconclusive. This scientific rigour enhances the credibility of the work.

While the book is largely free of errors—aside from a few typographical slips—there are areas where additional information would have added value. For instance, data on larval host plants, where available, could have enriched the text. Similarly, a dedicated section showcasing caterpillars across families would have broadened its appeal to both researchers and enthusiasts.

Overall, Moths of Agastya is a significant contribution to Indian lepidopteran studies. It will serve scientists, naturalists, moth watchers, and institutions as both a reference and a source of inspiration. By highlighting the moth diversity of the Eastern Ghats, it fills a critical gap in regional biodiversity literature. I hope this fine publication inspires further efforts to document and conserve the remarkable moth fauna of India.

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