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Cover: Freshly emerged Footman Moth *Nepita conferta* from the cocoon on a brightly painted wall in the Nilgiris. Digital art on Procreate. © Aakanksha Komanduri.

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ARTICLE

Morphometry and feeding notes of an endemic frog *Amolops spinapectoralis* (Amphibia: Ranidae) from Hue City, central Vietnam

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Abstract: This study presents the first record of the endemic ranid frog *Amolops spinapectoralis* in Hue City, Vietnam. Notably, the specimens collected exhibit cylindrical spines, a distinct morphological feature differing from the conical spines originally described, highlighting the species' local morphological diversity. Given the limited ecological data on this species, we analyzed its morphological characteristics and investigated the correlation between body size and feeding ecology, as well as sexual variation in diet composition and prey diversity. We identified 507 prey items across 19 prey categories. The dominant prey taxa included Orthoptera, Coleoptera, Diptera, Formicidae, Isoptera, insect larvae, and Hymenoptera, which collectively accounted for 71.16% of the frequency of occurrence, 68.24% of the total prey number, and 66.89% of the total volume, with a relative importance index of 68.77%. Furthermore, prey mass was positively correlated with temperature and relative humidity, independent of rainfall.

Keywords: Cylindrical spines, diet composition, feeding ecology, morphological feature, ranid frog, prey diversity, prey moss, sexual variation.

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Author contributions: Loi Duc Duong, the lead author of the paper, along with Giang Van Tran, who worked on the project DHH2023-03-181 and participated in processing the nutritional ecological characteristics; and Nghiep Thi Hoang, a member who performed the analysis of morphological characteristics of the rock-clinging frog (*Amolops*).

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INTRODUCTION

Spinyback Torrent Frog *Amolops spinapectoralis* Inger, Orlov & Darevsky, 1999 is a ranid frog endemic to Vietnam (Nguyen et al. 2009). However, it has now also been found in Laos and presumably in adjacent northeastern Cambodia (Frost 2025). In Vietnam, this species has been recorded in Gia Lai, Da Nang, Quang Nam, Quang Ngai, Kon Tum, Phu Yen, and Quang Nam Provinces (Frost 2025).

Recent studies on *Amolops* in Vietnam and around the world have mainly focused on taxonomy and have not focused on comprehensive and complete research on the biological, morphological, and ecological characteristics of this species group. This article focuses on studying the morphological characteristics and nutritional ecology of this species in Hue City.

We study the morphological characteristics and feeding ecology of *A. spinapectoralis* in Hue City, Vietnam. Specifically, our research focused on:

(1) Morphological characteristics of *A. spinapectoralis* living in Hue City;

(2) Diet composition and foraging strategy;

(3) Variation between males and females in prey composition;

(4) Variation between locations and seasons in feeding ecology;

(5) Correlations between morphological characteristics and prey; and

(6) Influence of environmental factors.

This study hypothesized that adult females of *A. spinapectoralis* possess larger head sizes than males. To test this, variation in prey consumption was explored across sites, seasons, and sexes. The foraging strategy was predicted to align with the 'sit-and-wait' model. Additionally, the species' foraging ecology was examined to estimate seasonal dietary variation and test the hypothesis of a positive correlation between body size, prey size, and diet. Specifically, mouth width was hypothesized to influence consumed prey size, with larger frogs predicted to consume larger prey.

MATERIAL AND METHODS

Study Site

This study was conducted in the tropical rain forests of Hue City 15.991^0 – 16.741^0 N,107.015^0–108.215^0 E, central Vietnam (Figure 1). On 1 July 2025, Thua Thien Hue Province was officially reorganized into a centrally run city named Hue City. According to Resolution No. 1675/NQ-UBTVQH15 (issued by the National Assembly Standing Committee on 20 June 2025), the new city comprises 40 commune-level administrative units, including 21 wards, and 19 communes.

The study area features a subtropical monsoon climate dominated by montane rain forests (700–1,400 m elevation) and cloud forests (>1,450 m elevation). There is no dry season; instead, the year comprises a light rainy season (January–April), an auxiliary rainy season (May–August), and a main rainy season (September–December). Annual rainfall ranges from 3,970–4,281 mm with an average temperature of 23.8–25.2 °C (Figure 2). (Nguyen et al. 2004; Ngo et al. 2012, 2013).

Stomach contents of *A. spinapectoralis* were collected at three sites in Hue City: (1) Do Quyen Stream (Phu Loc; 1,096 m elevation; N = 91); (2) Thuong Lo Stream (Khe Tre; 334 m elevation; N = 87); and (3) A Pat Stream (A Luoi 4; 1,021 m elevation; N = 83) (Figure 3).

Morphometric Analyses

A total of 261 individuals (130 males and 131 females) were collected for dietary studies. Of these, morphological data were recorded on only 235 individuals (84 males, 110 females, and 41 sub-adults). After completing stomach sampling and morphological measurements, the individuals were released back into the wild. All measurements were taken with a caliper to the nearest 0.01 mm following Duong & Ngo (2022), Pham et al. (2015, 2023a).

Abbreviations

SVL—snout-vent length, distance from tip of snout to anterior margin of vent | HL—head length, from tip of snout to rear of jaws | HW—Head width, horizontal line at posterior end of the mandible | SL—snout length, distance from anterior corner of eye to tip of snout | ED—eye diameter, from anterior corner to posterior corner of eye | EN—eye to nostril, distance from anterior corner of eye to the nostril | IND—internarial distance, least distance between upper eyelids | IOD—minimum distance between upper eyelids | MW—mouth width, horizontal line at the posterior angle of the jaw | TD—tympanum diameter, horizontal width of the tympanum at its widest point | TL—tibia length, from knee to heel | FL—foot length, from proximal end of inner metatarsal tubercle to tip of fourth toe | TFL—length of foot and tarsus, from tibiotarsal joint to tip of fourth toe | finger or toe length—distance between posterior margin of most proximal subarticular tubercle or crease of articulation and tip of finger or toe | width of disc on finger or toe—greatest width of terminal disc on finger

Figure 1. Map of Hue City, Vietnam, showing the geographical location and locations where we sampled *Amolops spinapectoralis* (blue circles): 1—Phu Loc commune (the old place name is Loc Tri commune, Phu Loc District) | 2—Khe Tre commune (the old place name is Huong Loc commune) | 3—A Luoi 4 commune (the old place name is A Roang commune)—location updated per Hue City's administrative map (from 1 July 2025).

or toe | thigh length—from the center of knee to the center of the hind limb insertion | foot length—from the base of the inner metatarsal tubercle to the tip of the fourth toe. Some ratios of head morphology and ratios of head measurements and tibia length compared to SVL, such as HL/HW, HL/SVL, HW/SVL, MW/SVL, and TL/SVL. To measure body mass (BM), we used electronic scales (Kern, Germany) accurate to 0.01 g.

Stomach Content Collection

We analyzed the nutritional ecology of 261 individuals (131 females, 130 males) from three localities in Hue City via stomach flushing. Samples were evenly distributed across three seasons (N = 87 each): low-rainy (January–April), secondary rainy (May–August), and main rainy (September–December). Gastric lavage was performed to collect stomach contents from frogs without causing harm (Solé et al. 2005; Pham et al. 2023a). To avoid oesophageal or gastric injury, especially in smaller frogs, we used tea strainers, a fine mesh sieve, two 60 ml syringes, and soft silicone tubing. Each frog underwent a single gastric lavage following the American Society of Ichthyologists and Herpetologists' animal care guidelines (Beaupre et al. 2004). Filtered stream water from the capture sites was used during the process. Frogs were monitored post-lavage and released within 30 minutes if found to be in good condition. Specimen sex was determined by examining the vocal sacs and gonads (Duong & Ngo 2022; Pham et al. 2023b).

All stomach contents were initially preserved in 95% ethanol for later laboratory analysis. Following examination, specimens and stomach contents were transferred to 70% ethanol and deposited in the Amphibian Collection at the University of Education, Hue University, Vietnam. Prey from each stomach sample was sorted and identified to the lowest possible taxonomic level, primarily to order, with identification made by family when possible. For taxonomic identification of invertebrates, we followed Thai (2003) and Johnson & Triplehorn (2005). Prey identification was conducted under a microscope (Olympus SZ 700) and stereo microscope (XT-203) using various keys (Millar et al. 2000; Johnson & Triplehorn 2005; Brusca et al. 2016). All individuals were released back into the wild after stomach contents were collected and morphological data were measured.

We measured the length and width (at the widest central part of the body) of each prey item using a digital caliper, accurate to 0.01 mm, or made the best estimate for incomplete items. Both animal and plant matter were classified as food. Unidentified materials, such as digested insects in the diet of *A. spinapectoralis*, were categorized as unidentified. Non-food materials, including sand and rocks, were excluded from the analysis. We calculated the volume fraction of each prey item and unidentified material, estimating the volume (V) using the formula for an expanded sphere with π = 3.14159 (Magnusson et al. 2003; Biavati et al. 2004; Valderrama-Vernaza et al. 2009; Caldart et al. 2012; Ngo et al. 2013; Pham et al. 2023a):

$$V = \frac{4\pi}{3} \text{x} \left(\frac{\text{length}}{2}\right) \text{x} \left(\frac{\text{width}}{2}\right)^2, \text{mm}^3$$

We used the relative importance index (IRI) to assess the significance of each prey species in the feeding ecology of *A. spinapectoralis*. The IRI offers a comprehensive estimate of prey consumption by combining three key components, providing a more complete evaluation than considering any single component. The formula for calculating the IRI is as follows (Biavati et al. 2004; Leavitt & Fitzgerald 2009; Ngo et al. 2013; Pham et al. 2023a):

$$\text{IRI} = \frac{\%\text{F} + \%\text{N} + \%\text{V}}{3}$$

The IRI represents the importance index for each food item, where F is the frequency of stomachs containing a specific prey item, N is the total number of prey items counted, and V is the volume of the corresponding prey. This index provides a more biologically meaningful assessment, offering a more realistic evaluation of prey significance compared to individual assessments of frequency (F), number (N), or volume (V) alone (Leavitt et al. 2009; Ngo et al. 2014). To estimate the influence of sex and season on the foraging ecology of *A. spinapectoralis*, we calculated an IRI for prey types, based on individual stomach contents and their importance values.

We use reciprocal Simpson's heterogeneity index, 1/D, to calculate dietary heterogeneity:

$$D = \frac{1}{N(N-1)} \sum n_i(n_i - 1)$$

n_i is the number of prey items in the i^{th} prey category and N is the total number of prey categories (Krebs 1999).

To estimate prey evenness, we used Shannon's index of evenness. Evenness is calculated from the equation:

from the equation: $$J' = \frac{H'}{H_{max}} = \frac{H'}{\ln S},$$

The maximum diversity (H_{max}) that could occur is that which would be found in a situation in which all taxa had equal abundance ($H = H_{max} = \ln S$), S is the total number of prey taxa, and H' is the Shannon-Weiner index of taxon diversity. Here's the complete formula for calculating the Shannon-Wiener diversity index (H'):

$$H' = -\sum (p_i \, x \, ln(p_i))$$

Where *pi* is the proportion of total food items belonging to the taxon relative to the i^{th} total food items in the sample (Magurran 2004; Pham et al. 2022). This index measures species diversity in a community, with higher values indicating greater diversity.

Foraging strategy

During three seasons, we observed foraging activity of *A. spinapectoralis* on the waterfalls. Each individual encountered was monitored for approximately 10 minutes, with movements and corresponding behaviours recorded every minute. These data were used to analyze and compare two main activity patterns: the "widely foraging" pattern and the "sit-and-wait" pattern. A total of 360 minutes of observation was conducted (30 minutes per survey, with 1 observation being 10 minutes).

Data Collection

Nighttime surveys were conducted along 2.0–3.0 km stream transects to hand-collect specimens for morphological measurement and non-lethal stomach flushing. All specimens were released back into their natural habitat immediately after processing. For each capture, we recorded environmental variables (date, time, temperature, humidity) and determined the species' distribution in Hue City using a GPS device (Garmin 64S; Garmin USA; Taiwan; WGS 84).

Statistical Analysis

Statistical analyses were performed using SPSS 22 with a significance level of $P \leq 0.05$, and data are presented as mean ± SD unless otherwise noted. Sexual size dimorphism (based on SVL) was tested using two-way ANOVA, followed by ANCOVA for other morphological traits (head, BM, SVL, MW) (Rosner 2010; Zar 2010; Ngo et al. 2014). We used one-way ANOVA to compare stomach counts and prey metrics across sexes, seasons, and localities; analyses were stratified by sex where significant sexual dimorphism occurred. Finally, multiple linear regression was employed to examine correlations between body size (SVL, BM, MW) and prey dimensions, as well as the effects of climatic factors (precipitation, temperature, humidity) on prey mass

(Ngo et al. 2014; Pham et al. 2022).

Genetic Analysis

The study was conducted using molecular data and phylogenetic analysis of the CO1 (Cytochrome c Oxidase Subunit 1) gene, which is located on the mitochondrial DNA (mtDNA) of *A. spinapectoralis* in Hue City. The DNA sequence after sequencing was edited and quality checked using BioEdit version 5.0.9 software. The edited sequences were then compared with the NCBI database using the BLAST tool to determine the level of similarity with known sequences (Benson et al. 2017).

RESULTS

During this study, our collections of *Amolops spinapectoralis* spanned the whole 12-month period, from February 2023 to January 2024, wherein the species was recorded at various locations in the Hue City (see Figure 1).

Genetic findings

The research sample coincided with the sequence of the standard sample *A. spinapectoralis* (voucher KIZ013694) stored on GenBank (MN953768.1) with a divergence of 0.22%. Comparison with the GenBank database showed that the obtained sequence had a high similarity with the species *A. spinapectoralis*.

Morphometry

The analysis results showed that, in the study area, the head length/body length ratio in adult females (n = 110) was significantly larger than that in adult males (n = 84) (Table 1).

Morphological characters (Image 2): Head is slightly longer than it is wide (female: HL/HW = 1.12 ± 0.13; male: HL/HW = 1.16 ± 0.14); blunt snout that projects forward relative to the lower jaw; nostrils are rounded and positioned closer to the eyes than to the snout tip (female: SL 12.74 ± 2.56; EN 7.02 ± 1.17; NS 3.29 ± 0.88; male: SL 11.18 ± 3.28; EN 5.92 ± 1.17; NS 2.94 ± 0.95); internasal distance is larger than both the interorbital distance and upper eyelid width (female: IOD 1.34 ± 0.46; IN 6.09 ± 1.25; male: IOD 1.38 ± 0.98; IN 5.98 ± 4.36); eyes are large and prominent, with a diameter larger than the tympanic membrane (female: ED 6.17 ± 2.05; TD 1.91 ± 0.97; male: ED 5.26 ± 0.96; TD 1.68 ± 0.67). A visible skin ridge is present above the tympanum; vomerine teeth are short and arranged in a V shape, and the tongue is slightly forked posteriorly; males have a vocal sac and white, cylindrical pectoral spines. Forelimbs: forelimbs lack swimming webs and with suction discs with a circum-marginal groove on the disc of the first finger; adult males possess ivory-white spinous pads at the base of the index finger. The relative lengths of the fingers are I<II<IV<III. Hind limbs: Hind digit discs are smaller than those of the forelimbs. The relative lengths of the hind digits are I<II<III<V<IV; swimming membranes are wide, extending fully to the discs of the hind digits, with no external tubercles present. Skin: Dorsal skin is rough with small pimples, while the ventral skin is smooth. Colour in life: Head and body are grey-blue or olive-grey, with dark black streaks and spots forming a network; eyes sockets are dark brown, and the flanks are covered in white pimples; ventral surface is white, with females showing yellow streaks or spots on the flanks in breeding season.

The snout-vent length (SVL) ranged 39.73–56.64 mm in adult males (n = 84), 39.73–556.64 mm in adult females (n = 110), and 15.91–337.95 mm in subadults (n = 41). On average, both SVL and body weight (BW) of males were noticeably smaller than those of females (Table 1). The largest female had an SVL of 56.64 mm, while the largest male measured 52.48 mm (Table 1). The mean SVL of adults did differ significantly between sexes (F = 135.148, Sig. < 0.001). The SVL did vary significantly across seasons, temperatures, and humidity (season: F = 8.256, Sig. < 0.001; temperature: F = 5.373, Sig. < 0.001; humidity: F = 7.012, Sig. < 0.001). There was no significant difference in SVL among localities (F = 1.718, Sig. = 0.182).

The basic head size measurements in Hue city, analyzed through a two-factor ANOVA for males and females, yielded significant results. For head length, males measured an average of 14.83 ± 1.59 mm, while females measured 16.85 ± 1.76 mm (F = 6.212; Sig. = 0.000). Head width showed a similar trend, with males at 12.94 ± 1.5 mm and females at 15.1 ± 1.75 mm (F1,59 = 5.809; Sig. = 0.000). Snout length (SL) averaged 11.18 ± 3.28 mm for males and 12.74 ± 2.56 mm for females (F = 3.065; Sig. = 0.003). For mouth width, males averaged 13.89 ± 2.12 mm, compared to 16.41 ± 1.63 mm for females (F = 7.868; Sig. = 0.000). Overall, adult females exhibited significantly larger head sizes than males. Linear regression analysis indicated that body mass increased with body length in both sexes. When adjusting for SVL, adult females still showed larger measurements than males across head length (HL: F = 554.214, Sig. = 0.000), head width (HW: F = 393.860, Sig. = 0.000), and mouth width (MW: F = 272.103, Sig. = 0.000). Furthermore, adult females had a significantly

Table 1. Morphological characteristics of *Amolops spinapectoralis* from Hue City, including weight (g), measurements (mm), and proportions of the specimens.

Character	Adult females (n = 110)		Adult males (n = 84)		Subadults (n = 41)	
Measurements	min–max	mean ± SD	min–max	mean ± SD	min–max	mean ± SD
SVL	39.73–56.64	48.97 ± 4.64	32.46–52.48	41.04 ± 5.92	15.91–37.95	30.71 ± 5.6
HL	12.58–20.34	16.85 ± 1.76	10.39–17.94	14.83 ± 1.59	8.41–18.96	12.25 ± 2.0
HW	10.03–18.1	15.1 ± 1.75	9.72–16.26	12.94 ± 1.5	6.6–16.81	10.57 ± 2.06
SL	3.96–16.85	12.74 ± 2.56	5.27–20.83	11.18 ± 3.28	2.38–13.63	8.63 ± 2.35
ED	3.53–15.84	6.17 ± 2.05	3.47–7.83	5.26 ± 0.96	1.53–6.6	4.04 ± 1.14
IOD	0.47–2.26	1.34 ± 0.46	0.36–6.9	1.38 ± 0.98	0.34–6.97	1.67 ± 1.64
TD	0.74–7.63	1.91 ± 0.97	0.45–4.99	1.68 ± 0.67	0.53–4.08	1.52 ± 0.79
ET	0.83–18.94	3.34 ± 2.27	1.16–4.02	2.69 ± 0.7	1.2–3.62	2.07 ± 0.56
TL	16.1–25.89	22.22 ± 2.36	2.22–25.08	19.67 ± 3.56	10.79–23.01	15.33 ± 3.23
FL	11.33–31.18	24.47 ± 3.24	15.52–27.32	21.36 ± 2.83	22.14–12.02	16.6 ± 3.06
HND	5.15–23.47	14.28 ± 2.59	8.86–17.74	12.34 ± 1.84	7.03–15.72	9.89 ± 2.03
PL	5.71–28.18	21.12 ± 3.91	12.26–27.27	18.46 ± 2.89	3.34–21.2	13.93 ± 3.65
IN	0.03–9.13	6.09 ± 1.25	2.94–33.12	5.98 ± 4.36	3.5–7.57	4.62 ± 0.85
P	8.4–82.78	18,52 ± 10,02	5.1–18.71	10.92 ± 3.09	0.99–9.36	4.3 ± 2.05
NS	1.3–6.06	3.29 ± 0.88	1.24–6.84	2.94 ± 0.95	1.6–3.77	2.53 ± 0.61
EN	2.54–8.69	7.02 ± 1.17	2.56–8.73	5.92 ± 1.17	3.27–7.5	5.79 ± 1
ML	4.37–16.52	8.96 ± 1.89	4.46–9.91	7.41 ± 1.27	4.44–9.32	6.41 ± 1.53
PL-4	5.9–24.28	15.69 ± 3.15	5.93–19.38	13.99 ± 2.27	6.3–16.84	10.42 ± 2.48
IML	2.05–6.32	5.04 ± 0.96	2.49–8.65	4.54 ± 1.07	2.7–6.38	3.76 ± 0.92
MW	11.31–19.03	16.41 ± 1.63	4.83–18.15	13.89 ± 2.12	6.44–19.08	11.01 ± 2.53
HL/HW	0.82–1.47	1.12 ± 0.13	0.72–1.44	1.16 ± 0.14	0.04–0.37	0.14 ± 0.15
IO/HL	0.03–0.14	0.08 ± 0.03	0.02–0.53	0.1 ± 0.08	0.04–0.37	0.14 ± 0.15
ED/HL	0.21–0.94	0.37 ± 0.12	0.24–0.49	0.36 ± 0.06	0.14–0.4	0.33 ± 0.07
IN/HL	0–0.18	0.12 ± 0.03	0.07–1.44	0.16 ± 0.19	0.31–0.52	0.38 ± 0.05
HL/SVL	0.28–0.41	0.35 ± 0.03	0.24–4.09	0.4 ± 0.41	0.34–1.19	0.42 ± 0.18
TL/SVL	0.35–0.52	0.45 ± 0.04	0.05–4.39	0.52 ± 0.43	0.37–1.45	0.52 ± 0.22
MW/SVL	0.28–0.4	0.34 ± 0.02	0.11–3.85	0.38 ± 0.39	0.28–1.2	0.38 ± 0.19

SD—Standard deviation | for other abbreviations see Materials and Methods.

greater body mass than their male counterparts (BM: F = 173.416, Sig. = 0.000).

In terms of body mass, adult females were significantly larger than adult males. The average body mass for females was 18.52 ± 10.02 g (range: 8.4–82.78 g), while males averaged 10.92 ± 3.09 g (range: 5.1–18.71 g). This difference was statistically significant (F = 1.940; Sig. = 0.000), indicating that female body mass is notably greater than that of males.

Figure 4A shows a strong correlation between head length and body length; individuals with longer bodies also have longer heads in both sexes. The regression coefficients indicate that this relationship is stronger in females (R^2 = 0.1366) than in males (R^2 = 0.4404). Figure 4B shows that body length is positively associated with head width; the correlation is higher in females (R^2 = 0.623) than in males (R^2 = 0.3339).

Figure 4C indicates a similar positive correlation between body length and mouth width; again, the relationship is stronger in females (R^2 = 0.6192) than in males (R^2 = 0.1953). The average body length of adult females is also significantly larger than that of adult males.

Figure 5A shows that the body mass and mouth width of *Amolops spinapectoralis* are closely related. Linear regression analysis shows that the larger the mouth width, the greater the increase in mass in both males and females. Through the regression coefficient,

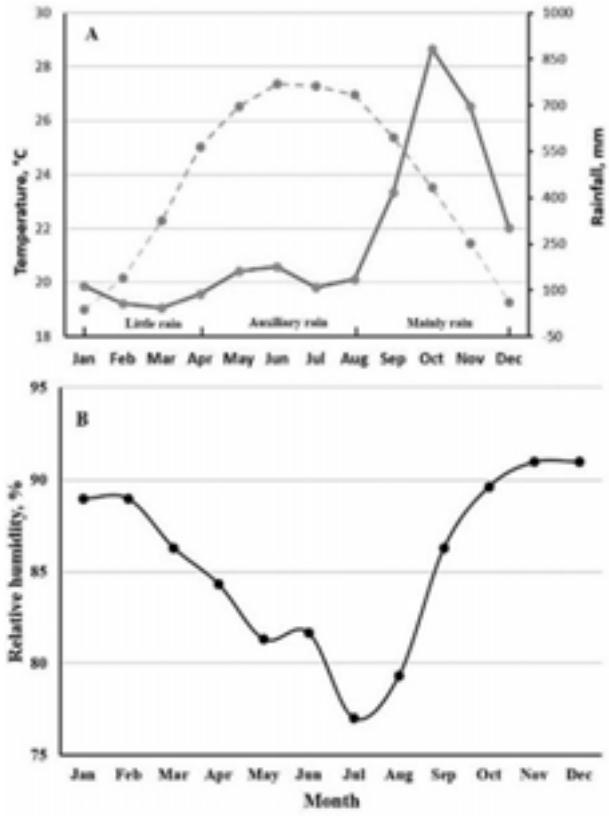

Figure 2. A—Monthly mean rainfall and temperature in the study area. Data correspond to the monthly mean temperature (broken line, in °C) and precipitation (solid line, in millimeters) over the last 20 years | B—Monthly mean relative humidity (solid line, in%) in the study area over the last 20 years. Data recorded from a statistic of the climatic hydrology characters of Hue City (Nguyen et al. 2004).

the relationship between BM and MW of males is closer than that of females (regression coefficient R^2 = 0.1899 in females; R^2 = 0.4487 in males); through Figure 5A, we see that when males and females have the same mouth width, the mass of females is larger than that of males, which partly shows that the nutritional needs of females are greater than that of males.

Figure 5B shows that body length and body mass are closely related; the larger the body length, the greater the body mass; through the regression coefficient, we see that the relationship between SVL and BM in males is slightly closer than in females (regression coefficient in females R^2 = 0.1533; males R^2 = 0.1899). Figure 5B also shows that with the same SVL size, the female's mass is larger than that of the male.

Dietary Observations

The majority of the time, 310 minutes (86.1%), was spent lying and waiting, which aligns with the "sit and wait" behaviour. The time spent moving was 23 minutes (6.39%), while hunting activity accounted for 25 minutes (6.94%). The remaining time was devoted to other behaviours, such as mating, escaping predators, and miscellaneous activities. Of the total, 86 stomachs (33%) were empty; thus, 175 stomachs containing food were retained for dietary analysis. The main food components were grasshoppers, beetles, insect larvae, flies, and ants with IRI of 16.17, 13.18, 10.93, and 9.12, respectively,

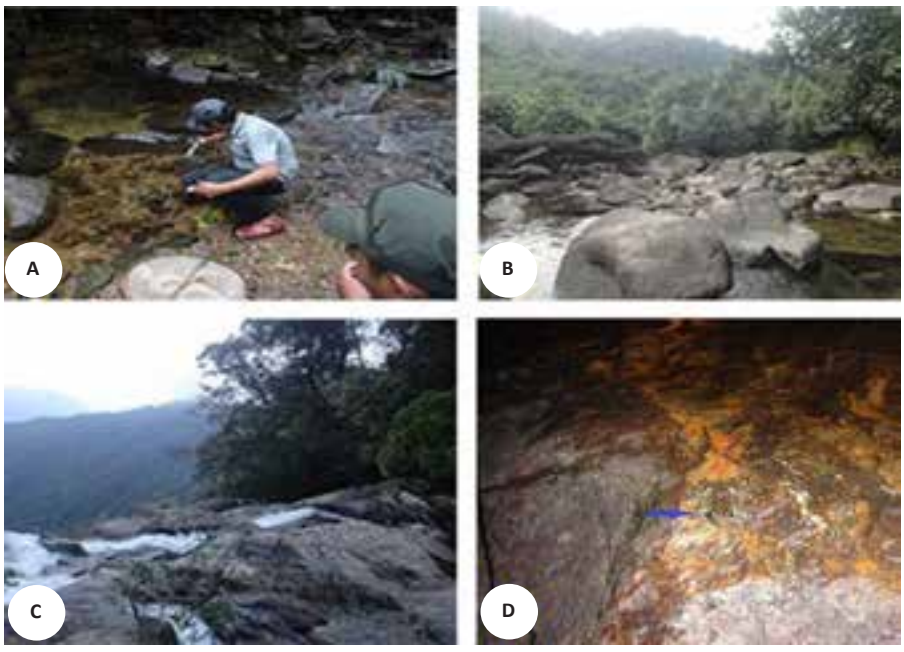

Image 1. Habitat of *Amolops spinapectoralis* at sampling sites in Hue City, Vietnam: A—A Luoi 4 commune | B—Khe Tre commune | C—Phu loc commune | D—Photographs of the habitat where the frogs were documented. © Loi Duc Duong.

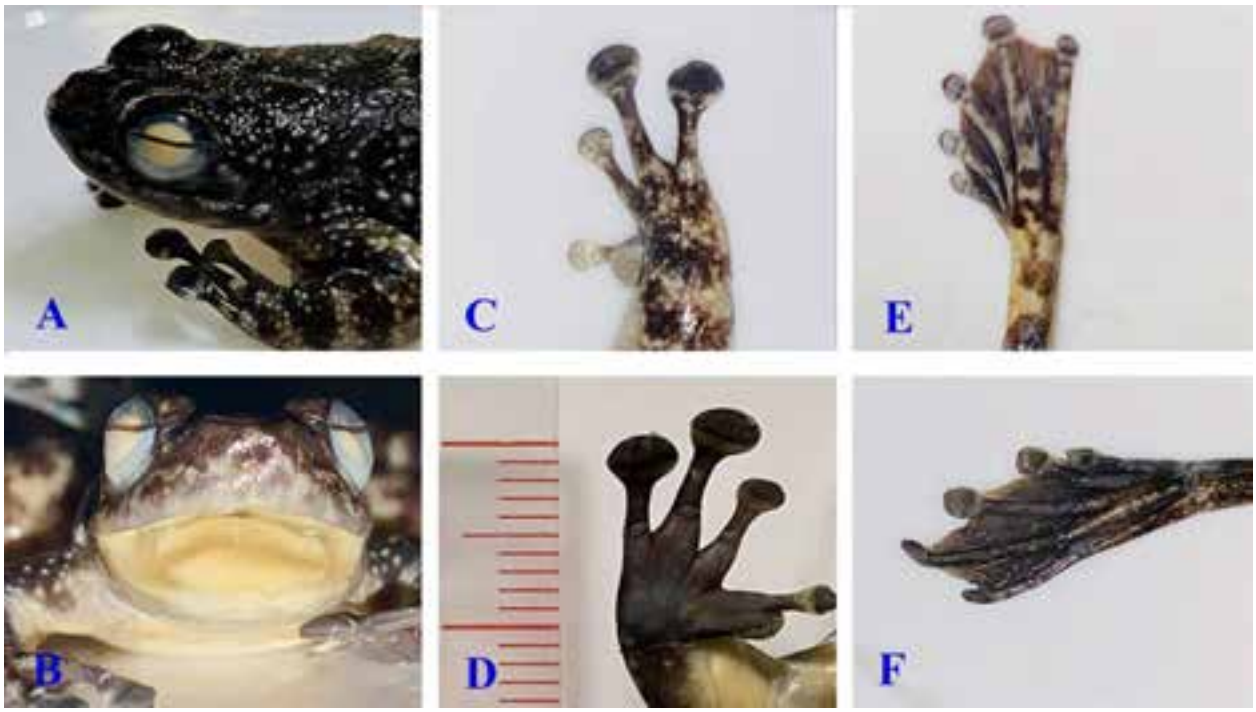

Image 2. Head, hand, and foot of *Amolops spinapectoralis* (male). Head: A—lateral view | B—oral cavity | Hand: C—dorsal view | D—ventral view | Foot: E—dorsal view | F—ventral view. © Loi Duc Duong.

which are common insect orders in fast-flowing waterfall environments. The diet comprised 18 animal prey categories (all insects), one plant category (consisting of seven species, primarily mosses), and 16 unidentified organisms. Traces of sand and rocks were also present, but no anthropogenic materials (e.g., plastics) were found. Prey measurements were as follows: mean length 8.93 ± 4.49 mm (range: 1.25–29.93 mm); mean width 3.39 ± 2.11 mm (range: 0.4–13.15 mm); and mean volume 91.97 ± 198.26 mm³ (range: 0.75–1873.21 mm³) (see Table 2).

Surveys at three locations in Phu Loc commune (Bach Ma National Park), Khe Tre commune (the old place name is Huong Loc commune), and A Luoi 4 commune (the old place name is A Roang commune) showed that the most abundant prey were Orthoptera, Coleoptera, Diptera, Formicidae, Isoptera, insect larvae, and Hymenoptera, accounting for 71.16% of the frequency of occurrence, 68.24% of the number of prey, and 66.89% of the total volume, with a relative importance index of 68.77% (Table 2). Based on the relative importance index, Coleoptera, Formicidae, insect larvae, and Diptera were the most important prey items, while Araneae, Blattodea, Gryllidae, Julidae, Lepidoptera, and Neuroptera were the less important prey items, accounting for 7.47% of the total prey items with a relative importance index of 6.52% (Table 2). The remaining prey items, such as Dermaptera, Hymenoptera, Isoptera, and Trichoptera, were intermediate in importance, with a relative importance index of 16.58% (Table 2). In addition, We found seven different types of plants in the stomach (these were mosses and small plants growing on the cliffs of the flowing waterfall) with a relative importance index of 6.11 % (Table 2). Some sand and some stones were also found in the stomach, but it is likely that they were accidentally swallowed along with the prey. Therefore, we excluded them from the analysis.

Male vs. female variations in prey composition

We identified a total of 507 prey items from the 175 stomachs containing food. Females consumed 274 items and males consumed 233 ($F = 2.932$, Sig. = 0.089, $p > 0.05$). On average, each individual consumed 2.66 prey items (range: 0–10).

In Figure 6, there are seven common food types; based on the IRI importance index, we can see that the food requirements of females are Coleoptera, Formicidae, insect larvae, and Isoptera higher than those of males in a total of 261 stomachs surveyed. On the contrary, in males, the food requirements of Orthoptera prey types are higher than those of females. Adult females (18 prey species) consumed more diverse prey species than adult

Table 2. Dietary composition of *Amolops spinapectoralis* in Hue City.

Prey category	Frequency (F)		Count (N)		Volume (V)		IRI
	F	%F	N	%N	V	%V	
Araneae	4	1.08	4	0.79	126.51	0.27	0.71
Blattodea	4	1.08	6	1.18	310.65	0.66	0.97
Coleoptera	45	12.13	66	13.02	6781.45	14.49	13.21
Dermaptera	9	2.43	14	2.76	342.58	0.73	1.97
Diptera	47	12.67	62	12.23	1161.08	2.48	9.13
Formicidae	26	7.01	38	7.5	5443.42	11.63	8.71
Gryllidae	6	1.62	9	1.78	274.07	0.59	1.33
Hymenoptera	17	4.58	25	4.93	2595.38	5.55	5.02
Insect larvae	35	9.43	47	9.27	6604.66	14.11	10.94
Isoptera	23	6.2	27	5.33	2439.13	5.21	5.58
Julidae	6	1.62	7	1.38	138.24	0.3	1.1
Lepidoptera	3	0.81	3	0.59	194.05	0.41	0.6
Neuroptera	7	1.89	8	1.58	819.68	1.75	1.74
Odonata	6	1.62	7	1.38	692.87	1.48	1.49
Ephemeroptera	2	0.54	2	0.39	277.89	0.59	0.51
Orthoptera	71	19.14	81	15.98	6282.69	13.42	16.18
Scorpiones	3	0.81	4	0.79	259.4	0.55	0.72
Trichoptera	9	2.43	12	2.37	3387.98	7.24	4.01
Plant materials	7	1.89	30	5.92	4923.87	10.52	6.11
Unidentified	41	11.05	55	10.85	3747.37	8.01	9.97
Total	371	100	507	100	46802.93	100	100

F—frequency of prey occurrence | N—number of prey items | V—prey volume (mm3) | IR—index of relative importance of each taxon, sampled in Hue City, Vietnam (n = 261 stomach contents).

males (15 prey species). The prey diversity index of adult females (2.6 with an evenness index of 0.7) was higher than that of adult males (2.36 with an evenness index of 0.66).

The number of prey items found in the stomachs of females was higher than that in males. The total prey volume was 28,490.85 mm³ in females and 18,312.08 mm³ in males. In females, prey measurements were as follows: length 9.28 ± 4.65 mm (F = 3.786, Sig. < 0.001), width 3.54 ± 2.4 mm (F = 2.501, Sig. = 0.001), and volume 98.69 ± 201.08 mm³ (F = 1.655, Sig. = 0.048). In males, prey measurements were: length 8.5 ± 4.26 mm (F = 9.264, Sig. < 0.001), width 3.21 ± 1.7 mm (F = 8.451, Sig. < 0.001), and volume 84.04 ± 195.01 mm³ (F = 3.040, Sig. < 0.001).

The type of prey differed significantly between males and females (F = 3.953, Sig. = 0.001). However, the relationship between prey and sex was not statistically significant (F = 1.395, Sig. = 0.221 > 0.05). In females, the composition, quantity, and volume of food items were all greater than in males, which is consistent with the efficiency of scale hypothesis (Forsman 1996) because females have larger body sizes and were able to consume larger prey items than males (Le et al. 2019). This evidence may partly explain the dietary differences of these prey groups between the sexes and why adult females consume a larger number of beetles, insect larvae, and termites (Figure 6), and the volume of food consumed by females is much larger than that of males.

Locations and season variation

We found that *Amolops spinapectoralis* is often confined to waterfalls and rarely ventures far from the water's edge. The species' diet reflects its limited range of activity and specific habitat. Since *Amolops spinapectoralis* is restricted to waterfall environments, its diet primarily consists of insects that inhabit these areas. For example, dragonflies, which rely on water for their reproductive cycle, were commonly found in the diet. On the other hand, we did not observe species like

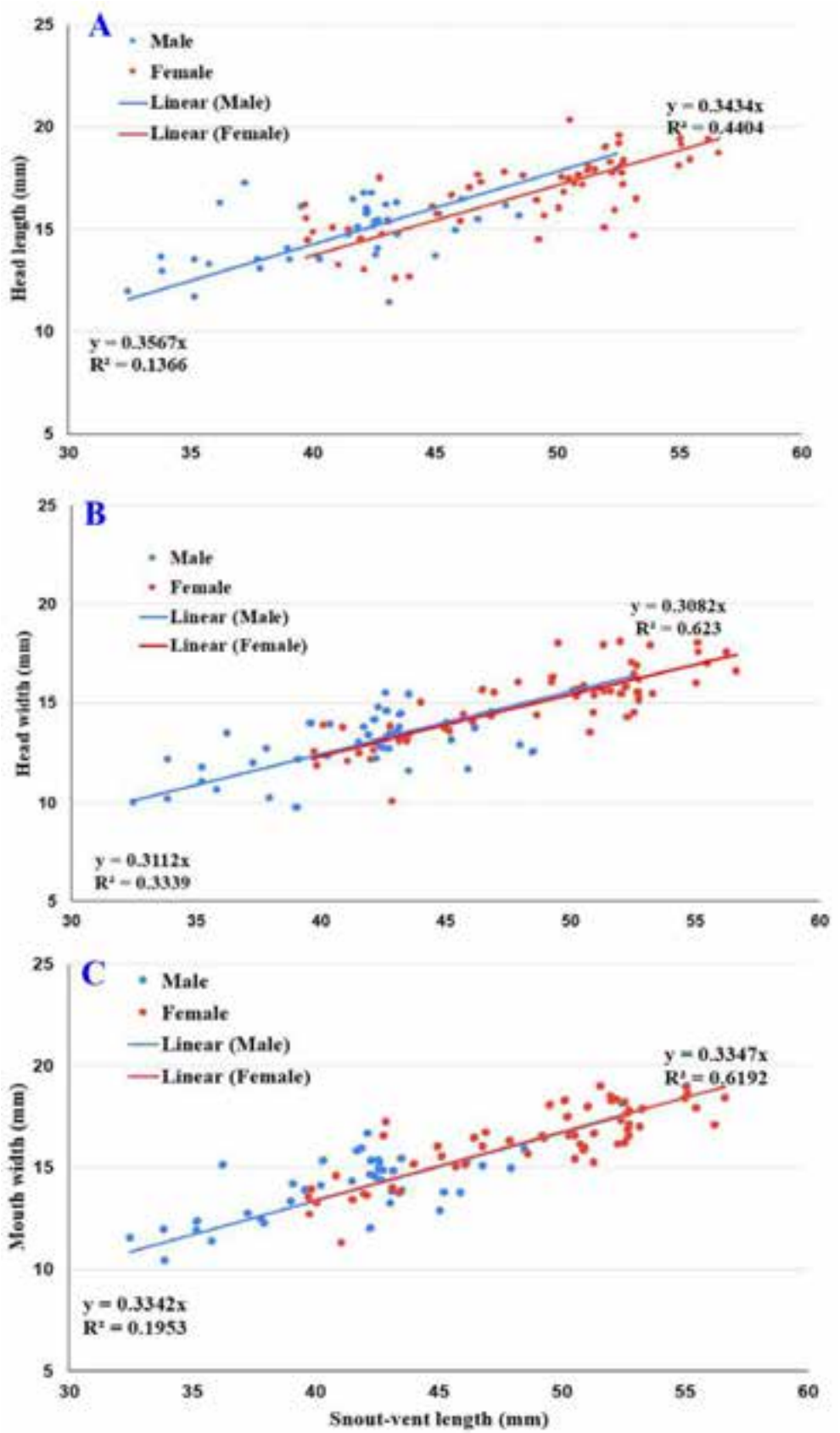

Figure 3. The relationships between: A—snout-vent length (SVL) and head length (HL) | B—head width (HW) | C—mouth width (MW) in adult males and females of *Amolops spinapectoralis*.

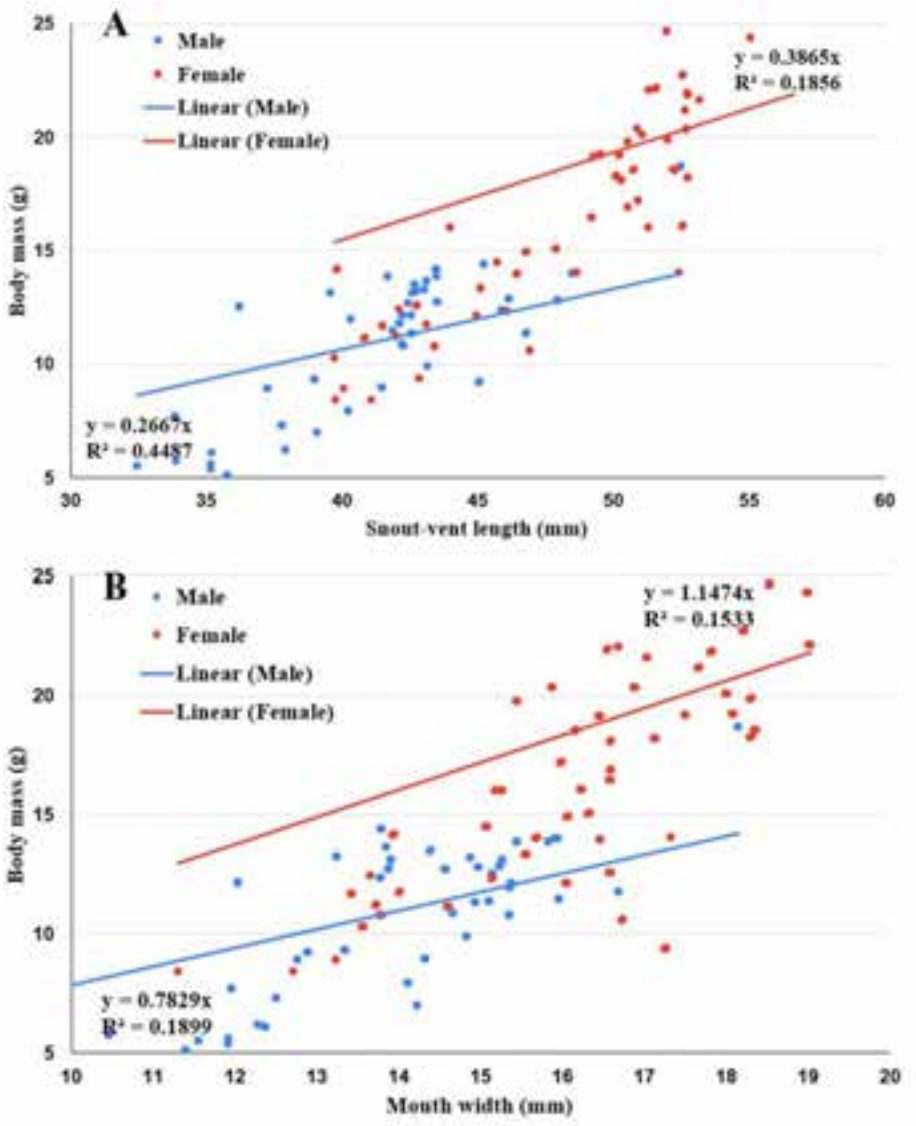

Figure 4. The relationships between: A—snout-vent length and body mass | B—mouth width and body mass of the *Amolops spinapectoralis*.

cockroaches and spiders in the food composition, as these organisms do not rely on water for reproduction and are rarely found in fast-flowing waterfall environments.

Seasonal prey consumption was recorded as follows: low-rainy season (204 items), auxiliary rainy season (153 items), and main rainy season (150 items) ($F = 19.885$, Sig. = 0.000). Prey varied between seasons, but this variation was not statistically significant ($F = 1.338$, Sig. = 0.223 > 0.05). In contrast, prey length and width did vary significantly between seasons (length: $F = 13.454$, Sig. < 0.001; width: $F = 6.697$, Sig. = 0.01).

Both the size and volume of prey consumed by both male and female *A. spinapectoralis* differed significantly between seasons (length: $F = 13.454$, Sig. < 0.001; width: $F = 6.749$, Sig. = 0.001; volume: $F = 3.628$, Sig. = 0.027).

Table 3. Simpson's index of diversity and Shannon-Wiener index among age groups, sites, and seasons in the diet of *Amolops spinapectoralis* from Hue City, Vietnam.

Contents	Shannon-Wiener index (Shannon-H, H')	Simpson's index 1/D
Adults	2.431	0.892
Subadults	2.383	0.883
Juveniles	2.163	0.869
Do Quyen (Phu Loc)	2.541	0.901
Thuong Lo (Khe Tre)	2.349	0.875
A Pat (A Luoi 4)	2.46	0.898
A little rainy season	2.515	0.903
Auxiliary rainy season	1.932	0.819
Main rainy season	2.214	0.872

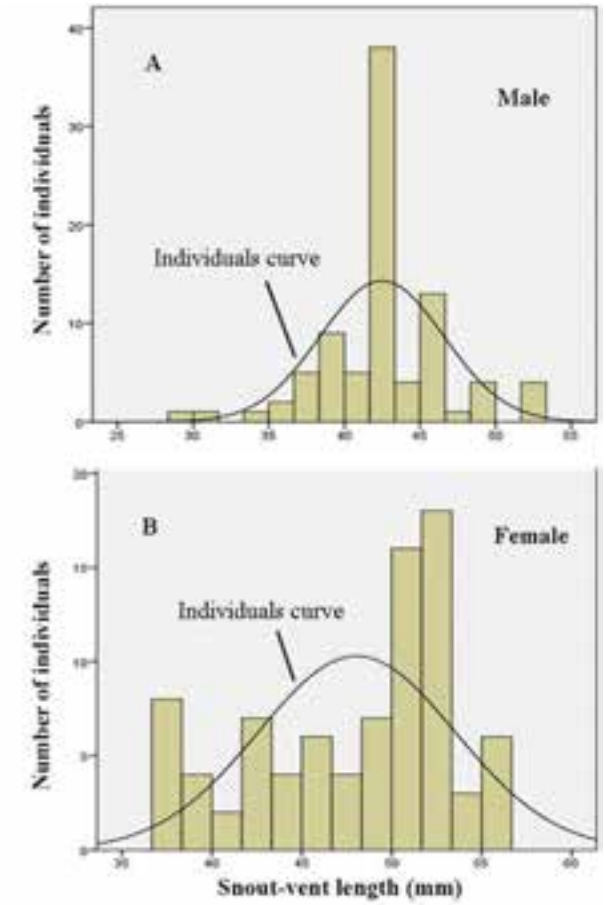

Figure 5. Normal distribution of snout-vent length (SVL, mm) for male (A) and female (B) *Amolops spinapectoralis* individuals, showing the distribution of individuals and sexual size dimorphism. For clarity, the upper bounds of the classes are shown. The curves in the figure are generated from a fit of the normal distribution for the data.

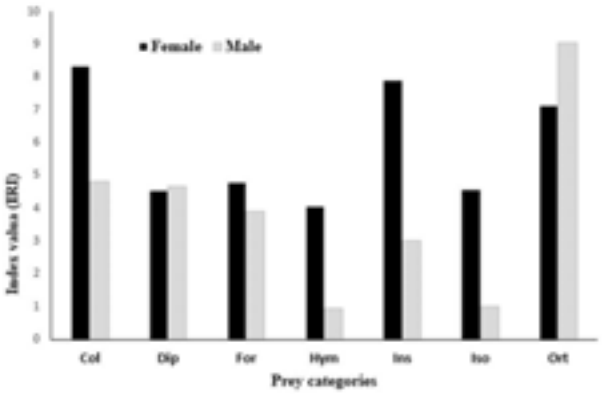

Figure 6. Index of relative importance (IRI) for major prey categories consumed by male and female *Amolops spinapectoralis* from Hue City, Vietnam: Col—Coleoptera | Dip—Diptera | For—Formicidae | Iso—Isoptera | Ins—Insect larvae | Iso—Isoptera | Ort—Orthoptera.

However, prey weight did not show significant seasonal variation (weight: F = 1.744, Sig. = 0.176). There were no significant differences in the size, volume, or weight of prey consumed across different localities (length: F = 0.24, Sig. = 0.815; width: F = 1.811, Sig. = 0.165; volume: F = 0.132, Sig. = 0.877; weight: F = 0.918, Sig. = 0.400).

In males, prey mass did not differ between seasons (F = 0.556, Sig. = 0.569), but prey size did (length: F = 8.355, Sig. < 0.001; width: F = 5.115, Sig. = 0.006). Prey mass and size consumed by males also did not vary significantly between localities. In females, prey mass did not differ by season (F = 1.744, Sig. = 0.176), but prey size did (length: F = 11.370, Sig. < 0.001; width: F = 597.496, Sig. < 0.001). Similar to males, prey mass and size consumed by females did not show significant differences across localities.

Discussion on seasonal factors

The seasonal prey numbers were: little rain (152 prey species), auxiliary rain (204 prey species), and main rain (151 prey species). Thus, we found that the secondary rainy season from May to August had a higher prey species than the other two seasons; the consistency of the data was shown in the main rainy season from September to December, when *A. spinapectoralis* had difficulty finding food in the high stream water conditions and stream frogs had to find shelter to avoid being swept away by the fast-flowing stream water. The low rainfall season is from January to April; however, January is still rainy, so foraging conditions remain difficult for *A. spinapectoralis*.

Morphometry and prey correlates

In the feeding ecology of this species, both SVL and MW were identified as important predictor variables for diet, as there were strong positive correlations between these morphological measurements (SVL and MW: r^2 = 0.4638, F = 147.737, Sig. < 0.001) and between MW and prey body mass (MW and prey BM: r^2 = 0.0534, F = 9.688, Sig. = 0.002).

In adult *A. spinapectoralis*, there was a significant positive correlation between mouth width (MW) and the size of prey consumed. However, regression analysis indicated that mouth width did not significantly affect prey size (mouth width and prey length: r^2 = 0.0024, F = 0.414, Sig. = 0.521; mouth width and prey width: r^2 = 0.0008, F = 0.135, Sig. = 0.714). Conversely, snout-vent length (SVL) was found to influence prey length (SVL and prey length: r^2 = 0.036, F = 6.437, Sig. = 0.012), but had no significant effect on prey width or mass.

Analyzing the relationship between prey size (length, width, and mass) and body size (SVL, MW) revealed that body size significantly influenced prey length (r^2 = 0.064, F = 5.792, Sig. = 0.004). However, body size did not have a significant effect on prey width (r^2 = 0.0062, F = 0.531, Sig. = 0.589) or prey mass (r^2 = 0.0279, F = 2.429, Sig. = 0.091).

In addition to habitat-driven prey availability, amphibians respond to various environmental factors. In our survey, we observed that during the auxiliary rainy season (from May to August) in the highlands, frequent fog significantly influences the composition and quantity of food, leading to emptier stomachs or stomachs containing only minimal or plant food. This results in a lower diversity and richness index of *A. spinapectoralis* diet during the auxiliary rainy season compared to both the little rainy season and the main rainy season (Table 3). A significant amount of plant material in the gut of frogs has been previously reported. This was reflected in a plant materials importance index (IRI) of 6.11%. These findings suggest that *A. spinapectoralis* has developed an adaptive response to the challenging conditions of its fast-flowing stream habitat (Image 1).

Environmental factor Influences

Environmental factors such as temperature, humidity, and rainfall affect the amount of prey consumed by Spinyback Torrent Frog. Analysis of the potential effects of temperature, relative humidity, and rainfall showed that these factors co-varied with season (overall: r^2 = 0.6856, F = 364.715, Sig. < 0.001). Temperature, relative humidity, and rainfall were significantly correlated with prey volume (r^2 = 0.0219, F = 3.734, Sig. = 0.011); however, prey mass was not significantly correlated with these climatic factors (r^2 = 0.0128, F = 2.175, Sig. = 0.09).

Multiple linear regression results indicated that temperature, relative humidity, and rainfall significantly affected prey numbers, with positive correlations overall (r^2 = 0.0581, F = 3.444, Sig. = 0.018). Specifically, temperature (r^2 = 0.0234, F = 4.070, Sig. = 0.045) and relative humidity (r^2 = 0.0003, F = 4.454, Sig. = 0.036) had significant positive effects, while rainfall showed an insignificant and negative correlation with prey numbers (r^2 = 0.0005, F = 0.085, Sig. = 0.771).

Distribution: This is the first record of *Amolops spinapectoralis* in Hue City with typical morphological characteristics as described above.

DISCUSSION

The body length, body mass, and head size of *Amolops spinapectoralis* in Hue City were different between the two sexes. Adult females had larger body length, head size, and body mass than males. These results are consistent with some data reported in many other rock frog species worldwide, such as *Amolops caelumnoctis* (Rao et al. 2007), *A. assamensis* (Sengupta et al. 2008), and *A. yunkaiensis* (Lyu et al. 2018). The morpholometric characteristics of our specimens agree well with the description by Inger et al. (1999). However, the special characteristic of *Amolops spinapectoralis* in Hue City is that the thoracic spines are not conical but obtuse (according to the description by Inger et al. 1999 of *A. spinapectoralis* in Gia Lai province, the thoracic stage is conical). With this morphological characteristic, many scientists confuse this species with *A. ricketti*. However, current data show that *A. ricketti* is not distributed in Vietnam. This confirms that *A. spinapectoralis* in Vietnam has some different morphological characteristics between regions.

In Vietnam, *A. spinapectoralis* has been recorded in the northern and central mountainous regions, including the provinces of Gia Lai, Da Nang, Quang Nam, Quang Ngai, Kon Tum, and Phu Yen (Frost 2025). Outside of Vietnam, it has been documented in Dakcheung District, Xekong Province, southeastern Laos, and is presumably found in adjacent northeastern Cambodia (Frost 2025).

To date, no dietary data have been reported for *A. spinapectoralis*, a poorly known frog species that was previously considered endemic to Vietnam (Nguyen et al. 2009). In this study, we identified 18 prey types in females and 15 prey types in males. Frogs are generally considered opportunistic carnivores, with their diet closely related to prey availability in their environment (Duellman & Trueb 1994). Their diet composition is primarily constrained by the availability and diversity of prey of suitable size (Wells 2007). Insects, the most frequent prey type, exhibit the highest species diversity, as previously documented by various studies. Insects are not only the most abundant prey in the environment but are also the most frequently consumed by frogs (Yousaf et al. 2010).

In general, the nutritional composition of *A. spinapectoralis*, which includes the suborder Orthoptera, termites, and insect larvae, may contain higher levels of protein (64.38~70.75%) and fat (18.55~22.8%) than those of Hymenoptera, Coleoptera, and Isoptera (according to Redford & Dorea 1984; Berenbaum 1996; Rumpold & Schlüter 2013). As insectivores, the natural

diet of amphibians will consist of 30% to 60% protein (McWilliams 2008; Browne 2009).

Our comparison results indicate that *A. spinapectoralis* primarily engages in lying and waiting, consistent with the 'sit-and-wait' model. This result aligns with existing research on the activity and hunting habits of the Ranidae family (Hadfield et al. 2006).

The division of habitats for frog species to exploit food resources is quite clear. In the survey, we observed that *Quasipaa verrucospinosa* to also often appear in low-slope streams. In *A. spinapectoralis* diet, cockroaches and spiders are almost absent in the collected stomach contents. In the three research locations, we found that the abundance of beetles and grasshoppers in the habitats is consistent with the food composition in the stomach of this species.

Our finding aligns with observations of amphibians inhabiting fast-flowing waterfalls, where increased rainfall causes streams to rise, and flow velocity to increase, making it more challenging for the animals to seek shelter and forage. These results are consistent with studies on amphibians that highlight the influence of ecological and climatic pressures, while no significant role for sexual selection was identified (Pincheira-Donoso et al. 2020).

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ARTICLE

Ectoparasites of Sumatran Elephants at Tangkahan Elephant Camp, Langkat, North Sumatra

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Abstract: The Sumatran Elephant *Elephas maximus sumatranus* is an endemic species of Indonesia, currently classified as 'Critically Endangered'. To ensure its continued existence, conservation efforts are crucial. One of the health threats faced by Sumatran elephants is ectoparasites. The present study, conducted from January–February 2020, investigates types, prevalence, and intensity of ectoparasite infestations in Sumatran Elephants at the Conservation Response Unit (CRU) Tangkahan, Langkat, North Sumatra. Eight Sumatran Elephants were sampled, including three juveniles (4 years old) and five adults (aged 26–50 years). The research employed palpation and sweeping net methods. Sample examination was conducted at the Animal Systematics Laboratory, Faculty of Mathematics and Natural Sciences, Universitas Sumatera Utara. The study identified 10 species of ectoparasites from 317 specimens: *Haemadipsa jeylanica*, *H. picta*, *H. pluvialis*, *Musca domestica*, *Stomoxys* sp., *Tabanus* sp.1, *Tabanus* sp.2, *Tabanus* sp.3, *Tabanus* sp.4, and *Tabanus* sp.5. *Haemadipsa jeylanica* exhibited the highest prevalence at 87.5%, categorized as 'usually,' while *Tabanus* sp.4 had the lowest prevalence at 50%, categorized as 'frequently.' Additionally, *Haemadipsa jeylanica* showed the highest intensity at 6.42, categorized as 'moderate,' whereas *Tabanus* sp.5 had the lowest intensity at 3.4, categorized as 'light.'

Keywords: Biting flies, conservation response unit, ectoparasites, *Elephas maximus sumatranus*, identification, Indonesia, leeches, parasite intensity, parasite prevalence, Sumatran Elephant, *Tabanus*, Tangkahan, wildlife health.

Abstrak: Gajah Sumatra (Elephas maximus sumatranus) merupakan spesies endemik Indonesia yang saat ini berstatus Kritis (Critically Endangered). Upaya konservasi sangat diperlukan untuk menjamin kelangsungan hidup spesies ini. Salah satu ancaman terhadap kesehatan gajah Sumatra adalah infestasi ektoparasit. Penelitian ini dilakukan pada Januari–Februari 2020 dengan tujuan mengkaji jenis, prevalensi, dan intensitas infestasi ektoparasit pada gajah Sumatra di Conservation Response Unit (CRU) Tangkahan, Kabupaten Langkat, Sumatra Utara. Sebanyak delapan individu gajah Sumatra diamati, terdiri atas tiga individu juvenil berusia 4 tahun dan lima individu dewasa berusia 26–50 tahun. Metode pengambilan sampel dilakukan melalui palpasi dan penyapuan menggunakan jaring serangga. Pemeriksaan sampel dilakukan di Laboratorium Sistematika Hewan, Fakultas Matematika dan Ilmu Pengetahuan Alam, Universitas Sumatera Utara. Hasil penelitian menunjukkan terdapat 10 spesies ektoparasit dari total 317 individu yang teridentifikasi, yaitu Haemadipsa jeylanica, H. picta, H. pluvialis, Musca domestica, Stomoxys sp., Tabanus sp.1, Tabanus sp.2, Tabanus sp.3, Tabanus sp.4, dan Tabanus sp.5. Haemadipsa jeylanica memiliki prevalensi tertinggi sebesar 87,5% yang dikategorikan sebagai "biasanya", sedangkan Tabanus sp.4 memiliki prevalensi terendah sebesar 50% yang dikategorikan sebagai "sering". Intensitas tertinggi juga ditunjukkan oleh Haemadipsa jeylanica dengan nilai 6,42 yang termasuk kategori "sedang", sementara intensitas terendah terdapat pada Tabanus sp.5 dengan nilai 3,4 yang termasuk kategori "ringan".

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INTRODUCTION

The Sumatran Elephant is exclusively found on the island of Sumatra. Elephant health is crucial for maintaining populations (Berliani et al. 2022), where challenges include ectoparasites that live on exterior surfaces such as the skin, ear cavities, nose, fur, tail, and eyes (Iqbal et al. 2014). Elephant ectoparasites include flies, lice, mosquitoes, ticks, and mites that can impair animal health by reducing appetite and blood-sucking, leading to weakened immunity, weight loss, and decreased skin quality, and they can also aid transmission of pathogens such as viruses, bacteria, protozoa, worms, and fungi (Levine 1990). Severe infestations can result in death (Sahito et al. 2017), and symptoms can also cause discomfort and restlessness, disrupting animal activities (Hadi et al. 2016).

The Conservation Response Unit (CRU) Tangkahan is a conservation organization for Sumatran Elephants. One of CRU's functions is to patrol and protect the forest from illegal activities that threaten conservation efforts. Healthy elephants are essential for effectively performing their roles and functions. The local community in Tangkahan also benefits from the presence of Sumatran elephants, as they help protect the forest and boost community welfare through ecotourism activities. Maintaining the elephants' health, particularly against diseases caused by ectoparasites, is crucial to enhancing their role.

METHODS

Study Area

This study was carried out from January to February 2020 at the Conservation Response Unit (CRU) Tangkahan, situated in Namo Sialang Village, Batang Serangan District, Langkat Regency, North Sumatra Province. Renowned for its pristine rainforests, Tangkahan offers a rich natural environment that includes wild orangutans, waterfalls, caves, and hot springs. The area supports a wide array of flora and fauna, including numerous plant species vital to the diet of Sumatran Elephants. Characterized by a tropical rainforest climate, Tangkahan experiences high humidity and substantial rainfall year-round. These lush environmental conditions make it an ideal habitat for diverse wildlife, particularly the Critically Endangered Sumatran Elephant.

Sampling Procedure and Ectoparasite Collections

The research subjects included eight Sumatran Elephants, three juveniles (4 years old), and five adults (aged 26–50 years). Data collection on ectoparasites was carried out using the palpation method over the entire body of the elephants and the sweep net method (net traps). Temperature and humidity were also measured. Sampling took place over 14 days, with captures conducted twice a day. The first capture was performed from 0900–1100 h and the second from 1500–1700 h. Morning sessions typically ranged 25–27 °C with high humidity, while afternoon sessions reached 28–30 °C with slightly lower humidity. Leeches were more abundant in cooler, more humid conditions, while flies were more active during warmer hours. The captured ectoparasites were placed in collection bottles containing 70% alcohol and labelled for subsequent identification and counting.

Ectoparasite Identification and Analysis

The identification of ectoparasities captured and stored with the help of keys and descriptions provided by Leahy (1987) and Borror et al. (1992). The prevalence of ectoparasites was calculated using the formula by Soulsby (1982), and the intensity of ectoparasite infestations was determined using the formula by Williams & Williams (1996).

$$\text{Intensity} = \frac{\text{Total number of individuals of a given ectoparasite species}}{\text{Number of elephant infested by that species}}$$

RESULTS AND DISCUSSION

Data for ectoparasites collected are summarized in Table 1. Specimens were identified from two phyla (Arthropoda and Annelida), two classes (Insecta and Clitellata), two orders (Diptera and Arhynchobdellida), three families (*Tabanidae*, *Muscidae*, and *Haemadipsidae*), five genera (*Tabanus*, *Haematopota*, *Stomoxys*, *Musca*, and *Haemadipsa*), and 10 species: *Tabanus* sp.1, *Tabanus* sp.2, *Tabanus* sp.3, *Tabanus* sp.4, *Tabanus* sp.5, *Haematopota pluvialis*, *Stomoxys* sp., *Musca domestica*, *Haemadipsa jeylanica*, and *Haemadipsa picta*. The most dominant ectoparasite species found was *Tabanus* spp. from the family Tabanidae. This is likely due to the suitability of the *Tabanus* spp. fly's environment with the research location. Ectoparasites attached to the elephants' skin, such as leeches (*Haemadipsa jeylanica* and *H. picta*), were collected by palpation. In contrast, flying ectoparasites (*Tabanus* spp., *Haematopota pluvialis, Stomoxys* sp., and *M. domestica*) were collected using sweep nets as they approached the elephants. Sampling was carried out twice daily, with morning sessions (0900–

Table 1. Types of ectoparasites collected.

Phylum	Class	Order	Family	Genus	Species
Arthropoda	Insecta	Diptera	Tabanidae	*Tabanus*	*Tabanus* sp.1
Arthropoda	Insecta	Diptera	Tabanidae	*Tabanus*	*Tabanus* sp.2
Arthropoda	Insecta	Diptera	Tabanidae	*Tabanus*	*Tabanus* sp.3
Arthropoda	Insecta	Diptera	Tabanidae	*Tabanus*	*Tabanus* sp.4
Arthropoda	Insecta	Diptera	Tabanidae	*Tabanus*	*Tabanus* sp.5
Arthropoda	Insecta	Diptera	Tabanidae	*Haematopota*	*Haematopota pluvialis*
Arthropoda	Insecta	Diptera	Muscidae	*Stomoxyy*	*Stomoxy* sp.
Arthropoda	Insecta	Diptera	Muscidae	*Musca*	*Musca domestica*
Annelida	Clitellata	Arhyncobdellida	Haemadipsidae	*Haemadipsa*	*Haemadipsa jeylanica*
Annelida	Clitellata	Arhyncobdellida	Haemadipsidae	*Haemadipsa*	*Haemadipsa picta*

Table 2. Number of ectoparasites found on individual elephants.

Ectoparasite	Number of ectoparasites on elephants (individuals)								
	Agustina (43 y.o.)	Sari (30 y.o.)	Theo (30 y.o.)	Olive (28 y.o.)	Yuni (29 y.o.)	Eropa (4 y.o.)	Christ (4 y.o.)	Albertina (4 y.o.)	Total
Haemadipsa jeylanica	10	8	7	7	5	5	3	0	45
Haemadipsa picta	9	8	6	5	5	4	0	0	37
Haematopota pluvialis	7	8	6	5	4	0	0	0	30
Musca domestica	9	9	7	5	6	3	0	0	39
Stomoxys sp.	9	8	8	6	0	5	0	1	37
Tabanus sp.1	9	8	6	7	5	0	0	0	35
Tabanus sp.2	8	4	6	5	5	4	0	0	32
Tabanus sp.3	6	5	5	6	4	5	0	0	31
Tabanus sp.4	5	4	3	0	0	0	2	0	14
Tabanus sp.5	6	3	0	0	2	0	4	2	17
Total	78	65	57	46	36	26	9	3	317

1100 h) yielding more leeches, while afternoon sessions (1500–1700 h) yielded higher numbers of biting flies. During sampling, morning sessions were cooler and more humid (approximately 25–27 °C), whereas afternoon sessions were warmer at 28–30°C with slightly lower humidity, supporting the observation that leeches were more abundant in cooler, humid conditions and flies were more active during warmer periods.

Regarding collection timings, we observed that biting flies (*Tabanus* spp., *Haematopota pluvialis*) were more frequently trapped in the late afternoon session (1500–1700 h), consistent with their diurnal peak activity in warmer sunlight hours. Conversely, leeches (*Haemadipsa* spp.) were more commonly recovered in the morning session (0900–1100 h), often after the elephants had contact with moist vegetation and forest floor.

The CRU is located adjacent to the forest and close to a river. This setting provides an ideal habitat for *Tabanus* sp. According to Changbunjong et al. (2018), *Tabanus* spp. females typically lay their eggs on the surface of leaves or places situated above the water surface. The presence of ectoparasites tends to be higher in forests with dense trees and proximity to streams. In the morning and at night, these flies tend to hide, while during full sunlight and towards the evening, they become active and approach the elephants to feed on their blood. Additionally, when the weather is cold or during rain, the flies seek warm hiding spots, such as between the thick hairs on the elephant's belly or in the inguinal area.

A total of 568 individual ectoparasites were found on the eight Sumatran Elephants, comprising 10 different species (Table 2). *Musca domestica* was recorded during sampling but is not considered a true ectoparasite, as it does not attach to the host or feed on blood. Instead,

this species functions as a nuisance fly and mechanical vector that is commonly associated with animals and their surrounding environment. Therefore, *M. domestica* is treated as an associated dipteran and discussed separately from obligate ectoparasitic taxa in this study. The number of ectoparasites found on adult elephants was higher compared to juvenile elephants. When elephants are active, it is assumed that ectoparasites, especially insects, find it more difficult to attach and feed.

The higher ectoparasite load observed in adult elephants, despite generally stronger immune systems, is likely influenced by ecological and behavioral factors rather than immunity alone. Adults have a larger body surface area, spend more time feeding within dense vegetation, and tend to be less active than juveniles, all of which increase exposure to ectoparasites and facilitate attachment. Unlike endoparasites, most ectoparasites (except leeches) are temporary parasites with limited interaction with host immunity, making their infestation patterns more dependent on environmental exposure and behavior than age-related immune resistance. This contrasts with findings on endoparasites (Levine 1990) and highlights the need to consider parasite groups separately when evaluating host–parasite dynamics in elephants.

Table 3 presents the prevalence values of 10 types of ectoparasites found on eight Sumatran Elephants in the CRU Tangkahan area. The highest prevalence was observed for *Haemadipsa jeylanica*, with a prevalence rate of 87.5%, categorized as "usually". The lowest prevalence was observed for *Tabanus* sp.4, with a prevalence rate of 50%, categorized as "frequently". Adults carried a total of 282 ectoparasites, while juveniles carried 38, confirming that infestation levels were substantially higher in adult elephants.

Haemadipsa jeylanica, or the mountain leech, is a blood-sucking organism closely related to earthworms and equipped with a sucker. *Haemadipsa* is a species commonly found in Indonesia, particularly in high-humidity mountainous regions. The life cycle of such parasites heavily depends on a suitable environment, especially high humidity and an adequate temperature (approximately 27 °C). In this study, *Haemadipsa* sp. was frequently found on the elephants' bodies, especially on the trunk and legs, when they were herded into the forest. According to Kendall (2012), most *Haemadipsa* species suck mammalian blood to survive. During their juvenile stage, *Haemadipsa* attaches to smaller hosts like rats, but as adults, they attach to larger hosts such as pigs and primates. The host's body size also influences the size of *Haemadipsa*; the larger the host, the more diverse the ectoparasitic fauna. Consequently, if *Haemadipsa* attaches to an elephant in large numbers, it could cause significant harm, such as blood loss.

The lowest prevalence value was found in *Tabanus* sp.4, at 50%, categorized as "frequently". This species is most commonly found in elephant bathing areas. Their activity increases during the dry season compared to the rainy season. Male flies use nectar as a food source, while females suck blood and are often significant pests for animals, especially large mammals like horses, deer, cattle, and elephants. *Tabanus* spp. are diurnal and active during hot weather conditions with high intensity sunlight (Kaufman et al. 2005). According to Foil & Hogsette (1994), the flying activity of *Tabanus* spp. for feeding by landing on hosts varies greatly depending on rhythm, weather, and type of vegetation. These differences can vary significantly between species. Generally, after female flies suck blood from their host, they lay eggs on organic leaf litter, which then hatch into pupae and larvae, and finally become adults within 1–3 weeks.

The intensity levels of ectoparasites on eight Sumatran elephants are presented in Table 4, with Tabanus spp. showing moderate intensity, and *Tabanus* sp.1 being the most frequently encountered species on the elephants' bodies. This is likely due to the environmental conditions at the research location being suitable for this species. The ambient temperature ranged 25–30 °C, which is favorable for the presence of *Tabanus* sp.1, particularly during the daytime when the sun is at its peak. Most *Tabanus* flies are active during the day, with their activity threshold peaking at 25 °C.

Conversely, *Tabanus* sp.5 exhibited the lowest intensity level of 3.4, classified as light. This species was the least frequently found on the elephants. The lower numbers of *Tabanus* sp.5 may be due to the research environment being less conducive to its survival.

Table 3. Prevalence of ectoparasites.

	Ectoparasite species	Prevalence (%)	Category
1.	*Haemadipsa jeylanica*	87.5	Usually
2.	*Haemadipsa picta*	75	Usually,
3.	*Haematopota pluvialis*	62.5	Frequently
4.	*Stomoxys* sp.	75	Usually
5.	*Musca domestica*	75	Usually
6.	*Tabanus* sp.1	62.5	Frequently
7.	*Tabanus* sp.2	75	Usually
8.	*Tabanus* sp.3	75	Usually
9.	*Tabanus* sp.4	50	Frequently
10	*Tabanus* sp.5	62.5	Frequently

Environmental conditions significantly influence the population size of a species. The low number of these species on the host may also be attributed to the disturbance caused by sampling activities, which could have disrupted the flies' infestation.

Ectoparasites on elephants exhibit distinct characteristics. The terrestrial leech *Haemadipsa*, which feeds on the blood of both animals and humans, is frequently observed attached to elephants, particularly on their trunks, front legs, and hind legs. The images, sketches, and morphology of *Haemadipsa* found on Sumatran Elephants at the CRU Tangkahan can be seen in Image 1. The sketches illustrate the ventral (Image 1A) and dorsal (Image 1B) morphology of *Haemadipsa*. The habitat and environmental temperature at the research location are believed to be suitable for this species, particularly in forests with high humidity levels. This species thrives among tree trunks, leaves, and moist soil, such as in forests and swamps. Typically, this species is brownish, dark green, and generally reddish-brown.

According to Saywer (1986), *Haemadipsa* has a complete digestive tract. When feeding, this species extends its proboscis out of its mouth, then uses its pharynx to suck blood. The nervous system of these leeches is more developed than other Annelida, as they possess large ganglia around the pharynx in the fifth and sixth segments of their bodies. The Hirudinae phylum has specialized sensory organs, including eyes and papillae. This species reproduces hermaphroditically, cannot reproduce asexually, and lacks regenerative abilities. Most of the Hirudinae phylum are parasitic, causing significant blood loss in their hosts.

From Image 1, it can be seen that *Haemadipsa jeylanica* (C) and *Haemadipsa picta* (D) have specific characteristics. *Haemadipsa jeylanica* is brightly colored with stripes of red, yellow, and brown. Its sucker is black, and its body is larger. This species is more often found on leaves, and its bite is more painful compared to *Haemadipsa picta*. On the other hand, *Haemadipsa picta* is uniformly brown, has a slimmer body, and is more commonly found in moist soil.

According to Foil & Hogsette (1994), *Haematopota pluvialis* is an ectoparasite belonging to the family Tabanidae. This insect is smaller than species of the genus *Tabanus*. Its morphology and life cycle are similar to those of *Tabanus* species. *Haematopota pluvialis* is highly adaptable for hunting, particularly during the day. It has a greyish-black colouration with white spots on its wings and eyes, forming various patterns. The body of this ectoparasite is elongated and slender. Adult female *Haematopota pluvialis* take blood from their hosts to support egg development, while adult males only feed on nectar from various flowering plants. Female *Haematopota pluvialis* typically lay their eggs in moist soil.

In Image 2, the morphology of *Haematopota pluvialis* is depicted, illustrating the various parts of its body. This species typically attacks large mammals. *Haematopota pluvialis* possesses a large mouth comprised of three pairs of elements that function to cut and pierce the skin, causing deep wounds. Subsequently, the flowing blood is absorbed through the labrum, which serves to store the blood (Russell et al. 2013).

The parasite-borne diseases transmitted through these highly painful bites can cause significant losses, particularly for large mammal farmers (Taylor et al. 2012). These losses can include reduced profit margins due to decreased animal live weight, lowered meat production, and skin irritation. Ectoparasites can act as vectors of disease, such as transmitting *Trypanosoma evansi*, the causative agent of surra. This protozoan parasite inhabits the blood plasma and tissue fluids of infected animals (Desquesnes et al. 2012).

Stomoxys sp., a stable fly from the Muscidae family,

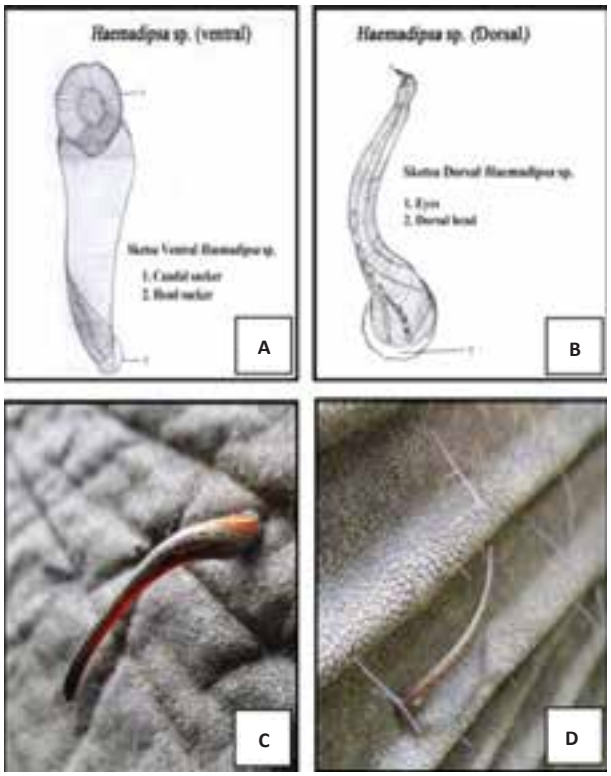

Image 1. A—Sketch of the ventral side of Haemadipsa | B—Sketch of the dorsal side of Haemadipsa | C—Photographic documentation of *Haemadipsa jeylanica* | D—Documentation of *Haemadipsa picta*. © Authors.

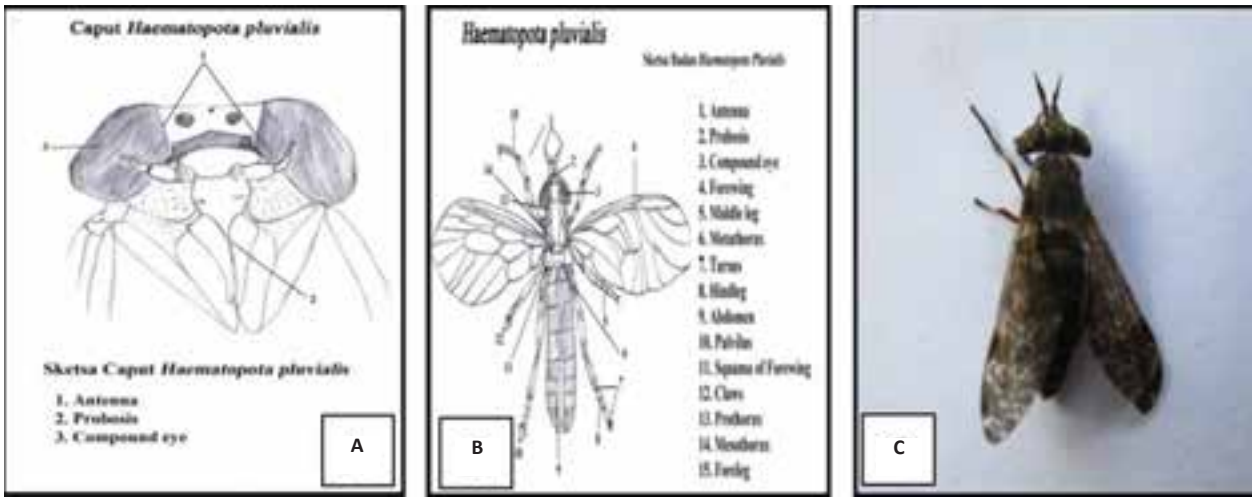

Image 2. A—Sketch of the body of *Haematopota pluvialis* | B—Sketch of the head of Haematopota pluvialis | C—Photographic documentation of *Haematopota pluvialis*. © Authors.

is an ectoparasite that attacks warm-blooded animals. *Stomoxys* sp. closely resembles the species *M. domestica* but differs in having a proboscis adapted for bloodsucking. Image 3 shows a morphological sketch of *Stomoxys* sp. found on a Sumatran Elephant. The body size of *Stomoxys* sp. ranges from 5–7 mm, with three dark stripes on the thorax and four veins on the wings. *Stomoxys* sp. is black, with a yellow abdomen; the antenna consists of three segments, with the last segment being the largest (Masmeatathip et al. 2006).

Stomoxys sp. feeds by sucking blood for 3–4 minutes per feeding session. The volume of blood ingested in a single session ranges from 0.05–0.10 cc per fly. This species reproduces by laying eggs. Its life cycle begins with eggs that hatch into larvae, then pupate, and finally mature into adults. These flies lay their eggs on manure, in animal enclosures, and in other places with high moisture and organic matter, such as animal waste (Cruz-Vazquez et al. 2004; Huang et al. 2007; Changbunjong et al. 2018). During the summer, these flies feed multiple times a day, and their bites are sharply painful. Once satiated, they seek preferred resting places to digest their meal. This species tends to aggregate in bright areas rather than dark ones (Chareonviriyaphap 2012). When they are hungry, cannibalism is common within their groups. They become highly active and aggressive, attacking each other and sucking blood by wounding the abdomen.

According to Phasuk et al. (2013), both male and female flies of this species are bloodsuckers with painful bites. In large numbers, they can prevent animals from resting properly. *Stomoxys* sp. can naturally act as a vector for the bacterium *Dermatophilus.* This species also serves as a mechanical vector for several pathogenic protozoa. For instance, *Trypanosoma evansi*, which causes Surra disease, and *Trypanosoma brucei*, which causes nagana disease in horses and cattle, can be transmitted by these flies (Desquesnes et al. 2012). Their repeated blood-feeding behaviour facilitates the transmission of nagana.

Table 4. Intensity of Ectoparasite Infestation.

	Type of Ectoparasite	Intensity	Category
1.	*Haemadipsa jeylanica*	6,42	Moderate
2.	*Haemadipsa picta*	6,16	Moderate
3.	*Haematopota pluvialis*	6,16	Moderate
4.	*Stomoxys* sp.	6,16	Moderate
5.	*Musca domestica*	6,5	Moderate
6.	*Tabanus* sp.1	5,8	Moderate
7.	*Tabanus* sp.2	5,3	Light
8.	*Tabanus* sp.3	5,16	Light
9.	*Tabanus* sp.4	3,5	Light
10	*Tabanus* sp.5	3,4	Light

Musca domestica is the most commonly encountered species worldwide and is generally found on farms or in human environments, making it a vector for several diseases affecting both humans and animals (Kaufman et al. 2005; Butler et al. 2010). This species thrives on manure, decaying garbage, foul-smelling drains, and spoiled wet food (Sanchez & Cappinera 2014).

Image 4 illustrates the anatomical features of *M. domestica*. This species is of medium size, measuring 6–8 mm in length. The thoracic cavity is grey, the abdomen is yellow, and it possesses compound eyes and antennae

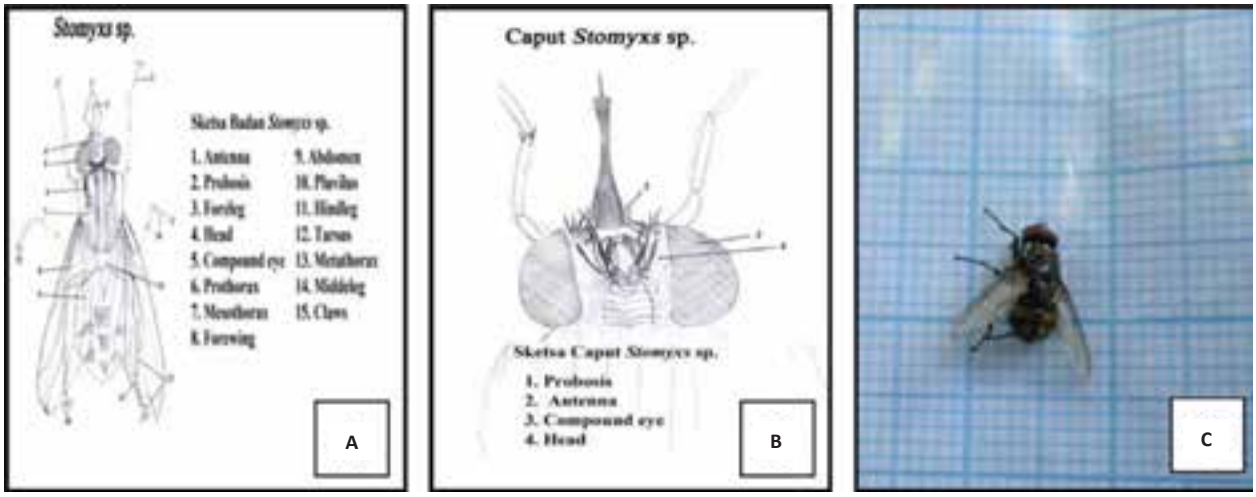

Image 3. A—Sketch of the body of *Stomoxys* sp. | B—Sketch of the head of *Stomoxys* sp. | C-—Photographic documentation of *Stomoxys* sp. © Authors.

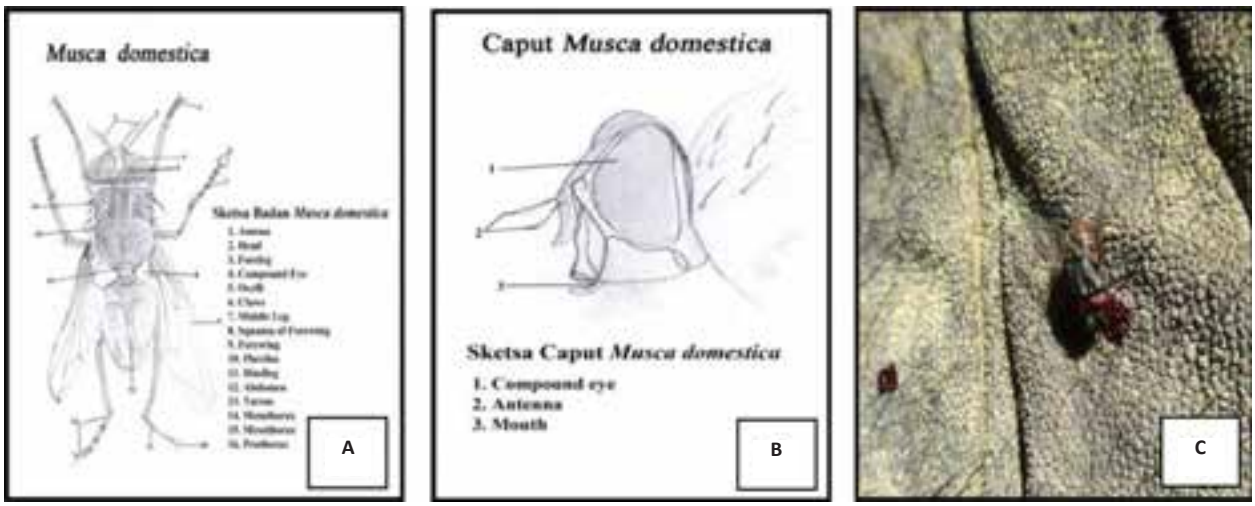

Image 4. A—Sketch of the body of *Musca domestica* | B—Sketch of the head of *Musca domestica* | C—Photographic documentation of *Musca domestica*. © Authors.

consisting of three segments, serving as both lickers and suckers. Adult female flies lay eggs on decaying organic matter and garbage contaminated with faeces and urine. The eggs are white, with a length ranging from 1.20–1.25 mm and a width of 0.25–0.30 mm. Their egg production can range from 120–150 eggs (Borror et al. 1992). The first instar larvae are small, slender, and white, with a length of 1.3–2.6 mm; the second instar measures 2.8–6.7 mm, while the third instar, whitish in color, ranges from 6.5–12.5 mm in length. Larvae typically mature within four to seven days. Development is hindered in cold weather, dry environments, or inadequate food supply, prompting them to leave breeding sites and pupate in the soil. The pupal stage of these flies generally ranges from 3–6 days and is reddish-brown in color during the summer. Food sources such as vegetables, decaying animals, bodily secretions, and wounds are their main diet. Most of them are active during the day, preferring light and sunlight, but their numbers decrease in winter (Borror et al. 1992).

The presence of *M. domestica* is suspected to act as a vector for disease transmission from contaminated body parts such as the mouth, feces, and other contaminated areas. According to Borror et al. (1992), favoured locations for these flies include moist areas, such as the eye can thus, mouth, ears, nose, vulva lips, and the surface of the penis hole. Ectoparasite attacks on the eyes can cause excessive tearing, attract more flies, and leading to keratitis and potential blindness.

Tabanus is a genus of the largest flies and is considered an important pest (Kalshoven 1981). These

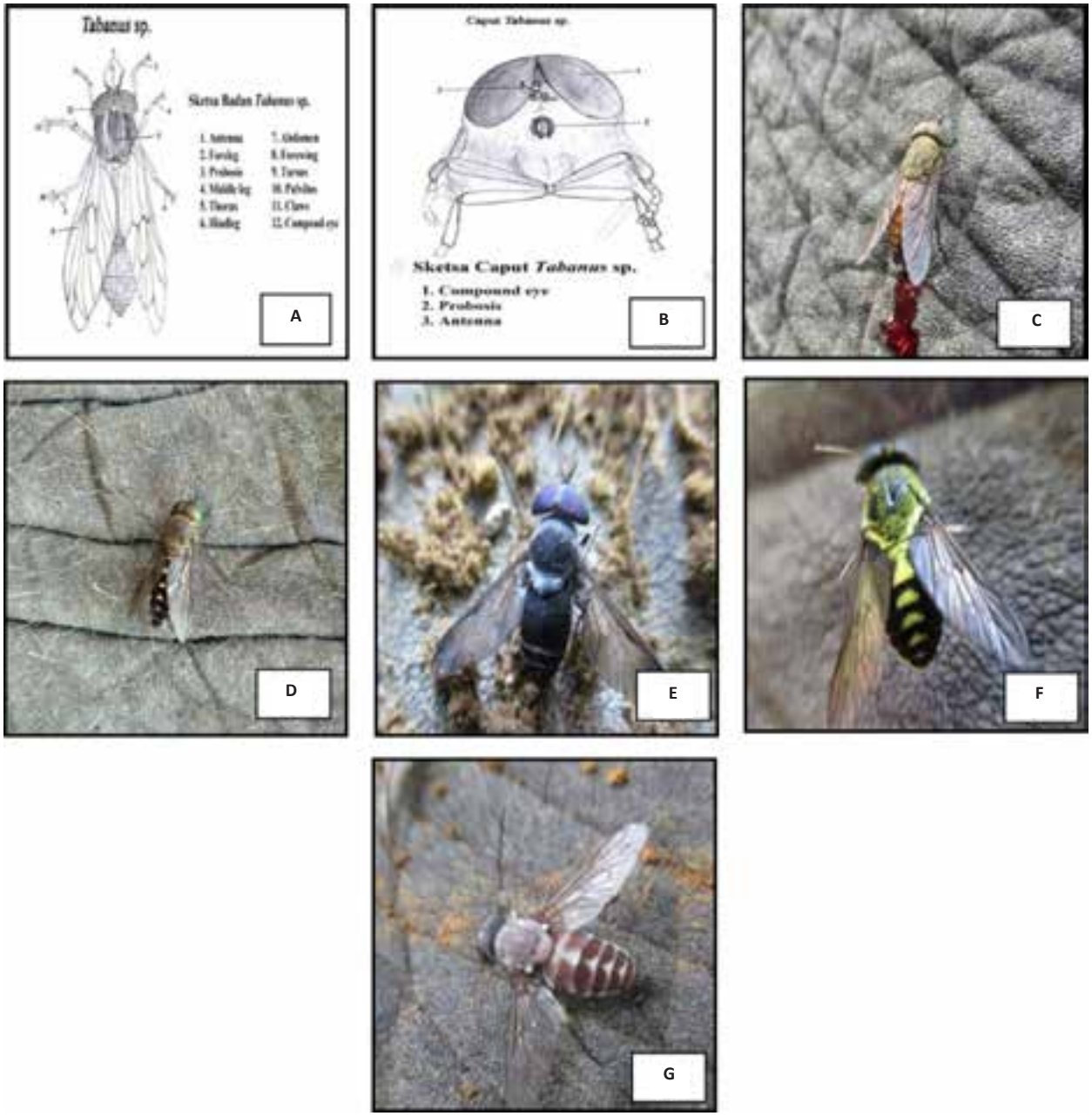

Image 5. A—Sketch of the body of Tabanus | B—Sketch of the head of Tabanus | C—*Tabanus* sp.1 | D—*Tabanus* sp.2 | E—*Tabanus* sp.3 | F—*Tabanus* sp.4 | G—*Tabanus* sp.5. © Authors.

flies are large, measuring up to 25–30 mm in length, with a sturdy body shape, wide wings, and strikingly large eyes. The wing veins have characteristic patterns, and their proboscis is short and soft, directed downwards. In the mouthparts, there are six organs fused into one used as a piercing apparatus, consisting of a pair of flat and sharply toothed mandibles, a pair of toothed maxillae, a hypopharynx, and an epipharynx. The mandibles are used for cutting, while the maxillae are used for piercing and tearing tissues along with the blood vessels (Borror et al. 1992). A morphological sketch of *Tabanus* spp. found on Sumatran Elephants in the CRU Tangkahan area can be seen in Image 5.

Based on Image 5, sketches of the body of *Tabanus* spp. (A), sketch of the head of *Tabanus* sp. (B), and documentation results of *Tabanus* sp.1 (C), *Tabanus* sp.2 (D), *Tabanus* sp.3 (E), *Tabanus* sp.4 (F), and *Tabanus* sp.5 (G) represent the morphology displaying various parts of *Tabanus*. Upon observation, these five species exhibit distinct characteristics, primarily in their respective

colours. In *Tabanus* sp.1, the thorax appears orangish-brown, with dark green eyes. *Tabanus* sp.2 exhibits a blackish-yellow thorax with bright green eyes. Moving on, *Tabanus* sp.3 has a whitish-black thorax, with bluish-green eyes. Furthermore, *Tabanus* sp.4 displays a black thorax with greenish stripes, along with dark blue eyes. Finally, *Tabanus* sp.5 presents a whitish-brown thorax and brown eyes.

Tabanus flies prefer laying their eggs on vegetation. Most egg clusters are found on plant clusters near elephant stall walls. These flies tend to seek places closest to their resting spots for egg deposition. They particularly favour leaf surfaces, presumably due to their relatively larger surface area compared to other plant parts. Therefore, they tend to deposit their eggs on the underside of leaves. According to Foil & Hogsette (1994), the eggs of these flies are laid on plant parts and neatly arranged in layers into a cluster.

Tabanus flies are commonly encountered during hot and sunny summer seasons, especially near their breeding grounds. They are highly active during hot and humid weather. Female flies are blood-sucking insects, while male flies feed on flower pollen or nectar from flowering plants. During the study, female flies were observed sucking blood from elephants, with their mouthparts acting as cutting and sucking tools. *Tabanus* primarily attacks large animals such as elephants, buffaloes, horses, and cattle. Their preferred feeding sites include the lower flank, around the navel, legs, and neck. Once engorged with blood, the flies leave the host and seek resting places on wood surfaces, rocks, building walls, or under leaf surfaces. Subsequently, they search for egg-laying sites (Foil & Hogsette 1994).

Each *Tabanus* fly can bite two to three times before feeding on blood. Animals bitten by these flies often bleed for a short period, causing painful wounds. Such biting behavior enhances their efficiency as mechanical vectors for various diseases. *Tabanus* also utilizes mandibles and serrated teeth. Their sharp upper jaws are used to pierce the skin and rupture blood vessels. The *Tabanus labrum* is then used to collect pooled blood formed from the fly's bites, known as telmophages (Seddon 1947).

According to Onyido (2011), Tabanus flies serve as primary intermediate hosts of *Trypanosoma evansi*, mechanically transmitting it. They can also transfer the blood parasite to elephants, horses, goats, dogs, and other animals. Other diseases transmitted by these flies include anthrax, equine infectious anemia, and anaplasmosis.

The low presence of ectoparasites on elephants in the CRU Tangkahan research site is attributed to the elephants receiving good care, including mandatory bathing twice daily—morning and evening—and regular cleaning of their pens. These practices are essential for preventing ectoparasite infestations and diseases. However, this condition should not be taken lightly by CRU management. There is a concern that neglecting ectoparasite control could lead to higher parasite burdens if not actively minimized. Hence, alongside the twice-daily bathing program, CRU Tangkahan management also provides medications to alleviate itching caused by ectoparasite bites and preventive medications for endoparasites.

Assisted by mahouts (elephant riders, trainers, or keepers), CRU Tangkahan management endeavours to meet the needs and understand the behaviour of captive Sumatran Elephants. This is evidenced by the elephants' overall good health and performance during various activities, whether as tourist attractions, in pens, or while grazing in the forest. Maintaining such conditions is crucial for enhancing ex-situ conservation efforts. This entails specific care for captive elephants, including bathing techniques, feeding, medications, and regular physical exercises. Considering the severity of ectoparasite infestations on elephants, their current condition is not alarming. However, CRU management also needs to assess the severity of endoparasite infestation levels to ensure optimal health care for Sumatran Elephants. Moreover, routine health examinations related to parasites are conducted.

According to Berliani et al. (2022), if worms are found in elephant faeces, further monitoring and treatment are carried out. Deworming of elephants is done every three months. Additionally, daily examinations of teeth, mouth, and hooves are performed. Furthermore, mahouts weigh the elephants once a month. In case of health deterioration in elephants, veterinarians and mahouts collect blood, urine, and faecal samples for laboratory analysis. Once the results are obtained, appropriate medications are administered based on the veterinarian's diagnosis. Therefore, by paying attention to and maintaining the health of elephants in the CRU Tangkahan area, efforts to conserve Sumatran Elephants' ex-situ are being enhanced.

CONCLUSION

Ten types of ectoparasites were identified: *Haemadipsa jeylanica*, *H. picta*, *Haematopota pluvialis*, *Musca domestica*, Stomoxys sp., *Tabanus* sp.1, *Tabanus* sp.2, *Tabanus* sp.3, *Tabanus* sp.4, and *Tabanus* sp.5.

The highest prevalence of ectoparasites were found in *Haemadipsa jeylanica*, with a prevalence rate of 87.5%, categorized as "usually", whereas the lowest prevalence was observed in Tabanus sp.4, at 50%, categorized as "frequently". The highest intensity value was recorded in Tabanus sp.1 among other *Tabanus* spp., with a score of 7, categorized as "moderate", while Tabanus sp.5 had the lowest intensity value of 3.4, categorized as "light".

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Author contributions: KB—wrote the first draft of the manuscript, managed the analyses of the study, proofread, and approved the manuscript. DS—managed the analyses of the study, literature searches, read and approved the manuscript. WA—managed the analyses of the study, literature searches, read and approved the manuscript. FE—designed the research project and approved the final manuscript. CG—read, finalization, submission, and approval of the manuscript.

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ARTICLE

Documenting the traditional hunting practices of the Nocte Tribe in Arunachal Pradesh: a case study of cultural legacy for posterity

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Abstract: The study on the Nocte tribe of Arunachal Pradesh critically documents their rich, yet rapidly eroding, traditional hunting practices, which utilise indigenous techniques and primitive tools such as unique traps (e.g., Kut-tai, Waa-khap, and Phaknong) and indigenous flintlock guns. Analysis of interviews with 204 households, grouped by age (18–30, 31–50, and over 50), confirms the continued relevance of these methods, with high utilisation rates for specific indigenous traps (Kut-tai: 15%; Waa-khap: 14.8%; Phaknong: 13.3%) and a significant 72% of hunters still using indigenous flintlock guns. Hunting is primarily motivated by food acquisition (64%) and cultural preservation (17%), underscoring its deep cultural significance. This invaluable knowledge is quickly depleting due to a critical lack of documentation and knowledge preservation, creating an urgent need to document these practices formally. This effort is essential to safeguard this rich heritage and ensure its transmission to future generations, thereby mitigating the erosion of these traditional cultural values.

Keywords: Fishing, hunting techniques, indigenous practices, preservation, rituals, sustainability, taboos, Tirap District, traps, traditional knowledge.

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Author contributions: MT conceptualized, collected data, analysed the data, interpreted, and drafted the manuscript. AM organized and edited the manuscript. KB reviewed and edited the manuscript.

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INTRODUCTION

Traditional knowledge (TK) is a form of knowledge, innovation, and expertise cultivated through extensive experience and developed to fit the specific cultural and environmental context over time (Xue & Guo 2001). TK involves the idea of belongingness, i.e., people and nature are interconnected, and these elements are maintained in harmony and should be treated with care (Whap 2001). It is expressed within kin groups and communities over generations through formal and informal means, such as social interactions, verbal traditions, ceremonial rituals, and various other communal activities (Xue & Guo 2001; Bruchac 2014). This knowledge is also protected by specialists with expertise in ethnomedicine, shamans who perform traditional rituals, and traditional folklore chanters.

Several authors have confirmed that TK encompasses information and skills related to sustenance, encompassing areas like food, medicine, hunting, fishing, agriculture, home gardening, handicrafts, and other capabilities devised to support the local community (Turner 2005; Singh et al. 2009; Mishra et al. 2011). Traditional hunting has been central to the subsistence, culture, and identity of indigenous people across continents (Luz et al. 2015; Fang et al. 2025). It is an age-old tradition, and its practice has been passed down through generations (Aiyadurai 2011) within many indigenous communities globally.

In many indigenous communities, including the Inuit of the Arctic, Amazonian tribes, and African pastoral groups, hunting is governed by a set of rituals, taboos, and ethical codes that regulate the relationship between humans and animals (Colding & Folke 2001; Desjardins & Gotfredsen 2021; Sinthumule 2024). Likewise, in southeastern Asia, indigenous groups employ diverse hunting methods like snares, blowpipes, and poisoned arrows, reflecting their ecological knowledge, but are widely restricted by their national wildlife policies (Loke et al. 2020; Fang et al. 2025).

In India, hunting has historically been an integral activity among tribal communities like Birhor, Chenchu, Nayaka, Ongee, Jarwa, Sentinelese, offering essential protein, fostering social cohesion, and involving rituals closely linked to seasonal cycles and local deities (Padhan 2023). Similar practices are observed within the tribal communities of Odisha, where game animals are hunted during their annual hunting festival known as Chaitra Parah or Choith Porv (Sabat et al. 2025). Furthermore, in Jharkhand, Madhya Pradesh, and Chhattisgarh, hunting remains connected to agricultural rhythms and the reinforcement of communal identity. With wildlife depletion and the enforcement of strict conservation laws, these practices have often been forced into illegality or secret continuation.

While traditional hunting holds immense cultural importance (Adeola 1992), it is generally conducted after the harvest of crops to welcome a prosperous new year void of illness, bad luck, and unpleasant calamities (Aiyadurai et al. 2010; Basar 2018). Since old times, in many northeastern states of India, traditional hunting has been associated as a symbol of honour, pride, and masculinity (Lohe 2014; Khual 2021), for example, skulls of primates are adorned in men's traditional attire, while skulls of large mammals are decorated at houses as a sign of pride and strength (Jugli et al. 2019), symbolising traditional hunting as a cultural purpose.

Arunachal Pradesh, the largest state in the northeastern region, constitutes an integral part of the eastern Himalayan biodiversity hotspot (Myers et al. 2000). The state is renowned as a hub of biocultural diversity, boasting a mosaic of more than 26 major human tribes and 105 subtribes, each characterized by unique dialects, social structures, culinary traditions, and ways of life (Solanki & Chutia 2004). These rich variations of ethnic diversity and biological resources have given rise to the development of various ethnozoological knowledge systems (Kato & Gopi 2009), encompassing domains like food traditions, ethnomedicinal practices, and ritual purposes. The indigenous communities in this state have an intrinsic connection with the forest, as their livelihoods are intricately intertwined with its resources. Their very survival hinges upon their ability to proficiently and responsibly manage the biological wealth provided by the forest (Solanki & Chutia 2004).

The Nocte tribe residing in Tirap District is one of the 26 major tribes of Arunachal Pradesh (Solanki & Chutia 2004). The Nocte tribe, akin to numerous other indigenous communities within the state, exhibit a distinct and multifaceted cultural expression. Their expertise includes diverse hunting techniques and craftsmanship, manifested in their production of flintlock rifles. Additionally, the Nocte tribe adheres to a set of well-established and deeply entrenched customs. The tribe believes and connects itself with the spirits of nature and therefore depends on nature for its sustenance (John et al. 2022).

Hunting is highly prevalent in the region because of its ethnozoological purposes, for instance, wild meat as food, primate skulls, and hornbill feathers for cultural purposes and as traditional medicines (Gogoi et al. 2018). Therefore, the villagers excel in designing traditional

traps for hunting and fishing; also, different types of traps are mostly designed based on the knowledge of the local biodiversity and the size of the target animals.

With the onset of modernisation and the introduction of the Indian Wildlife (Protection) Act of 1972, the techniques of hunting and traditional knowledge of making and laying traps are eroding. Traditional knowledge forms the cornerstone of many indigenous communities, encompassing a vast array of practices, skills, and cultural beliefs. It is generally passed down orally from one generation to the next, hence written records are hardly available (Chinlampianga et al. 2013). Thus, this study aims to preserve and document their traditional knowledge of hunting through written records and creative methods.

MATERIALS AND METHODS

Study area

The present study was conducted in the Tirap District of Arunachal Pradesh, covering an area of 1,170 km^2. The district lies between 26.633°–27.783° N and 96.266°–95.666° E. It is situated in a unique geographical setting bounded by Burma in the South, Assam in the North, Nagaland in the West, and Changlang District of Arunachal Pradesh in the East (Image 1). The field survey was carried out from August 2022 to January 2024 in 92 villages inhabited by the indigenous Nocte population, which falls under eight circles, viz., Borduria, Khonsa, Namsang, Lazu, Bari-Basip, Dadam, Soha, and Longgo. The region is inhabited by the Nocte tribe, one of the major tribes of Arunachal Pradesh, including its two sub-tribes, the Tutsa and Ollo. The region has a population of 55,022 with a sex ratio of 931 females per 1,000 males and a literacy rate of 52.2% (Census Report 2011, after Longding District was carved out in 2012). The major occupations are agriculture, farming, handicrafts, and handlooms, along with hunting and fishing to sustain themselves (Table 1).

Data collection

Data was collected from 92 villages using snowball sampling (Newing et al. 2011) as the target group of hunters was particularly difficult to reach for interviews. Semi-structured questionnaires and personal interviews with residents of the villages were conducted. A total of 204 households voluntarily agreed to the survey (Table 2). The majority, 91% of the respondents, were male, as hunting is a male-dominant activity. The respondents were sampled into three age groups: 18–30 years, 31–50 years, and >50 years (Alvi 2016). This method was utilized to compare responses across age groups and assess the potential shifts of traditional techniques into modern techniques. Due to the requirement for parental consent, the age group under 18 was excluded from the study.

Interviews were recorded after receiving verbal consents from respondents. As the researcher herself belonged to the same tribe, the local dialect, i.e., Nocte, was used for conversing with the villagers. The villagers developed a sense of security and relief and enthusiastically participated in the survey.

During the fieldwork, morning and afternoon hours were used to interview the elders of the villages, while middle-aged villagers offered their evenings. This was because most of the villagers were farmers and returned

Table 1. Demography of Tirap District.

Name of District	Tirap
Administrative Headquarter	Khonsa
Number of Administrative Circles	8 (viz. Khonsa, Namsang, Lazu, Dadam, Longgo, Bari-Basip, Borduria, Soha)
Total Number of villages	112
Total Number of Towns (Urban Centre)	2 (viz. Khonsa & Deomali)
Total Number of Households	11,185
Total Population	55,022
Male Population	28,894
Female Population	26,128
Rural Population	38,446
Urban Population	16,576
Total Area of Tirap District	1,170 km^2
Total Urban Area	2.58 km^2
Khonsa Town Deomali Town	7.3 km^2
Total Rural Area of the District	1,160.12 km^2
Density of Population	47 persons per sq. km^2
Sex Ratio	931
Literacy Rate	52.2%
Total Literate Population	37,830
Total Literate Male	22,880
Total Literate Female	14,950
Number of Rural Development Blocks	5 (Namsang, Borduria, Khonsa, Lazu, Dadam)
Total Forest Cover	967.47 km^2
Name of Indigenous Tribes	Nocte
Sub- Tribes	Tutsa & Ollo
Important Festival of the District	Loku
Main Crops	Paddy, Maize, Millet, Tapioca

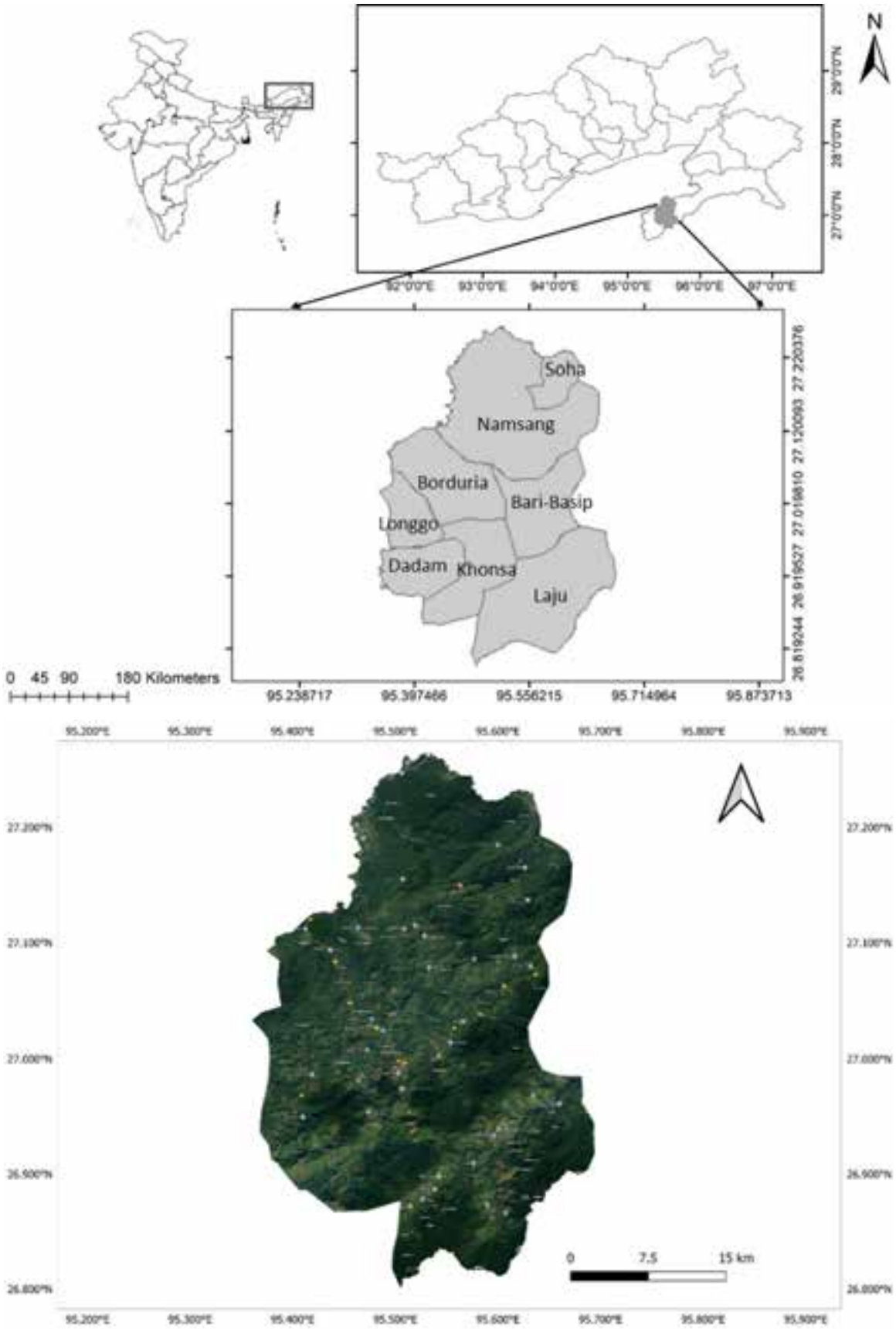

Image 1. Study area map of Tirap District, Arunachal Pradesh.

from their fields in the evening. Focus group discussions with hunters usually took place on rainy evenings or at sundown.

Personal interviews were done with each village's key informants, village chief ('lowang') and village head (gaon bura). Secondary data was collected from the State Library, Itanagar, District Library, Khonsa, and District Museum, Khonsa.

Statistical analysis

Data was analysed using IBM SPSS Statistics *v.* 25 (SPSS, Chicago, USA). The binary logistic regression analysis was conducted to examine the predictors of hunting prevalence among the Nocte tribe. The analysis included four predictor variables (age, education, occupation, and income) that might influence the likelihood of hunting within this demographic. The odds ratio was utilised to compare the probabilities of involvement in hunting. An odds ratio of 1 indicates that a specific perception is equally probable in both groups. An odds ratio greater than 1 suggests that the perception is more prevalent in the first group, while an odds ratio less than 1 indicates that the perception is less likely to occur in the first group (Sarker et al. 2011). To assess the model's goodness of fit and its ability to explain variations in perceptions, both Cox & Snell and Nagelkerke pseudo R^2 values were utilized as metrics for evaluating predictive capacity

RESULTS

A total of 204 households were surveyed, and a total of 134 hunters (regular and recreational hunters) (Table 2) were identified and selected for personal interviews. The maximum number of self-reported hunters was found in the age group > 50 years old (60) followed by 31–50 years (53) and 18–30 years (21).

Rather than following a scheduled hunting pattern, hunters used the traditional method of foreseeing and predicting suitable days and directions of the hunt by conducting 'Tansok' (Nocte = pre-hunting ritual). The 'Tansok' ritual played a central role in the religious and cultural ceremonial practices of the Nocte tribe. The ritual was conducted by the village shaman, or a 'Tanwa' (Nocte = Ritual specialist), using the leaves of *Thysanolaena* sp. to mediate with spirits (Image 2). The ritual was employed within the tribe for several other cultural events, including the naming of babies, the selection of agricultural lands for optimized harvest, and the prognostication of successful hunting expeditions.

Image 2. Demonstration of *Tansok* ritual used for scheduling hunting time. © Miatcha Tangjang.

Hunting Techniques and Traps

The Noctes used several traditional techniques, traps, and tools for hunting and fishing purposes, as shown in Images 3 & 4. The mechanism of traps changed depending on the size and type of target animal (Table 3).

Indigenous hunting techniques

Hunting with dogs: As one of the oldest hunting methods, using self-trained domestic dogs was common due to their exceptional sense of smell. This technique was preferred for community hunting ('Lojun /Ngamjun'), which was observed during late December to early January after the harvesting of crops. Around 30–40 dogs were unleashed by 'Huthing-te' (Nocte = dog trainers) near animal tracks, and these dogs signalled back by barking when prey was in sight. The 'Bam-takte/ Ngam-bamte' (Nocte = pre-positioned trackers) and hunters then shot the target animal during the chase. In this community hunting tradition, the animal's head was offered to the 'Lowang', (Nocte = village chief), as a symbol of respect. A reward system existed where the first three successful hunters and the leading dog received specific limbs of the animal. Dog trainers and trackers received portions of wild meat, with the remainder being distributed among the villagers.

Persistent hunting: Hunters employed a dynamic tracking strategy, alternating high-speed movement during clear trails with slower, methodical searching (including pauses) when tracks became obscured. This optimized hunting efficiency by capitalizing on clear tracks for rapid progress while allowing thoroughness in navigating difficult terrain. This method necessitated

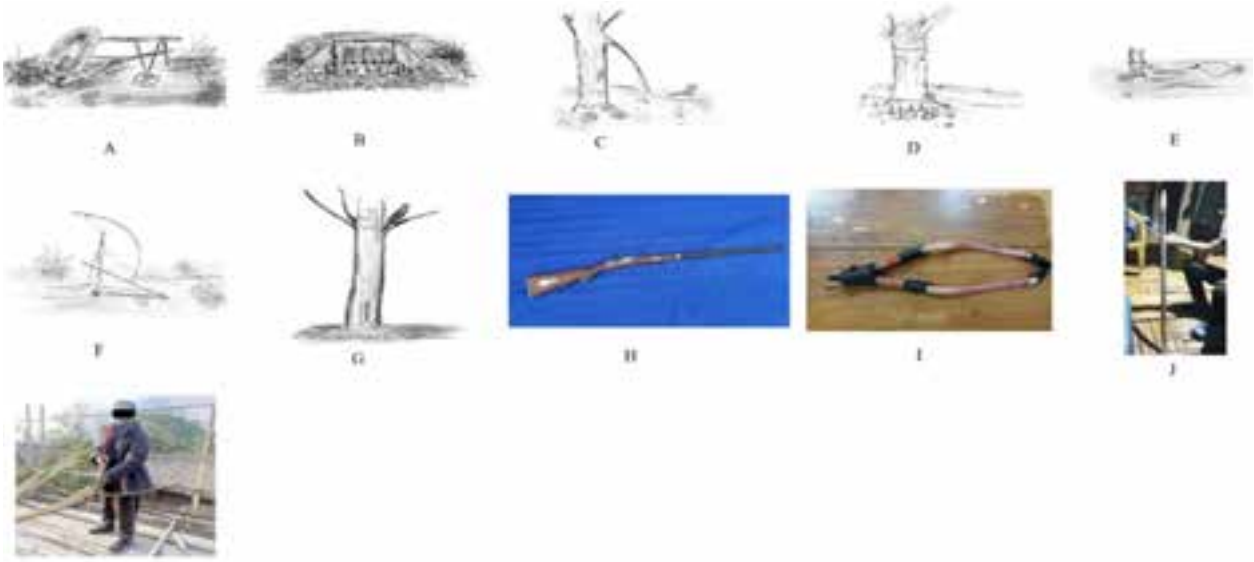

Image 3. Indigenous hunting traps and tools: A—Taai Tzann/Long-pá | B—Chom | C—Kut-tai/Bey | D—Wat-tai | E—Phaknong/Bey | F—Kunthong/Waa-khap | G—Ney/Ney-chah | H—Gun | I—Catapult | J—Spear | K—Crossbow.

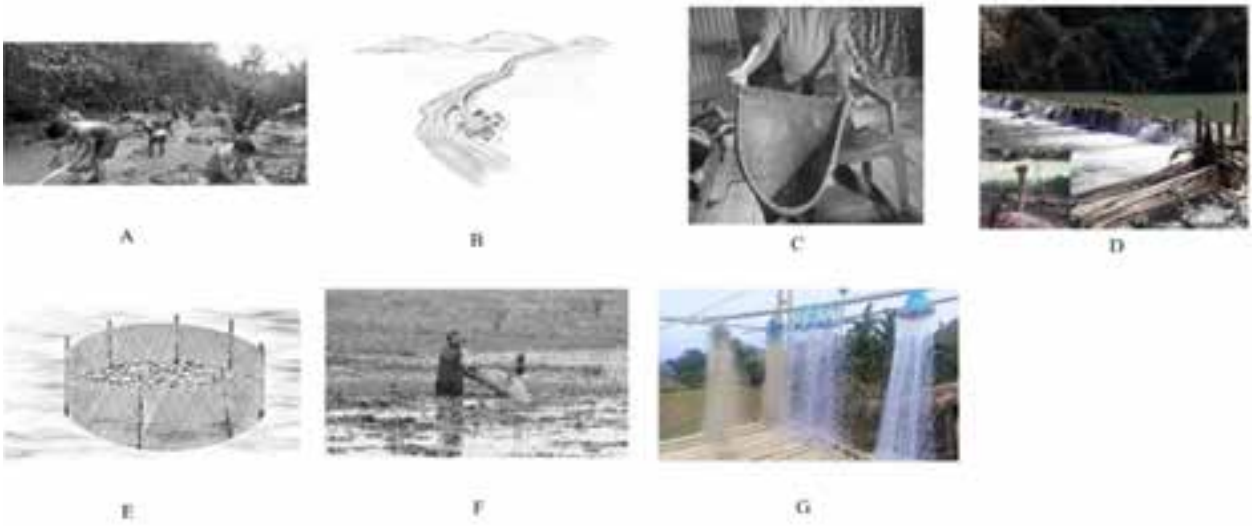

Image 4. Indigenous Fishing Techniques and Traps: A—Noknyu-ngakat/Juruh | B—Jo-chan | C—Chelang | D—Haptang (in the inset bottom left- Hapsak) | E—Longphongtook | F—Boak-nak | G—Fishing net (Chaak).

a profound understanding of animal behaviour and considerable physical stamina.

Sit and wait hunting: In this technique, a high-raised platform was made of bamboo, which was placed on the branches of fruiting trees where the hunters positioned themselves concealed between the leaves. Hunters patiently waited for the animal to arrive and struck at the right time upon sighting.

Indigenous fishing techniques and traps

Noknyu-ngakaat/Juruh: Also known as community fishing, Noknyu-ngakaat is a fishing technique observed once a year. A bifurcated river stream is chosen where one side of the stream is blocked using twigs, leaves, and bamboo. On the other stream, a blockade of the same type is made, leaving a small opening. Another full barricade is made just 20–30 m after this blockade. Leaves, fruits, and roots of *Juglans regia*, and *Zanthoxylum armatum* are beaten and smashed violently in the upstream river. The sap produced from the thrashing agitates the fish and sedates them. The fish rush towards the small opening of the barricade and

Table 2. Demography of the respondents.

	Number of respondents and percentage
Age	
18–30	66 (32.4)
31–50	57 (27.9)
>50	81 (39.7)
Gender	
Male	185 (91)
Female	19 (9)
Education	
Illiterate	31 (15.2)
Primary	16 (7.8)
Above Primary	159 (77.9)
Occupation	
Farmer	78 (38.2)
Government Employed	22 (10.8)
Student	43 (21.1)
Others (Private sector)	37 (18.1)
Unemployed	24 (11.8)
Annual Average Income	
<50,000	156 (76.5)
50,000–1 lakh	44 (21.6)
>1 Lakh	4 (2.0)
Involvement in Hunting	
Non-hunters	68 (33.3)
Recreational Hunters	75 (36.8)
Self-claimed hunters	61 (29.9)

get caught, unable to exit through the second barricade. The team responsible for sedation fires a gunshot to signal the downstream team that the sedation process has been initiated. This technique demands muscular strength and endurance.

Jo-chan/Nga-chan: In this technique, a temporary river path is created to minimize the water level of the original path and fishes are caught when the water level slowly goes down and clarity increases. A winnowing fan made of bamboo which is locally known as 'Chelang' (Nocte = fishing sieve) (Image 3C) is dipped underwater to catch fish and flail.

Hap-tang: When the water current reduces, a large dam structure is constructed across the river, and shallow bamboo traps called 'hap-sak' are installed at chokepoints of the dam where fish get trapped. After the fish are collected at their maximum, the dam structure is left unattended so that villagers can also take fish from the trap when they pass by it. The bamboo dam was washed off with heavy rain and strong water currents.

Longphongtook/Longkuan: The literal translation of Longphongtook is 'piling of stones'. This trap is set for the winter season in September when water currents are less. A shallow river spot is chosen to construct this trap. Stones and boulders are piled on top of each other while bigger boulders are set in the middle to provide a slight entrance for fish to get in. The trap is approximately 1 m in height. Marks are made as a sign of ownership of Longphongtook, and the trap is then left undisturbed for three months. In January, preparations are made to trap to take out the fish that have resided inside for warmth during the winter. Bamboo poles are inserted around the trap and nets are wrapped around it to prevent fish from escaping. This is one of the oldest and most sustainable fishing techniques used by the Noctes.

Boak-nak: In this method, people throw mud and pebbles continuously in knee-deep waters to make it murky and cloud the fish's vision. Fishes are then simply caught by hand. This is a simple method that is generally used by women and children.

Chaak (Nocte = Fishing Net): Fishing nets have also become popular among the villagers as an effective and convenient method of catching fish.

Use the pattern of indigenous hunting traps and tools

The primary motivation of hunting was acquiring food, accounting for 64% of responses, followed by cultural preservation (17%), recreational activity (14%), and commercial pursuits (5%). The findings indicated that most hunting activities were driven by practical considerations, specifically food acquisition and cultural practices, rather than being purely recreational.

The Noctes depended on traditional traps for hunting and fishing. Among the various indigenous traps utilized, 'Kut-tai' (15.0%), 'Waa-khap' (14.8%), and 'Phaknong' (13.3%) were predominantly employed for hunting (Figure 1). In contrast, the 'Jochan' trap was primarily used for fishing, accounting for 20.5% of their fishing activity; 72% of hunters utilised indigenous flintlock guns for shooting large and mid-sized animals caught in traps. In contrast, other hunting tools such as crossbows (2%), spears (23%), and catapults (3%) are less commonly employed, although they remain part of the hunting equipment (Figure 2).

However, the emergence of modern firearms, which offered superior accuracy and efficiency, has rapidly diminished the reliance on these traditional trapping methods, posing a significant challenge to the preservation of indigenous practices such

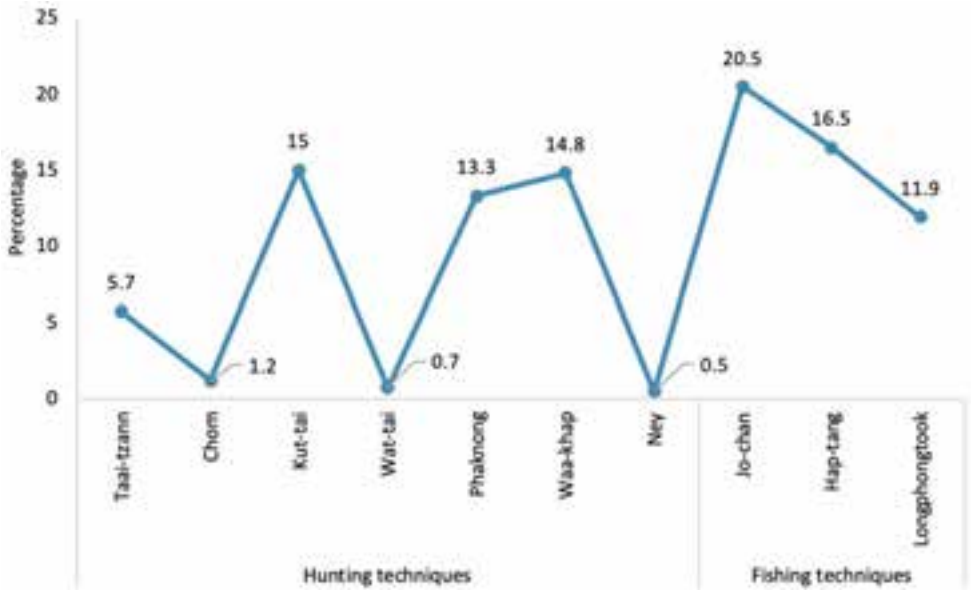

Figure 1. Indigenous hunting and fishing traps used by the Noctes.

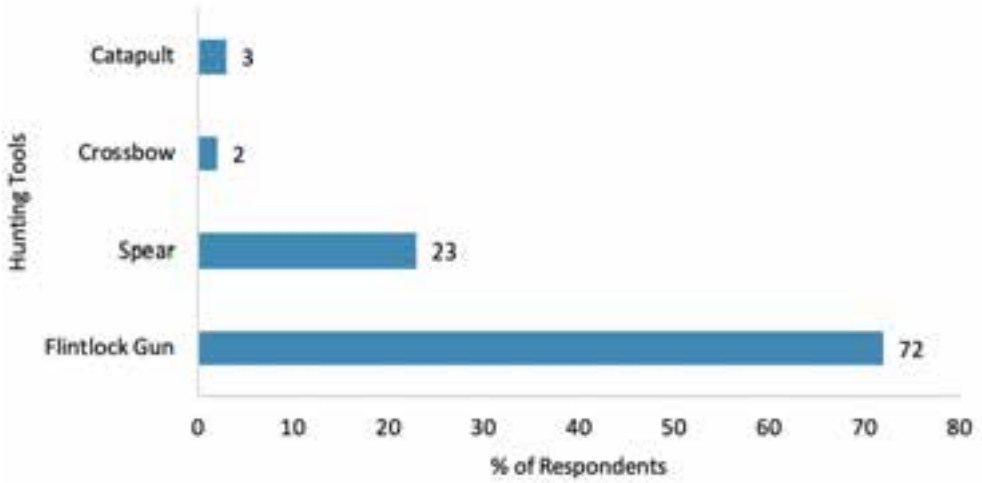

Figure 2. Indigenous hunting tools utilised by the Nocte tribe.

as 'Chom', 'Wat-tai', and 'Ney', which are being increasingly replaced by more contemporary hunting technologies

Sharing of the hunt

In the Nocte tradition, there are established customs and regulations for distributing the spoils of both communal and individual/group hunts. During community hunts, the harvested animal was divided among the hunters in a systematic manner. As customary law, the head of the captured animal was offered to the Village Chief (Lowang) as a tribute. The first, second, and third shooters who successfully hit the animal were rewarded with the prey's right hindlimb, right forelimb, and left forelimb, respectively. The left hindlimb was rewarded to the lead hunting dog. In the case of individual or group hunts, the hunters have full ownership over the captured animal. However, if they borrowed weapons from others for the hunt, a portion of the catch is typically offered to the weapon's owner as a gesture of gratitude.

Similarly, in the context of community fishing, there were specific customs for sharing the catch. The largest fish caught was presented as a tribute to the village chief, followed by the next biggest fish, which was offered to the 'Raam-Waa' (Nocte = event informer). Subsequently,

Table 3. Descriptions of different indigenous hunting traps/tools.

Indigenous hunting traps/Tools	Mechanism	Target species
Taai Tzann /Long-pá (Nocte =Deadfall Trap)	It requires a large rock supported by sturdy sticks with pointy ends that keep the rock in position. A bait is used to lure animals in, and when the trigger stick is moved, the animal is hit down by the rock.	Rodents
Chom	A type of booby trap in which a pit is dug out, and bamboo spikes are partially inserted. The pit is then covered with twigs and leaves.	Bear, Wild boar
Kut-tai/Bey	A sturdy tree branch is pulled down and tied with a long string, mostly cable wires or roots of creepers, to one end of the branch and the other end is made into a noose using a scaffold knot. The tree branch is then supported to the ground using bamboo sticks, which act as a trigger, and upon movement, the animal gets caught in the noose.	Bear, Barking Deer, Sambar
Wat-tai	The tree *Artocarpus* sp. is used as bait to lure the bear. A bell is tied around the tree, while bamboo spikes are inserted close to the tree on the ground. When the bear approaches the fruit, it startles upon hitting the bell and stumbles on the bamboo spikes, inflicting major injuries to the bear.	Bear
Phak-nong/Bey	A noose is created from the roots of creepers at the height of the animal's head, and its position is maintained by sticks and bushes or simply laid on the ground. The loose end of the string is tied to a tree trunk.	Barking deer
Kun-thong/Waa-Khap	Sticks are placed at proper angles to create tension on the trigger, which drops on contact, making the animal immobile. It is placed on fruiting tree branches or on the ground, which easily attracts birds and rodents.	Birds and rodents
Ney/Ney-chah	Resin is pre-collected and smeared on small sticks, which are placed on tree trunks and branches bearing fruits. A live bird is caught and used as bait to lure other birds to the tree.	Birds
Wantho (Nocte = Gun)	Traditional Flintlock guns are a dominant tool in hunting due to their effectiveness and ease of use. Compared to tools like spears or bows, guns offer greater accuracy and power, allowing hunters to take down prey from a safer distance.	All mammals and birds
Chunu/Thunu (Nocte = Catapult)	Their projectiles, typically clay balls or pebbles, lack the power to hunt large mammals at a distance. Catapults usually serve as a training tool for young hunters.	Birds and rodents
Pá (Nocte = Spear)	Spears were employed for both throwing and thrusting, making them adaptable to various hunting scenarios and prey sizes. Early versions used sharpened wood or stones, while later iterations incorporated more durable materials like metal.	Bear, Barking deer
Chanchuan (Crossbow)	Crossbows allowed for a stable shooting platform and eliminated the need for upper body strength to hold the draw, making them easier to use for hunters of various physical abilities. Crossbows boast a longer effective range, allowing for more precise shots at greater distances.	Barking deer, Sambar, Wild Boar

the remaining fish were distributed to the assembled group based on their age hierarchy. After the village chief and 'Raam-Waa', the oldest man present received the third fish, and the process continued until everyone in the gathering had received their portion.

Influence of demographics on hunting trends

The binary logistic regression analysis provides evidence supporting the hypothesis that hunting was prevalent within the Nocte tribe, particularly influenced by age and education levels. The results indicated that younger individuals (aged 18–30) were significantly less likely to engage in hunting compared to older age groups (31–50), which had a positive coefficient of 1.469 (Table 4), indicating that individuals in the 31–50 age group were four times as likely to hunt compared to those aged 18–30. Additionally, individuals with primary level education were 13 times more likely to participate in hunting compared to those without formal education, signifying a strong positive correlation between educational attainment and the likelihood of engaging in hunting activities. The occupation variable revealed a significant negative coefficient for students, leading to an odds ratio of 0.125, suggesting that students were substantially less likely to engage in hunting activities when compared to individuals in other occupations. Furthermore, the income variable was not statistically significant ($p = 0.972$), indicating that income did not have a significant impact on the likelihood of hunting among the Nocte tribe. The model was further supported by a Nagelkerke R^2 value indicating that approximately 82.8% of the variability in hunting prevalence can be attributed to the predictor variables included in the analysis. Additionally, an overall correct prediction percentage of 92.6% demonstrated high accuracy in predicting whether individuals from the Nocte tribe engage in hunting based on the specified predictors.

DISCUSSION

For several tribes in Arunachal Pradesh, hunting and trapping are ancient and deeply ingrained traditional practices. It is a practice characterized by a diverse collection of techniques and traps, with subtle variations marking the uniqueness of each tribe's approach to this ancestral art (Tana et al. 2014; Aiyadurai 2022). The study unveils the traditional knowledge, hunting

Table 4. Binary logistic regression model of the influence of demography over hunting trends.

Predictor variables	Coefficient (B)	Significance (p)	Odds ratio Exp (B)	95% CI	
				Lower	Upper
Age (18–30) (30–50)	-1.808 1.469	**<0.001** **0.011**	0.164 4.344	0.080 1.397	0.336 13.514
Education (Primary)	2.575	**0.019**	13.125	1.533	112.402
Occupation (Student)	-2.081	**<0.001**	0.125	0.040	0.386
Income	18.632	0.972	0.000	-	-

Statistically significant estimated are written in bold; Hosmer & Lemeshow test χ^2 = 1.008 | df = 6 | p = 0.985 | -2Log likelihood = 74.559 | Nagelkerke R^2 = 0.828 | Overall percentage of correct prediction = 92.6%.

practices, hunting tools, techniques, and the traditional rituals that hold deep cultural importance for the Nocte tribe. Although the Nocte tribe's hunting traditions hold deep cultural and subsistence significance, these practices are not legally sanctioned under the Indian Wildlife (Protection) Act of 1972, which prohibits hunting of wild species across India. Current practices thus represent a continuation of pre-1972 traditions that persist informally, similar to other tribal groups of Northeast India (Aiyadurai et al. 2010; Lohe 2014; Reena 2019). It is also driven by the potential medicinal uses of animal parts (Velho & Laurance 2013) and for cultural purposes. The Noctes uphold the sacred tradition of hunting, relying steadfastly on age-old diverse traps and methods for hunting and fishing which are locally crafted. The use of age-old traditional techniques like 'Long-pa', 'Chom', 'Hapsak', and 'Waa-khap' is similar to several tribes of Arunachal Pradesh, viz., Wancho (Tag et al. 2008; Reena 2019); Nyishi (Tana et al. 2014); Mishmis (Aiyadurai 2022), and the Nagas (Lohe 2014) of Nagaland and Manipur. While similar hunting techniques and traps were observed during the study, the hunting traps 'Wat-tai' and 'Ney-chah' were found original to the Nocte tribe.

The fishing techniques are among the most sustainable methods used by the Noctes. The use of *Juglans regia* and other wild plants (Wangpan et al. 2023) as fish poison and traps made locally with bamboo, cane, and stones are relevant and most nature-friendly methods. Similar fishing techniques and traps are used by the indigenous tribes of northeastern India (Gurumayum & Choudhury 2009).

While traditional fishing methods continue to exist, some have turned to quicker, yet destructive methods which include the use of dynamite, batteries, generators, and harmful chemicals like dichloro-diphenyl-trichloroethane (DDT) and pesticides. The aim of documenting these techniques is to curb the harmful effects of this equipment and protect the environment.

Extensive and unregulated hunting and trapping practices significantly threaten wildlife populations. Controlled trapping can be valuable for ecological balance (Heffelfinger et al. 2013; White et al. 2015). Winter is the most preferred season for hunting and setting traps (Aiyadurai 2022; Chetia et al. 2022); while monsoon is unfavoured due to heavy rainfall and mainly due to the breeding activity within wildlife populations. This strategic approach reflects a subtle understanding of the ecosystem dynamics among the Nocte society. Also, taboos related to specific species help in conserving several animals (Landim et al. 2023).

Overall, the indigenous people have developed a rich collection of trapping techniques, forming a cornerstone of their cultural heritage and subsistence strategies. These practices, meticulously honed over generations, represent an effective adaptation to local environments and a deep understanding of animal behaviour. Unlike written documents, this knowledge is primarily transmitted through oral traditions and embodied skills, making it vulnerable to loss in the face of modernisation.

It's crucial to recognise the potential ecological benefits of these indigenous trapping methods. Unlike modern industrial practices, these techniques are often highly selective, targeting specific animals and minimising bycatch. With the decline of the animal population and recognising the anthropogenic threats towards the wildlife population, the youths of several Nocte villages have now formed groups that engage in raising awareness towards prohibiting hunting and conserving wildlife. The village panchayat has also supported the initiative and has enacted policies to restrict harmful equipment within its forest territory. While also encouraging to shift towards alternate use of animal products for cultural purposes, for example,

ceramics and wood-based armlets are used instead of ivory, and artificial hornbill feathers have replaced the original feathers. Also, few people have voluntarily surrendered firearms following the 'Airgun surrender abhiyan' a wildlife conservation initiative by the Arunachal Pradesh Forest Department, to demonstrate their commitment to reduce anthropogenic pressure on wildlife populations. Since the Noctes depend on healthy ecosystem resources for their sustenance, they are inherently motivated to manage these resources sustainably. Therefore, documenting their indigenous knowledge of wildlife management practices becomes essential to understanding the cultural dimensions that can aid conservation efforts. However, while these practices embody ancestral knowledge, ecological understanding, and communal identity, they may also conflict with existing conservation mandates established under the Indian Wildlife (Protection) Act, 1972, which seeks to protect endangered fauna. Reconciling these differing perspectives necessitates culturally sensitive dialogue and collaboration between local communities and governing agencies. Developing community-led conservation models and inclusive policy frameworks that integrate indigenous ecological knowledge within the legal conservation paradigm can ensure both cultural preservation and biodiversity protection in a balanced and ethically sound manner.

CONCLUSION

The hunting and trapping practices of the Nocte tribe embody a delicate balance between cultural heritage, ecological stewardship, and sustainable resource management. These practices are not driven solely by the need for sustenance but are imbued with spiritual significance passed down through generations as a sacred tradition. Rituals and taboos associated with hunting are strictly followed to obtain a successful hunt. This intricate knowledge of the land and its inhabitants forms the foundation of their cultural identity and shapes their approach to resource management. Navigating the challenges of modernization and environmental degradation necessitates both the preservation of this traditional knowledge and the embrace of community-based conservation strategies. This can be achieved by reviving traditional hunting rituals that promote selectivity and respect for wildlife, alongside implementing penalties for using highly destructive hunting and fishing equipment. Collaborative wildlife management plans, incorporating the Nocte community's knowledge and expertise, should be established alongside quotas and monitoring programs developed with wildlife officials. By combining the indigenous knowledge of the Nocte people with these recommended practices, a future can be secured where the tribe's cultural traditions seamlessly co-exist with the long-term well-being of both wildlife and human communities. This collaborative effort, blending indigenous knowledge with contemporary conservation practices, will pave the way for a harmonious relationship between humans and nature and ensure sustainable well-being of upcoming generations.

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ARTICLE

Floristic composition and plant functional types on the lateritic plateau of Panchgani Tableland, Maharashtra, India

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Abstract: The conservation zone of Panchgani Tableland lies within the Mahabaleshwar Panchgani Eco-sensitive Zone, Satara District, Maharashtra, India, in northern Western Ghats. The present paper reports 189 species across 54 families recorded throughout the year on this lateritic plateau. The most represented family is Poaceae, and it also shows the highest endemism (nine taxa). During the study, 78 endemic taxa were recorded, which makes up to 48% endemism. A total of 12 threatened taxa have been recorded during the study, of which four are 'Endangered' (*Dipcadi ursulae* var. *ursulae* Blatt., *Curcuma caulina* (J.Graham) Baker, *Iphigenia stellata* Blatt., and *Isachne swaminathanii* V.Prakash & S.K.Jain), two are 'Vulnerable' (*Eriocaulon tuberiferum* A.R.Kulkarni & Desai, *Utricularia albocaerulea* Dalzell) and six are 'Near Threatened' (*Arisaema murrayi* (J.Graham) Hook., *Euphorbia khandallensis* Blatt. & Hallb., *Habenaria grandifloriformis* Blatt. & McC., *Pinda concanensis* (Dalzell) P.K.Mukh. & Constance, *Utricularia praeterita* P. Taylor, and *Vigna khandalensis* (Santapau) Sundararagh. & Wadhwa). Though a large number of species are therophytes (73.4%), 12.5% of the taxa are geophytes, and 4.7% are carnivorous. Remaining taxa belong to other plant functional types viz. helophytes, hydrophytes, succulents, hemiparasites, and epiphytes. The study also explored the impact of anthropogenic pressures such as tourism, grazing, and soil alteration that threaten the diversity on the plateau. A comparison with floristic data by Blatter (1909) revealed the absence of 12 taxa in the existing vegetation, including the two rare species *Adelocaryum malabaricum* (C.B.Clarke) Brand., and *Smithia purpurea* Hook., and recorded another 129 species that were not recorded earlier.

Keywords: Carnivorous plants, disturbance, endemism, geophytes, Mahabaleshwar Panchgani Eco-sensitive Zone, natural heritage site, plant diversity, therophytes, threatened species.

पांचगणी टेबललॅण्डचे संवर्धन क्षेत्र हे उत्तर पश्चिम घाटातील महाबळेश्वर-पांचगणी या पर्यावरणदृष्ट्या संवेदनशील क्षेत्रात (सातारा जिल्हा, महाराष्ट्र, भारत) स्थित आहे. सदर शोधनिबंधात या जांभ्याच्या पठारावरील 54 कुळांतील 189 रोपटेवजा सपुष्प वनस्पतींच्या प्रजातींची नोंद केली आहे. येथे पोएसी कुळातील सर्वाधिक प्रजाती आढळल्या असून त्यामध्ये प्रदेशनिष्ठ प्रजातींची संख्याही सर्वात जास्त (9) आहे. सदर अभ्यासात एकूण 78 प्रदेशनिष्ठ प्रजातींची नोंद केली असून त्या एकूण प्रजाती संख्येच्या 48% आहेत. एकूण 12 संकटग्रस्त प्रजातींपैकी 4 एंडेंजर्ड (लुप्तावस्थेकडे जाणाऱ्या/ धोक्यात आलेल्या) (*Dipcadi ursulae var. ursulae* Blatt., *Curcuma caulina* (J.Graham) Baker, *Iphigenia stellata* Blatt., and *Isachne swaminathanii* V.Prakash & S.K.Jain), 2 व्हल्नरेबल (संवेदनशील) (*Eriocaulon tuberiferum* A.R.Kulkarni & Desai, *Utricularia albocaerulea* Dalzell), 6 निअर थ्रेटन्ड (अती संकटग्रस्त) (*Arisaema murrayi* (J.Graham) Hook., *Euphorbia khandallensis* Blatt. & Hallb., *Habenaria grandifloriformis* Blatt. & McC., *Pinda concanensis* (Dalzell) P.K. Mukh. & Constance, *Utricularia praeterita* P. Taylor, and *Vigna khandalensis* (Santapau) Sundararagh. & Wadhwa) प्रजातींची नोंद या अभ्यासादरम्यान केली.वनस्पतींच्या प्रजातींपैकी जास्त प्रमाण थेरोफाईट (73.4%)यांचे असून 12.5% जिओफाईट्स तर 4.7% कार्निव्होरस वनस्पतींच्या प्रजाती आहेत.उरलेल्या प्रजाती हेलोफाईट्स, हायड्रोफाईट्स, सक्युलंट्स, हेमीपॅरॅसाईट्स आणि एपिफाईट्स या प्रकारच्या आहेत. सदर अभ्यासात पर्यटन, चराई, मातीची हलवाहलव अशा जैवविविधतेला घातक मानवनिर्मित दबावांचा (कृतींचा) प्रभाव अभ्यासला गेला. तसेच ब्लॅटर (1909) यांनी केलेल्या नोंदींशी तुलना करता असे आढळून आले की त्या काळी नोंदवलेल्या प्रजातींपैकी 12 प्रजाती आता आढळत नाहीत, यात दोन संकटग्रस्त वनस्पतींचा समावेश आहे. *Adelocaryum malabaricum* (C.B.Clarke) Brand., and *Smithia purpurea* Hook याशिवाय पूर्वी नोंद न झालेल्या 129 प्रजाती आता नव्याने आढळून आल्या.

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RANWA

INTRODUCTION

The famous hill station of Panchgani in Satara District, Maharashtra, is in the Mahabaleshwar Panchgani Eco-sensitive zone declared in 2001 (ESZ notification 2001). This region includes five different plateaus and Tableland, the largest of the five, spanning over 100 acres, is a major tourist attraction and the most visited location. All these plateaus are declared conservation zones as per the development plan of the region (Pandit 2014; Urban Development Department 2013).

The Tableland witnesses the challenges due to anthropogenic pressures like exploitative tourism, trampling, grazing, fires, littering, and the introduction of alien species. The High Court has ordered the preparation of a conservation plan for the plateau in 2006, but there are data gaps. Therefore, as a step towards minimizing the data gaps, this study aims to document the herbaceous angiosperm diversity of the Tableland with a specific focus on threatened and endemic taxa.

The Panchgani Tableland has a history of botanical study dating back to the British era. This historical context provides a valuable opportunity to assess changes in floristic composition over time. This paper presents data from the plateau for a complete monsoon season and compares it with previous work by Blatter (1909).

Rock outcrops are landscapes having large proportions of exposed bedrock and are of common occurrence in the Western Ghats (Watve 2006). The environment on rock outcrops ranges from very hot & arid most of the year to waterlogged in the wet season. Along with seasonal water availability, shallow soil cover, low nutrient availability, high light, and wind intensities are also key environmental features associated with rock outcrops (Deil 2005; Porembski 2007). Organisms inhabiting such environments have developed adaptive strategies to resist, avoid, and tolerate drought through morphological and physiological traits (Bell 2012; Bechtold 2018). The habitats on the plateau include exposed rock surfaces, ephemeral pools, soil-covered areas, and disturbed soil layers.

The present study identifies angiosperm diversity on the plateau along with their habit, habitats, plant functional types, endemicity, and conservation status.

MATERIALS AND METHODS

Study area

Tableland is the largest among the five plateaus around Panchgani (Satara District, Maharashtra, India), and is a natural heritage site lying within the Mahabaleshwar–Panchgani Eco-sensitive Zone. It is located between 17.903° N, 73.845° E and 17.924° N, 73.803° E at an elevation of 1,330 m (Image 1).

Geology

High-level Ferricretes (HLF) occur between 15–18.333° N, extend inland to 74° E, and are located between 800–1,400 m (Widdowson & Cox 1996). The soil formation on the outcrops is extremely slow, and the soil depth varies from a few centimeters on flat areas to about a meter in deep cracks and depressions. The soil is sandy to sandy loam in texture, highly acidic, and poor in phosphates (Jalal & Jayanthi 2018). The Tableland is covered by ferricrete patches all over and is underlined with brown saprolite (chemically weathered rock). There are a few caves, towards the western edge of the Tableland, where the duricrust has a maximum thickness of 25 m, and where the saprolite has been eroded out (Deshpande 1998).

Climatic conditions

The climate is characterized by three distinct seasons: heavy rains during monsoon (June–September) along with strong winds, drier winters (October–January) and scorching hot summers (February–May). Panchgani Tableland receives an average annual rainfall of approx. 1,700 mm (Kale 2014), resulting in relative humidity often reaching up to 90% during monsoons. Nevertheless, humidity is only 14% during the dry period, when the temperature of the exposed rock surface is very high (58 °C) in summer (Watve 2009) (Image 2).

Methods

Scientific literature related to floristic diversity of lateritic plateaus in Satara District was consulted (Blatter 1909; Watve 2013) as a reference material. Monthly visits were conducted from early monsoon to early winter (June–November) from 2022–2024. The plants observed while exploring the plateau were recorded and identified using local and regional flora (Deshpande et al. 1995). Endemicity was verified using Singh et al. (2015). The plant functional types (PFT) classification for vascular plants on rocky plateaus was adopted and modified from Kulkarni et al. (2021). The status of the species was listed as per the IUCN Red List (https://www.iucnredlist.org).

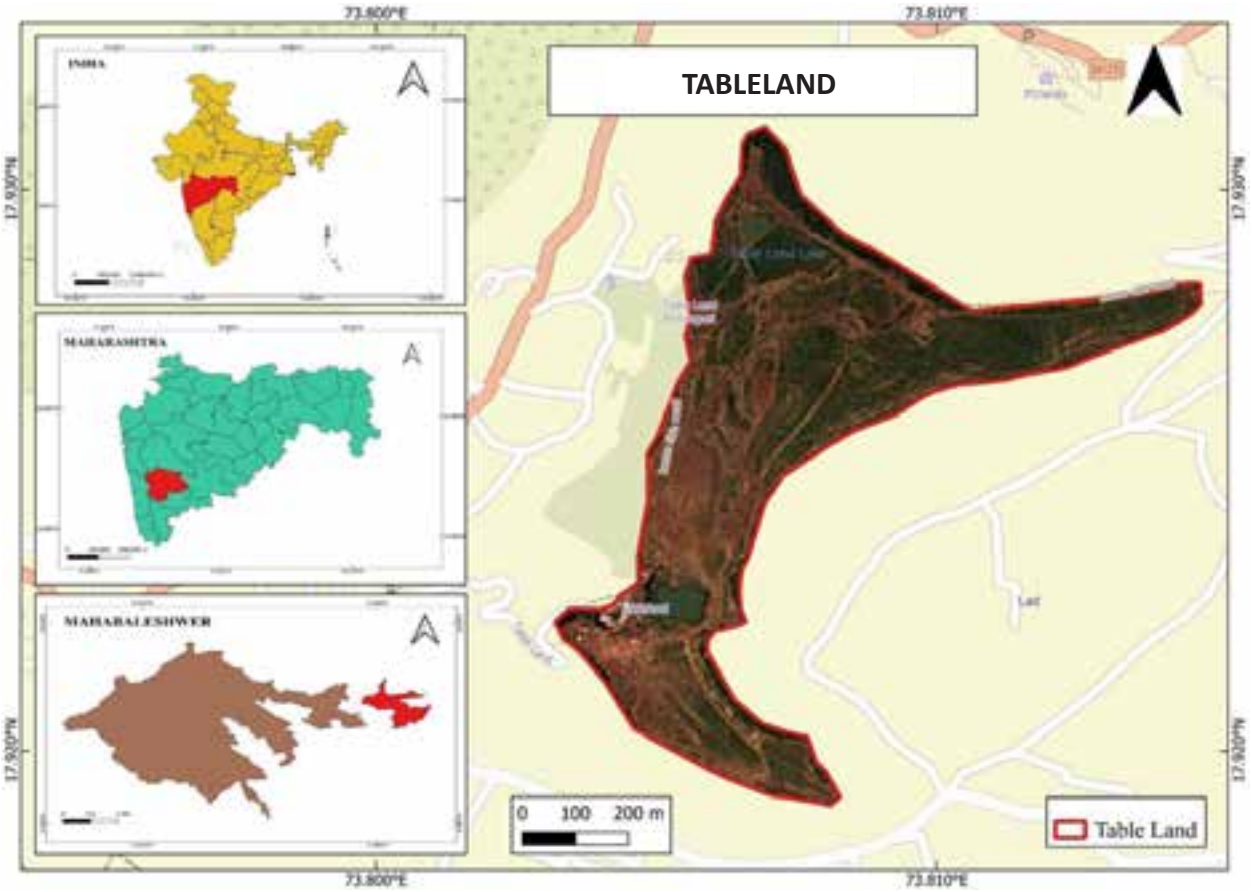

Image 1. Study Area (Panchgani Tableland, Satata Dist., Maharashtra).

RESULTS AND DISCUSSIONS

Types of microhabitats and vegetation

Plants on the plateaus are adapted to various microhabitats, and each microhabitat is unique in its edaphic properties, water availability, and species composition. The most common habitat types observed on plateaus are described below by following an established categorization for rock outcrops by Porembski & Barthlott (2000), and Jacobi et al. (2007) with some modifications (Image 3). Table 1 describes each of the habitats present along with the typical species found in that habitat. The habitats observed on the Tableland are: crust edges and cliffs, ephemeral flush vegetation, exposed rock surfaces, rock crevices & fissures, seasonal ponds, small ephemeral pools, soil-covered areas, soil-filled depressions, tree cover & tree associates, introduced compacted soil, disturbed soil layer, and soil introduced for plantation. Boulders were absent.

Floristic composition

A total of 189 species were observed on Panchgani Tableland, with 94% of them being herbs. The recorded species span 54 families. The most represented families are Poaceae (38 species), Fabaceae (16 species), Asteraceae (13 species), Acanthaceae (10 species), Commelinaceae (8 species), Orchidaceae (8 species), Lamiaceae (7 species), Lentibulariaceae (7 species), and Rubiaceae (7 species) (Figure 1).

The largest genus is *Utricularia* (7 species), followed by *Eriocaulon* (5 species). Most gregarious flowering is shown by *Utricularia arcuata* Wight, *Eriocaulon eurypeplon* Körn., *Smithia hirsuta* Dalzell, *Exacum lawi* C.B.Clarke, *Linum mysorense* B.Heyne ex Benth., and *Parasopubia delphinifolia* (L.) H.-P.Hofm. & Eb.Fisch.

Carnivorous plants observed are seven species of *Utricularia* and two species of *Drosera. Striga densiflora* (Benth.) Benth., *Striga gesnerioides* (Willd.) Vatke, *Rhamphicarpa fistulosa* (Hochst.) Benth., and *Parasopubia delphinifolia* (L.) H.-P.Hofm. & Eb.Fisch. are hemiparasitic plants observed on the plateau.

Image 2. Study area across seasons: Panchgani Tableland. left - August , right - December. © Sarita Gosavi.

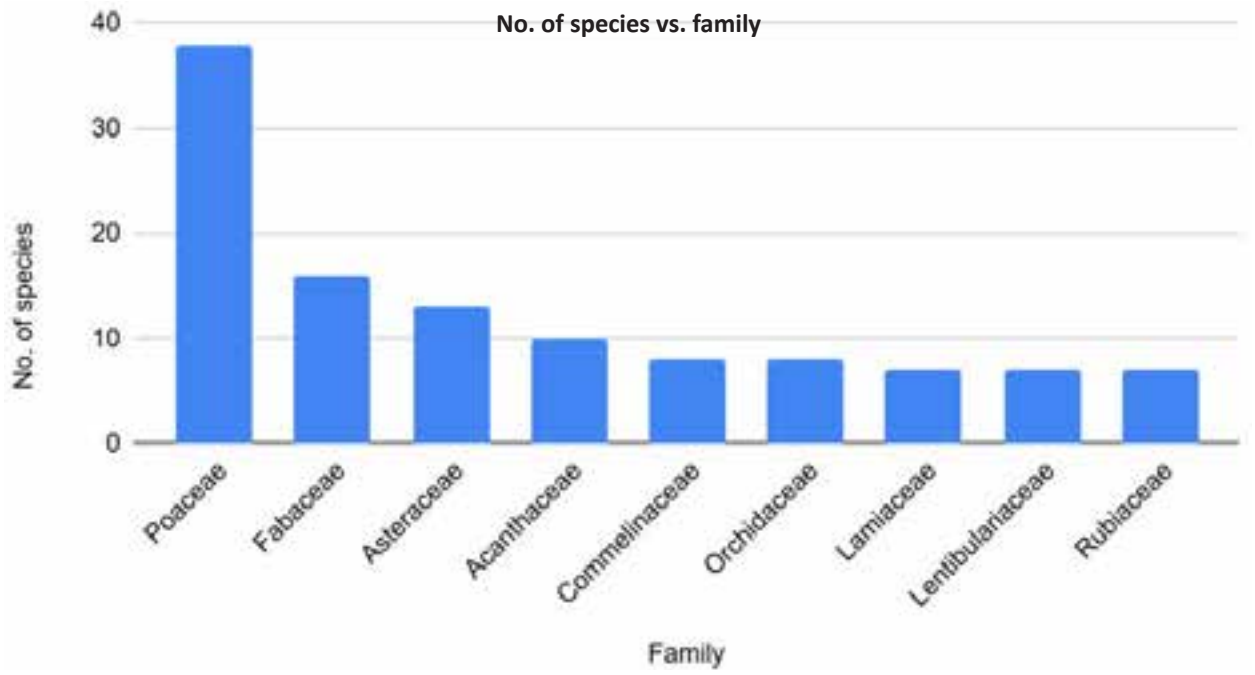

Figure 1. Most common families of angiosperms observed on the plateau- Panchgani Tableland.

Rare plants on the plateau

Between the year 2022 and 2024, 12 species of threatened plant species have been recorded. Four species are 'Endangered', viz., *Dipcadi ursulae* var. *ursulae* Blatt., *Curcuma caulina* (J.Graham) Baker, *Iphigenia stellata* Blatt., and *Isachne swaminathanii* V. Prakash & S.K. Jain. Two species are 'Vulnerable', viz., *Eriocaulon tuberiferum* Kulkarni & Desai, *Utricularia albocaerulea* Dalzell. Six species are 'Near Threatened', viz., *Arisaema murrayi* (J.Graham) Hook., *Euphorbia khandallensis* Blatt. & Hallb., *Habenaria grandifloriformis* Blatt. & McC., *Pinda concanensis* (Dalz.) P.K.Mukh. & Constance,

Table 1. Habitats observed on Panchgani Tableland with their description and commonly observed species.

	Habitat Type	Description	Typical plants associated with the particular habitat
1	Crust Edges or Cliffs (C)	Edges of the plateau	*Begonia crenata, Pinda concanensis, Pimpinella adscendens*
2	Ephemeral Flush Vegetation (EFV)	Stretches of rock covered with a sheet of water through the rainy season with negligible soil deposition	*Utricularia arcuata, Eriocaulon sedgewickii, Rotala densiflora, Pogostemon deccanensis*
3	Exposed Rock Surfaces (ERS)	Flat or uneven rock surfaces exposed to direct sunlight with absence of soil. The tiny crevices accumulate soil that can host small plants	*Moss, Riccia, Indopoa paupercula, Eriocaulon eurypeplon, Utricularia arcuata*
4	Rock Crevices (RC)	Present along the edge of the plateau, provides a unique niche	*Hitchenia caulina, Indigifera dalzelli, Nanotis foetida*
5	Seasonal Ponds (SP)	Small ponds formed only during the monsoon	*Marsilia, Scleria rugosa*
6	Small Ephemeral Pools (SEP)	Shallow depression inundated with water, with very little soil deposition	*Rotala densiflora, Fimbristylis bispicula*
7	Soil Covered Areas (SCA)	Soil thickness less than 20 cm	*Habenaria grandifloriformis, Hypoxis aurea, Iphigenia stellata, Peristylis densus, Euphorbia panchganiensis, Smithia hirsuta, Smithia bigemina, Drosera indica*
8	Soil Filled Depressions (SFD)	Depressions that accumulate soil and water	*Eriocaulon tuberiferum, Pogostemon deccanensis, Rotala densiflora*
9	Soil Rich Areas (SRA)	Stretches with soil thickness more than 20 cm	*Smithia hirsuta, Murdannia simplex*
10	Tree Cover And Tree Associates (T)	Some trees grow on the slopes of the plateau, the shady areas beneath the trees and the moist branches provide a unique habitat	*Mosses, Eria reticosa, Utricularia striatula*
11	Introduced Compacted Soil (ICS)	Soil introduced and compacted for making pathways shows a drastically different habitat	*Habenaria grandifloriformis, Exacum lawii*
12	Disturbed Soil Layer (DSL)	Soil excavated from pools is deposited on some stretches of plateau. It has invited weeds	*Argemone Mexicana, Nicandra physallodes, Amaranthus spinosus, Ageratum conyzoides, Alternanthera sessilis*
13	Soil Introduced For Plantation	High mounds of soil along the edges of lakes provide deep soil for the bigger introduced plants	*Ziziphus jujuba, Nerium oleander, Lantana camara*

Utricularia praeterita P. Taylor, and *Vigna khandalensis* (Santapau) Sundararagh. & Wadhwa) as per IUCN Red List (Table 2).

Two threatened species, *Adelocaryum malabaricum* (C.B.Clarke) Brand. (Endangered, B1ab(iii)+2ab(iii)) and *Smithia purpurea* Hook (Near Threatened, B1b(iii)+2b(iii)), observed by Blatter (1909), could not be recorded in the present exploration between 2022–2024.

Endemism

Among the species recorded (192) on Panchgani Tableland, 78 species are endemic, which constitute about 40% of the existing vegetation. Families with highest endemism are Poaceae (nine species), Fabaceae (nine species), Orchidaceae (six species), Commelinaceae (five species), Gentianaceae (five species), Apiaceae (four species), and Eriocaulaceae (four species) (Figure 2).

Plant Functional Types

The observed plants are classified into plant functional types according to Kulkarni et al. (2021). Cryptophytes have been further divided into geophytes, helophytes, and hydrophytes. Graminoids (Poaceae and Cyperaceae) and leguminous plants have been identified separately, and other seed-bearing plants have been classified under therophytes. Analysis of life form shows that 82 plant species (42.7%) are therophytes (other than graminoids and leguminous), 43 species (22.4%) are graminoids, 24 species (12.5%) are geophytes, 16 species (8.3%) are leguminous, nine species (4.7%) are carnivorous, six species (3.1%) are helophytes, four species (2.1%) are hemiparasites, three species (1.6%) are hydrophytes, three species (1.6%) are succulents, and two species (1%) are epiphytes (Figure 3).

Seasonal succession and phenology

A chronological succession is observed among the plant communities observed on the plateau. Most of the plants start their growth with the advent of monsoon. Four major phases that can be identified are pre-monsoon, monsoon, post-monsoon, and summer. The early-monsoon phase (June–July) is characterized by the growth of grasses on the plateaus. The common grass genera are *Eragrostis, Glyphochloa, Indopoa, Isachne,* and *Paspalum*. Early flowering is seen in *Eria reticosa* Wight, *Habenaria grandifloriformis* Blatt. & McC., *Iphigenia stellata* Blatt., *Hypoxis aurea* Lour., and *Indigofera dalzelli* T.Cooke. The monsoon phase

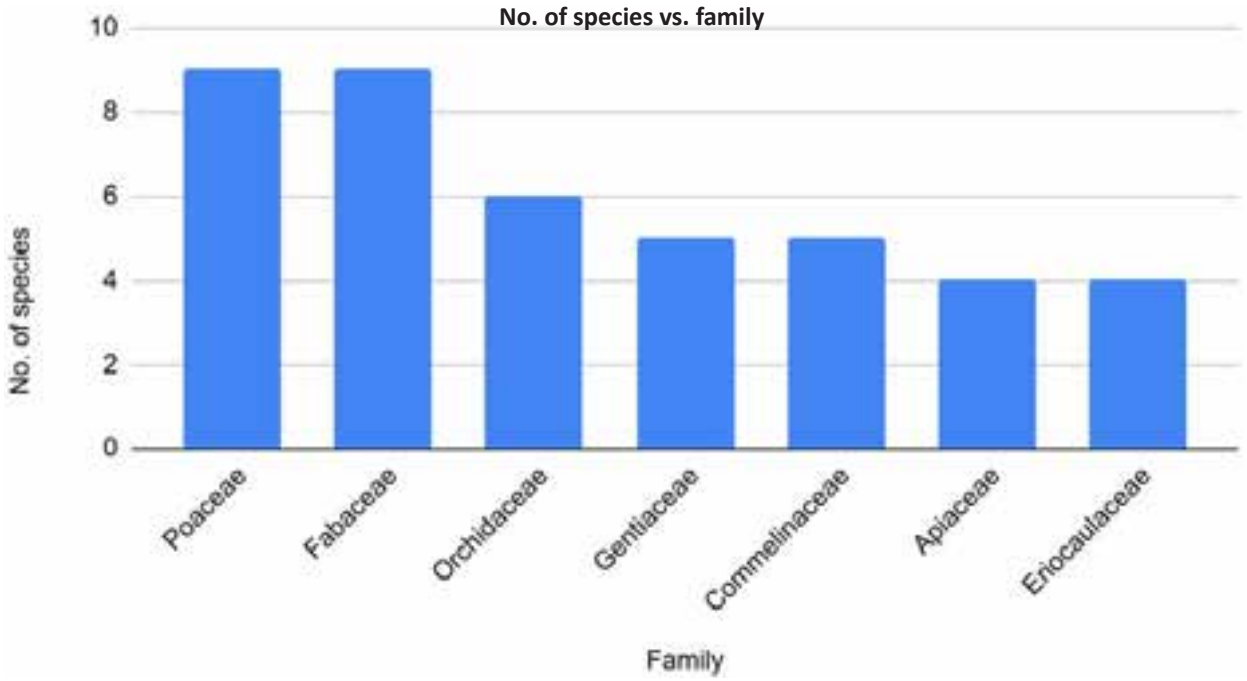

Figure 2. Endemism across topmost plant families recorded from Panchgani Tableland.

Table 2. Threatened plant species observed on the Panchgani Tableland.

	Species	IUCN status	Criteria	Population trend
1.	*Arisaema murrayi* (J.Graham) Hook.	NT	B2b(iii)	Unknown
2.	*Dipcadi ursulae* Blatt.	EN	B2ab(iii,v)	Stable
3.	*Eriocaulon tuberiferum* Kulkarni & Desai	VU	B1ab(ii,iii)+2ab(ii,iii);D2	Decreasing
4.	*Euphorbia khandallensis* Blatt. & McCann	NT	B1ab(iii)+2ab(iii)	Unknown
5.	*Habenaria grandifloriformis* Blatt. & McC.	NT	B2b(ii,iii,iv)	Decreasing
6.	*Hitchenia caulina* Baker	EN	B1ab(iii)	Unknown
7.	*Iphigenia stellata* Blatt.	EN	B2ab(i,ii,iii,v)	Decreasing
8.	*Isachne swaminathanii* V.Prakash & S.K.Jain	EN	B2ab(I,ii,iii)	Unknown
9.	*Pinda concanensis* (Dalz.) P.K.Mukh. & Constance	NT	B2b(iii)	Decreasing
10.	*Utricularia albocaerulea* Dalzell	VU	B1ab(i,ii,iii)+2ab(i,ii,iii)	Unknown
11.	*Utricularia praeterita* P.Taylor	NT	---	Unknown
12.	*Vigna khandalensis* (Santapau) Raghavan & Wadhava	NT	---	Unknown

(August–September) is characterised by mass blooming of mainly geophytes such as *Habenaria suaveolens* Dalzell, *Habenaria heyneana* Lindl., *Habenaria rariflora* A.Rich. and *Eriocaulon tuberiferum* Kulkarni & Desai. A few other abundant ephemerals that flower along with geophytes are *Smithia hirsuta* Dalzell, *Smithia bigemina* Dalz., *Utricularia arcuata* Wight, *Eriocaulon eurypeplon* Körn., *Eriocaulon stellulatum* Körn., and *Striga gesnerioides* (Willd.) Vatke. In the post-monsoon phase (October–December), grasses like *Arundinella spicata* Dalzell, *Eulalia shrirangii* Salunkhe & Potdar, *Indopoa paupercula* (Stapf) Bor ex Ramamoorthy, and *Ischaemum impressum* Hack enter flowering. *Rotala densiflora* (Roth) Koehne and *Swertia densifolia* (Griseb.) Kashyapa, are among few other taxa. The dry summer marks the fourth phase (January–May) during which only a few herbaceous species such as *Blumea lacera* (Burm.f.) DC., *Euphorbia khandallensis* Blatt. & Hallb., *Lepidgathis cuspidata* Nees, *and Alternanthera sessilis* (L.) DC. bloom. Few other shrubs that have been introduced to the plateau by anthropogenic activities also survive the dry summer; examples being *Lantana camara* L., *Nerium*

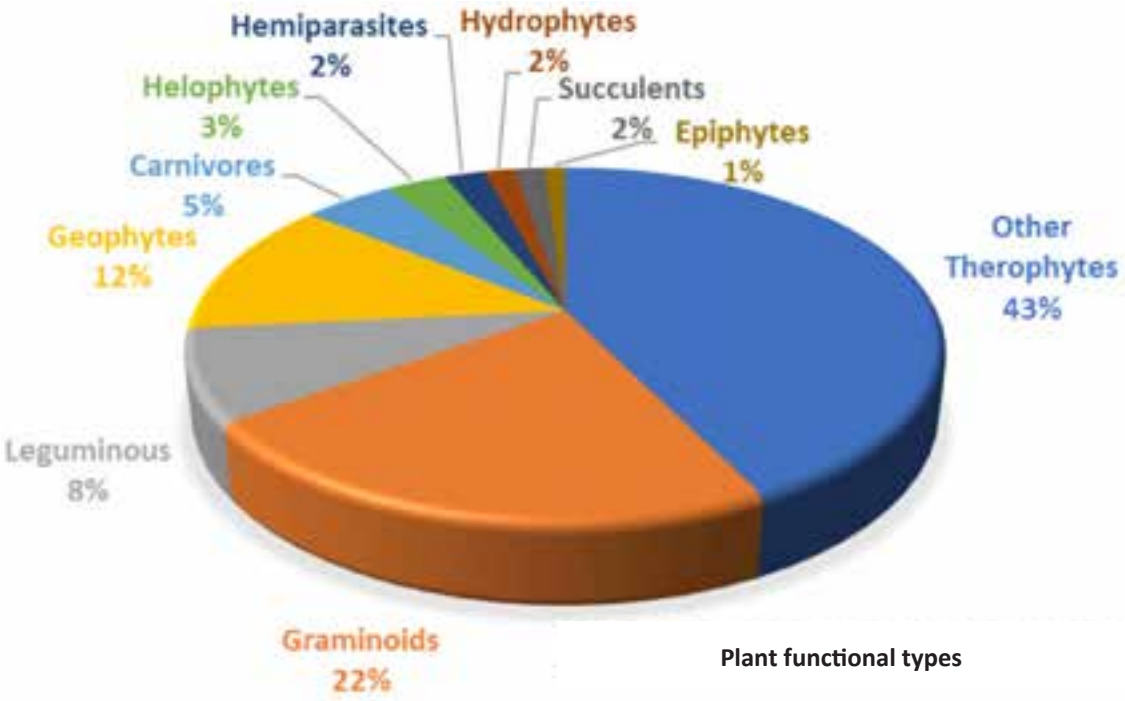

Figure 3. Plant functional types recorded from Panchgani Tableland.

Table 3. Comparison of species composition on Pachgani Tableland in 1909 and 2022–2024.

	Total no. of species	No. of species reported in 1909	No. of species reported in 2022–24
Total no. of species reported	189	62	177
Endemic	77	29	71
Rare species	15	7	12
Aliens	24	9	24

Table 4. Comparison of plant functional types recorded from Panchgani Tableland in 1909 and 2022–2024.

	Total no. of species	No. of species reported in 1909	No. of species reported in 2022–24
Other therophytes	82	37	74
Graminoids	43	4	43
Leguminous	15	3	14
Geophytes	26	9	26
Carnivores	8	2	8
Helophytes	6	0	6
Hemiparasites	4	2	4
Hydrophytes	3	2	1
Succulents	3	2	3
Epiphytes	2	1	2

oleander L., and *Ziziphus jujuba* Mill. The phenological observations showed that approximately 93% of species complete their reproductive cycle between August and January. These annuals complete their life-cycle during the favourable edapho-climatic conditions before the onset of a long dry spell.

Adaptive traits

The plants on the plateau show certain traits that help them overcome the hot and dry summers, the light intensity, and the nutrient deficiency. A detailed account on the adaptation/ecophysiology of vascular plants of rock outcrops is provided by Kluge & Brulfert (2000). Some of the common adaptive traits that are observed on the Panchgani plateau are based on the description by Lekhak & Yadav (2012)

Carnivory: The acidic soil conditions deficient in Nitrogen, Phosphorus, and Sulfur can support carnivorous plants like *Drosera* spp. and *Utricularia* spp. These species are abundant in areas with a negligible layer of soil.

Succulence: Succulent plants are known to store water in different organs which allow them to withstand the harsh climate. The typical leaf succulents on the plateau are *Cyanotis fasciculata* (B.Heyne ex Roth) Schult. & Schult.f., *Euphorbia khandallensis* Blatt. &

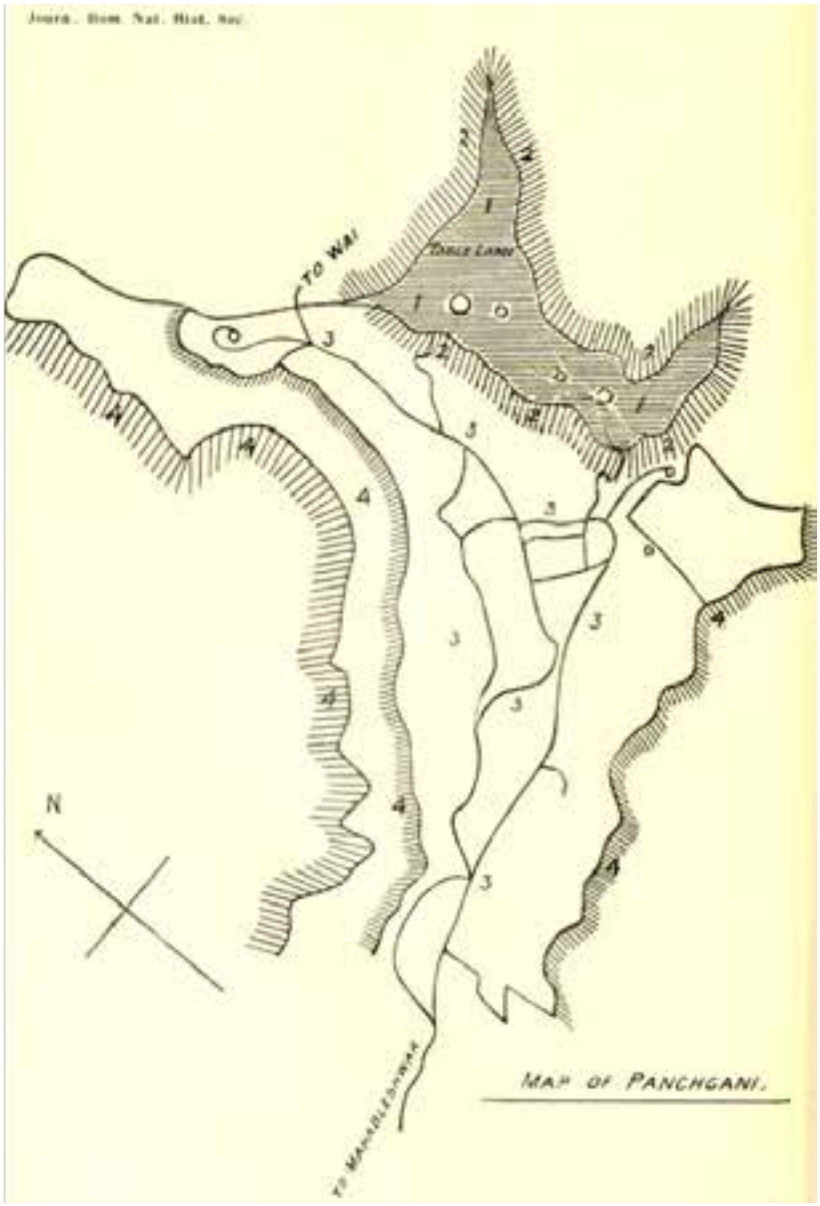

Figure 4. Old map of Panchgani showing table land and surroundings (Blatter 1909).

Hallb., and *Kalanchoe olivacea* Dalzell.

Poikilohydry: These plants can withstand dry climates by varying water content following the humidity in the environment. On the plateau, *Glyphochloa forficulata* (C.E.C.Fisch.) Clayton, *Indopoa paupercula* (Stapf) Bor ex Ramamoorthy, and *Tripogon bromoides* Roth are poikilohydrous grasses (Smrithy 2023) that can resurrect when sufficient moisture is available.

Subterranean perennating organs: These plants can survive the dry season by producing underground organs like corms, rhizomes, bulbs, and tubers. Geophytes like *Hypoxis aurea* Lour., *Dipcadi ursulae* Blatt., *Eriocaulon tuberiferum* Kulkarni & Desai, *Euphorbia khandallensis* Blatt. & Hallb., *Flemingia nilgheriensis* (Benth. ex Baker f.) Wight ex T. Cooke, *Iphigenia* spp., *Habenaria* spp., *Peristylus* spp., and *Zingiber* spp. fall in this category.

Vegetative propagation: Some plants produce bulbs or bulbils at the leaf tips that can help them survive the dry season. *Curculigo orchioides* Gaertn. is one such species present on the plateau.

Anthropogenic influence: Panchgani Tableland, like most other plateaus in Maharashtra, is dominated by annual herbaceous vegetation, which is neglected as compared to the surrounding forest area. The plateau is also barren for a major part of the year, i.e., from December to May. This plateau has unique geological

Image 3. Habitats on tableland: a—soil filled depression | b—small ephemeral pool | c—introduced soil | d—seasonal ponds | e—crust edge and cliffs | f—cave | g—exposed rock surface | h—soil covered area. © Ankur Patwardhan.

features like lateritic caves attracting tourists and the plateau is visited by nearly one lakh tourists every year throughout the year. The plateau features numerous food stalls and paved parking spaces, while continuous trampling has led to barren soil patches. Movement of horses, horse carts, and tourists across vegetated areas further exacerbates trampling and vegetation loss. Major anthropogenic disturbances apart from these are grazing by horses and cattle, fires, uprooting the herbs, garbage littering, and soil deposition by local authorities. The lakes on the plateau are also visited by locals for immersion of idols.

Aliens: Many alien species are observed on the plateau, which are not characteristic of the region. Many of them are found at sites where the soil layer is disturbed. The silt in the permanent ponds has been removed and deposited on the plateau. This has carried seeds of Marigold *Tagetes erecta*, which is offered to the idols immersed in water after the Ganesh Festival. *Ageratum conyzoides* L., *Alternanthera sessilis* (L.) DC., *Amaranthus spinosus* L., *Argemone mexicana* L., *Cardamine trichocarpa* Hochst. ex A.Rich., *Celosia argentea* L., *Polygonum plebeium* R.Br., *Verbascum coromandelianum* (Vahl) Hub. Mor., *Gynura bicolor* (Roxb.ex Willd.) DC., *Tagetes erecta* L., and *Nicandra physalodes* (L.) Gaertn. have been observed on the plateau. The aliens are slowly invading the undisturbed parts of the plateau.

Introduced plants: Some plants like *Ziziphus jujuba* Mill., *Lantana camara* L., and *Nerium oleander* L. have been introduced along the lakes for beautification.

Panchgani Tableland over the last century

The plateau was studied for flora by Blatter (1909) and the data was compared with observations in recent years (2022–2024). Blatter had identified four zones based on land use and marked the presence of species. Figure 4 shows an old map published in the paper by Blatter (1909).

Of the 192 species documented in this study, 62 were previously recorded by Blatter either on the plateau or in its vicinity. In 1909, only 31 of these species were reported as occurring directly on the plateau. The remaining species were documented from adjacent zones and were not known to inhabit the plateau at that time. The current occurrence of these species on the plateau suggests that they may have been introduced intentionally or have arrived through natural dispersal processes over the past century (Table 3). The data collection has been more exhaustive recently as is evident from the number of species recorded.

Out of the 62 species reported in 1909, 14 are not observed on the plateau in the recent past. Among these, there are three rare species *Adelocaryum malabaricum* (C.B.Clarke) Brand. (Endangered), *Adelocaryum coelestinum* (Lindl.) Brand., and *Smithia purpurea* Hook. (Near Threatened).

Comparison of plant life forms of species recorded in 1909 and 2022–24 (Table 4) sheds light on the number of species recorded by Blatter in 1909 and by the authors in 2024 along with the numbers and percentages for various life forms. It is further interpreted that the percentage of cryptophytes (geophytes, helophytes, and hydrophytes) among the recorded species has significantly increased in the recent past. Geophytes recorded by Blatter included nine species, the number has risen to 23 in present study; six helophytes are recorded now which were missing earlier; and a species of hydrophytes is missing now as the number reduces from two to one. Cryptophytes have a special advantage of surviving harsh climates with the help of subterranean perennating organs.

CONCLUSION

The ever-increasing popularity of Panchgani Tableland as a tourist place makes it susceptible to anthropogenic pressures. It has also been recently notified as a conservation zone within the Mahabaleshwar Panchgani Eco-sensitive zone. A comparison of data collected from the plateau nearly a century ago (Blatter 1909) with current data sheds light on some of the significant species that are not reported now. Notable amongst them are species like *Adelocaryum malabaricum* (Endangered), *Adelocaryum coelestinum* (Near Threatened), *Smithia purpurea* (Near Threatened), and *Nymphoides* sp. Therefore, these species should be given a key priority in restoration. The increasing percentage of cryptophytes may be correlated with edaphoclimatic data to conclude about the influence of the latter. A significant increase in the number of aliens is alarming. It is evident from observations that anthropogenic factors like the dumping of soil have largely aided the spread of aliens such as *Argemone mexicana* and *Alternanthera sessilis* that are not characteristic of lateritic plateau habitat. This study, therefore, provides a strong basis for guiding interventions on the plateau towards conservation and restoration.

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Appendix 1. Panchgani Tableland checklist of angiosperms.

Species name (Accepted as per POWO)	Synonyms	Family	Life form	Ende-micity	IUCN Red List	Recorded by Blatter (1909)	Recorded by authors in 2024
Asystasia dalzelliana Santapau		Acanthaceae	Therophyte	E			On Panchgani Tableland
Asystasia gangetica (L.) T. Anderson var. *gangetica*	*Asystasia violacea* Dalzell	Acanthaceae	Therophyte			On Panchgani Tableland	On Panchgani Tableland
Dicliptera sp.		Acanthaceae	Therophyte				On Panchgani Tableland
Nicoteba betonica (L.) Lindau	*Justicia betonica* L.	Acanthaceae	Therophyte			In the vicinity of Tableland	On Panchgani Tableland
Rostellularia procumbens (L.) Nees	*Justicia procumbens* L.	Acanthaceae	Therophyte			In the vicinity of Tableland	On Panchgani Tableland
Nicoteba trinervia (Vahl) Lindau	*Justicia trinervia* Vahl	Acanthaceae	Therophyte	E		On Panchgani Tableland	On Panchgani Tableland
Lepidagathis cuspidata Nees		Acanthaceae	Therophyte				On Panchgani Tableland
Rungia elegans Dalzell & A.Gibson		Acanthaceae	Therophyte				On Panchgani Tableland
Achyranthes aspera L.		Amaranthaceae	Therophyte			On Panchgani Tableland	On Panchgani Tableland
Alternanthera sp. (Pink)		Amaranthaceae	Therophyte				On Panchgani Tableland
Alternanthera sessilis (L.) DC.	*Alternanthera triandra* Lam.	Amaranthaceae	Therophyte			On Tableland cliff	On Panchgani Tableland
Amaranthus spinosus L.		Amaranthaceae	Therophyte				On Panchgani Tableland
Celosia argentea L.		Amaranthaceae	Therophyte		LC	In the vicinity of Tableland	On Panchgani Tableland
Gomphrena serrata L.		Amaranthaceae	Therophyte				On Panchgani Tableland
Pinda concanensis (Dalz.) P.K.Mukh. & Constance	*Heracleum concanense* Dalzell	Apiaceae	Geophyte	E	NT	On Tableland cliff	On Tableland cliff
Pimpinella adscendens Dalz.		Apiaceae	Therophyte	E			On Tableland cliff
Pimpinella candolleana Wight & Arn.		Apiaceae	Therophyte			On Tableland cliff	Absent
Pimpinella wallichiana (Miq.) Gandhi	*Pimpinella monoica* Dalzell	Apiaceae	Therophyte	E		On Tableland cliff	Absent
Pimpinella tomentosa Dalzell ex C.B.Clarke		Apiaceae	Therophyte	E		On Tableland cliff	Absent
Nerium oleander L.		Apocynaceae	Therophyte		LC		On Panchgani Tableland
Arisaema leschenalutii Blume		Araceae	Geophyte				On Panchgani Tableland
Arisaema murrayi (J.Graham) Hook.		Araceae	Geophyte	E	NT	On Tableland cliff	On Tableland cliff
Dipcadi montanum (Dalzell) Baker		Asparagaceae	Geophyte	E			On Panchgani Tableland
Dipcadi ursulae var. *ursulae* Blatt.	*Dipcadi ursulae* Blatt.	Asparagaceae	Geophyte	E	EN		On Panchgani Tableland
Adenoon indicum Dalzell		Asteraceae	Therophyte	E	LC	On Panchgani Tableland	Absent
Ageratum conyzoides L.		Asteraceae	Therophyte		LC	On Tableland cliff,3	On Panchgani Tableland
Blumea lacera (Burm.f.) DC.		Asteraceae	Therophyte		DD		On Panchgani Tableland
Chromolaena odorata (L.) R.M.King & H.Rob.		Asteraceae	Therophyte				On Panchgani Tableland
Eschenbachia stricta (Willd.) Raizadae	*Conyza stricta* Willd.	Asteraceae	Therophyte			On Panchgani Tableland	On Panchgani Tableland
Galinsoga parviflora Cav.		Asteraceae	Therophyte				On Panchgani Tableland
Gynura bicolor (Roxb.ex Willd.) DC.		Asteraceae	Therophyte				On Panchgani Tableland

Species name (Accepted as per POWO)	Synonyms	Family	Life form	Ende-micity	IUCN Red List	Recorded by Blatter (1909)	Recorded by authors in 2024
Gynura nitida DC.		Asteraceae	Geophyte				On Panchgani Tableland
Senecio bombayensis Balakr.		Asteraceae	Therophyte	E			On Panchgani Tableland
Synedrella nodiflora (L.) Gaertn.		Asteraceae	Therophyte				On Panchgani Tableland
Tagetes erecta L.		Asteraceae	Therophyte				On Panchgani Tableland
Tridax procumbens L.		Asteraceae	Therophyte			In the vicinity of Tableland	On Panchgani Tableland
Impatiens balsamina L.		Balsaminaceae	Therophyte				On Panchgani Tableland
Impatiens dalzellii Hook.f. & Thomson		Balsaminaceae	Therophyte	E		On Tableland cliff	On Panchgani Tableland
Begonia crenata Dryand.		Begoniaceae	Geophyte	E		On Tableland cliff	On Tableland cliff
Cynoglossum zeylanicum (Sw. ex Lehm.) Thunb. ex Brand	*Cynoglossum denticulatum* var. *zeylanicum* (Sw. ex Lehm) C.B.Clarke	Boraginaceaae	Therophyte			On Panchgani Tableland	Absent
Adelocaryum coelestinum (Lindl.) Brand.	*Paracaryum coelestinum* (Lindl.) Benth. ex C.B.Clarke/ *Paracaryopsis coelestina* (Lindl.) R.R.Mill	Boraginaceaae	Therophyte	E	NT	On Tableland cliff	Absent
Adelocaryum malabaricum (C.B.Clarke) Brand.	*Paracaryum malabaricum* C.B.Clarke / *Paracaryopsis malabarica* (C.B.Clarke) R.R.MIll	Boraginaceaae	Therophyte	E	EN	On Tableland cliff	Absent
Brassica sp.		Brassicaceae	Therophyte				On Panchgani Tableland
Cardamine trichocarpa Hochst. ex A.Rich.	*Cardamine subumbellata* Hook. ex Hook.f.	Brassicaceae	Therophyte			In the vicinity of Tableland	On Panchgani Tableland
Wahlenbergia erecta (Roth ex Schult.) Tuyn.	*Cephalostigma schimperi* Hochst. ex A.Rich.	Campanulaceae	Therophyte			On Panchgani Tableland	Absent
Iphigenia pallida Baker		Colchicaceae	Geophyte	E			On Panchgani Tableland
Iphigenia stellata Blatt.		Colchicaceae	Geophyte	E	EN		On Panchgani Tableland
Murdannia simplex (Vahl) Brenan	*Aneilema sinicum* Ker Gawl.	Commelinaceae	Geophyte	E	LC	On Panchgani Tableland	On Panchgani Tableland
Commelina forskaolii Vahl		Commelinaceae	Therophyte				On Panchgani Tableland
Commelina sp.		Commelinaceae	Therophyte				On Panchgani Tableland
Cyanotis fasciculata (B.Heyne ex Roth) Schult. & Schult.f.		Commelinaceae	Succulent	E	LC	On Tableland cliff	On Panchgani Tableland
Cyanotis tuberosa (Roxb.) Schult. & Schult.f.		Commelinaceae	Geophyte	E			On Panchgani Tableland
Murdannia crocea (Griff.) Faden		Commelinaceae	Therophyte	E			On Panchgani Tableland
Murdannia lanuginosa (Wall. ex C.B.Clarke) G.Brückn.		Commelinaceae	Geophyte	E	LC		On Panchgani Tableland
Murdannia semiteres (Dalz) Sant.		Commelinaceae	Therophyte		LC		On Panchgani Tableland
Kalanchoe olivacea Dalzell		Crassulaceae	Succulent	E		On Panchgani Tableland	On Tableland cliff
Crotalaria sp.		Crotalariaceae	Therophyte				On Panchgani Tableland
Cucumis sp.		Cucurbitaceae	Therophyte				On Panchgani Tableland

Species name (Accepted as per POWO)	Synonyms	Family	Life form	Ende-micity	IUCN Red List	Recorded by Blatter (1909)	Recorded by authors in 2024
Cyperus flavidus Retz.		Cyperaceae	Graminoid		LC		On Panchgani Tableland
Fimbristylis tenera Schult		Cyperaceae	Graminoid				On Panchgani Tableland
Bulbostylis densa (Wall.) Hand.-Mazz.		Cyperaceae	Graminoid		LC		On Panchgani Tableland
Fimbristylis bispicula Govind		Cyperaceae	Graminoid	E			On Panchgani Tableland
Scleria rugosa R.Br.		Cyperaceae	Graminoid		LC		On Panchgani Tableland
Drosera burmanni (Vahl)		Droseraceae	Carnivores		LC		On Panchgani Tableland
Drosera indica L.		Droseraceae	Carnivores		LC		On Panchgani Tableland
Eriocaulon odoratum Dalzell		Eriocaulaceae	Therophyte	E	LC		On Panchgani Tableland
Eriocaulon eurypeplon Körn.		Eriocaulaceae	Therophyte	E	LC		On Panchgani Tableland
Eriocaulon sedgwickii Fyson		Eriocaulaceae	Therophyte	E	LC		On Panchgani Tableland
Eriocaulon stellulatum Körn.		Eriocaulaceae	Therophyte	E	LC		On Panchgani Tableland
Eriocaulon tuberiferum Kulkarni & Desai		Eriocaulaceae	Helophyte	E	VU		On Panchgani Tableland
Euphorbia khandallensis Blatt. & Hallb.	*Euphorbia panchganiensis* Blatt. & McCann	Euphorbiaceae	Succulent/ Geophyte	E	NT		On Panchgani Tableland
Desmodiastrum belgaumens (Wight) A. Pramanik &Thoth.	*Alysicarpus belgaumensis* Wight	Fabaceae	Legume	E		On Panchgani Tableland,3	On Panchgani Tableland
Alysicarpus monilifer (L.) DC.	*Alysicarpus vaginalis* Hochst. ex Baker	Fabaceae	Legume				On Panchgani Tableland
Alysicarpus tetragonolobus Edgew.		Fabaceae	Legume				On Panchgani Tableland
Desmodium rotundifolium DC.		Fabaceae	Legume				On Panchgani Tableland
Grona triflora (L.) H.Ohashi & K.Ohashi	*Desmodium triflorum* (L.) DC.	Fabaceae	Legume				On Panchgani Tableland
Flemingia nilgheriensis (Benth. Ex Baker f.) Wight ex T.Cooke	*Flemingia nilgheriensis* (Baker) T.Cooke	Fabaceae	Legume/ Geophyte	E			On Panchgani Tableland
Geissaspis cristata var. *tenella* (Benth.) M.R.Almeida	*Geissaspis tenella* Benth.	Fabaceae	Legume	E			On Panchgani Tableland
Indigofera dalzellii T.Cooke		Fabaceae	Legume	E			On Panchgani Tableland
Smithia bigemina Dalz.	*Smithia agharkarii* Hem.	Fabaceae	Legume	E			On Panchgani Tableland
Smithia hirsuta Dalzell		Fabaceae	Legume	E	LC		On Panchgani Tableland
Smithia purpurea Hook.		Fabaceae	Legume	E	NT	On Panchgani Tableland	Absent
Smithia setulosa Dalzell		Fabaceae	Legume	E		On Panchgani Tableland	On Panchgani Tableland
Tadehagi triquetrum (L.) H.Ohashi		Fabaceae	Legume				On Panchgani Tableland
Vigna khandalensis (Santapau) Sundararagh. & Wadhwa		Fabaceae	Legume / Geophyte	E	NT		On Panchgani Tableland
Zornia gibbosa Span.		Fabaceae	Legume				On Panchgani Tableland
Canscora diffusa (Vahl) R.Br. ex Roem. & Schult.		Gentianaceae	Therophyte			On Tableland cliff	On Panchgani Tableland
Exacum lawii C.B.Clarke		Gentianaceae	Therophyte	E	LC	In the vicinity of Tableland	On Panchgani Tableland
Exacum pumilum Griseb.		Gentianaceae	Therophyte	E			On Panchgani Tableland

Species name (Accepted as per POWO)	Synonyms	Family	Life form	Ende-micity	IUCN Red List	Recorded by Blatter (1909)	Recorded by authors in 2024
Swertia densifolia (Griseb.) Kashyapa	*Swertia decussata* Nimmo ex C.B.Clarke / *Ophelia densifolia* Griseb.	Gentianaceae	Therophyte	E		On Panchgani Tableland	On Panchgani Tableland
Lomatogonium minus (Griseb.) Fernald	*Swertia minor* (Griseb.) Knobl. / *Ophelia minor* Griseb.	Gentianaceae	Therophyte	E		On Panchgani Tableland	On Panchgani Tableland
Hydrocharita sp.		Hydrocharitaceae	Hydrophyte				On Panchgani Tableland
Curculigo orchioides Gaertn.		Hypoxidaceae	Geophyte			On Panchgani Tableland	On Panchgani Tableland
Hypoxis aurea Lour.		Hypoxidaceae	Geophyte				On Panchgani Tableland
Coleus strobilifer (Roxb.) A.J.Paton	*Anisochilus carnosus* (L.f.) Wall. ex Benth var. *glabrior*	Lamiaceae	Therophyte	E			On Panchgani Tableland
Pogostemon stellatus (Lour.) Kuntze	*Dysophylla stellata* (Lour.) Benth. ex Wall.	Lamiaceae	Therophyte	E	LC	On Panchgani Tableland	On Panchgani Tableland
Isodon lophanthoides (Buch.-Ham. ex D.Don) H.Hara		Lamiaceae	Therophyte				On Panchgani Tableland
Leucas montana (Roth) Spreng.		Lamiaceae	Therophyte	E		On Panchgani Tableland	On Panchgani Tableland
Leucas stelligera Wall. ex Benth.		Lamiaceae	Therophyte			On Panchgani Tableland	On Panchgani Tableland
Pogostemon deccanensis (Panigr.) Press		Lamiaceae	Therophyte	E			On Panchgani Tableland
Utricularia albocaerulea Dalzell		Lentibulariaceae	Carnivores	E	VU	On Panchgani Tableland	On Panchgani Tableland
Utricularia arcuata Wight		Lentibulariaceae	Carnivores	E	LC		On Panchgani Tableland
Utricularia caerulea L.		Lentibulariaceae	Carnivores			On Panchgani Tableland	Absent
Utricularia praeterita P.Taylor		Lentibulariaceae	Carnivores	E	NT		On Panchgani Tableland
Utricularia striatula Sm.		Lentibulariaceae	Carnivores		LC		On Panchgani Tableland
Utricularia uliginosa Vahl		Lentibulariaceae	Carnivores		LC		On Panchgani Tableland
Linum mysorense B.Heyne ex Benth.		Linaceae	Therophyte			In the vicinity of Tableland	On Panchgani Tableland
Rotala belgaumensis S.R. Yadav, Malpure & Chandore		Lythraceae	Helophyte	E			On Panchgani Tableland
Rotala biglandulosa Arun Pr. & Sardesai		Lythraceae	Helophyte				On Panchgani Tableland
Rotala densiflora (Roth) Koehne		Lythraceae	Helophyte		LC		On Panchgani Tableland
Sida acuta Burm.f.		Malvaceae	Therophyte	E		On Tableland cliff	On Panchgani Tableland
Nymphoides hydrophyllum (Lour.) Kuntze	*Limnanthemum cristatum* (Roxb.) Griseb.	Menyanthaceae	Hydrophyte		LC	On Panchgani Tableland	Absent
Nymphoides indica (L.) Kuntze	*Limnanthemum indicum* Thw.	Menyanthaceae	Hydrophyte		LC	On Panchgani Tableland	Absent
Trigastrotheca pentaphylla (L.)	*Mollugo pentaphylla* L.	Molluginaceae	Therophyte			In the vicinity of Tableland	On Panchgani Tableland
Oenothera rosea L'Hér. ex Aiton		Onagraceae	Therophyte				On Panchgani Tableland
Eria reticosa Wight		Orchidaceae	Epiphyte	E			On Tableland cliff
Habenaria grandifloriformis Blatt. & McC.		Orchidaceae	Geophyte	E	NT		On Panchgani Tableland
Habenaria heyneana Lindl.		Orchidaceae	Geophyte	E		On Panchgani Tableland	On Panchgani Tableland
Habenaria suaveolens Dalzell	*Habenaria panchganiensis* Sant & Kap.	Orchidaceae	Geophyte	E		On Panchgani Tableland	On Panchgani Tableland

Species name (Accepted as per POWO)	Synonyms	Family	Life form	Ende-micity	IUCN Red List	Recorded by Blatter (1909)	Recorded by authors in 2024
Habenaria rariflora A.Rich.		Orchidaceae	Geophyte	E	L C		On Panchgani Tableland
Peristylus densus (Lindl.) Santapau & Kapadia		Orchidaceae	Geophyte	E			On Panchgani Tableland
Peristylus stocksii (Hook.f.) Kraenzl.		Orchidaceae	Geophyte				On Panchgani Tableland
Porpax jerdoniana (Wight) Rolfe	*Porpax lichenora* (Lindl.) T.Cooke	Orchidaceae	Epiphyte	E		On Panchgani Tableland	On Tableland cliff
Striga densiflora (Benth.) Benth.		Orobanchaceae	Hemiparasite				On Panchgani Tableland
Striga gesnerioides (Willd.) Vatke	*Striga orobanchoides* (R. Br.) Beth.	Orobanchaceae	Hemiparasite			On Panchgani Tableland	On Panchgani Tableland
Biophytum sensitivum DC.		Oxalidaceae	Therophyte				On Panchgani Tableland
Oxalis corniculata L.		Oxalidaceae	Geophyte			On Panchgani Tableland	On Panchgani Tableland
Argemone mexicana L.		Papavaeraceae	Therophyte			In the vicinity of Tableland	On Panchgani Tableland
Glossostigma diandrum (L.) Kuntze		Phrymaceae	Helophyte		LC		On Panchgani Tableland
Glossostigma elatinoides (Benth.) Hook.f.		Phrymaceae	Helophyte				On Panchgani Tableland
Arthraxon hispidus (Thunb.)		Poaceae	Graminoid				On Panchgani Tableland
Arthraxon raizadae S.K.Jain, Hemadri & Deshp.		Poaceae	Graminoid	E			On Panchgani Tableland
Arthraxon villosus C.E.C.Fisch.		Poaceae	Graminoid				On Panchgani Tableland
Arundinella spicata Dalzell		Poaceae	Graminoid	E		In the vicinity of Tableland	On Panchgani Tableland
Chloris pycnothrix Trin.		Poaceae	Graminoid				On Panchgani Tableland
Coelachne minuta Bor.		Poaceae	Graminoid	E	LC		On Panchgani Tableland
Cynodon dactylon (L.) Pers.		Poaceae	Graminoid			On Panchgani Tableland	On Panchgani Tableland
Dichanthium armatum (Hook.f.) Blatt. & McCann		Poaceae	Graminoid				On Panchgani Tableland
Dimeria ornithopoda Trin.	*Dimeria ornithopoda* var. *megalantha* Bor	Poaceae	Graminoid		LC	On Panchgani Tableland	On Panchgani Tableland
Dimeria sp.		Poaceae	Graminoid				On Panchgani Tableland
Echinochloa crus-galis (L.) P.Beauv.		Poaceae	Graminoid		LC		On Panchgani Tableland
Echinochloa crus-galli subsp. *utilis*	*Echinochloa crus-galli* f. *aristata* (Vasinger) Morariu	Poaceae	Graminoid				On Panchgani Tableland
Eleusine indica (L.) Gaertn.		Poaceae	Graminoid		LC		On Panchgani Tableland
Eragrostis nigra Nees ex Steud.		Poaceae	Graminoid				On Panchgani Tableland
Eragrostis tenella (L.) P. Beauv. ex Roam. & Schult.		Poaceae	Graminoid	E			On Panchgani Tableland
Eragrostis unioloides (Retz.) Nees ex Steud.		Poaceae	Graminoid				On Panchgani Tableland
Eulalia shrirangii Salunkhe & Potdar		Poaceae	Graminoid	E			On Panchgani Tableland
Pseudopogonatherum trispicatum (Schult.) Ohwi	*Eulalia trispicata* (Schult.) Henrard	Poaceae	Graminoid				On Panchgani Tableland
Glyphochloa forficulata (C.E.C.Fisch.) Clayton		Poaceae	Graminoid	E			On Panchgani Tableland
Heteropogon contortus (L.) P.Beauv. ex Roem. & Schult.		Poaceae	Graminoid				On Panchgani Tableland
Indopoa paupercula (Stapf) Bor ex Ramamoorthy	*Tripogon pauperculus* Staph	Poaceae	Graminoid		LC		On Panchgani Tableland

Species name (Accepted as per POWO)	Synonyms	Family	Life form	Ende-micity	IUCN Red List	Recorded by Blatter (1909)	Recorded by authors in 2024
Isachne elegans Dalzell		Poaceae	Graminoid	E	LC		On Panchgani Tableland
Isachne globosa (Thunb. ex Murray) Kuntze		Poaceae	Graminoid	E	LC		On Panchgani Tableland
Isachne lisboae Hook.f.	*Isachne lisboae* Hook.f.	Poaceae	Graminoid	E			On Panchgani Tableland
Isachne swaminathanii V.Prakash & S.K.Jain		Poaceae	Graminoid		EN		On Panchgani Tableland
Ischaemum impressum Hack		Poaceae	Graminoid	E			On Panchgani Tableland
Jansenella griffithiana (C.Muell.) Bor		Poaceae	Graminoid				On Panchgani Tableland
Oryza rufipogon Griff.		Poaceae	Graminoid		LC		On Panchgani Tableland
Panicum sumatrense Roth		Poaceae	Graminoid	E	LC		On Panchgani Tableland
Paspalidium sp.	*Paspalidium* sp.	Poaceae	Graminoid				On Panchgani Tableland
Paspalum canarae (Steud.) Veldkamp	*Paspalum canarae* var. *fimbriatum* (Bor) Veldk	Poaceae	Graminoid		LC		On Panchgani Tableland
Paspalum distichum L.	*Paspalum paspalodes* (Michx.) Scribn.	Poaceae	Graminoid		LC		On Panchgani Tableland
Paspalum scrobiculatum L.		Poaceae	Graminoid		LC	In the vicinity of Tableland	On Panchgani Tableland
Pseudanthistiria heteroclita (Roxb.) Hook.f.		Poaceae	Graminoid				On Panchgani Tableland
Setaria pumila (Poir.) Roem. & Schult.		Poaceae	Graminoid				On Panchgani Tableland
Sporobolus indicus (L.) R.Br.		Poaceae	Graminoid		LC		On Panchgani Tableland
Themeda quadrivalvis (L.) Kuntze		Poaceae	Graminoid	E			On Panchgani Tableland
Tripogon bromoides Roth.	*Tripogon bromoides* Roem. & Schult.	Poaceae	Graminoid				On Panchgani Tableland
Polygala persicariifolia DC.		Polygalaceae	Therophyte	E		In the vicinity of Tableland	On Panchgani Tableland
Persicaria chinensis (L.) H.Gross	*Persicaria chinensis* (L.) Nakai	Polygonaceae	Therophyte				On Panchgani Tableland
Persicaria nepalensis (Meisn.) H. Gross	*Polygonum alatum* (Meisn.) H.Gross	Polygonaceae	Therophyte			On Tableland cliff	On Panchgani Tableland
Polygonum plebeium R.Br.		Polygonaceae	Therophyte		LC	On Tableland cliff	On Panchgani Tableland
Anagallis arvensis L.		Primulaceae	Therophyte			On Tableland cliff	On Panchgani Tableland
Thalictrum dalzellii Hook.		Ranunculaceae	Therophyte	E			On Panchgani Tableland
Ziziphus jujuba Mill.		Rhamnaceae	Therophyte		LC		On Panchgani Tableland
Oldenlandia stocksii Hook.f.	*Hedyotis stocksii* (Hook.f.) R.S.Rao & Hemadri	Rubiaceae	Therophyte				On Panchgani Tableland
Neanotis subitilis (Miq.) Govaerts ex Punekar & Lakshmin.	*Neanotis foetida* (Dalzell) W.H.Lewis	Rubiaceae	Therophyte	E			On Panchgani Tableland
Neanotis lancifolia (Hook.f.) W.H.Lewis		Rubiaceae	Therophyte	E			On Panchgani Tableland
Nicandra physalodes (L.) Gaertn.		Rubiaceae	Therophyte				On Panchgani Tableland
Spermacoce pusilla Wall.		Rubiaceae	Therophyte				On Panchgani Tableland
Spermadictyon suaveolens Roxb.		Rubiaceae	Therophyte				On Panchgani Tableland
Rhamphicarpa fistulosa (Hochst.) Benth.	*Rhamphicarpa longiflora* (Arn.) Bth.	Scrophulariaceae	Hemiparasite	E	LC		On Panchgani Tableland

Species name (Accepted as per POWO)	Synonyms	Family	Life form	Ende-micity	IUCN Red List	Recorded by Blatter (1909)	Recorded by authors in 2024
Parasopubia delphiniifolia (L.) H.-P.Hofm. & Eb.Fisch.	*Sopubia delphinifolia* (L.) G.Don	Scrophulariaceae	Hemiparasite			On Panchgani Tableland	On Panchgani Tableland
Sopubia trifida Buch.-Ham, ex D.Don		Scrophulariaceae	Therophyte			On Panchgani Tableland	On Panchgani Tableland
Verbascum coromandelianum (Vahl) Hub.-Mor.	*Verbascum chinensis*	Scrophulariaceae	Therophyte				On Panchgani Tableland
Solanum virginianum L.		Solanaceae	Therophyte				On Panchgani Tableland
Lantana camara L.		Verbenaceae	Therophyte			On Panchgani Tableland	On Panchgani Tableland
Curcuma neilgherrensis Wight		Zingiberaceae	Geophyte				On Tableland cliff
Curcuma caulina (J.Graham) Baker	*Hitchenia caulina* (J.Graham) Baker	Zingiberaceae	Geophyte	E	EN	On Tableland cliff	On Tableland cliff

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OPEN ACCESS

COMMUNICATION

Distribution of Smooth-coated Otters (Mammalia: Carnivora: Mustelidae: *Lutrogale perspicillata*) in the coastal mangroves of Maharashtra: a case study of Savitri River and Kalinje Mangrove Ecosystem

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Abstract: This study aimed to document the distribution of Smooth-coated Otters *Lutrogale perspicillata* within two ecologically distinct but poorly studied habitats in Maharashtra.: the Savitri River covering a 65 km stretch from Mahad to Bankot in Ratnagiri District, and the Kalinje Mangrove encompassing 8.4 km^2 in Raigad District. Using indirect sign surveys, we estimated that otters occupied 36% of the surveyed length of the Savitri River and 13% of the Kalinje Mangrove area. Encounter rates were recorded at 0.65 signs/km in the Savitri River, and 0.41 signs/km in the Kalinje Mangrove. These observations contribute to baseline understanding of otter habitats in these landscapes and offer useful insights for conservation. Promoting long-term protection of otters will require collaboration with diverse stakeholders including fisherfolk, students and local forest departments to foster awareness, encourage co-existence, and integrate otter conservation into community-based stewardship.

Keywords: Encounter rate, GIS, habitat, otter conervation, percentage of occurrence, research, survey.

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Competing interests: The authors declare no competing interests.

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Author contributions: SRP has conceptualized and designed they study; conducted field surveys, sign surveys, and data collection; performed data analysis and interpretation; and led manuscript writing and revisions. MM provided project faciliation, administration support, and coordination with revelant authorites, and contributed inputs towards study planning and implementation. Both authors reviewed and approved the final manuscript.

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INTRODUCTION

India is home to three otter species: the Smooth-coated Otter *Lutrogale perspicillata*, the Asian Small-clawed Otter *Aonyx cinerea*, and the Eurasian Otter *Lutra lutra*. Since most freshwater sites lie outside protected areas or Ramsar-listed wetland sites, otter populations face threats from land use changes. According to the Amendments in the Wild Life (Protection) Act, 2022, these otters are listed as Schedule species, prohibiting hunting, trapping, trade, or killing. Populations continue to decline due to unsustainable development, large-scale wetland conversion, deteriorating water quality, and poaching (Duplaix & Savage 2018).

In the tropics, protected areas occupy less than 10% of the total area, and a substantial amount of biodiversity exists outside protected areas (Schmitt et al. 2009). In landscapes lacking protected areas, human-modified landscapes often provide critical habitats and refuges for biodiversity (Chazdon et al. 2009). As protected areas continue to shrink and human-modified landscapes continue to expand, conservation and research attention must be focused on these heterogeneous landscapes, especially river basins. Conservation of charismatic species like otters in such a heterogeneous landscape is critical, as they occupy some of the best habitats available for them. The habitats are essential for otters, providing space for spraint deposition, grooming, and creation of holts (dens), which play a vital role in their social interactions and in marking territories.

Our main objective is to improve the understanding of Smooth-coated Otters in the Kalinje Mangrove of Raigad District, and along the Savitri River between Raigad and Ratnagiri districts of Maharashtra.

METHODS

Study Area

Kalinje (18.039° N, 73.029° E) is a small village situated between Harihareshwar and Shrivardhan, known for its stunning mangroves and diverse wildlife. Most people residing here are either fishermen, drivers, or employees. In recent years, mangrove tourism has become popular as more and more people are recognizing the values of this unique ecosystem. The Mangrove Foundation of the Maharashtra Forest Department has undertaken a community-based conservation initiative, called Kalinje Ecotourism, for the upliftment of local communities.

Savitri River (18.048° N, 73.165° E) is one of five rivers originating from Mahabaleshwar in Maharashtra. It flows through Bankot Village en route to the Arabian Sea, and forms a natural boundary between Ratnagiri and Raigad districts. Most villagers residing on the banks of the Savitri are involved in fishing and agriculture.

Baseline data on the distribution of otters in Raigad, Maharashtra.

Sign surveys: For the study of the distribution of otters and their habitat preference, the sign survey method was used. Sign surveys are generally done by looking for indirect evidence of the species such as scat/spraints (Image 11), latrines, pugmarks (Image 8), leftover food, and dens/burrows/holts (Images 9 & 10). Our study area was divided into multiple transects of 1,000 x 50 m (Prakash et al. 2012; Atul et al. 2014; Patil & Yardi 2022). To ensure spatial independence, transects werelaid at intervals of 500 m. The study area was thoroughly surveyed for “otter sites” (signs/evidence of otter presence) and “non-otter sites” (signs/evidence of otter absence), recording:

a. Date and time of the survey.
b. GPS location.
c. The presence & absence of otter signs.
d. Anthropogenic activities or any other disturbances.
e. Den locations: The active dens were noted as “active plots” and inactive dens were marked as “inactive plots” (Images 9 & 10).

Spatial habitat data: GIS software was used to map down vegetation cover, otter distribution, and denning sites along the river stretch. As vegetation cover plays a major role in the selection of denning sites, it served as an aid in the evaluation of potential wildlife habitats. Observed anthropogenic activities along the river stretch were also mapped to understand the impact on the distribution pattern of otters.

Analysis: To estimate the percentage of area occupied by otters, we used Principal Component Analysis (PCA) coupled with logistic regression. These scores were considered as percentages of the Occurrence of Otters.

Encounter rate method: Based on the survey/ transect length, which was Savitri River as well as Kalinje Mangrove. The transect length was kept the same throughout the site and duration (Manjrekar & Prabu 2014).

$$\text{Encounter Rate} = \frac{\text{No. of sightings}}{\text{Total km covered}}$$

The analysis was carried out separately for both Savitri and Kalinje. We also analysed seasonal encounter rates

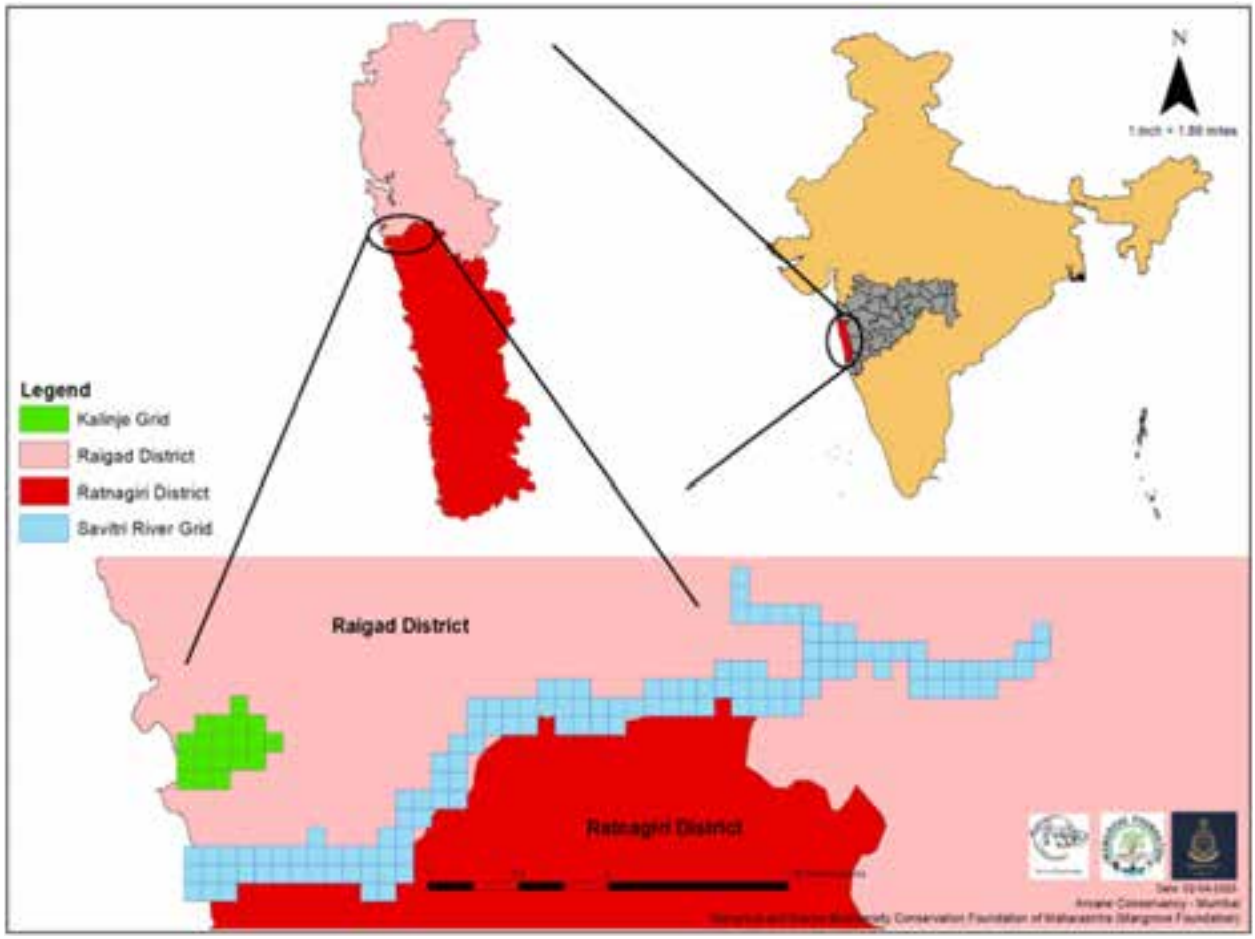

Image 1. Map showing the Savitri River (field site) situated between Raigad and Ratnagiri districts.

by considering pre-monsoon and post-monsoon surveys.

RESULTS

Savitri River

To achieve the study's objectives, a 1 x 1 km grid was deployed along the entire Savitri River, starting from Mahad to Velas, using Google Earth and ArcGIS software. A total of 124 grids were created along the Savitri River (Image 2).

Of these, 103 transect surveys were conducted, covering the river from Bankot to Mahad on the right bank and from Mahad to Bagmandala on the left bank. Certain sites, such as Umroli and Nigdi, remained inaccessible owing to presence of crocodiles (Image 3). Out of the 124 grids, 92 were surveyed, with 34 grids showing positive otter presence.

From the 103 surveys conducted along the Savitri River, 37 surveys yielded positive otter signs (Image 7), indicating that 36% of the area was occupied by otters. The sign surveys were influenced by tidal variations (high and low tides), which affected the detection probability of signs. In total, 67 otter signs were observed during the surveys, including denning areas (holts) and defecation areas, primarily on mangrove island patches.

Kalinje Mangrove

A total of 19 grids were created in the Kalinje Mangrove (Image 4). Each grid had a survey transect with fixed replicates. These surveys assessed the presence or absence of otters, recorded habitat parameters, and noted any threats to the habitat. Additionally, camera trapping was conducted at selected sites based on the presence of direct and indirect otter signs. A total of 296 hours were spent on camera trapping across the Kalinje and Savitri areas (Images 5 & 6).

In the Kalinje Mangrove, 19 grids were surveyed, and 39 transects were conducted. Priority was given to active otter sites to maximize sightings. Surveys were

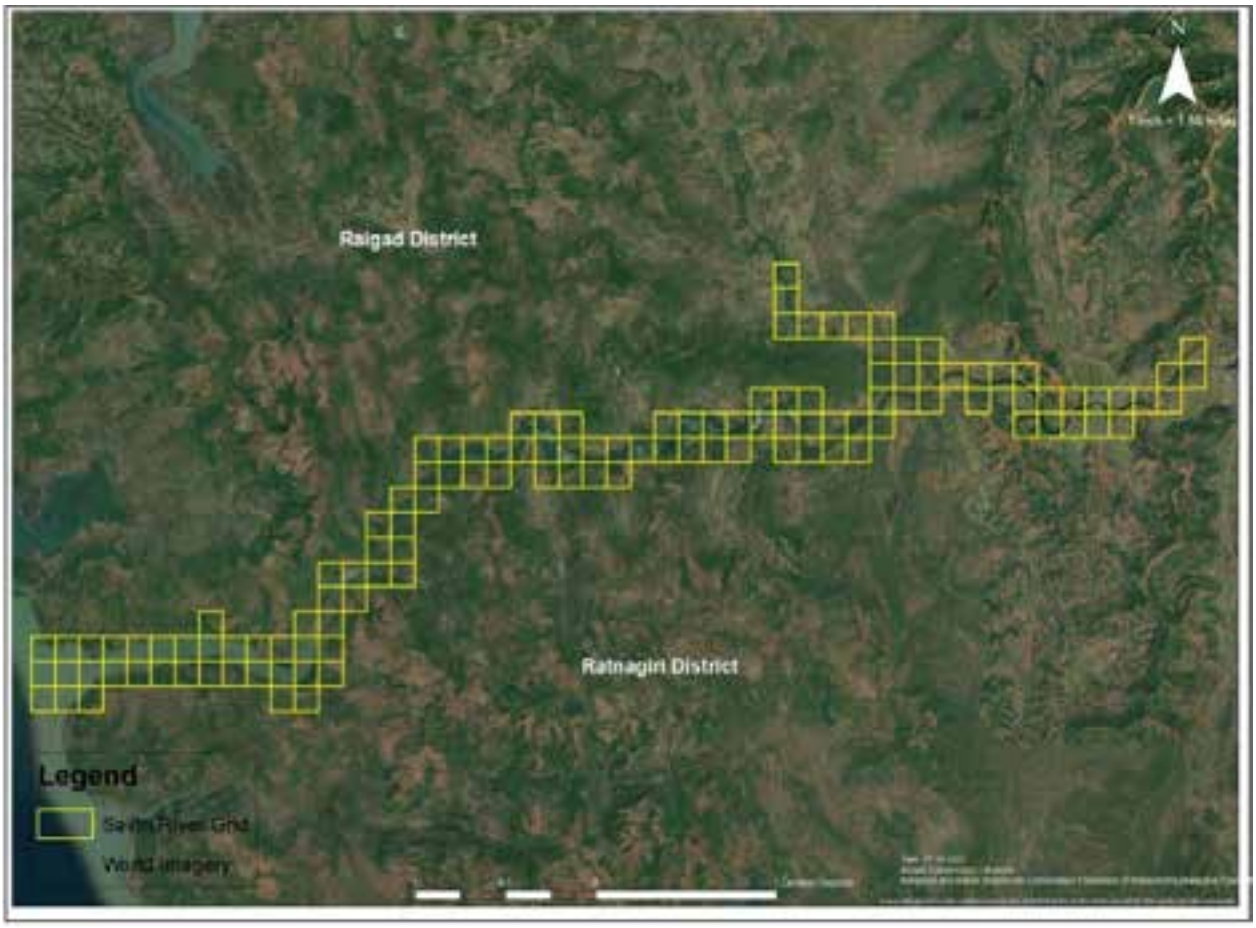

Image 2. Map of survey grid deployed on the Savitri River from Mahad to Velas.

Image 3. Drone shot of a crocodile basking, observed during the otter survey. © Siddharth Pednekar - Arcane Conservancy Trust.

Image 4. Map showing 1 x 1 km survey grid deployed on the Kalinje Mangrove.

Image 5. Camera trap image showing Smooth-coated Otter resting in a mangrove patch in Kalinje. © SArcane Conservancy Trust.

Image 6. Camera trap image showing a pair of Smooth-coated Otters near Shipole Village on Savitri River. © Arcane Conservancy Trust.

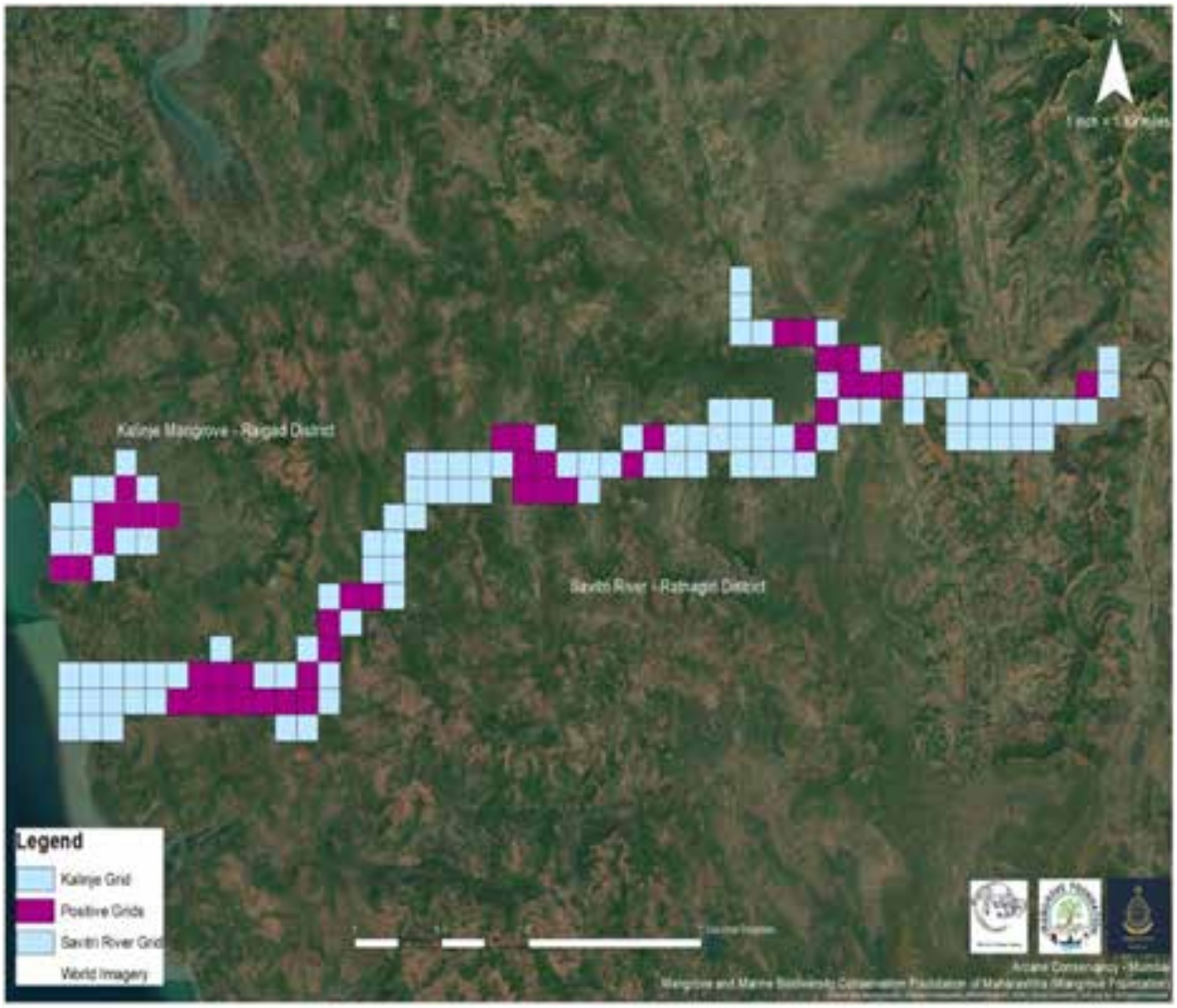

Image 7. Map showing positive field sites/ grids with observed otter signs.

Table 1. Results of principal component analysis with eigenvalues, percentage of variance, and the contribution of habitat variable of Smooth-coated Otters in Savitri River (PC1) and Kalinje Mangrove (PC2).

Variable	PC1 – Savitri River	PC2 – Kalinje Mangrove
Main River	0.740	0.180
Creek	0.690	0.540
Bandh	0.710	0.480
Sandy Bank	0.650	0.320
Farmland	-0.600	-0.620
Rocky Bank	-0.670	-0.220
Elgen Values	4.31	1.54
% Variance	**35.92%**	**12.82%**
%Cumulative Variance	**35.92%**	**48.74%**

Image 8. Otter pugmark. © Arcane Conservancy Trust.

Table 2. Table summarizing the key results for both study locations.

Parameters	Savitri River	Kalinje Mangrove
Total length	65.26 km	8.40 km^2
Total number of grids	124	19
Total number of grids surveyed	92	18
Total number of transects carried	103	39
Encounter rate	0.65 signs/km	0.41 signs/km
Detection probability pre-monsoon	0.53 signs/km	0.66 signs/km
Detection probability post-monsoon	0.67 signs/km	0.38 signs/km

Image 9. An inactive otter den (debris fallen, entrance covered with twigs & leaves). © Arcane Conservancy Trust.

also carried out at and near fish and prawn farms, where informal interviews with workers confirmed regular otter visits. A total of 12 boat surveys were also conducted. Two FnX IR Camera traps were deployed in areas with a high concentration of otter signs, such as defecation or denning areas.

Of the 19 grids surveyed, 8 showed otter signs in the Kalinje Mangrove (Image 7). From the 39 surveys conducted, five yielded positive otter signs, contributing to an estimated 12.82% of the area occupied by otters. A total of 16 otter signs were recorded, with six signs observed in mangrove patches and 10 signs on muddy embankments near prawn farms, particularly on the 'bandhs' (Hindi: Mud embankments) of abandoned prawn farms.

Comparative Seasonal Analysis

Between May 2022 and February 2023, 103 surveys were conducted along the Savitri River and 39 transects in the Kalinje Mangrove. The total distance covered was 103 km for the Savitri River and 39 km for the Kalinje Mangrove. The encounter rate for otter signs (pugmarks and spraint) was 0.65 signs/km along the Savitri River and 0.41 signs/km in the Kalinje Mangrove.

Seasonal patterns were analyzed to understand otter

Image 10. Active otter den. © Arcane Conservancy Trust.

Image 11. Otter spraint/ scat (presence of fish scales and small bones). © Arcane Conservancy Trust.

detection probability during pre- and post-monsoon seasons (May–June and November–January). Due to the shorter study duration in the pre-monsoon period, achieving the same number of surveys for each season was challenging.

For the pre-monsoon season, three surveys were conducted in the Kalinje Mangrove and 15 in the Savitri River, resulting in detection probabilities of 0.53 signs/km and 0.66 signs/km, respectively. In the post-monsoon season, 88 transects were conducted along the Savitri River and 36 in the Kalinje Mangrove, yielding encounter rates of 0.67 signs/km and 0.38 signs/km, respectively.

CONCLUSIONS

The estimated proportion of the length of Savitri River occupied by Smooth-coated Otters was 36% based on our sign survey. This suggests that otters are relatively widespread across approximately one-third of the surveyed areas, utilizing different sections of the river for foraging, resting, denning, and other activities. In contrast, the Kalinje Mangrove showed a lower occupancy rate of 12.8%, indicating a more limited distribution of otters in this habitat.

Our encounter rates of 0.65 signs/km in the Savitri River and 0.41 signs/km in the Kalinje Mangrove reflect the challenges of detecting otter signs in dynamic environments where tides regularly submerge and expose the riverbanks. This fluctuation likely reduces the visibility of otter signs, impacting the detection probability and suggesting that our estimates may be conservative.

The principal component analysis (PCA) further supports these observations. In Savitri River, PC1 accounted for 35.9% of the variance and revealed that otter presence is positively associated with key riverine features such as main river channels, creeks, bandhs, and sandy banks. These variables were consistently linked to habitat use, underscoring their ecological importance. In contrast, PC2 in the Kalinje Mangrove accounted for 12.8% of the variance, with otters showing a preference for creeks and bandhs, although the overall influence of habitat variables was lower, reflecting limited habitat suitability in this mangrove-dominated system. Additionally, farmland and rocky banks were negatively associated with otter presence across both landscapes, likely due to disturbance and poor suitability for resting and denning. These results suggest that otters prefer relatively undisturbed, structurally diverse aquatic environments, and actively avoid modified banks.

The survey suggests that without such baseline data, there will be a lack of informed decision-making, which might lead to a further decline in the population of the species or its suitable habitat. The presence/absence data will be vital in creating conservation hotspots.

Table 3. GPS locations of otter signs.

	Latitude	Longitude	Type of sign	Species ID
1	17.985	73.081	Defecation area	Smooth-coated Otter
2	17.98586	73.084	Scat/Spraint	Smooth-coated Otter
3	17.985	73.085	Scat/Spraint	Smooth-coated Otter
4	17.985	73.086	Scat/Spraint	Smooth-coated Otter
5	17.984	73.087	Scat/Spraint	Smooth-coated Otter
6	17.984	73.087	Scat/Spraint	Smooth-coated Otter
7	17.981	73.092	Scat/Spraint	Smooth-coated Otter
8	17.981	73.092	Scat/Spraint	Smooth-coated Otter
9	17.981	73.092	Scat/Spraint	Smooth-coated Otter
10	17.981	73.094	Scat/Spraint	Smooth-coated Otter
11	17.98094	73.095	Defecation area	Smooth-coated Otter
12	17.979	73.098	Defecation area	Smooth-coated Otter
13	17.980	73.098	Defecation area	Smooth-coated Otter
14	18.04178	73.038	Defecation area	Smooth-coated Otter
15	18.048	73.046	Defecation area	Smooth-coated Otter

A significant amount of otter distribution lies outside protected areas, emphasizing the need for research projects that can generate information on such species. This information could be useful in future with respect to undertaking sustainable developmental activities and implementing effective conservation measures (Defries et al. 2010).

Advances in technology such as camera traps have proven invaluable in this research. These tools allow for the non-intrusive monitoring of otters, providing insights into their behaviour and activity patterns.

In conclusion, this study highlights the need for ongoing research and the integration of modern technologies in wildlife conservation. Our data suggest that otters have a relatively widespread distribution over approximately one-third of the surveyed area, utilizing different sections of the river for foraging, resting, denning, and other activities.

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Image 12. A Smooth-coated Otter foraging through the mangroves. © Arcane Conservancy Trust.

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COMMUNICATION

Population dynamics and habitat preference in Painted Stork *Mycteria leucocephala* and Woolly-necked Stork *Ciconia episcopus* in Dighal Wetland, Jhajjar, Haryana, India

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Abstract: The current study looks at the Painted Stork *Mycteria leucocephala* and Woolly-necked Stork *Ciconia episcopus* populations and their habitat utilization in the wetlands of Dighal, Haryana. The distribution and abundance of both species were evaluated through field surveys in various wetland habitats. The findings show that the Painted Stork population exhibited considerable habitat fluctuation, indicating a strong preference for specific wetland locations that offer the best chances for foraging and breeding. The range of the Woolly-necked Stork, on the other hand, was comparatively consistent throughout various habitats, suggesting a wider ecological tolerance. Painted Stork was most commonly observed in wetlands, whereas Woolly-necked Stork was observed in marshes and dry areas. Among the different habitats, the highest number of individuals of Painted Stork (7.41 ± 1.83) was seen in wetland, and Woolly-necked Stork (0.75 ± 0.37) was seen in agricultural land. The lowest number of individuals of Painted Stork (2.66 ± 0.69) was seen in barren land, and Woolly-necked Stork (0.66 ± 0.35) was seen in wetland. These results demonstrate importance of preserving Dighal's varied wetland habitats to sustain both specialized and generalist stork species and further knowledge of their ecological needs in a constantly shifting landscape.

Keywords: Anthropogenic activities, coexistence, conservation, line transect method, point count method, seasonal variation, species abundance, vegetation, waterbirds, wetland ecology.

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Author contributions: First author (S) has collected data, analyses the data and give this data a form of rough manuscript. Second author (SR) designed the study along with the first author and give the rough draft a final manuscript form.

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INTRODUCTION

There are 20 species of storks in the world, the majority of which are found in tropical or subtropical regions. With 20 living species, storks are a prominent pan-global freshwater flagship taxon listed on the IUCN Red List (Gula et al. 2023). This study concentrates on the Painted Stork *Mycteria leucocephala* Pennant, 1769 and Woolly-necked Stork *Ciconia episcopus* Boddaert, 1783, two of the least researched water-bird species worldwide (Sundar 2020). Both the species Painted Stork and Woolly-necked stork are large wading birds that belong to the family Ciconiidae under the order Ciconiiformes, found in India and southeastern Asia (Kalam & Urfi 2008), inhabit a variety of habitats including marshes, woods, agricultural regions, and freshwater wetlands (Sundar 2006; Kittur & Sunder 2021). The Painted Stork is distinguished by its colourful plumage, which consists of black, white, and a characteristic pinkish tint on its wings. Males and females are largely similar in appearance because there is little sexual dimorphism in this species. Males often have longer wingspans and more body mass than females, making them slightly larger (Kalam & Urfi 2006; Jangra & Verma 2024). Studies have shown that Painted Stork exhibit a strong preference for natural wetlands over rice fields and irrigation canals across seasons (Sundar 2006). While wetland saw relatively few Woolly-necked Stork sightings, with the majority being in agricultural fields (Kittur & Sunder 2020; Sundar 2020). Woolly-necked Stork is characterized as a single species of forest-nesting stork (Sundar 2020). The Painted Stork is listed as 'Least Concern' whereas the Asian Woolly-necked Stork conservation status is currently regarded as 'Near Threatened' on the IUCN Red List (IUCN 2025). The colonial nester Painted Stork is widely distributed in Sri Lanka and India (Tiwary & Urfi 2016). Woolly-necked Storks are solitary nesters that perch atop telephone towers, cliffs, and trees (Roshnath & Greeshma 2020). India is home to many Painted Storks which breed in mixed colonies and build their nests on trees that grow on islands in marshes, village tanks, urban water bodies, and parks (Tiwary & Urfi 2016; Byju et al. 2025). Woolly-necked Storks often exhibit seasonal migrations throughout the summer months in other parts of southern Asia (Sundar 2020). Numerous biological and environmental elements, including vegetation types, aquatic life, climate, and water quality, have a significant impact on the species diversity and population density of birds in wetland conditions (Bhawnani et al. 2025). Although there are regional variations in the species' population, habitat loss, pollution, and human activities pose dangers to it (Sundar 2020; Bhawnani et al. 2025). The composition and activities of wetlands are particularly impacted by urbanization. Urban wetlands offer vital habitat for birds and significant ecosystem services in an ecologically altered landscape, despite their simplified shape and diminished function (Suryawanshi & Sundar 2019; Kumar et al. 2025). The purpose of the study is to evaluate the two species' populations and distribution patterns, paying special attention to habitat usage and species-specific preference. Dighal Wetland is an ecologically significant location for these water-birds to forage and roost, as evident by the data showing notable variations in abundance across months and wetland microhabitats. The results of this study help to influence wetland management methods and provide useful baseline data for tracking conservation status. To protect the species, effective conservation measures are essential, especially since human pressures are still endangering their natural habitats. The development of conservation strategies for these species is urgently needed because of the extreme stresses on their habitat (Kalam & Urfi 2008).

MATERIALS AND METHODS

Study Area

The current study was conducted in the village of Dighal, Jhajjar District. The entire area of the state of Haryana is 1,834 km^2, of which 670 km^2 are dedicated to agricultural land (Anjali & Rana 2021). Dighal Wetland covers a total area of 131.1 ha (Parul & Kumar 2023, 2024). It is located in the north-west of the state of Haryana, 20 km from the district headquarters and 70 km from Delhi. The villages of Sampla to the east, Kalanaur to the west, Rohtak to the north, and Jhajjar to the south encircle it (Soni & Rana 2023). The district has a subtropical climate with four distinct seasons: summer (May–July), autumn (August–October), winter (November–January), and spring (February–April). The climate in district of Jhajjar is frigid in the winter and scorching in the summer. This area receives roughly 577 mm of annual rainfall, with the monsoon season accounting for over 75% of that total (Anjali & Rana 2022). Village Dighal was declared a potential Important Bird and Biodiversity Area (IBBA) (IN-HR-06) by BirdLife International (Anjali & Rana 2024). The Dighal wetland is suitable for migratory birds in the winter because they are encircled by irrigated agricultural fields with wheat and paddy crops, as well as tree species like Safeda (*Eucalyptus* spp.), Kikar (*Acacia* spp.), and Ber (*Ziziphus*

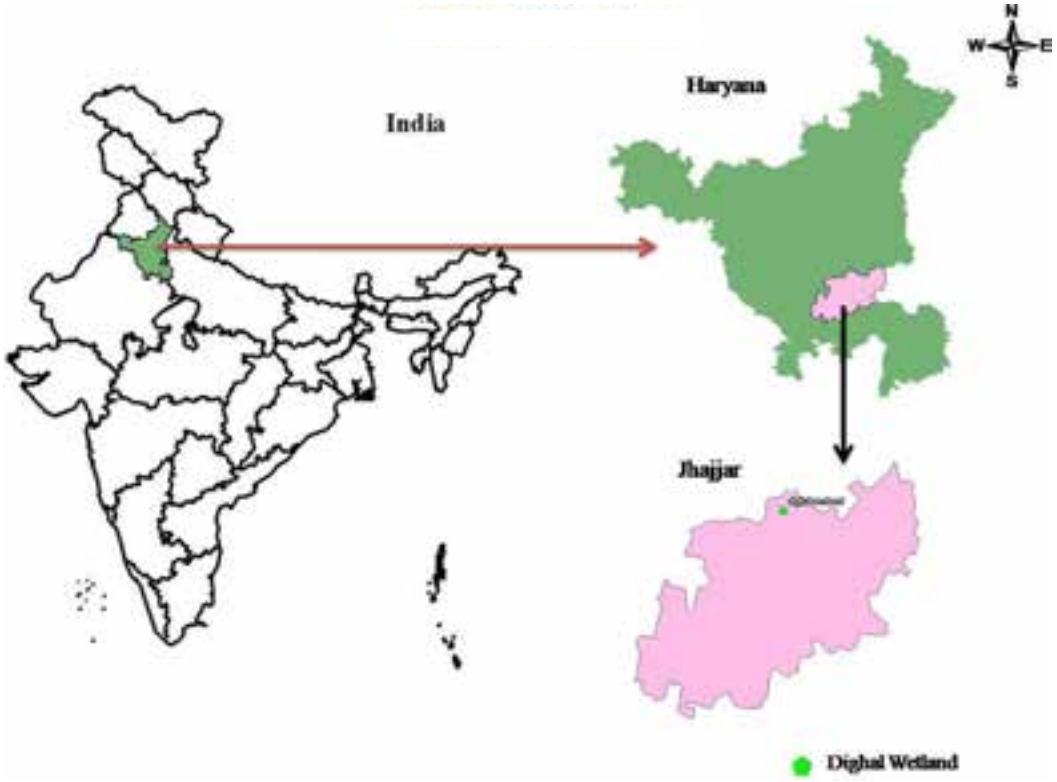

Figure 1. Map of study area showing location of Dighal Wetland, Jhajjar, Haryana, India.

spp.) along the wetland edges (Parul & Kumar 2023).

Bird Survey

The field visits were carried out from August 2024 to July 2025, twice a month. To assess the population dynamics of Painted Stork and Woolly-necked Stork**,** the point count and line transect methods were employed, depending on habitat openness and accessibility. Nikon Coolpix digital camera P950 and Nikon 10x50 binoculars were used for all observations. The study area was chosen after a reconnaissance survey, which involved preliminary visits to different wetland habitats in Dighal to assess habitat characteristics, bird presence, and anthropogenic activities. Based on these observations, Dighal Wetland was chosen for a detailed study of the Painted Stork and Woolly-necked Stork.

The point count locations were selected at fixed spots distributed across wetland's different habitats (open water, marshland, and agricultural areas) with broad visibility for 10 minutes, recording all individuals within a 100 m radius between 0600–1800 h in good weather. With this approach, all habitat types were covered, allowing for a reliable assessment of bird abundance. We observed species, their behaviour, and habitat. In dense or complex vegetation area, transects of 500–700 about 500 m to 1.5 km were laid to observe the storks, recording birds seen within 250 m and estimating their perpendicular distance. This combined approach ensured comprehensive coverage across diverse microhabitats for an accurate assessment of stork abundance and distribution. It is an easy technique that offers a consistent way to count birds throughout time or in different places. Randomly assigned point counts can serve as representative samples over a vast area. In order to verify the habitat composition for ground truthing, a single GPS location was recorded for each flock. Painted Stork and Woolly-necked Stork were recorded within 250 m on both sides of transect (Anjali & Rana 2024) (Figure 2).

Ecological studies employ the line transect method as a sampling approach to determine the distribution and abundance of species in various habitats. The population data for both storks were shown as mean ± standard error (SE). Using the one-way analysis of variance (ANOVA), the populations of Painted Stork and Woolly-necked Stork were compared at several locations. IBM SPSS 23 Software was used for all statistical analyses (Table 1).

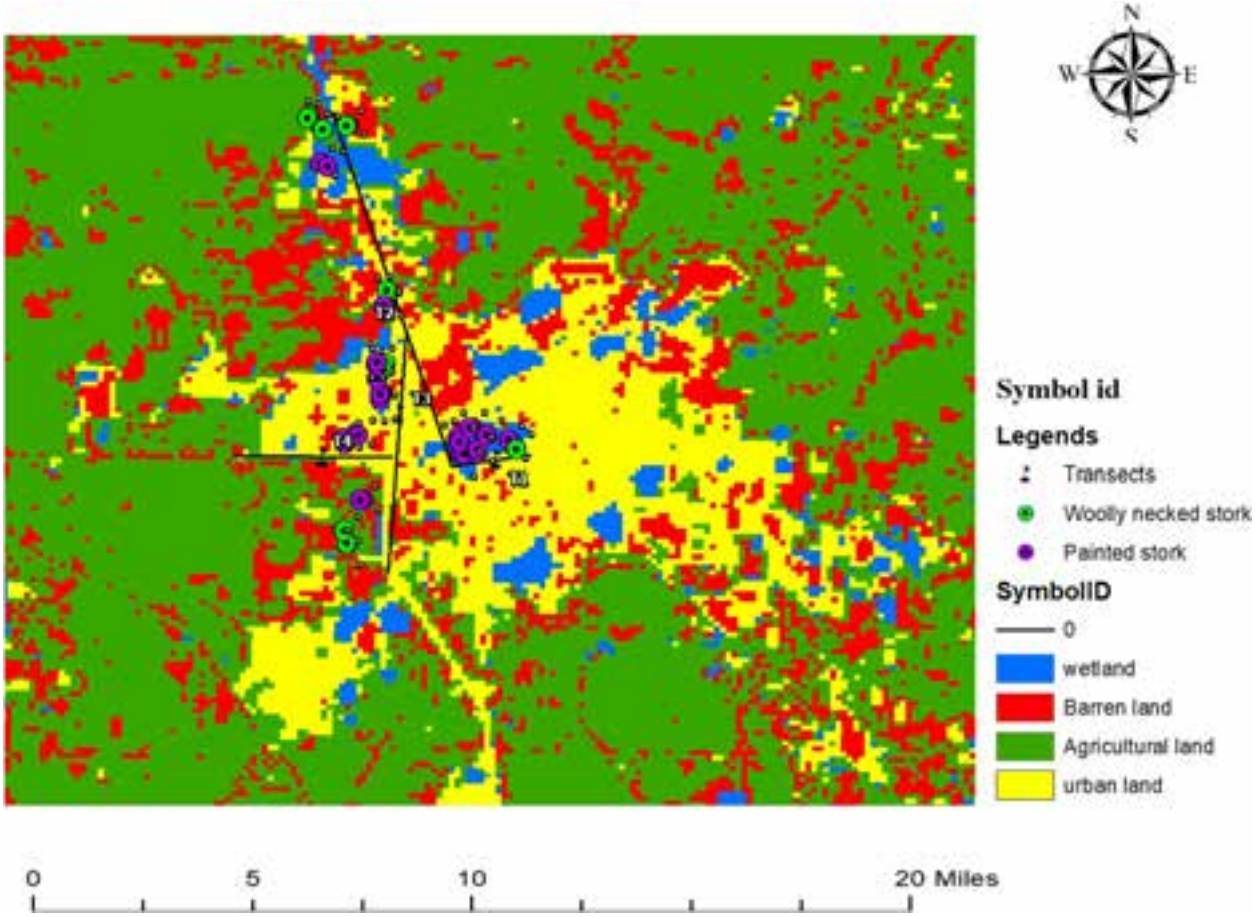

Figure 2. LULC map showing different habitat composition in Dighal Wetland.

RESULTS

In this study, a total of 169 Painted Storks and 31 Woolly-necked Storks were observed from the distinct habitats. Painted Storks were mostly recorded from Wetlands, followed by agricultural, and barren land. On the other hand, Woolly-necked Storks were dominant in marshes and arid areas (Figure 2). Among the different habitats, the highest number of individuals of Painted Stork (7.41 ± 1.83) was seen in the wetland and Woolly-necked Stork (0.75 ± 0.37) was observed in agricultural land. The lowest number of individuals of Painted Stork (2.66 ± 0.69) was seen in barren land and Woolly-necked Stork (0.66 ± 0.35) was seen in wetland, respectively. The habitat-wise population of Painted Stork varies significantly ($P < 0.05$), whereas that for Woolly-necked Stork shows no statistically significant difference ($P > 0.05$) (Table 1). Population abundance of Painted Stork was found to be significantly greater in wetland habitat ($P < 0.05$, $F = 3.78$) as compared to agricultural and barren landscapes; similarly, the population of Woolly-necked Stork was also found to be significantly greater in agricultural land area ($P > 0.05$, $F = 0.61$) as compared to other habitats, as shown in Table 1. During August 2024–July 2025, there was a discernible seasonal change in the Painted Stork and Woolly-necked Stork abundance. The winter months (December to February) had the maximum numbers of both species, peaking in mid-December. There was significantly more Painted Stork (84.5%) than Woolly-necked Stork (15.5%). On the other hand, lesser abundance of both species was observed in the summer season (May to July). From October to December, when the migratory season began, a steady rise in population (i.e., total number of individuals recorded in each habitat type) was observed (Figure 3).

DISCUSSION

The current study highlights the distinct ecological distinctions between the Painted Stork and Woolly-

Table 1. Habitat-wise population of Painted Stork and Woolly-necked Stork from August 2024 to July 2025.

Habitat	Painted Stork				Woolly-necked Stork			
	N	%	Mean ± standard error	95% CI (Min–Max)	N	%	Mean ± standard error	95% CI (Min–Max)
Wetland	89	52.66%	7.41 ± 1.83	2.00–24.00	8	25.80%	0.66 ± 0.35	0.00–4.00
Agricultural land	48	28.40%	4.00 ± 0.95	1.00–13.00	14	45.16%	0.75 ± 0.37	0.00–4.00
Barren land	32	18.93%	2.66 ± 0.69	0.00–9.00	9	29.03%	1.16 ± 0.29	0.00–3.00
P-value	0.03				0.59			
F-value (F)	3.78				0.61			

N—Total number of observations | CI—Confidence interval. All values are presented in mean ± standard error by one-way ANOVA, significant level at (P <0.05).

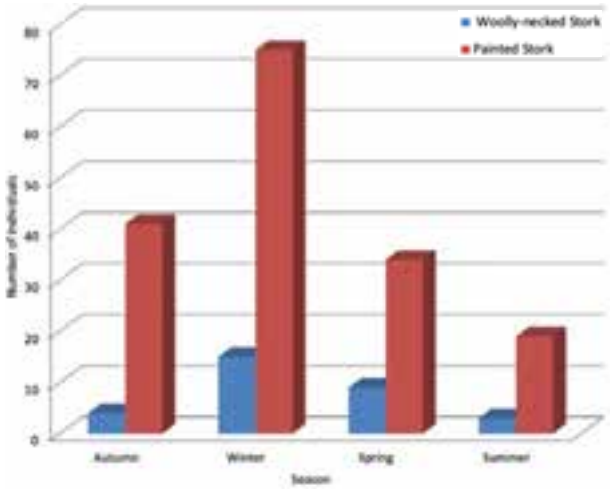

Figure 3. Showing Seasonal variations in population of Painted Stork and Woolly-necked Stork across one yearat the study area.

necked Stork in the Dighal Wetland, Haryana. The current study demonstrated distinct seasonal changes in the Painted Stork and Woolly-necked Stork populations at Dighal Wetland. In addition to migratory movement from other areas, the availability of open water and foraging grounds during this season may be the reason for the greater winter abundance of Painted Storks. Painted Stork was more commonly found in areas around and near waterbodies and open marshes, while the Woolly-necked Stork usually used agricultural fields, shallow ditches, and canal sides. This variation in how habitat is used could be a result of differences in foraging tactics, prey availability, and preferred water depth. The ready availability of fish and other aquatic prey in shallow waters is probably the reason why the Painted Stork preferred wetlands (Zakaria et al. 2023; Bhawnani et al. 2025), consistent with findings of this study. The Woolly-necked Stork, on the other hand, exhibits its adaptation to human-modified ecosystems by using natural and agricultural habitats (Kittur & Sundar 2021), a finding supported by this study. The two species may coexist more easily and compete less if their habitats are segregated. A species-specific approach to foraging and habitat selection is shown by the Woolly-necked Stork, particularly for peripheral areas like ditches and agricultural fields. The greater number of Painted Storks and Woolly-necked Storks were found in wetland habitat and agricultural land, respectively**.** Whereas smallest number of Painted Storks were found in agricultural land and barren land and Woolly-necked Stork were found in wetland and barren land. This study shows that by using different areas of waterbodies, Painted Stork is extremely suited to life in urban wetland. Furthermore, the study's findings show that Painted Storks favour areas with fewer human disturbances and predatory risks, which ensure a secure foraging and breeding environment, and help to sustain the species' population (Zakaria et al. 2023), a supporting observation with this study. According to rough population estimates, the extent of this species (Woolly-necked Stork) population was previously underestimated, and the greatest known global population of this species lives in agricultural environments (Kittur & Sunder 2020). The present findings also agree with the earlier research which indicated that flock size and habitat utilization varied significantly by season and location, and Woolly-necked Stork are also adaptable to shifting conditions on agricultural landscapes (Kittur & Sunder 2020). Storks may have been drawn to canals because of the decreased human use of irrigation canals and the small wetlands that formed alongside them from water escaping the canals. Furthermore, canals had longer hydroperiods than most marshes, whereas wetlands were highly seasonal (Kittur & Sundar 2021).

Both the Storks face several significant threats, including the degradation of feeding habitats, overfishing in key wetlands, and deforestation that impacts the availability of nest-building trees (Jangra & Verma 2024;

Image 1. Woolly-necked Stork: A—wetland | B—agricultural land | C & D—barren land. Painted Stork: E—wetland | F—agricultural land | G & H—barren land. © Sony.

Bhawnani et al. 2025), these findings are supported by the current study. Because of anthropogenic activities and the way this species behaves in its natural habitat, it has been determined that these activities are causing storks to shift their eating habits more frequently, which raises the energy requirements for flying and food search (Prabhakar & Dudhmal 2016). Due to increasing agricultural usage and monsoon failure, the wetland's water supply has become unstable in recent years, posing a major threat to the ecosystem. The area around it is largely degraded due to heavy cultivation and grazing (Anjali & Rana 2022). Since a substantial tract of agricultural land borders Haryana, it is subject to the strain of human activity. Therefore, to maintain a healthy ecosystem, such areas must be protected (Gulati & Rana 2022). The present study supports previous research on storks' susceptibility to habitat loss and human disturbance, but they also draw attention to the underappreciated function of agricultural landscapes as alternative habitats. The need for species-specific conservation measures is highlighted by the different habitat preferences found for Painted Stork and Woolly-necked Stork. Stork populations can be supported by preserving habitat variability, which is essential to their existence, while also encouraging sustainable agriculture practices and protecting wetlands. This study offers fresh perspectives on Dighal Wetland's seasonal population dynamics, habitat flexibility, and human-mediated habitat use. Although continuous anthropogenic concerns require ongoing monitoring and habitat management, local populations, especially of Painted Storks, may be bigger and more resilient than previously reported.

CONCLUSION

The Painted Stork and Woolly-necked Stork at Dighal Wetland exhibit distinct habitat preferences, which are reflected in their population patterns across the study area. Painted Storks were mostly recorded in higher numbers around open wetland zones such as large waterbodies and Jheel areas, where they find suitable conditions for foraging and feeding. In contrast, Woolly-necked Storks were more commonly observed in smaller numbers along agricultural margins, particularly in ditches, canal edges, and flooded crop fields. This difference in habitat use likely reduces direct competition between the two species and helps explain the variation in their local population distribution, shaped by their differing ecological needs and foraging behaviours.

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COMMUNICATION

A preliminary checklist of avian fauna of the Raha sub-district of Nagaon, Assam, India

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Abstract: The present study was conducted from February 2024 to May 2025 in the Raha sub-district of Nagaon, Assam, to provide the first avian checklist of the region. Surveys were conducted weekly, with observations carried out on four days each week across five villages using the point count method. One-hundred-and-one-bird species were documented, representing 17 orders and 41 families. Passeriformes was the most represented order, with 45 species, whereas Ardeidae contributed the highest number of species (seven) among the families. Residency patterns showed that 81 species were residents, 19 were winter migrants, and one summer migrant. Most species (96) were 'Least Concern', while three were 'Near Threatened', and two were 'Vulnerable' according to the IUCN Red List. Most of the resident species were observed in human-modified vegetation and forest edges. The occurrence of species such as the Great Hornbill *Buceros bicornis* (Near Threatened), River Tern *Sterna aurantia* (Vulnerable), Lesser Adjutant *Leptoptilos javanicus* (Vulnerable), Blossom-headed Parakeet *Psittacula roseata* (Near Threatened), and Red-breasted Parakeet *Psittacula alexandri* (Near Threatened) underlines the conservation importance of the area. This study provides baseline data for future ecological assessments and emphasizes the need for long-term monitoring and conservation planning.

Keywords: Birds, conservation, documentation, habitat, human settlements, IUCN Red List, migrants, Passeriformes, point count.

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Author contributions: BG and JK contributed to manuscript writing. BM and SB were responsible for data collection. LMG, AK, and BS reviewed, edited, and critically analyzed the findings. BM and JK are acknowledged as equal contributors. The final draft of the manuscript was read and approved by all the authors.

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INTRODUCTION

Avian diversity is an important component of forest ecosystems, as the avifauna composition in any landscape helps in conservation and associated ecosystems (Byju et al. 2025). Birds are involved in pollination, seed dispersal, insect predation, and the consumption of various resources. They are also widely used as indicators of habitat quality and function as indicators of the areas they inhabit (Blair 1999; Michel et al. 2020; Ceia et al. 2023).

Of the 1,353 species and subspecies of avifauna reported from the Indian subcontinent (Naveen et al. 2025), approximately 700 species have been recorded in Assam, a northeastern state of India. Owing to its location in the eastern Himalaya and the Brahmaputra River basin, the state supports bird populations in Important Bird and Biodiversity Areas (IBAs) as well as in urban and semi-urban sites, including institutional campuses (Bhaduri & Rathod 2022; BirdLife International 2022).

Monitoring bird populations can yield valuable information on the health of ecosystems (Fraixedas et al. 2020). Substantial contributions have been made to study the diversity, distribution, and ecology of birds in Assam in recent years (Barua & Sharma 2005; Choudhury 2006; Das & Deori 2010; Ahmed & Dey 2014; Chakdar et al. 2019; Kakati et al. 2022; Rahmani et al. 2023). But many areas remain to be studied. Therefore, extensive surveys are required to uncover all such unexplored regions.

In this context, the present study was conducted in the Raha sub-district of Nagaon, Assam. Despite its proximity to forested and riverine habitats, no avifaunal documentation from this region has been reported. Therefore, the current study provides the first avian checklist for the area and establishes baseline data for future ecological research and conservation initiatives.

MATERIALS AND METHODS

Study Area

The study was conducted in Raha sub-district of Nagaon, located in central Assam within the Nagaon Forest Division. The surveyed villages include Amsoi, Niz-Chahari, Balichara, Boralimari, and Pachim Bula, situated between 26.116°–26.179° N and 92.424°–92.438° E (Image 1). The surveyed villages are located within a 46 km² landscape that exhibits marked topographical and ecological variability. The area is bordered by the reserved forests of the western division of the Nagaon Forest Division and the Karbi Hills to the south, while the Kopili River flows along the northern boundary. A water channel formed by the Kopili River, locally known as 'Bula' is also present in the area. The landscape is composed of riverine and hilly terrain with paddy fields, human settlements, open forests, moderately dense hill forests, and floodplain habitats, such as swamps and marshes, with emergent vegetation.

Bird surveys

The study was conducted from February 2024 to May 2025 using the point count method, with each count lasting 15 minutes (Drapeau et al. 1999). A total of 11 fixed point count stations were established across the study landscape, spaced 1.5–2.5 km apart and collectively visited 120 times during the study period (Naveen et al. 2025). The points were selected to represent the major habitat types present in the area, including paddy fields, human settlements, open forests, moderately dense hill forests, and floodplain habitats such as swamps and marshes with emergent vegetation. As the objective was to compile a species list, point counts with an unlimited radius were applied (Bibby et al. 2000). All birds that were seen and heard were recorded. Surveys were carried out between 0600–0900 h and 1500–1700 h by teams of two to three observers, and GPS coordinates were collected at each point. Field surveys were conducted four days per week. Birds were observed with a spotting scope (20 × 60) and a Nikon D5600 camera, and identification was performed using standard field guides (Grimmett et al. 2016). Taxonomy followed the Clements et al. (2023). The migratory status of the birds is given as per Billerman et al. (2022).

RESULTS

A total of 101 bird species were recorded, distributed across 17 orders and 41 families. Passeriformes was the dominant order with 45 species, followed by Pelecaniformes with eight species, Charadriiformes with seven species, Piciformes with six species, Accipitriformes and Coraciiformes with five species each, and Columbiformes with four species (Table 1; Figure 1; Image 2–5). Orders such as Anseriformes, Gruiformes, Cuculiformes, Falconiformes, Ciconiiformes, Psittaciformes, Strigiformes, and Suliformes were represented by fewer species. Among the recorded families, Ardeidae contributed the highest number of species (seven), followed by Sturnidae (six), Accipitridae (five), Columbidae, Muscicapidae, and Picidae (four

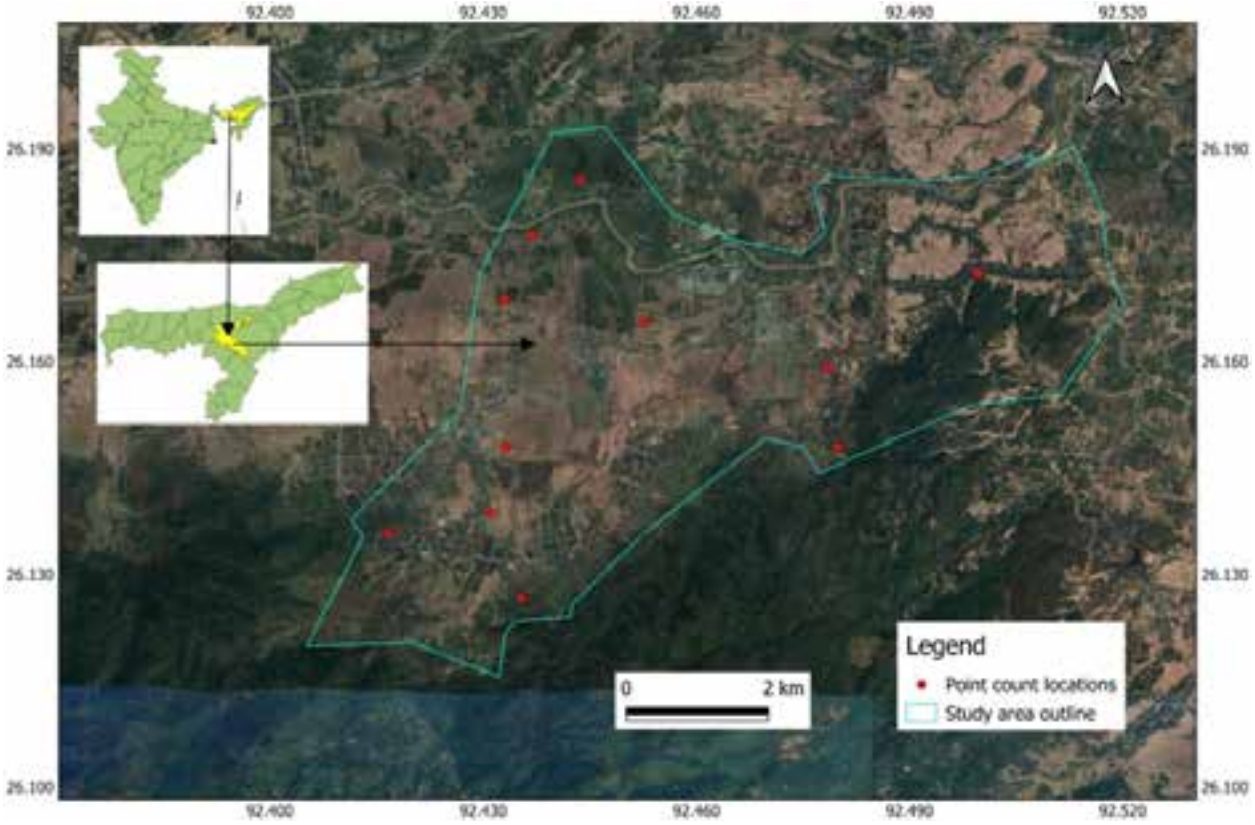

Image 1. Location map of the study area showing point count locations.

each). Families such as Charadriidae, Cuculidae, Rallidae, Motacillidae, Nectariinidae, and Psittaculidae were represented by three species each, while Falconidae, Alcedinidae, Alaudidae, Cisticolidae, Corvidae, Dicruridae, Laniidae, Passeridae, Phylloscopidae, Pycnonotidae, and Phalacrocoracidae had two species each. The remaining families, including Anatidae, Bucerotidae, Upupidae, Jacanidae, Laridae, Scolopacidae, Ciconiidae, Coraciidae, Meropidae, Aegithinidae, Campephagidae, Chloropseidae, Estrildidae, Hirundinidae, Leiothrichidae, Monarchidae, Oriolidae, Ploceidae, Stenostiridae, Turdidae, Vangidae, Zosteropidae, Threskiornithidae, Megalaimidae, Anhingidae, and Strigidae, were each represented by a single species (Table 1). With respect to conservation status, 96 species were listed as 'Least Concern', three species as 'Near Threatened', and two species as 'Vulnerable' on the IUCN Red List. Residency patterns showed that 81 species were resident, 19 were winter migrants, and one summer migrant.

DISCUSSION

This study recorded 101 bird species across 17 orders and 41 families, comparable to the 228 species from 18 orders and 64 families reported in the Suang Reserve Forest, Assam (Bora et al. 2024). The higher representation of Passeriformes with 45 species indicates the presence of heterogeneous habitat types in the study area (Hilaluddin & Sharma 2008). Such patterns suggest that the forest supports good habitat quality and retains significant biodiversity value (Saikia & Rabha 2006; Byju et al. 2023).

Species including the Common Hoopoe *Upupa epops*, Oriental Turtle Dove *Streptopelia orientalis*, Red Collared Dove *Streptopelia tranquebarica*, Spotted Dove *Spilopelia chinensis*, Yellow-footed Green Pigeon *Treron phoenicopterus*, Indochinese Roller *Coracias affinis*, Common Hawk-Cuckoo *Hierococcyx varius*, Bengal Bush Lark *Mirafra assamica*, Ashy Woodswallow *Artamus fuscus*, Golden-fronted Leafbird *Chloropsis aurifrons*, Common Tailorbird *Orthotomus sutorius*, Zitting Cisticola *Cisticola juncidis*, House Crow *Corvus splendens*, Rufous Treepie *Dendrocitta vagabunda*, Black Drongo *Dicrurus macrocercus*, White-rumped Munia *Lonchura*

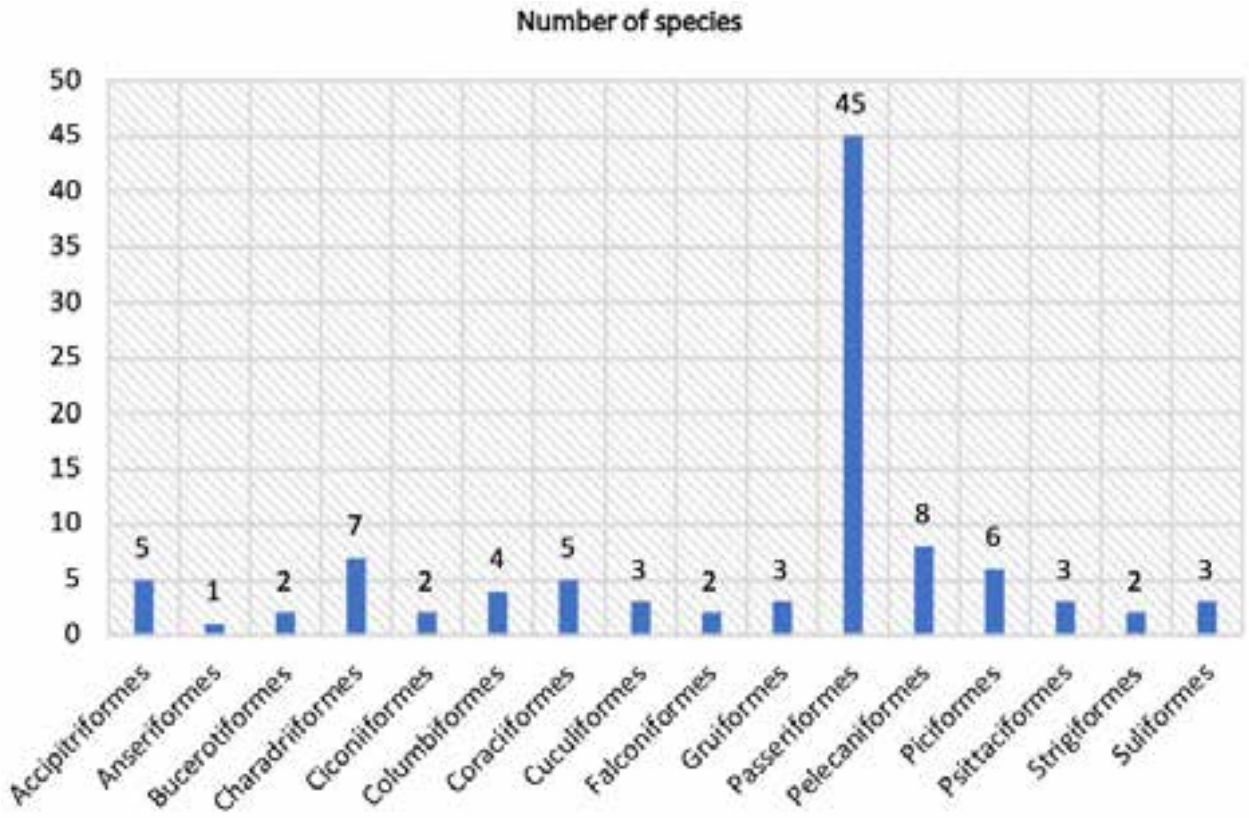

Figure 1. Order-wise species richness of avian fauna in the study area.

striata, Jungle Babbler *Argya striata*, Oriental Magpie-Robin *Copsychus saularis*, Crimson Sunbird *Aethopyga siparaja*, Little Spiderhunter *Arachnothera longirostra*, Black-hooded Oriole *Oriolus xanthornus*, Red-vented Bulbul *Pycnonotus cafer*, Black-crested Bulbul *Rubigula flaviventris*, Grey-headed Canary Flycatcher *Culicicapa ceylonensis*, Indian Pied Starling *Gracupica contra*, Chestnut-tailed Starling *Sturnia malabarica*, Common Myna *Acridotheres tristis*, Jungle Myna *Acridotheres fuscus*, Indian White-eye *Zosterops palpebrosus*, Blue-throated Barbet *Psilopogon asiaticus*, Lineated Barbet *Psilopogon lineatus*, Greater Flameback *Chrysocolaptes guttacristatus*, Black-rumped Flameback *Dinopium benghalense*, and Brown-capped Pygmy Woodpecker *Yungipicus nanus* were found to be abundant. These species were mostly observed in human-modified vegetation and forest edges. As residents, they were frequently encountered in the study area and adjoining agricultural lands. The prevalence of such species indicates the adaptability of many resident birds to mosaic landscapes shaped by anthropogenic activities. These areas, which include village surroundings and cultivated fields, provide foraging and nesting opportunities, thereby supporting a diverse assemblage of generalist and edge-tolerant bird species.

The area also lies within the migratory route of the Amur Falcon *Falco amurensis*. This species was observed in the study area between the first and third weeks of November. The occurrence of species such as the Great Hornbill *Buceros bicornis* and River Tern *Sterna aurantia*, both listed as 'Vulnerable', along with the Lesser Adjutant *Leptoptilos javanicus*, Blossom-headed Parakeet *Psittacula roseata*, and Red-breasted Parakeet *Psittacula alexandri*, categorized as 'Near Threatened', highlights the conservation importance of the study area. The persistence of these species indicates that their h abitat continues to provide critical resources, although their threatened status underscores the need for targeted monitoring and protection measures (Bora et al. 2024; Ali et al. 2025).

The only threat to the nearby forest habitat observed during the study period was tree-felling by local inhabitants. It is recommended that a detailed scientific study be undertaken on the biodiversity of the reserve forest, including its avifaunal community, as no previous documentation exists for this region. Such efforts would provide essential information for future conservation planning, with a particular focus on species

Table 1. List of avian species observed in the Raha sub-district of Nagaon

	Common name	Scientific name	Current IUCN Red List status	Residency
Order: Accipitriformes Family: Accipitridae				
	Black Kite	*Milvus migrans* (Boddaert, 1783)	LC	Resident
	Black-winged Kite	*Elanus caeruleus* (Desfontaines, 1789)	LC	Resident
	Hen Harrier	*Circus cyaneus* (Linnaeus, 1766)	LC	Winter Migrant
	Jerdons Baza	*Aviceda jerdoni* (Blyth, 1842)	LC	Resident
	Shikra	*Tachyspiza badia* (Gmelin, JF, 1788)	LC	Resident
Order: Anseriformes Family: Anatidae				
	Lesser Whistling Duck	*Dendrocygna javanica* (Horsfield, 1821)	LC	Resident
Order: Bucerotiformes Family: Bucerotidae				
	Great Hornbill	*Buceros bicornis* (Linnaeus, 1758)	VU	Resident
Family: Upupidae				
	Eurasian Hoopoe	*Upupa epops* (Linnaeus, 1758)	LC	Resident
Order: Charadriiformes Family: Charadriidae				
	Grey-headed Lapwing	*Vanellus cinereus* (Blyth, 1842)	LC	Winter Migrant
	Pacific Golden Plover	*Pluvialis fulva* (Gmelin J.F., 1789)	LC	Winter Migrant
	Red-wattled Lapwing	*Vanellus indicus* (Boddaert, 1783)	LC	Resident
Family: Jacanidae				
	Bronze-winged Jacana	*Metopidius indicus* (Latham, 1790)	LC	Resident
Family: Laridae				
	River Tern	*Sterna aurantia* (Gray, 1831)	VU	Resident
Family: Scolopacidae				
	Common Snipe	*Gallinago gallinago* (Linnaeus, 1758)	LC	Winter Migrant
	Wood Sandpiper	*Tringa glareola* (Linnaeus, 1758)	LC	Winter Migrant
Order: Ciconiiformes Family: Ciconiidae				
	Lesser Adjutant	*Leptoptilos javanicus* (Horsfield, 1821)	NT	Resident
	Asian Openbill Stork	*Anastomus oscitans* (Boddaert, 1783)	LC	Resident
Order: Columbiformes Family: Columbidae				
	Oriental Turtle Dove	*Streptopelia orientalis* (Latham, 1790)	LC	Resident
	Red-collared Dove	*Streptopelia tranquebarica* (Hermann, 1804)	LC	Resident
	Spotted Dove	*Spilopelia chinensis* (Scopoli, 1786)	LC	Resident
	Yellow-footed Green Pigeon	*Treron phoenicopterus* (Latham, 1790)	LC	Resident
Order: Coraciiformes Family: Alcedinidae				
	Common Kingfisher	*Alcedo atthis* (Linnaeus, 1758)	LC	Resident
	White-throated Kingfisher	*Halcyon smyrnensis* (Linnaeus, 1758)	LC	Resident
Family: Coraciidae				
	Indochinese Roller	*Coracias affinis* (Horsfield, 1840)	LC	Resident
Family: Meropidae				
	Asian Green Bee-eater	*Merops orientalis* (Latham, 1801)	LC	Resident
	Blue-tailed Bee-eater	*Merops philippinus* (Linnaeus, 1767)	LC	Resident

	Common name	Scientific name	Current IUCN Red List status	Residency
Order: Cuculiformes Family: Cuculidae				
	Asian Koel	*Eudynamys scolopaceus* (Linnaeus, 1758)	LC	Resident
	Common Hawk-cuckoo	*Hierococcyx varius* (Vahl, 1797)	LC	Resident
	Indian Cuckoo	*Cuculus micropterus* (Gould, 1838)	LC	Summer Migrant
Order: Falconiformes Family: Falconidae				
	Amur Falcon	*Falco amurensis* (Radde, 1863)	LC	Winter Migrant
	Common Kestrel	*Falco tinnunculus* (Linnaeus, 1758)	LC	Winter Migrant
Order: Gruiformes Family: Rallidae				
	White-breasted Waterhen	*Amaurornis phoenicurus* (Pennant, 1769)	LC	Resident
	Common Coot	*Fulica atra* (Linnaeus, 1758)	LC	Winter Migrant
	Grey-headed Swamphen	*Porphyrio poliocephalus* (Latham, 1801)	LC	Resident
Order: Passeriformes Family: Alaudidae				
	Bengal Bush Lark	*Plocealauda assamica* (Horsfield, 1840)	LC	Resident
Family: Artamidae				
	Ashy Woodswallow	*Artamus fuscus* (Vieillot, 1817)	LC	Resident
Family: Aegithinidae				
	Common Iora	*Aegithina tiphia* (Linnaeus, 1758)	LC	Resident
Family: Campephagidae				
	Large Cuckooshrike	*Coracina macei* (Lesson, 1831)	LC	Resident
Family: Chloropseidae				
	Golden-fronted Leafbird	*Chloropsis aurifrons* (Temminck, 1829)	LC	Resident
Family: Cisticolidae				
	Common Tailorbird	*Orthotomus sutorius* (Pennant, 1769)	LC	Resident
	Zitting Cisticola	*Cisticola juncidis* (Rafinesque, 1810)	LC	Resident
Family: Corvidae				
	House Crow	*Corvus splendens* (Vieillot, 1817)	LC	Resident
	Rufous Treepie	*Dendrocitta vagabunda* (Latham, 1790)	LC	Resident
Family: Dicruridae				
	Black Drongo	*Dicrurus macrocercus* (Vieillot, 1817)	LC	Resident
	Hair-crested Drongo	*Dicrurus hottentottus* (Linnaeus, 1766)	LC	Resident
Family: Estrildidae				
	White-rumped Munia	*Lonchura striata* (Linnaeus, 1766)	LC	Resident
Family: Hirundinidae				
	Barn Swallow	*Hirundo rustica* (Linnaeus, 1758)	LC	Winter Migrant
Family: Laniidae				
	Brown Shrike	*Lanius cristatus* (Linnaeus, 1758)	LC	Winter Migrant
	Long-tailed Shrike	*Lanius schach* (Linnaeus, 1758)	LC	Winter Migrant
Family: Leiothrichidae				
	Jungle Babbler	*Argya striata* (Dumont, 1823)	LC	Resident
Family: Monarchidae				
	Black-naped Monarch	*Hypothymis azurea* (Boddaert, 1783)	LC	Resident

	Common name	Scientific name	Current IUCN Red List status	Residency
Family: Motacillidae				
	Citrine Wagtail	*Motacilla citreola* (Pallas, 1776)	LC	Winter Migrant
	White Wagtail	*Motacilla alba* (Linnaeus, 1758)	LC	Winter Migrant
	Paddy-field pipit	*Anthus rufulus* (Vieillot, 1818)	LC	Resident
Family: Muscicapidae				
	Oriental magpie-Robin	*Copsychus saularis* (Linnaeus, 1758)	LC	Resident
	Taiga Flycatcher	*Ficedula albicilla* (Pallas, 1811)	LC	Winter Migrant
	Siberian Stonechat	*Saxicola maurus* (Pallas, 1773)	LC	Winter Migrant
	Whinchat	*Saxicola rubetra* (Linnaeus, 1758)	LC	Winter Migrant
Family: Nectariinidae				
	Crimson Sunbird	*Aethopyga siparaja* (Raffles, 1822)	LC	Resident
	Little Spiderhunter	*Arachnothera longirostra* (Latham, 1790)	LC	Resident
	Purple Sunbird	*Cinnyris asiaticus* (Latham, 1790)	LC	Resident
Family: Oriolidae				
	Black-hooded Oriole	*Oriolus xanthornus* (Linnaeus, 1758)	LC	Resident
Family: Passeridae				
	Eurasian Tree Sparrow	*Passer montanus* (Linnaeus, 1758)	LC	Resident
	House Sparrow	*Passer domesticus* (Linnaeus, 1758)	LC	Resident
Family: Phylloscopidae				
	Tickell's Leaf Warbler	*Phylloscopus affinis* (Tickell, 1833)	LC	Winter Migrant
	Dusty Warbler	*Phylloscopus fuscatus* (Blyth, 1842)	LC	Winter Migrant
Family: Ploceidae				
	Baya Weaver	*Ploceus philippinus* (Linnaeus, 1766)	LC	Resident
Family: Pycnonotidae				
	Red-vented Bulbul	*Pycnonotus cafer* (Linnaeus, 1766)	LC	Resident
	Black-crested Bulbul	*Rubigula flaviventris* (Tickell, 1833)	LC	Resident
Family: Stenostiridae				
	Grey-headed Canary Flycatcher	*Culicicapa ceylonensis* (Swainson, 1820)	LC	Resident
Family: Sturnidae				
	Indian Pied Starling	*Gracupica contra* (Linnaeus, 1758)	LC	Resident
	Chestnut-tailed Starling	*Sturnia malabarica* (Gmelin, 1789)	LC	Resident
	Common Myna	*Acridotheres tristis* (Linnaeus, 1766)	LC	Resident
	Common Hill Myna	*Gracula religiosa* (Linnaeus, 1758)	LC	Resident
	Jungle Myna	*Acridotheres fuscus* (Wagler, 1827)	LC	Resident
	Spot-winged Starling	*Saroglossa spiloptera* (Vigors, 1831)	LC	Winter Migrant
Family: Turdidae				
	Orange-headed Thrush	*Geokichla citrina* (Latham, 1790)	LC	Resident
Family: Vangidae				
	Common Woodshrike	*Tephrodornis pondicerianus* (Gmelin, 1789)	LC	Resident
Family: Zosteropidae				
	Indian White-eye	*Zosterops palpebrosus* (Temminck, 1824)	LC	Resident
Order: Pelecaniformes Family: Ardeidae				

	Common name	Scientific name	Current IUCN Red List status	Residency
	Cattle Egret	*Bubulcus ibis* (Linnaeus, 1758)	LC	Resident
	Cinnamon Bittern	*Ixobrychus cinnamomeus* (Gmelin, 1789)	LC	Resident
	Eastern Cattle Egret	*Bubulcus coromandus* (Boddaert, 1783)	LC	Resident
	Great Egret	*Ardea alba* (Linnaeus, 1758)	LC	Resident
	Indian Pond Heron	*Ardeola grayii* (Sykes, 1832)	LC	Resident
	Little Egret	*Egretta garzetta* (Linnaeus, 1766)	LC	Resident
	Purple Heron	*Ardea purpurea* (Linnaeus, 1766)	LC	Resident
Family: Threskiornithidae				
	Glossy Ibis	*Plegadis falcinellus* (Linnaeus, 1766)	LC	Resident
Order: Piciformes Family: Megalaimidae				
	Blue-throated Barbet	*Psilopogon asiaticus* (Latham, 1790)	LC	Resident
	Lineated Barbet	*Psilopogon lineatus* (Vieillot, 1816)	LC	Resident
Family: Picidae				
	Greater Flameback	*Chrysocolaptes guttacristatus* (Tickell, 1833)	LC	Resident
	Black-rumped Flameback	*Dinopium benghalense* (Linnaeus, 1758)	LC	Resident
	Brown-capped Pygmy Woodpecker	*Yungipicus nanus* (Vigors, 1832)	LC	Resident
	Rufous Woodpecker	*Micropternus brachyurus* (Vieillot, 1818)	LC	Resident
Order: Psittaciformes Family: Psittaculidae				
	Rose-ringed Parakeet	*Psittacula krameri* (Scopoli, 1769)	LC	Resident
	Blossom-headed Parakeet	*Psittacula roseata* (Biswas, 1951)	NT	Resident
	Red-breasted Parakeet	*Psittacula alexandri* (Linnaeus, 1758)	NT	Resident
Order: Suliformes Family: Anhingidae				
	Oriental Darter	*Anhinga melanogaster* (Pennant, 1769)	LC	Resident
Family: Phalacrocoracidae				
	Little Cormorant	*Microcarbo niger* (Vieillot, 1817)	LC	Resident
	Great Cormorant	*Phalacrocorax carbo* (Linnaeus, 1758)	LC	Resident
Order: **Strigiformes** Family: Strigidae				
	Spotted Owlet	*Athene brama* (Temminck, 1821)	LC	Resident
	Barred Owlet	*Glaucidium cuculoides* (Vigors, 1830)	LC	Resident

IUCN—International Union for Conservation of Nature | LC—Least Concern | NT—Near Threatened | VU—Vulnerable.

of conservation concern. This survey provides important baseline data on the region's avifaunal composition, including the presence of several 'Near Threatened' and 'Vulnerable' species.

CONCLUSION

These findings highlight the ecological importance of the area and its potential role in supporting both resident and migratory bird populations of conservation concern.

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Motacilla alba *Lonchura striata* *Treron phoenicopterus* *Saxicola rubetra*

Micropternus brachyurus *Passer montanus* *Phylloscopus affinis* *Ficedula albicilla*

Spilopelia chinensis *Plocealauda assamica* *Saxicola maurus* *Dendrocitta vagabunda*

Tachyspiza badia *Psittacula krameria* *Vanellus indicus* *Pycnonotus cafer*

Image 2. Photographs of some bird species observed in the Raha sub-district of Nagaon. © Bhrigumohan Manta.


Streptopelia tranquebarica


Cinnyris asiaticus


Streptopelia orientalis


Anthus rufulus


Ardea purpurea


Geokichla citrina


Copsychus saularis


Leptoptilos javanicus


Anastomus oscitans


Pluvialis fulva


Chloropsis aurifrons


Ardeola grayii


Aviceda jerdoni


Vanellus cinereus


Falco tinnunculus


Phylloscopus fuscatus

Image 3. Photographs of some bird species observed in the Raha sub-district of Nagaon. © Bhrigumohan Manta.


Aethopyga siparaja


Hierococcyx varius


Motacilla citreola


Sturnia malabarica


Eudynamys scolopaceus


Rubigula flaviventris


Rubigula flaviventris


Falco amurensis


Alcedo atthis


Artamus fuscus


Passer montanus


Bubulcus ibis


Oriolus xanthornus


Milvus migrans


Gracupica contra


Halcyon smyrnensis

Image 4. Photographs of some bird species observed in the Raha sub-district of Nagaon. © Bhrigumohan Manta.


Microcarbo niger


Psilopogon asiaticus


Acridotheres fuscus


Orthotomus sutorius


Acridotheres tristis


Cuculus micropterus


Saroglossa spilopterus


Psilopogon lineatus


Anhinga melanogaster


Ploceus philippinus

Image 5. Photographs of some bird species observed in the Raha sub-district of Nagaon. © Bhrigumohan Manta.

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COMMUNICATION

Assemblage structure and diversity of ichthyofauna in a low-order stream of the Pamba River in the Western Ghats of southern Kerala, India

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Abstract: This study investigates the assemblage structure and diversity of ichthyofauna in the second-order stream Chorakakki, a tributary of the Pamba River in the Western Ghats of southern Kerala, India. Monthly surveys conducted between January 2019 and June 2021 documented 20 ichthyofaunal species belonging to three orders, six families, and 14 genera. The stream exhibited diverse physico-chemical characteristics, including an average width of 6.17 ± 1.8 m, depth of 0.71 ± 0.28 m, a current velocity of 2.01 ± 0.19 m/s, water temperature of 27.3 ± 0.8°C, dissolved oxygen of 7.8 ± 0.8 mg/L, and slightly acidic pH (6.04 ± 0.23). Stream substrate composition varied, comprising bedrock, boulders, cobbles, pebbles, gravel, sand and silt, which created diverse mesohabitats supporting species-specific preferences. The ichthyofaunal community was dominated by *Garra mullya* (42.63%) and *Mesonoemacheilus triangularis* (25.48%). Habitat preferences were evident, with *Haludaria fasciata* frequenting pools and Balitoridae members inhabiting riffles. Diversity indices such as Margalef's (2.85), Shannon's (1.67), Dominance (0.27), and Evenness (0.26) revealed moderate species richness and uneven species distribution. The presence of 'Vulnerable' *Schistura denisonii* and 'Critically Endangered' *Homaloptera montana* underscores the conservation importance of the investigated stream. In addition to highlighting the significance of low-order streams in maintaining a variety of freshwater fish species, this study offers insightful information for Western Ghats conservation planning and management.

Keywords: Abundance distribution, conservation, habitat preference, mesohabitat, physico-chemical properties, stream substrates, rheophilic species, threat status.

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Author contributions: RT—conceptualisation and research design, field data collection, data compilation and analysis, and manuscript drafting. RTK—Methodological guidance, taxonomic support, species verification, manuscript review and revision, and supervision.

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INTRODUCTION

Low-order streams, characterised by their small size and limited discharge, are vital components of freshwater ecosystems. These streams typically originate in mountainous or forested catchments and significantly contribute to the biodiversity of river systems and their riparian networks, supporting both permanent resident species and seasonal migrants that utilize headwaters during specific life stages or seasons (Shrestha 1993; Dudgeon 2000; Meyer et al. 2007; Richardson & Sato 2015; Zbinden & Matthews 2017). Headwater streams, as the origin points of freshwater networks, offer unique and sensitive habitats that support specialist and often endemic species, contribute to evolutionary diversification, and are critical for various life stages of numerous freshwater taxa, yet remain highly vulnerable to degradation due to their small size, catchment dependence, and ease of physical alteration (Johnson & Douglass 2009; Lapointe et al. 2014; Richardson 2019). Globally, ecologically sensitive and biodiverse stream systems are increasingly threatened by a range of anthropogenic pressures, such as habitat loss, hydrological modifications, land-use change, invasive species, and pollution (Wohl 2017; Grzybowski & Lewczuk 2019).

In the Indian context, rivers of the Western Ghats and their headwater streams are increasingly affected by a range of anthropogenic pressures across their catchments, including pollution from large-scale pilgrimage, intensive agriculture, and unregulated land-use changes. These stressors contribute to the growing vulnerability of stream fish communities in the region, particularly due to habitat degradation, deforestation, dam construction, and the impacts of climate change (Arunachalam 2000; Johnson & Arunachalam 2010; Abraham & Kelkar 2012; Shilly et al. 2016).

The aquatic ecosystems in the state of Kerala region, particularly the lower-order streams, exhibit diverse flow patterns, substrate types, and water chemistry. These factors create microenvironments that support a wide range of fish fauna. However, these ecosystems remain understudied in comparison to larger rivers. The ichthyofaunal diversity is a crucial indicator of ecosystem health and vitality. The studies of Hora (1921, 1937, 1941) and Hora & Misra (1938) focused particularly on the freshwater fish fauna of the Western Ghats. The variety of ichthyofauna seen in the high range of Travancore was documented by Silas (1951). Gopi (2000) and Easa & Shaji (2003) have provided comprehensive analyses of ichthyofaunal diversity in Kerala. Devi et al. (2005) listed 88 fish species from the Anamalai Hill ranges. The biodiversity status of the low-order streams of the Pamba River in the Western Ghats has not yet been studied adequately. In southern Kerala, however, significant streams and rivers have been the subject of in-depth research on ichthyofaunal diversity (Jancy & Jobiraj 2017; Arunkumar & Arunachalam 2018; Salu & Ambili 2019). Vishnu et al. (2023) listed 35 fish species from a perennial tributary of the Achankovil River in Kerala.

The Pamba River, one of the longest rivers in Kerala, is fed by numerous low-order streams that collectively shape its hydrology and biodiversity. The specific contributions of these tributaries, particularly in terms of ichthyofaunal diversity, remain underexplored. Understanding the dynamics of low-order streams is essential for conserving the unique biodiversity of the Western Ghats, a global biodiversity hotspot. The current study is aimed at examining the fish assemblage structure in a low-order stream of the Pamba River, by emphasising habitat preference and threat status under the current ecological conditions. The study of such streams is crucial to identify and mitigate threats to aquatic biodiversity, including habitat degradation and climate change. It may aid in the effective management and sustainable use of these aquatic resources.

MATERIALS AND METHODS

Study area

Chorakakki, situated within the Ranni forest division of Kerala, India, is a second-order tributary of the Pamba River (Image 1). Positioned at an altitude of 163 m within the Western Ghats, its geographic coordinates are approximately 9.304° N & 77.054° E. This perennial stream encompasses various mesohabitat units, including rapids, glides, pools, riffles, runs, and waterfalls. The study examined the assemblage structure of fishes in a specific 200 m section of the stream from January 2019–June 2021, every month. Both fish sampling and habitat assessments were carried out within this same 200 m stretch. This location was selected to minimise variability. To capture variations in mesohabitat structure, a total of eight sampling sites were established at intervals of approximately 20–30 m along the 200 m stream section.

Assessing the physico-chemical and biological parameters

Water samples were collected in sterilised 1L bottles

Image 1. Satellite map from GoogleMaps ® displaying the location of the studied low-order stream of the Pamba River in the Western Ghats of southern Kerala, India

after cleaning with distilled water. Water temperature was measured on-site using an HM Digital Water Tester (Model: AP-1), and pH was determined with a pen-type pH meter (Model: PH-009 IA). The Winkler method was used to estimate dissolved oxygen (mg/L). Additionally, stream substrate types, instream cover (%), and bank stability were visually assessed. Riparian shade was measured with a spherical crown densiometer, while current velocity was measured using a pygmy-type current meter (No. 4010, M/S National Instruments Corporation, Roorkee). Stream width and depth were recorded using a measuring tape and a graduated wading rod, respectively. Bank stability was assessed using visual qualitative habitat assessment based on erosion, bank collapse, and vegetation cover.

The physico-chemical parameters were recorded monthly to capture consistent environmental conditions across sampling sites. This approach aimed to provide a baseline understanding of the stream's characteristics without seasonal biases.

Assessing the assemblage structure of the ichthyofaunal community

Fish surveys and identification were conducted utilising non-destructive sampling techniques tailored to the characteristics of the stream, including its order, flow regime, instream cover, habitat/channel unit, and presence of aquatic vegetation. Scoop nets (mesh size 2 mm) and cast nets (mesh size 14 mm, length 2.33 m, nylon webbing) were employed for fish sampling, with captured specimens preserved in 10% Formalin for subsequent investigations. During the sampling process, the abundance of each species was meticulously documented. Additionally, relative abundance was calculated for each species, providing a standardised measure of their prevalence within the ecosystem. To confirm the identity of preserved specimens, standard reference manuals such as Talwar & Jhingran (1991) and Jayaram (2010) were used. Drawing upon available scientific literature, including notable works by Dahanukar et al. (2004), Kurup et al. (2004), and Radhakrishnan & Kurup (2010), a thorough review was conducted to evaluate the current status of fish populations within the southern Kerala region of India (on a regional level). The conservation status of all identified species was cross-checked with the latest regional assessments, and the regional status was prioritised to reflect local ecological contexts and conservation priorities.

The assemblage structure of ichthyofauna was thoroughly analysed using various univariate indices (Margalef Index, Dominance Index, Shannon Index, and Evenness Index), each offering unique insights into the ecological information of the studied ecosystem.

Species octave curves and rank abundance curves (RACs) were employed to predict, model, and elucidate the distribution of species abundance within the studied stream. These analytical approaches were conducted utilising Paleontological Statistics (PAST) software version 4.03.

RESULTS

The stream exhibited varying physico-chemical and biological characteristics across its stretch (Table 1). The average stream width was 6.17 ± 1.8 m, with a maximum width of 8.2 m. The average depth was 0.71 ± 0.28 m, reaching a maximum of 1.2 m. Stream velocity averaged 2.01 ± 0.19 m/s, while water temperature and dissolved oxygen were 27.3 ± 0.8°C and 7.8 ± 0.8 mg/L, respectively. The pH was slightly acidic, with an average value of 6.04 ± 0.23. Riparian shade covered approximately 39.71 ± 9.99% of the stream.

The surveyed stream exhibited notable diversity, hosting 20 ichthyofaunal species, belonging to three orders, six families, and 14 genera (Table 2). Stream substrate composition and mesohabitat types positively influenced the distribution of fish species. Deep pools, boulder edges, and overhangs served as critical habitats for the stream inhabitants. Riffles were primarily observed in the surveyed stream, which supported rheophilic species due to its fast-flowing and oxygen-rich conditions. *Garra mullya* was the most abundant species (42.63), followed by *Mesonoemacheilus triangularis* (25.48), indicating its ecological importance in the ecosystem. Within the order Cypriniformes, species such as *Haludaria fasciata* and *Rasbora daniconius* preferred pool habitats. While species from the family Balitoridae were exclusively associated with riffle habitats. Bagrid members *Mystus malabaricus* and *M. montanus* were found in lower abundance and primarily inhabited

Table 1. Major physico-chemical and biological parameters recorded from the low-order stream of the Pamba River in the Western Ghats of southern Kerala, India.

Variable	Description
Stream width	6.17 ± 1.8 m (8.2 m maximum)
Stream depth	0.71 ± 0.28 m (1.2 m maximum)
Stream velocity	2.01 ± 0.19 m/s
Water temperature	27.3 ± 0.8 °C
Dissolved oxygen	7.8 ± 0.8 mg/L
pH	6.04 ± 0.23
Substrate types	Bedrock, boulder, cobble, pebble, gravel, sand and silt
Instream cover	Deep pool, boulder edge, overhangs, aquatic macrophytes and leaf litter
Bank stability	Good
Riparian shade	39.71 ± 9.99%

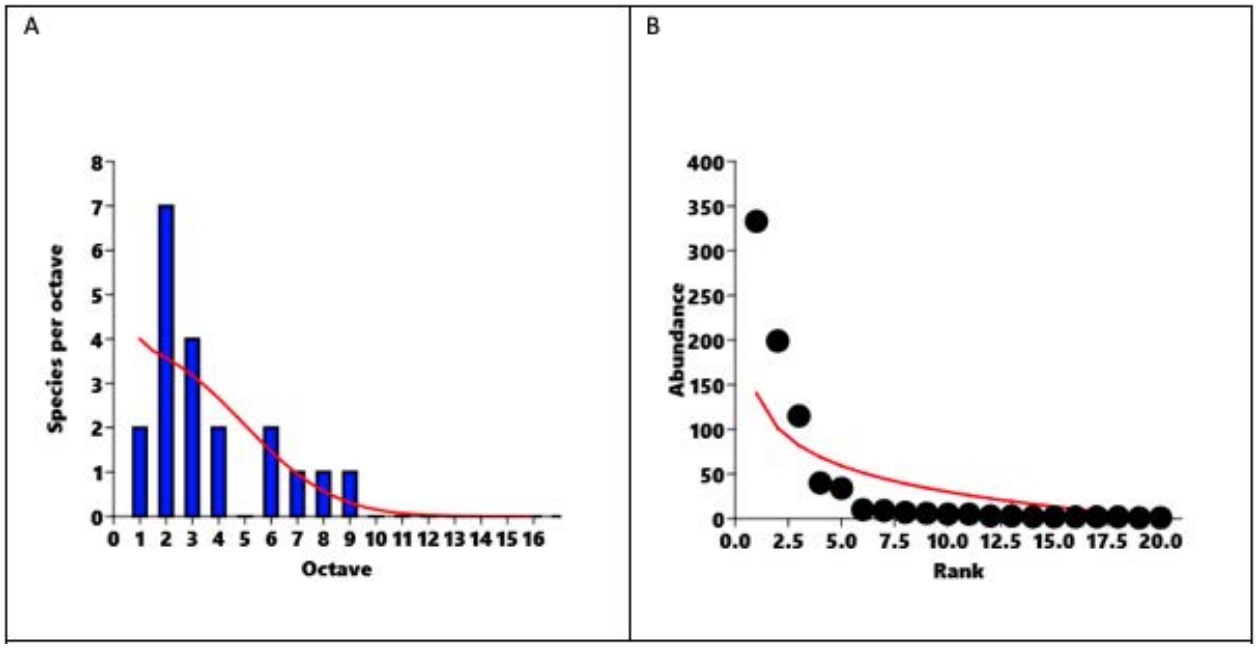

Figure 1. Freshwater fish species composition and abundance distribution in a low-order stream of the Pamba River, Western Ghats, Kerala, India: A—species octave | B—rank abundance curves.

Table 2. List of freshwater fish species recorded from the low-order stream of the Pamba River in the Western Ghats of southern Kerala, India. The species mentioned also include their preferred habitat/channel unit, relative abundance, and threat status.

	Species	Habitat/Channel unit preferred	Relative abundance	Threat status (Regional)
	Order: Cypriniformes			
	Family: Cyprinidae			
1	*Haludaria fasciata* (Jerdon, 1849)	Pool	5.12	LC
2	*Barilius bakeri* (Day, 1865)	Pool, Run	14.72	LC
3	*B. barna* (Hamilton, 1822)	Pool, Run	0.25	LC
4	*B. bendelisis* (Hamilton, 1807)	Pool, Run	0.896	LC
5	*B. gatensis* (Valenciennes, 1844)	Pool, Run	1.15	LC
6	*Devario aequipinnatus* (McClelland, 1839)	Pool, Run	0.64	LC
7	*D. malabaricus* (Jerdon, 1849)	Pool, Run	0.25	LC
8	*Rasbora daniconius* (Hamilton, 1822)	Pool	4.35	LC
9	*Garra mullya* (Sykes, 1839)	Pool, Riffle, Run	42.63	LC
10	*G. menoni* (Rema Devi & Indra, 1984)	Pool, Riffle, Run	0.25	VU
11	*Amblypharyngodon* sp.	Pool	0.76	DD
	Family: Balitoridae			
12	*Bhavania australis* (Jerdon, 1849)	Riffle	1.28	NT
13	*Homaloptera montana* (Herre, 1945)	Riffle	0.25	CR
14	*Travancoria jonesi* (Hora, 1941)	Riffle	0.38	EN
	Family: Nemacheilidae			
15	*Mesonoemacheilus triangularis* (Day, 1865)	Pool, Riffle, Run	25.48	LC
16	*Schistura denisonii* (Day, 1867)	Pool	0.64	VU
	Order: Siluriformes			
	Family: Bagridae			
17	*Mystus malabaricus* (Jerdon, 1849)	Pool	0.12	DD
18	*M. montanus* (Jerdon, 1849)	Pool	0.12	DD
	Family: Sisoridae			
19	*Glyptothorax* sp.	Rapid, Riffle	0.25	DD
	Order: Anabantiformes			
	Family: Channidae			
20	*Channa gachua* (Hamilton, 1822)	Pool, Riffle	0.38	VU

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

pools. The presence of *Channa gachua* in the stream indicates the presence of labyrinth fish, though they are not very abundant. Among the noted ichthyofauna, *Garra menoni*, *Schistura denisonii*, and *Channa gachua* were categorised (based on regional-level assessments) as 'Vulnerable'. While *Homaloptera montana* formed the 'Critically Endangered' (CR) category (Dahanukar et al. (2004); Kurup et al. (2004); Radhakrishnan & Kurup (2010).

Figures 1 & 2 show the fish species composition and the diversity indices of the ichthyofauna in the stream under investigation. The species octave curves (Figure 1A) demonstrate a varied distribution of species abundance across different octaves, indicating an uneven distribution within the community. Similarly, the steep decline observed in the rank abundance curve (Figure 1B) suggests an uneven abundance distribution among species.

This indicates a low evenness in the fish community, with a few dominant species overshadowing many others with lower abundances. The Margalef Index, representing species richness, was 2.853, while the

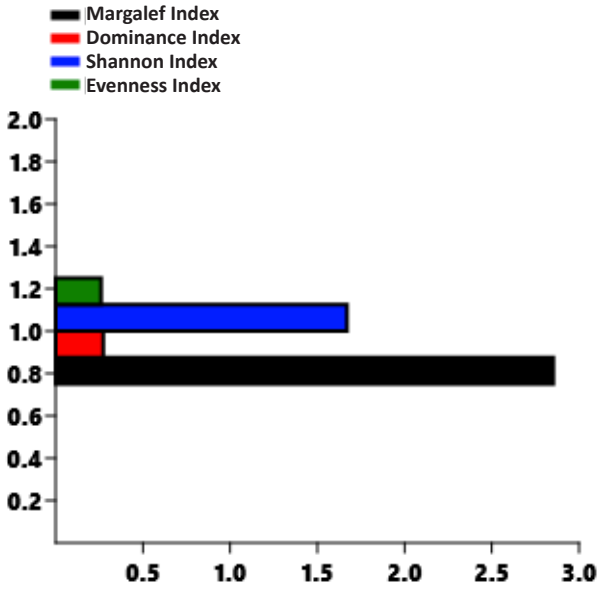

Figure 2. Diversity indices of freshwater fish in a low-order stream of the Pamba River, Western Ghats, Kerala, India.

Dominance Index (D), indicating dominant species abundance, was 0.273. The Evenness Index was 0.26, revealing a disparity in species distribution. The Shannon Index, representing richness and evenness, was 1.67 (Figure 2).

DISCUSSION

The low-order stream under study offers important insights into its ecological dynamics and ichthyofaunal community structure. Environmental factors at local scales and regional scales affect fish communities (Angermeier & Winston 2015); transient upstream habitats generally tend to have lower diversity and richness when compared to diverse downstream habitats (Pease et al. 2012; Bahuguna 2020). In this study, the stream exhibited varying physico-chemical and biological characteristics across its stretch. Parameters such as current velocity, substrate composition, and riparian vegetation played a crucial role in shaping the assemblage structure. For example, substrate diversity provided microhabitats that supported species with specific ecological preferences, as noted by Magalhaes et al. (2002). Nsor & Obodai (2016) further emphasized the significance of habitat heterogeneity in sustaining ichthyofaunal diversity, a pattern corroborated by our observations in the Chorakakki stream. The substantial diversity found in the low-order stream of the Pamba River draws attention to the distinct ecological dynamics of low-order streams, which generally have fewer species than main river courses. Studies focusing on the diversity of fish communities within the low-order stream systems of the Pamba River remain scarce, despite the availability of numerous studies examining major tributaries and the main channels (Radhakrishnan 2006; Radhakrishnan & Kurup 2010; Renjithkumar et al. 2011; Benno 2018). *Garra mullya* formed the most prevalent species in the respective stream reach, followed by *Mesonoemacheilus triangularis*, demonstrating the ecological significance of these species in determining the composition of the community. Both species are known to exhibit specific microhabitat preferences and strong associations with key stream features such as substrate type, flow, and proximity to cover. These habitat selection patterns reflect species-specific morphological, physiological, and trophic adaptations in the respective stream (Thomas & Thomas 2024). Hillstream loaches from the families Balitoridae, Nemacheilidae, and Sisoridae thrive in low-order streams because of their adaptation to the swift currents and diverse stream habitats that may provide a range of food resources (plants to insects). These hillstream specialists exhibit rheophily, utilising specialised morphological and behavioural adaptations to withstand extreme hydrological forces, as described by Lujan & Conway (2015). According to Crawford et al. (2020), rheophilic hillstream loaches from southern and southeastern Asia, particularly those in the family Balitoridae, demonstrate diverse pelvic girdle morphologies, reflecting adaptations for effective locomotion in fast-flowing waters. The prevalence of rheophilic fish in lowland rivers is also supported by Aarts et al. (2004); Puijenbroek et al. (2019); Liu et al. (2021); Stoffers et al. (2021). The calculated diversity indices and species abundance distribution analysis further corroborate these findings, with the Margalef Index indicating moderate species richness, while the Dominance Index and Evenness Index reflect disparities in the species abundance distribution. Several studies have highlighted the role of physical habitat structure in shaping fish distribution, abundance, and community composition in the southern Western Ghats (Johnson & Arunachalam 2010; Arunkumar & Arunachalam 2018). Presence of a diverse and unique fish assemblage, particularly species sensitive to habitat disturbance, suggests that the sampled stream section remains relatively undisturbed and ecologically intact (Sarkar et al. 2017; Mandal 2018).

As mentioned earlier, headwater streams face mounting threats from hydrological alterations, land-use changes, pollution, and riparian degradation, all of which

impact aquatic biodiversity and ecosystem services. In the southern Western Ghats, as per our previous study (Thomas & Thomas 2023), streams are increasingly affected by agricultural activities, loss of riparian cover, hydrologic disruption, and pilgrimage-related tourism. These anthropogenic stressors alter stream morphology, destabilise pool-riffle patterns, and shift fish community structure, favouring tolerant generalist species over habitat-sensitive specialists.

In contrast, the current study stream supports a relatively intact fish assemblage, indicating favourable habitat conditions. These findings reinforce the need for proactive conservation efforts—such as regulating religious tourism, restricting destructive land-use practices, and restoring riparian buffers—to safeguard the ecological integrity of headwater streams in the Western Ghats. The documentation of species richness, abundance, and threat status provides valuable insights for conservation planning and management efforts aimed at preserving the unique biodiversity of this ecosystem in the Western Ghats.

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COMMUNICATION

Addition of *Wallophis brachyura* (Günther, 1866) (Colubridae) and *Calliophis melanurus* (Shaw, 1802) (Elapidae) to the reptile fauna of Rajasthan, India

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Abstract: Two uncommon snakes, *Wallophis brachyura* (Günther, 1866) and *Calliophis melanurus* (Shaw, 1802), are reported from the dry deciduous forests of Pratapgarh, southern Rajasthan, based on findings of live individuals of both species. In the same work, the presence of these snakes in adjacent Madhya Pradesh is discussed, and other important unpublished localities are provided to confirm their wider presence in the central-western Indian region.

Keywords: Central India, distribution, dry deciduous forests, endemic, farmlands, Madhya Pradesh, Pratapgarh, Indian Smooth Snake, Slender Coral Snake.

सार: दक्षिणी राजस्थान के प्रतापगढ़ के शुष्क पर्णपाती वनों से कम देखे जाने वाले दो सर्प *वालोफिस ब्राकियुरा* (गुँथर, 1866) एवं *कैलियोफिस मेलानुरस* (शॉ, 1802) जीवित नमूनों की प्राप्ति के आधार पर दर्ज किये गए हैं। इसी शोध में भौगोलिक रूप से संलग्न मध्य प्रदेश में इन सर्पों की उपस्थिति पर विचार किया गया है एवं पश्चिम-मध्य भारत में इनकी विस्तृत भौगोलिक उपस्थिति को दर्शाने के लिए अन्य अप्रकाशित स्थानों का उल्लेख किया गया है।

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Author contributions: VS: designed and wrote manuscript. BLM: captured individuals of both species from Pratapgarh city outskirts and provided initial photographs. LKJ: provided data of two juvenile *Calliophis melanurus* from Dalot Village, Pratapgarh District and provided photographs of species. DK: took taxonomic data of both species, contributed in designing and writing manuscript.

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INTRODUCTION

Rajasthan is geographically the largest state of India. It is largely known for its arid and desert biodiversity because around 3/5th of the central-western part of the state is covered by the Thar desert. On the eastern edge of Thar, Aravalli Hill range runs diagonally from the north-east to south-west of the state and leaves around 2/5th part as eastern plains and restricts deserts on its west. Eastern side of the Aravalli Hills is richer in both dry deciduous and scrub forests because it receives better rainfall than Thar Desert (Khandal et al. 2016). Biodiversity found in this zone can be generalized as species belonging to dry deciduous forest type. Several reptile and amphibian species which are widely available in adjacent central India are also available in eastern plains of Rajasthan. They demand more extensive observations to enrich their knowledge in the state.

Wallophis brachyura (Günther, 1866) is a small colubrid that is considered a rarity in Indian snake fauna (Whitaker & Captain 2004). In fact, for a long time until Mistry 2005, it was shown from not more than five localities of western India's Maharashtra State and one from Madhya Pradesh State. In the past few years, it has been reported from new states with significant range extensions. So far, it is reported from dry lowlands of most of the Maharashtra, central-southern Gujarat, central-western Madhya Pradesh, central-western Chhattisgarh, northwestern Telangana and recently from northeastern Karnataka (Patel et al. 2015; Patel & Vyas 2019; Visvanathan et al. 2022; Deepak et al. 2023).

Similarly, *Calliophis melanurus* (Shaw, 1802) is another lesser seen but relatively more widely distributed small-sized elapid of the Indian subcontinent (Whitaker & Captain 2004). Apart from its type locality in Bengal (= West Bengal?), it is found in most of the lower peninsular India, including the Western Ghats, dry deciduous plains and most of the peninsular Indian hills, which are known for receiving relatively lower rainfall. So far, it is reported from most states of Peninsular India in patchy form, from West Bengal to Saurashtra of Gujarat and southwards (Vyas & Vyas 1981; Whitaker & Captain 2004; Deshmukh et al. 2018; Patel & Vyas 2019; Ganesh & Guptha 2021; see Image 1, Table 1). In this work, we add one more significant locality for *W. brachyura* and two localities for *C. melanurus*, which occur in adjacent Madhya Pradesh and Gujarat, but yet unreported from Rajasthan State.

MATERIAL AND METHODS

Live individuals of both species were obtained from outskirt localities of Pratapgarh City (24.028° N, 74.782° E) by the second author and from Dalot Village (23.668° N, 74.844° E) by the third author. Both localities come under of Pratapgarh District of Rajasthan. After realizing the scientific value of the finding, one of us (Dharmendra Khandal) visited these localities to document the individuals of both species in live condition. Scalation data was recorded manually and digitally with the help of a macro lens and macro mode in smart phones. Individuals of *C. melanurus* were very small, hence they were placed over thin transparent glass to photograph their ventral and subcaudal scales for counting on a large screen. Recorded data were compared with the most recent morphological accounts of species (Patel et al. 2015; Parmar 2019 for *Wallophis brachyura*). Ventral scales were counted by following Dowling 1951. Individuals were released unharmed near the capture site within legal terms.

RESULTS

***Wallophis brachyura* (Günther, 1866)**

On 30 March 2024 at 1515 h second author captured a live adult *W. brachyura* (Image 2) from an outskirt house of Pratapgarh City (24.044° N, 74.781° E; 516 m). It was hiding in the gaps of the door frame, from where it was successfully removed for safe relocation.

A total 457 mm long individual had following characters (jointly written for both sides of head as recorded data was same): nine supralabials, 5–6 in contact with eyes, lowest posterior temporal almost half wedged between 7–8 supralabials; one loreal; one preocular; two postoculars; 2+3 temporals; dorsal scales smooth, in 23 mid body rows; 232 ventrals, followed by undivided anal; 45 pairs of subcaudals with additional single terminal scute. Head elongated, not depressed, slightly broader than the neck; eyes moderate, with a rounded pupil. Head's ground colour was glossy metallic grey-brown, slightly darker than the rest of the upper body. The top of the head was patternless, but the scales had greyish shades. A fine, obscure but visible blackish preocular streak was running above the upper edges of anterior supralabials from nasals to eyes. Upper lips were lighter than the dorsal part of the head. Dorsal body appeared superficially patternless, glossy grey-brown but, on careful examination, flanks (up to 6 dorsal rows in mid body) had darker shades, which were most

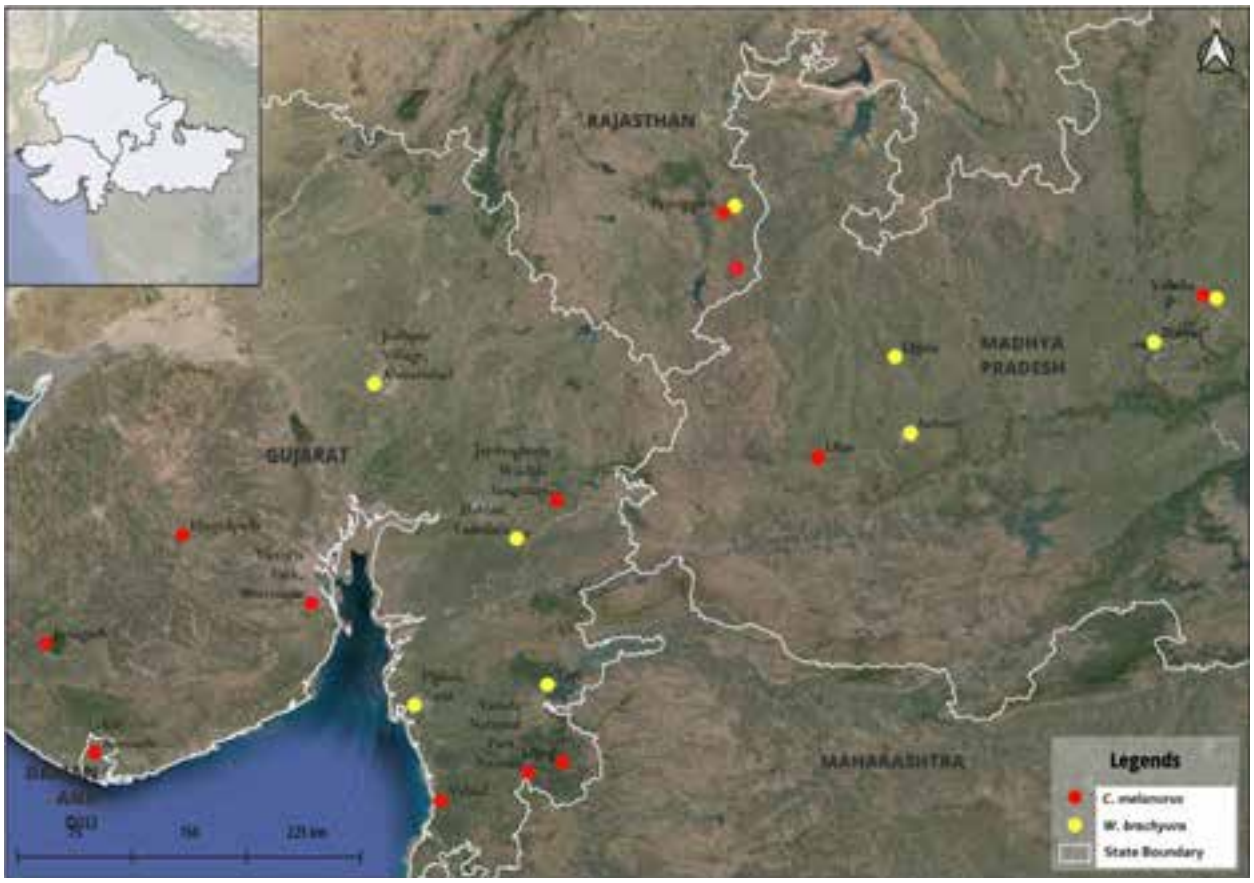

Image 1. Map of central-western India showing published and unpublished district-wise distribution records of *Wallophis brachyura* and *Calliophis melanurus* from Gujarat, Madhya Pradesh, and Rajasthan. Localities are denoted by red and yellow circles for *C. melanurus* and *W. brachyura*, respectively. District headquarters is represented as locality the precise location the village/town is unavailable in cited works. If multiple localities are reported in a district, record the closest the district headquarters is chosen except for Pratapgarh District, where records of *C. melanurus* were done in two different localities. Also see Table 1 to check locality data along with citations.

prominent from start of the mid body till the start of the tail. The underside was off-white, with greyish edges on the outer sides of the ventrals.

***Calliophis melanurus* (Shaw, 1802)**

While the above finding of *W. brachyura* was being discussed with the second author, he showed his past finding of an unidentified snake, not far from the locality of *W. brachyura* (24.051° N, 74.763° E; 516 m. This observation was done on 15 February 2021 at 1030 h. The individual was discovered while digging a pile of soil meant for making bricks.

Later, the third author was able to contribute his findings of two juvenile individuals of *C. melanurus* (Image 3) from nearby Dalot Village (23.674° N, 74.849° E; 561 m and 23.684° N, 74.849° E; 551 m) on 16 July and 31 July of 2025, respectively. First individual was found on the classroom floor of the school, while the second was found in a shop's floor at daytime. Both sites were surrounded by farmlands on the outskirts of town. DK visited the village to document live individuals and took morphological data which is as follows (First individual's data written first, followed by data of second individual. Also, data of head scales was recorded only from left side of head): 140 mm and approximately 150 mm total length, six supralabials, 3–4 in contact with eyes; loreal absent hence single preocular in contact with posterior nasal; two postoculars; one large anterior temporal; dorsal scales smooth, in 13 mid body rows; 256 and 269 ventrals, followed by divided anal; 32 and 26 pairs of subcaudals with rounded tail tip. Head rounded, not depressed, not broader than the neck; eyes moderate, with entirely black cornea, hence pupil invisible. Head's ground color up to nape was glossy black, with characteristic rounded white spots on internasal, upper posterior temporals and one off-white colored oval spot on the top of nape. Upper lip had white colouration on the anterior and posterior sides by leaving the area

Image 2. Live individual of *Wallophis brachyura* from Pratapgarh Town, Pratapgarh District, Rajasthan. © Dharmendra Khandal.

under the eyes black. An additional incomplete collar was present, which was barely reaching the top. Dorsal body appeared superficially patternless, glossy brown, but on closer look, scales could be seen with darker longitudinal lines, which overall made the dorsal surface plain brown. The anterior one-third body's underside was plain white, but it gradually started turning yellow-orange, and these colours were most vibrant before the anal. Upperside of tail had two large black spots, one at the starting and one just before the end of the tail tip. The underside of the tail was largely bluish-white with black blotches. Both individuals had subcaudal scales starting with black blotches, while others were seen before the end of the tail.

DISCUSSION

Record of *W. brachyura* is 143 km from the nearest published locality in Ujjain, Madhya Pradesh (Ingle & Sarsavan 2011). In neighboring state of Madhya Pradesh, one specimen of *W. brachyura* was collected from Bhopal in 1945 (Mistry 2005). Whitaker & Captain (2004) did not include this locality. Later, Ingle & Sarsavan (2011)

Table 1. Published and unpublished district-wise distribution records of *Wallophis brachyura* and *Calliophis melanurus* from Gujarat, Madhya Pradesh, and Rajasthan.

	Wallophis brachyura		*Calliophis melanurus*	
1	Ahmedabad, Gujarat	Vyas & Patel 2007	Dang, Gujarat	Vyas 1998
2	Piplod, Surat, Gujarat	Vyas & Patel 2007; Patel et al. 2015	Junagadh, Gujarat	Vyas 1998
3	Vadodara, Gujarat	Patel & Vyas 2019	Rajkot, Gujarat	Vyas 1998
4	Tapi, Gujarat	Parmar 2019	Valsad, Gujarat	Vyas 1998
5	Ujjain, Madhya Pradesh	Ingle & Sarsavan 2011	Gir Somnath, Gujarat	Bhatt et al. 1999
6	Bhopal, Madhya Pradesh	Ingle & Sarsavan 2011	Navsari, Gujarat	Vyas 2004
7	Indore, Madhya Pradesh	Deepak et al. 2023; this work	Panchmahal, Gujarat	Vyas 2006
8	Vidisha, Madhya Pradesh	This work	Bhavnagar, Gujarat	Vyas 2008
9	Pratapgarh, Rajasthan	This work	Dhar, Madhya Pradesh	Vyas & Vyas 1981
10			Vidisha, Madhya Pradesh	This work
11			Pratapgarh, Rajasthan	This work

Image 3. Live individual of *Calliophis melanurus* from Dalot Village, Pratapgarh District, Rajasthan. © Dharmendra Khandal.

recorded *W. brachyura* from Ujjain and confirmed its presence in the state. In recent years, with the help of local wildlife allies, first author personally verified two specimens from Indore (22.733° N, 75.883° E) and one from Vidisha (23.515° N, 77.803° E) , which lie within 50 km air distance from the nearest published localities, Ujjain and Bhopal, respectively. A total of four localities in Madhya Pradesh and one locality in Rajasthan indicate

a wider presence of *W. brachyura* in central-western India and encouraging future herpetologists to seek them further northwards.

Dalot Village, where *Calliophis melanurus* was observed, is closer to the Madhya Pradesh border, and it is 128 km from the nearest published locality in Dhar, Madhya Pradesh (Vyas & Vyas 1981), which remained the only known locality of the species for this state for about four decades. In 2021, the first author managed to document two adult specimens from Vidisha (23.521° N, 77.821° E) and confirmed its presence in Madhya Pradesh. Both snakes in Pratapgarh City were recorded at short distances from the same locality. Similarly, the distance between capturing sites of two juveniles of *C. melanurus* from Dalot town was 1.1 km. These places are largely surrounded by lowland degraded deciduous forests and irrigated farmlands. Such a matrix of dry deciduous forests and farmlands is found in most of the eastern plains of Rajasthan. These new records represent the northernmost localities of both species, but we believe most of the eastern plains of Rajasthan are suitable to accommodate these further north along the Aravalli.

Pratapgarh District, situated in the south-eastern part of Rajasthan, holds a unique ecological significance owing to its geographical positioning at the intersection of the Aravalli Hill range, Vindhyan Hill range, and the Malwa Plateau (Central Ground Water Board 2022). The relatively gentle terrain, coupled with three perennial rivers- Jakham, Sitamata, and Karmoi — fosters a habitat conducive to tropical moist deciduous plant species. The Pratapgarh District hosts forests classified under II-Dry tropical forests, further categorized into group 5-Tropical dry deciduous forest, with subdivisions 5A-Southern tropical dry deciduous forest and 5B-Northern tropical dry deciduous forest (Central Ground Water Board, 2013). The climatic conditions, characterized by distinct winter, summer, and monsoon seasons, play a pivotal role in shaping the ecosystem dynamics. Winters, commencing from November and extending to December-January, witness minimum temperatures plummeting to 6°C, while summers, intensifying from mid-March to April, record scorching temperatures reaching up to 45°C. The monsoon season, spanning from mid-June to mid-September, contributes to an average rainfall of 756 mm, with occasional winter showers occurring in January–February (Central Ground Water Board 2013).

This intricate ecosystem supports a diverse array of micro and macro habitats, harbouring several conservation-significant floral and faunal species. Furthermore, Pratapgarh stands as a crucial distribution limit for a plethora of species originating from the Himalaya, Indo-Malayan region, African regions, and even the Western Ghats (Sharma et al 2016). In conclusion, Pratapgarh District emerges as a crucial ecological hotspot, offering a unique blend of biodiversity owing to its geographical positioning, climatic diversity, and rich riparian ecosystems. Understanding and conserving this intricate web of life is imperative for maintaining ecological balance and preserving the natural heritage of the region (FES 2010).

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OPEN ACCESS

COMMUNICATION

Checklist of moths (Lepidoptera: Heterocera) of Lumami campus, Nagaland University, India

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Abstract: The present study was carried out to document the moth fauna of Lumami campus between February 2024 to April 2024 using the light trapping method with a 100 W LED bulb. A total of 106 species belonging to 83 genera under 12 families and seven superfamilies were recorded. The family Erebidae dominated with 46 species (43%), followed by Geometridae with 32 species (30%), Notodontidae with five species (4%), Crambidae and Saturniidae with four species each (4%), Drepanidae, Lasiocampidae, and Sphingidae with three species (3% each), Euteliidae and Nolidae with two species each (2%), and Zygaenidae and Noctuidae with one species each (1% each). Of the 106 moth species, 36 species are first reports from Nagaland; of which Geometridae dominates with 18 genera (e.g., *Amblychia* sp., *Hypomecis seperata*), followed by Erebidae with 13 genera (e.g., *Asota heliconia*, *Dierna strigata*, *Ommatophora* sp.), Euteliidae with two genera (e.g., *Targalla apcifascia*, *Eutelia discistriga*), and Nolidae with two genera (e.g., *Westermannia superba*, *Xenochroa* sp.). Species such as *Acosmeryx naga* are potential pollinators, and *Chadisra bipartita* is an indicator of forest health, as their decline suggests detrimental environmental changes such as increased pesticide use or habitat degradation. This study thereby offers baseline data for future studies on moth fauna as well as for the creation of sustainable forest development and conservation strategies.

Keywords: Biodiversity, conservation, diversity, environmental change, first record, habitat degradation, light trap, moth fauna, northeastern India, Zunheboto.

Editor: Anonymity requested.

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Author contributions: KY: field survey, sample collection, preservation, photography, data compilation, data analysis, writing. LM: conceptualization, research design, data analysis, taxonomic assessment, manuscript drafting, reviewing, editing, supervision.

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INTRODUCTION

With almost 180,000 species described, Lepidoptera is the second largest and most diverse order of insects (Khan et al. 2023). As biologically, economically, and aesthetically highly significant groups of insects, moths (Heterocera) are phytophagous, cosmopolitan, potential pollinators and important bioindicators as well (Devoto et al. 2011; LeCroy et al. 2013; Dey et al. 2015). Although moths account for roughly 88% of the Lepidopteran diversity, they have received less scientific attention in comparison to the butterflies due to their cryptic colouration and mostly nocturnal activity, which makes them less visible. Moths can survive in an incredibly diverse range of habitats, from frozen Arctic tundra (Kumar et al. 2019) to high-altitude mountain slopes to humid rainforests excluding Antarctica. Perhaps, it is this adaptability to change morphologically, physiologically, and behaviourally that has allowed Lepidoptera to endure on the earth for the past millions of years (Kaur et al. 2024).

Moths are a notable group of insects in the terrestrial ecosystem as they serve as important pollinators. Recent studies have revealed that nocturnal moths visit more plant species than day-active bees do, given the super-pollinator status of bees, stressing their relevance to pollen transport and having wide-ranging tastes in flowers (Wagner 2025). Moths serve as important indicator taxa due to their sensitivity to changes in their environment, including changes in climate, habitat, anthropogenic activities, vegetational changes, and their response to successional processes (Thomas 2005; Hilt & Fiedler 2006; Dey et al. 2015). Their diversity, abundance, functional significance, high capability for reproduction, short generation time, sensitivity to disturbance, and simplicity of sampling make them significant indicator species that can be used to track environmental change and assess its effectiveness (Andersen et al. 2004). Due to their significant conservation importance and use as model organisms in scientific study (Regier et al. 2009), this group of insects has currently gained prominence.

Numerous studies have documented a global decline in moth ranges and abundance across a variety of ecosystems (Wagner 2012; Maes et al. 2024). Over the past decades, many habitats and continents have been strongly affected by the changing climate (Walther et al. 2002). Over the same period, many landscapes have also changed because of the intensification of agriculture, deforestation or urbanization (Warren et al. 2001; Thomas et al. 2004). Urbanization significantly affects community assemblages by altering landscapes, which include habitat destruction, fragmentation, heightened pollution levels, and altered hydrology (Grimm et al. 2008). The main factors causing the long-term loss of moth diversity are climate change, habitat deterioration, and human activities such as industrialized and agricultural landscapes (Fox 2013). Moths are negatively affected by climate change and are therefore well suited for uncovering patterns in the effects of climate change on ecosystems as this group of insects demonstrates how organismal (genetics, physiology, behaviour, morphology), phenological (host synchrony, voltinism), population-level (geographic ranges), and community-level (trophic interactions, e.g., parasitoid–herbivore) processes interact and respond to change. Changes in the temperature not only reduce their abundance but also create conflict between morphological characteristics, including body and wing size, and ecological factors like dispersal (Hill et al. 2021).

The northeastern region of India is one of the ten biogeographic regions of the nation and has significant importance for determining the biodiversity space of India. Northeastern India is one of the major and important hotspots among the 35 biodiversity hotspots of the world, which is known for “endemism” (Kumar et al. 2016). Due to the unique climatic conditions and varied topography, northeastern India occupies a distinct and diversified ecosystem, and it has become the natural abode for Lepidopterans. The most recent research lists 3,265 moth species from 1,519 genera spread across 60 families of 24 superfamilies under five clades from the northeastern biogeographic zone of India. With 716 species within the superfamily Noctuoidea, Erebidae is the most prevalent family (Joshi et al. 2021). In Nagaland, about 855 species belonging to 24 families have also been reported by Joshi et al. (2021). No research has been conducted on moth diversity at Lumami Campus, Nagaland University; therefore, the current study seeks to investigate the various moth species present on the campus.

MATERIALS AND METHODS

Study area

The present study was carried out in Lumami (Figure 1), a village in Zunheboto District located at 26.202° N & 94.471° E and 942 m. It is situated 8 km away from the sub-district headquarters in Akuluto and 40 km away from the district headquarters in Zunheboto. Owing to the high altitude, the district enjoys a monsoon climate almost throughout the year with cold winters and hot

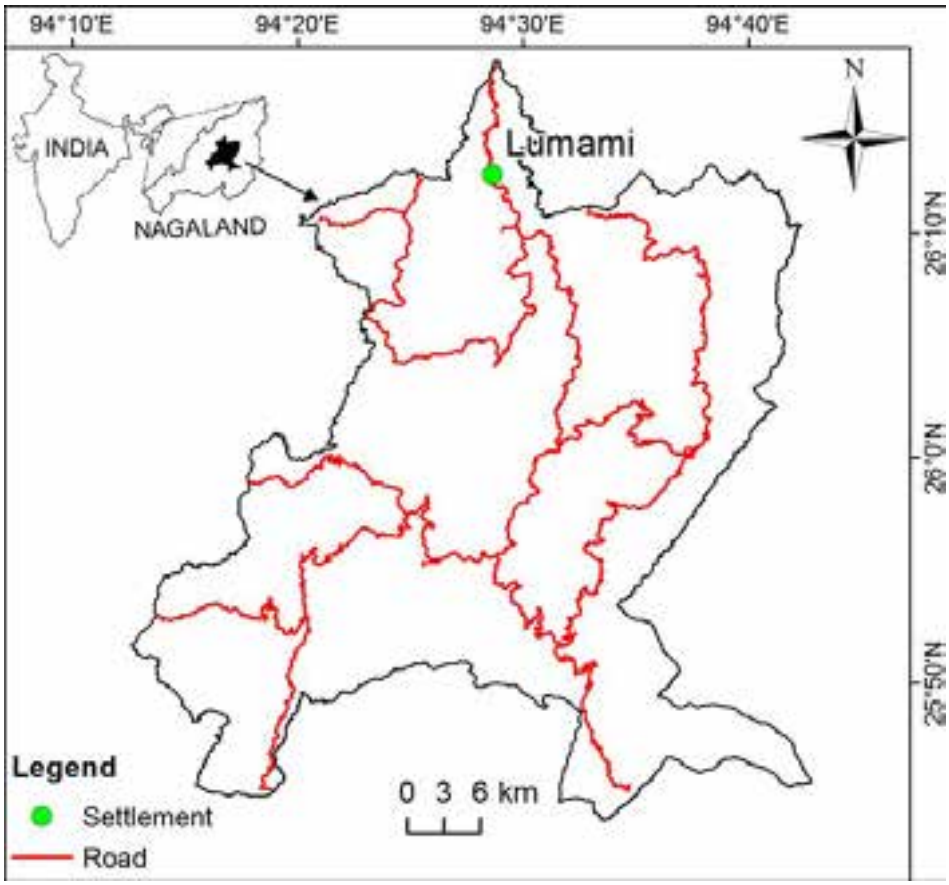

Figure 1. Location of Lumami (Zunheboto District), Nagaland (Source: Survey of India Toposheets).

summers. The average rainfall is about 200 cm (https://snwc.nagaland.gov.in). The area is dominated by *Abroma augusta* (L.) L.f., *Bauhinia variegata* (L.) Benth, *Callicarpa arborea* Roxb, *Duabanga grandiflora* (Roxb. ex DC.) Walpers, *Ficus racemosa* L., *Lagerstroemia speciosa* (L.) Pers., Oak trees (*Quercus griffithii* Hook.f. & Thomson ex Miq. and *Quercus serrata* (Murray)), *Prunus cerasoides* Buch.-Ham. ex D.Don, *Schima wallichii* (DC.) Korth. and *Terminalia myriocarpa* van Heurck & Müll. Arg (Mozhui et al. 2020).

Methodology

The study was conducted in 2024 between February and April. The specimens were collected by light trapping using a 100 W LED bulb and handpicking from areas near light sources. The sites were sampled for one to two hours every day (1800–2000 h); the majority of the samples were collected at night; some were also collected during the day. Following that, ethyl acetate was used in killing jars to kill moths, then they were fastened to the board using entomological pins. Using a Canon EOS700D DSLR camera, the observed moths were photographed, recorded, and brought to the laboratory for further taxonomic studies. The moths were identified with the help of relevant literature (Hampson 1892–1896; Haruta 1992–2000; Sondhi & Sondhi 2016; Chettri et al. 2021; Joshi et al. 2021). Experts were consulted, and references from https://www.mothsofindia.org and https://www.inaturalist.org were used to identify species. The taxonomic classification and arrangement by Nieukerken et al. (2011) was followed.

RESULT AND DISCUSSION

In the present study, a total of 106 species of moths belonging to 83 genera under 12 families and seven superfamilies were documented (Table 1 & Images 1–4). The family Erebidae represented the maximum number with 46 species (43%), followed by Geometridae with 32 species (30%), Notodontidae with five species (4%), Crambidae, and Saturniidae with four species each (4% each), Drepanidae, Lasiocampidae, and Sphingidae with three species each (3% each), Euteliidae and Nolidae

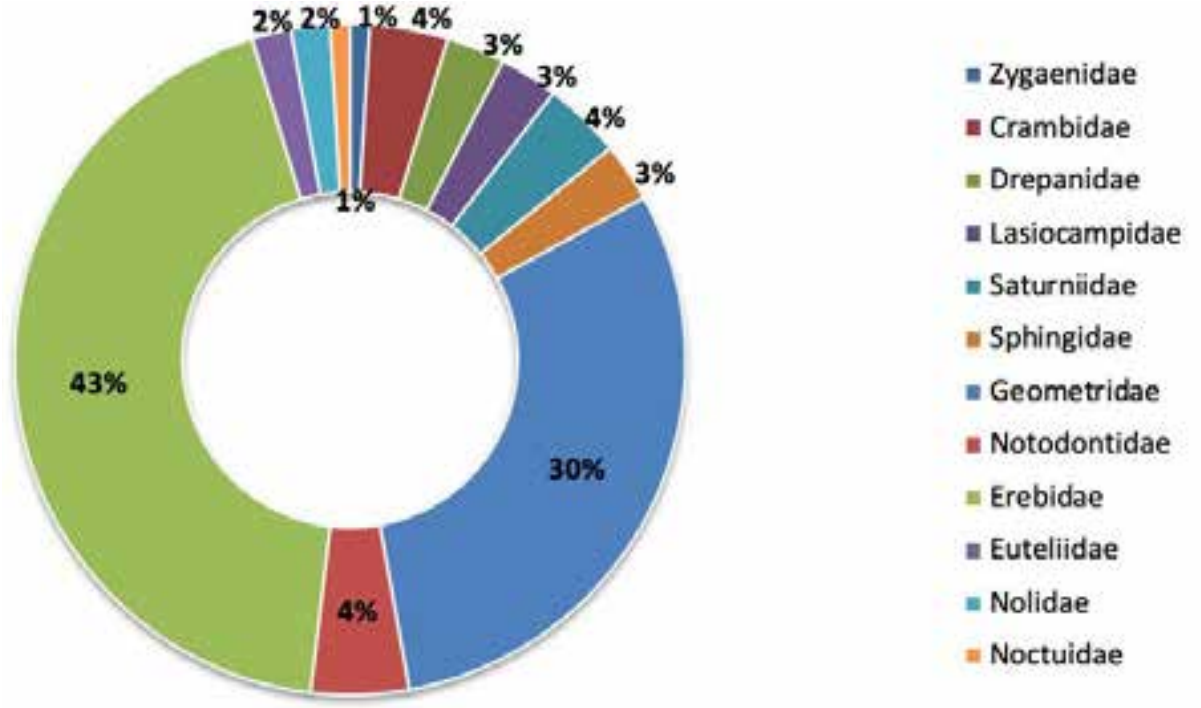

Figure 2. Percentage contribution of different families to moth fauna of Nagaland (calculated by counting the total number of moth species representing each family).

with two species each (2% each), and Zyganidae and Noctuidae with one species each (1% each) (Figure 2). The percentage contribution of the families was calculated by counting the total number of moth species representing each family. Among the 106 documented species, 36 moth species represent first records for the state, thus contributing to the moth diversity of Nagaland as per Joshi et al. (2021). List of some first reported species includes *Macrocilix maia, Amblychia* sp., *Cleora fraterna*, *Fascellina plagiata*, *Hypomecis transcissa*, *Krananda semihyalina*, *Lassaba albidaria*, *Maxates thetydaria*, *Ophthalmitis xanthypochlora*, and *Asota heliconia*.

Due to their domestication for the production of silk, moths such as *Bombyx mori*, *Antheraea pernyi*, *Antheraea assamensis*, *Hyalophora cecropia*, and *Samia cynthia*, among others, have a significant economic impact on the ecology (Zethner et al. 2015). Many animals also depend on moths (such as *Attacus atlas*, *Biston betularia*, and *Plodia interpunctella*) as a source of vital nutrients. Certain moth species can seriously harm plants during their larval stage (Nneji et al. 2020). For example, the Potato Tuber Moth *Phthorimaea operculella* is a significant pest of potatoes. In addition to being one of the most taxonomically tractable and speciose families of insects, Lepidoptera play crucial functions in forests as pollinators, detritivores, selective herbivores, and prey for migratory passerines (Schowalter et al. 1986). Moths are crucial to the ecosystem as potential pollinators since certain insects are essential to the pollination of food sources and the overall health of an ecosystem. With little knowledge of what occurs at night, the majority of pollination study focuses on insects that fly during the day. A significant component of the natural ecosystem and an essential component of many ecological communities are pollinating insects. Moths are becoming more significant and helping to pollinate more types of plant pollen as wild day pollinating insects like bees and butterflies are becoming less common. According to recent research, moths pollinate more quickly at night and are more effective pollinators than bees and other day-flying pollinators (Anderson et al. 2023).

Lepidoptera demonstrate potential as surrogates for several insect species, including Hymenoptera (Kerr et al. 2000), and serve as indicators of forest health. Consequently, a vital group for tackling concerns associated with forest biodiversity and spatial dimensions is the Lepidoptera. Kitching et al. (2000) indicate that specific moth families and subfamilies, including Arctiinae, Catocalinae, Heliothinae, Noctuinae, Herminiidae, and Phycitinae, exhibit positive responses

Table 1. Moth species observed at Lumami Campus during the study.

	Taxa	Author, year	Distribution in northeastern India	Distribution in Indian States and elsewhere
Superfamily: Zygaenoidea Family: Zygaenidae Subfamily: Chalcosiinae Tribe: Chalcosiini				
1	*Eterusia aedea*	(Linnaeus, 1763)	AS, ML, NL	SR, NP, TW, JPN, CN, MH
Superfamily: Pyraloidea Family: Crambidae Subfamily: Pyralinae Tribe: Pyralini				
2	*Heortia vitessoides*	(Moore, [1885])	ML, TR	CN, SR, TH, MY, FJ, AU
Subfamily: Spilomelinae Tribe: Margaroniini				
3	*Terastia egialealis*	(Walker, 1859)	NL	MH, AP, AR
Subfamily: Pyraustinae Tribe: Portentomorphini				
4	*Hyalobathra* sp.		NE	AU, SR, TW, JPN, MM, UK
Subfamily: Crambinae				
5	*Eoophyla* sp.		NE	MH, AP, AR
Superfamily: Drepanoidea Family: Drepanidae Subfamily: Drepaninae Tribe: Drepanini				
6	*Canucha specularis*	(Moore, 1879)	AS	SR, CN, SK
7	**Macrocilix maia*	(Leech, 1888)	ML, AS	JPN, TW, KR, CN, BOR, MY
8	*Tridrepana lunulata*	(Butler, 1887)	NE	MM, CN, SR, TH, MY, ID, NP, BT, AU, WB, UK
Superfamily: Lasiocampoidea Family: Lasiocampidae Subfamily: Lasiocampinae Tribe: Odonestini				
9	*Odonestis bheroba*	Moore, 1859	AS	SR, NP, TH, CN, MM, TW
Tribe: Pinarini				
10	*Lebeda nobilis nobilis*	Walker, 1855	MN, ML, NL	CN, NP, MM, TW, NL, ML, JK, UK, MH, WB, SK
Tribe: Trabalini				
11	*Trabala vishnou*	(Lefebvre, 1827)	AS, MN	SR, MM, MY, TH, ID, CN, TW, MP, BR
Superfamily: Bombycoidea Family: Saturniidae Subfamily: Saturniinae Tribe: Saturniini				
12	*Actias maenas*	Doubleday, 1847	NE	KL, KA
13	*Antheraea assamensis*	Helfer, 1837	AS, MN, ML, NL, MZ	NP, ID, MM, SR
14	*Loepa* cf. *katinka*	Westwood, 1848	AS, ML, MN, NL	SEA
15	*Rinaca cidosa*	(Moore, 1865)	NE	NP, BT, MM, TH, HP, JK, UK
Family: Sphingidae Subfamily: Macroglossinae Tribe: Macroglossini				
16	*Acosmeryx naga*	(Moore, [1858])	ML	SR, NP, BT, MM, TH, MY
Subfamily: Smerinthinae Tribe: Ambulycini				
17	**Ambulyx moorei*	(Moore, [1858])	AS	SR, NP, BT, MM, TH, MY, KA
Subfamily: Sphinginae Tribe: Sphingini				
18	*Meganoton analis*	(Felder, 1874)	ML	SEA, JK, UK, AR
Superfamily: Geometroidea Family: Geometridae Subfamily: Ennominae				
19	**Metapercnia ductaria*	(Walker, 1862)	MN, MZ	TH, WB

	Taxa	Author, year	Distribution in northeastern India	Distribution in Indian States and elsewhere
Subfamily: Ennominae Tribe: Abraxini				
20	*Abraxas* sp.		NE	SEA
Subfamily: Ennominae Tribe: Boarmiini				
21	*Alcis* sp. 1		NE	SEA, WB
22	*Alcis* sp. 2		NE	SEA, WB
23	**Amblychia* sp.		AS	SR, NP, MY, ID, KR, JPN, AU, UK
24	*Amraica recursaria*	(Walker, 1860)	ML	WB, TN
25	*Coremecis nigrovittata*	(Moore, 1868)	ML, NL	MY, NP, AR, SK
26	**Cleora fraterna*	(Moore, 1888)	NE	CN, TW, NP, BT, HP, BR, MH, WB, UP, TN
27	*Cleora* sp. 1		NE	CN, TW, NP, BT, HP, BR, MH, WB, UP, TN
28	*Cleora* sp. 2		NE	CN, TW, NP, BT, HP, BR, MH, WB, UP, TN
29	**Gasterocome pannosaria*	(Moore, 1868)	ML	NP, BT, CN, TW
30	**Harutaea flavizona*	Sato, 2000	NE	NP, TW,TH, MY, ID, AR
31	**Hypomecis separata*	(Walker, 1860)	ML	SR, BOR, TN, WB, MP, UK, KL
32	**Hypomecis transcissa*	(Walker, 1860)	AS, MR	SR, BOR, TN, WB, MP, UK, KL
33	**Krananda semihyalina*	(Moore, [1868])	ML, MR	JPN, MY, TW, CN, KR, WB
34	**Lassaba albidaria*	(Walker, 1866)	ML	JK, WB, UK
35	**Ophthalmitis xanthypochlora*	(Wehrli, 1924)	NE	CN, TH
Tribe: Hypochrosini				
36	**Fascellina plagiata*	Walker, 1866	NE	SEA
37	**Hypochrosis* sp.		NE	SEA
Tribe: Plutodini				
38	*Plutodes costatus*	Butler, 1886	ML	CN, NP, TH, MM, MY, ID, WB
39	**Plutodes flavescens*	Butler, 1880	AS	SEA, WB
Tribe: Ourapterygini				
40	**Ourapteryx* sp.		NE	NE- INDIA
Subfamily: Sterrhinae Tribe: Scopulini				
41	**Scopula vicina*	(Thierry Mieg, 1907)	NE	CN, MY, SR, MH, HP
42	*Scopula* sp.		NE	SR, SEA, AU
Subfamily: Geometrinae Tribe: Nemoriini				
43	**Eucyclodes textilis*	(Butler, 1880)	NL	SR, MM, MH
Tribe: Hemitheini				
44	*Hemithea* sp. 1		NE	NP
45	*Hemithea* sp. 2		NE	NP
46	**Maxates thetydaria*	(Guenée, 1857)	AS, MR	BD
47	*Pelagodes* sp. 1		NE	SR, FJ, MY, AU, WB, KR
48	*Pelagodes* sp. 2		NE	SR, FJ, MY, AU, WB, KR
49	*Pelagodes* sp. 3		NE	SR, FJ, MY, AU, WB, KR
Tribe: Pseudoterpnini				
50	*Pingasa rubicunda*	(Warren, 1894)	ML, NL	AR, PH
Superfamily: Noctuoidea Family: Notodontidae Subfamily: Phalerinae				
51	*Phalera grotei*	Moore, 1860	AS, NL	SR, CN, KR, MM, BT, ID, MH, KR, KL, TN

	Taxa	Author, year	Distribution in northeastern India	Distribution in Indian States and elsewhere
Subfamily: Notodontinae Tribe: Netrini				
52	*Netria* sp. 1		NE	CN, SR, NP, MM, TH, UK, MH
53	*Netria* sp. 2		NE	CN, SR, NP, MM, TH, UK, MH
Tribe: Notodontini				
54	*Formofentonia orbifer*	(Hampson, [1892])	NE	TW
55	*Chadisra bipartita*	Matsumura, 1925	NE	MM, NP, PK, SR, MH
Family: Erebidae Subfamily: Arctiinae Tribe: Arctiini				
56	*Aglaomorpha plagiata*	(Walker, 1855)	AS, ML	CN, NP, MM, KK, HP, UK
57	*Areas galactina*	(van der Hoeven, 1840)	ML. NL	CN, TW, NP, BT, UK, HP, WB
58	*Creatonotos transiens*	(Walker, 1855)	AS, MN, ML, NL, TR	SEA
59	**Nyctemera arctata*	Walker, 1856	NE	CN, NP, BT, MM, TW, ID, WB, CG
60	*Nyctemera adversata*	(Schaller, 1788)	AS, NL, MN, TR, MR	CN, JPN, MM, TH, ID, NP
61	*Spilarctia obliqua*	Walker, 1855	AS, NL, MN, TR, MR	PK, BT, MM, BD
62	*Spilarctia* sp.		NE	PK, BT, MM, BD
Tribe: Syntomini				
63	*Amata divisa*	(Walker, 1854)	AS, ML, NL	CN, NP, MM
64	*Eressa confinis*	(Walker, 1854)	AS, ML, NL	BT, SR, MM, TW, CN, UK, TN, AP, KA, MP
65	*Syntomoides imaon*	(Cramer, [1779])	MN, ML, NL	SR, TH, MM, NP, CN, BD, TN, KL
Tribe: Lithosinii				
66	*Ammatho cuneonotatus*	Walker, 1855	AS	CN, NP, TH, MY, TN, KL, KR
67	**Barsine linga*	(Moore, 1859)	AS, ML, MR	WB, SK, AR
68	**Brunia* sp.		NE	SR, CN
69	**Brunia sarawaca*	(Butler, 1877)	NE	MY, BOR
70	*Cyana peregrina*	(Walker, 1854)	AS, MN, ML, MR, NL, TR	AF, SEA, AU, HP, UK, WB
71	**Macrobrochis gigas*	(Walker, 1854)	AS	CN, BT, NP, ID, TH, TW, MH, KR, MP, WB, KL
72	**Miltochrista undulosa*	(Walker, 1854)	NE	NP, MM, CN
Subfamily: Aganainae				
73	*Asota caricae*	(Fabricius, 1775)	AS, MN, ML, MR, NL, TR	SR, MY
74	**Asota heliconia*	(Linnaeus, 1758)	NE	SR, MM, AU
Subfamily: Calpinae Tribe: Phyllodini				
75	**Phyllodes eyndhovii*	Vollenhoven, 1858	AS	SR, TW, TH
Tribe: Calpini				
76	**Dierna strigata*	(Moore, 1867)	ML	MM, SR, HP, UK, AR
Subfamily: Erebinae				
77	**Fodina oriolus*	Guenée, 1852	AS, ML	SR, BT
Tribe: Erebini				
78	*Erebus caprimulgus*	(Fabricius, 1781)	AS, MN, ML, MR, NL, TR	SR, MM, MY, BOR, KL, MH, KR, TN
79	*Erebus macrops*	(Linnaeus, 1768)	AS, MN, ML, MR, NL, TR	SR, MM, KL
Tribe: Ommatophorini				
80	**Ommatophora* sp.		NE	TW, SEA
Tribe: Hulodini				
81	*Ericeia eriophora*	(Guenée, 1852)	NE	SR, TH, MY, TN
82	*Speiredonia mutabilis*	(Fabricius, 1794)	NE	SR, MM, AU

	Taxa	Author, year	Distribution in northeastern India	Distribution in Indian States and elsewhere
Tribe: Ophiusini				
83	*Dysgonia* sp.		NE	CN, ID, JPN, CN, KR, TN, UK
84	**Ophiusa trapezium*	(Guenee, 1852)	AS	SR, NP
Tribe: Sypnini				
85	*Daddala* sp.		NE	TH, TW, JPN
Subfamily: Hypocalinae Tribe: Hypocalini				
86	*Hypocala* sp. 1		NE	SR, AF, AU, TN, UK, AP, KR, MP
87	*Hypocala* sp. 2		NE	SR, AF, AU, TN, UK, AP, KR, MP
Subfamily: Lymantriinae Tribe: Lymantriini				
88	*Lymantria* cf. *bivittata*	Hübner, [1819]	MN, ML, NL	TW, TH
89	**Lymantria lepcha*	(Moore, 1879)	ML	JPN, SR, MM
90	*Lymantria mathura*	Moore, [1866]	MN, ML, NL	CN, NP, JPN, KR, MP, MH, AR
91	*Lymantria* sp.		NE	CN, NP, JPN, KR, MP, MH, AR
Tribe: Leucomini				
92	*Perina nuda*	(Fabricius, 1787)	AS, MN, ML, MR, NL, TR	CN, TH
93	*Arna bipunctapex*	(Hampson, 1892)	ML, NL	TW, TH
94	*Euproctis fraterna*	Moore, 1883	AS, MN, ML, MR, NL, TR	SR
95	*Euproctis* sp.		NE	SR
96	*Somena scintillans*	Walker, 1856	AS, MN, ML, MR, NL, TR	SR, MM, SEA
Tribe: Orgyiini				
97	**Calliteara angulata*	Hampson, 1895	ML	NP, SEA
98	*Calliteara grotei*	(Moore, 1859)	NE	SEA
99	*Calliteara* sp.		NE	SEA
100	*Dasychira* sp.		NE	AF, AU
101	*Ilema cf. chloroptera*	(Hampson, [1893])	ML, NL	HP, AR
Family: Euteliidae Subfamily: Euteliinae				
102	**Targalla apicifascia*	Hampson, 1894	NE	SR, MM, TN, HP, MH, WB
103	**Eutelia discistriga*	Walker, 1865	NE	SR
Family: Nolidae Subfamily: Westermanniinae				
104	**Westermannia superba*	Hübner, 1823	NE	SR, AU, TN, KL, KR
Subfamily: Chloephorinae Tribe: Careini				
105	*Xenochroa* sp.		NE	BT, SR, BOR, TN, KL, MH
Family: Noctuidae Subfamily: Acronictinae				
106	*Acronicta* sp.		NE	CN, KR, JPN

* indicates first report from Nagaland.

AF—Africa | AP—Andhra Pradesh | AR—Arunachal Pradesh | AS—Assam | AU—Australia | BD—Bangladesh | BOR—Borneo | BT—Bhutan | CG—Chhattisgarh | FJ—Fiji | HP—Himachal Pradesh | ID—Indonesia | JK—Jammu & Kashmir | JPN—Japan | KA—Karnataka | KL—Kerela | KR—Korea | MH—Maharashtra | ML—Meghalaya | MM—Myanmar | MN—Manipur | MP—Madhya Pradesh | MR—Mizoram | MY—Malaysia | NE—North-east | NL—Nagaland | NP—Nepal | PK—Pakistan | SEA—southeastern Asia | SR—Sri Lanka | TH—Thailand | TN—Tamil Nadu | TR—Tripura | TW—Taiwan | UK—Uttarakhand | WB—West Bengal.

to disturbances, while others, such as Ennominae, Geometrinae, Epipaschiinae, Lymantriidae, and Anthelidae, demonstrate negative responses. A multitude of nocturnal moth species have specific distributional boundaries associated with their host plants and climatic constraints, rendering them effective indicators of changing climate conditions in both local and regional contexts. Moths serve as effective biological indicators of climate change impacts due to their variable maturation rates in response to annual temperature fluctuations (Highland et al. 2013). This often indicates that the ecosystem is a conducive habitat and teeming with diverse fauna. Pūrerehua, especially moths, are essential for nitrogen and carbon cycling due to their capacity to decompose coarse organic matter and rejuvenate soils (Merien 2021). The decline in moth populations, given their pivotal role in food webs and their significance as a food source for mammals, songbirds, and other insects, would consequently influence the entire ecosystem and affect all other animals (Peralta et al. 2014).

Consequently, if comprehensive research is conducted in this domain and other locations are included, a greater diversity of species may be documented compared to the recent study. In Nagaland, research is limited, and advancement has been sluggish due to a dearth of literature. Despite the study area indicating a substantial population of moths, further exploration is necessary for comprehensive research on moths. Nagaland possesses significant biodiversity; nonetheless, many regions remain unexamined for moth research. This study, not exhaustive, seeks to elucidate the moth variety of Lumami, Nagaland, and its adjacent regions. The current findings, despite temporal limitations, establish a basis for future long-term, comprehensive, and targeted moth surveys. Additionally, the results of this study can inform judgments about the conservation of natural resource management, particularly concerning moth biodiversity. Consequently, a comprehensive survey accompanied by long-term monitoring programs will facilitate the assessment of species status and may potentially result in additional discoveries within these insect groups.

CONCLUSION

This study found a rich and diverse assemblage of moths, reflecting variations in species richness, variety, and familial representation. Enhanced comprehension of biodiversity and ecosystem health, along with comprehensive research and monitoring of moth habitat alterations due to pollution, climate change, and anthropogenic activities, might yield more insights into ecosystem health. Moreover, examining the effects of climate change can be achieved by understanding species distribution, population dynamics, the impact of urbanization, and their direct effects on the dependent fauna and flora. This work enhances the comprehension of moth ecology in Lumami by broadening the catalogue of known moth species and elucidating their ecological functions within local ecosystems.

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Image 1. 1—*Eterusia aedea* | 2—*Heortia vitessoides* | 3—*Terastia egialealis* | 4—*Hyalobathra* sp. | 5—*Eoophyla* sp. | 6. *Canucha specularis* | 7—*Macrocilix maia* | 8—*Tridrepana lunulata* | 9—*Odonestis bheroba* | 10—*Lebeda nobilis nobilis* | 11—*Trabala vishnou* | 12—*Actias maenas* | 13—*Antheraea assamensis* | 14—*Loepa* cf. *katinka* | 15—*Rinaca cidosa* | 16—*Acosmeryx naga* | 17—*Ambulyx moorei* | 18—*Meganoton analis* | 19—*Abraxas* sp. | 20—*Metapercnia ductaria* | 21—*Alcis* sp. 1. | 22—*Alcis* sp. 2. | 23—*Amblychia* sp. | 24—*Amraica recursaria* | 25—*Coremecis nigrovittata*. © Keneisano Yhoshii.

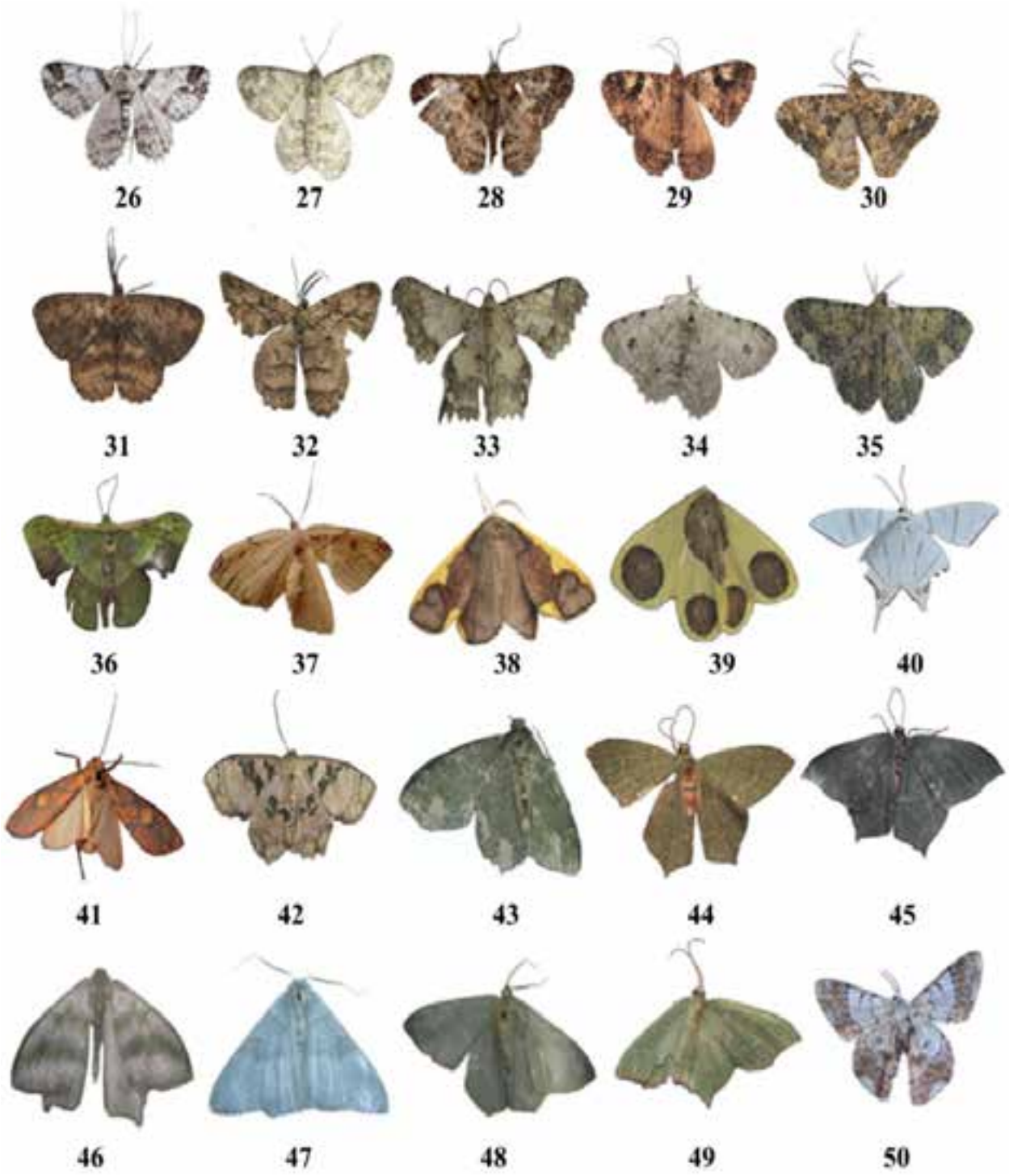

Image 2. 26—*Cleora fraterna* | 27—*Cleora* sp.1 | 28—*Cleora* sp.2 | 29—*Gasterocome pannasaria* | 30—*Harutaea flavizona* | 31—*Hypomecis separata* | 32—*Hypomecis transcissa* | 33—*Krananda semihyalina* | 34—*Lassaba albidaria* | 35—*Ophthalmitis xanthypochlora* | 36—*Fascellina plagiata* | 37—*Hypochrosis* sp.| 38—*Plutodes costatus* | 39—*Plutodes flavescens* | 40—*Ourapteryx* sp.| 41—*Ammatho cuneonotatus* | 42—*Scopula vicina* | 43—*Eucyclodes textilis* | 44—*Hemithea* sp.1 | 45—*Hemithea* sp.2 | 46—*Maxates thetydaria* | 47—*Pelagodes* sp.1 | 48—*Pelagodes* sp.2 | 49—*Pelagodes* sp.3 | 50—*Pingasa rubicunda*.

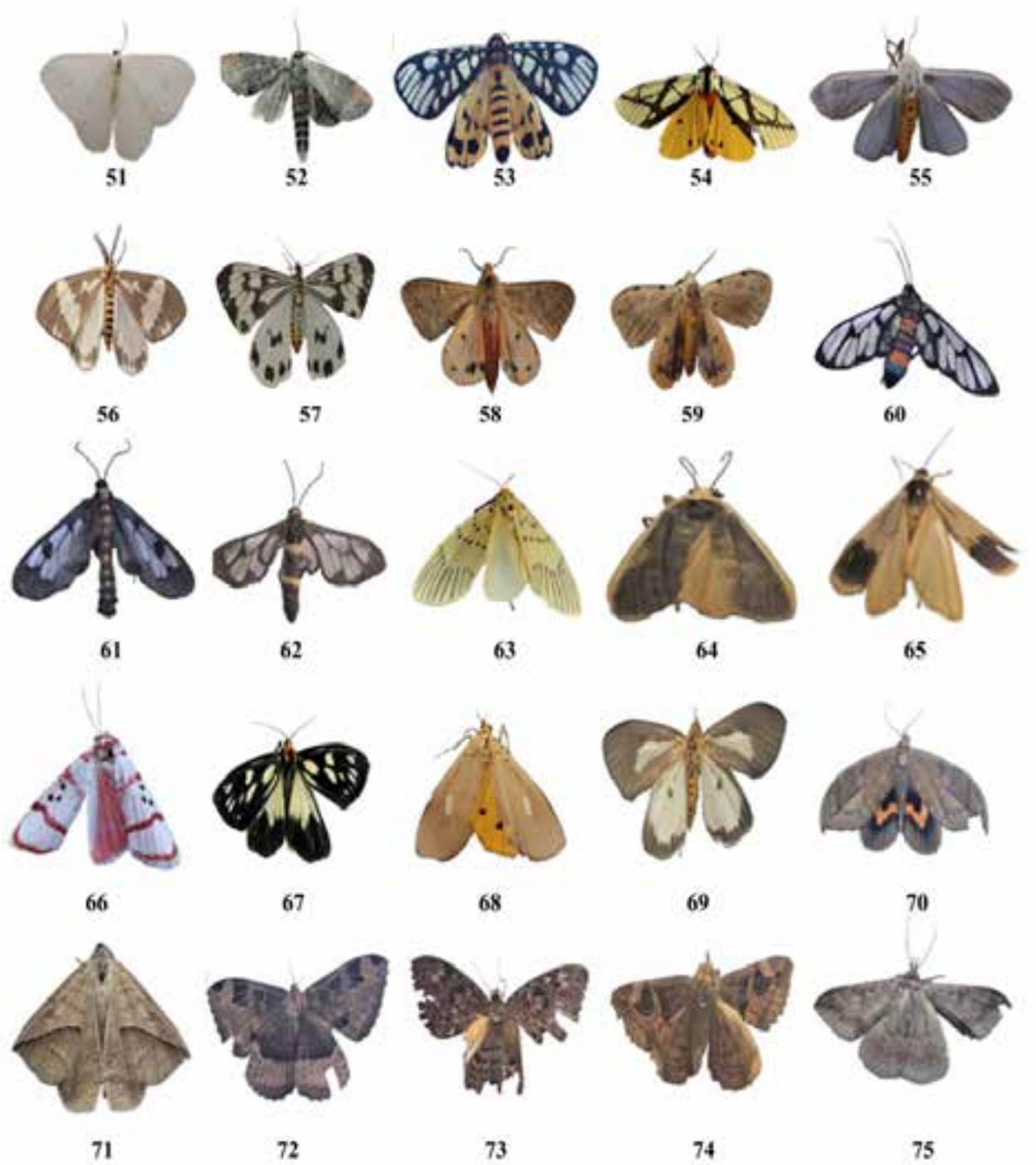

Image 3. 51—*Scopula* sp. | 52—*Phalera grotei* | 53—*Aglaomorpha plagiata* | 54—*Areas galactina* | 55—*Creatonotos transiens* | 56—*Nyctemera arctata* | 57—*Nyctemera adversata* | 58—*Spilarctia obliqua* | 59—*Spilarctia* sp. | 60—*Amata divisa* | 61—*Eressa confinis* | 62—*Syntomoides imaon* | 63—**Barsine linga* | 64—*Brunia* sp. | 65—*Brunia sarawaca* | 66—*Cyana peregrine* | 67—*Macrobrochis gigas* | 68—*Asota caricae* | 69—*Asota heliconia* | 70—*Phyllodes eyndhovii* | 71—*Dierna strigata* | 72—*Erebus caprimulgus* | 73—*Erebus macrops* | 74—*Ommatophora* sp. | 75—*Ericeia eriophora.* © Keneisano Yhoshii.

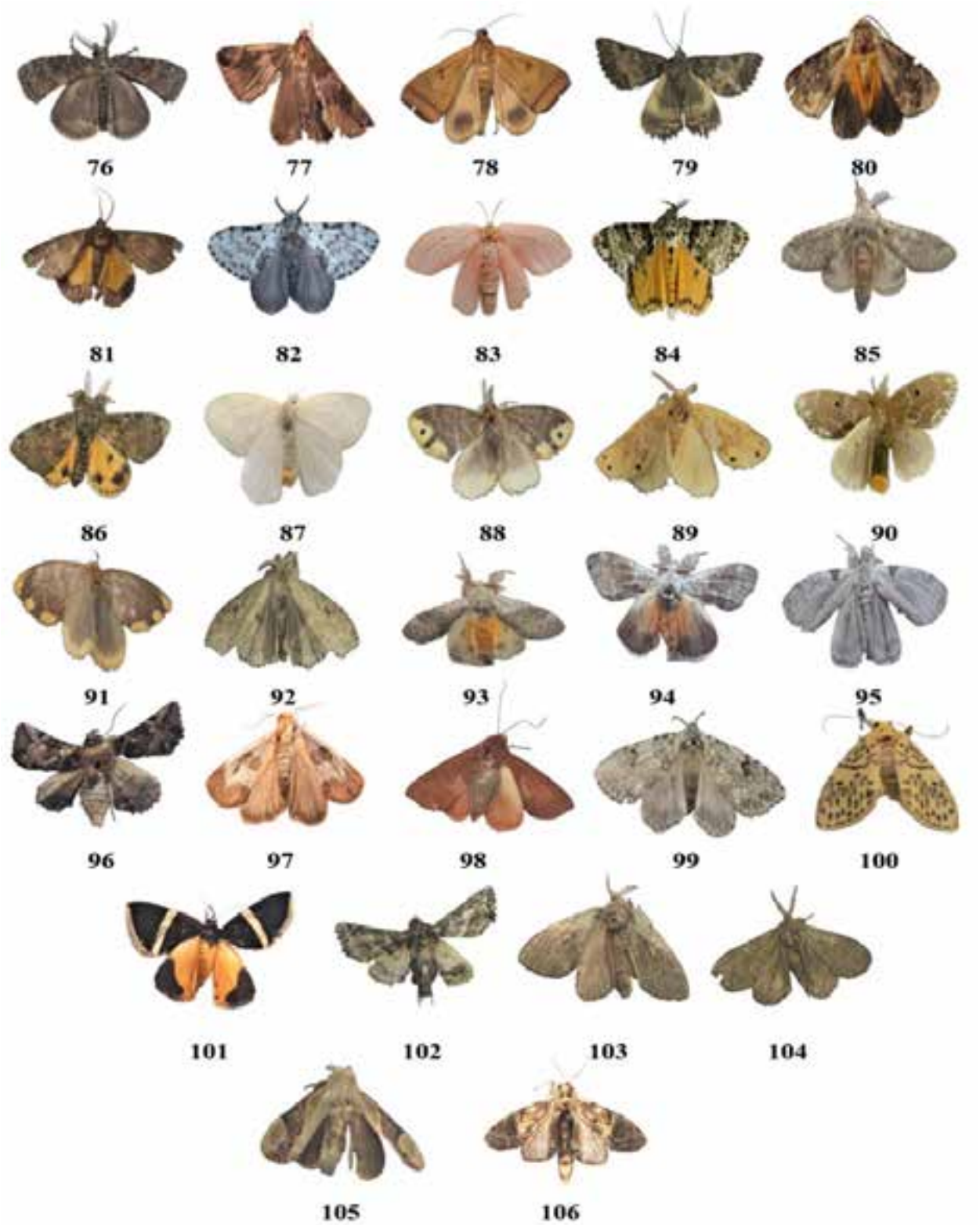

Image 4. 76—*Speiredonia mutabilis* | 77—*Dysgonia* sp. | 78—*Ophiusa trapezium* | 79—*Daddala* sp. | 80—*Hypocala* sp.1 | 81—*Hypocala* sp.2 | 82—*Lymantria* cf. *bivittata* | 83—*Lymantria Lepcha* | 84—*Lymantria Mathura* | 85—*Lymantria* sp. | 86—*Ilema* cf. *chloroptera* | 87—*Perina nuda* | 88—*Arna bipunctapex* | 89—*Euproctis fraterna* | 90—*Euproctis* sp. | 91—*Somena scintillans* | 92—*Calliteara angulata* | 93—*Calliteara grotei* | 94—*Calliteara* sp. | 95—*Dasychira* sp. | 96—*Targalla apicifascias* | 97—*Westermannia superba* | 98—*Xenochroa* sp. | 99—*Acronicta* sp. | 100—*Miltochrista undulosa* | 101—*Fodina oriolus* | 102—*Eutelia dicistriga* | 103—*Netria* sp.1 | 104—*Netria* sp.2 | 105—*Formofentonia orbifer* | 106—*Chadisra bipartite.* © Keneisano Yhoshii.

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COMMUNICATION

New population report of the 'Critically Endangered' Golden Himalayan Spike *Phlomoides superba* (Magnoliopsida: Lamiales: Lamiaceae) from Samba and Udhampur districts of Jammu & Kashmir, India

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Abstract: The present study reports four newly discovered populations of the critically endangered *Phlomoides superba* (Royle ex Benth.) Kamelin & Makhm. from the Shiwalik region of Samba and Udhampur districts in Jammu & Kashmir, India. The species holds significant ethnoveterinary importance, particularly its roots, which are traditionally used to treat mastitis and enhance milk production in cattle. However, excessive utilisation for these purposes (82.4%) and a strong competition from the invasive weed *Lantana camara* L. (14.7%), have contributed to a marked decline in its natural populations. To mitigate these threats, informants recommended in situ conservation interventions such as controlling *Lantana camara* invasion and adopting sustainable usage of root tubers. The discovery of new populations not only broadens the known range of *Phlomoides superba* but also enhances its survival prospects by increasing genetic diversity and diminishing the species' susceptibility to extinction. Furthermore, comprehensive phytochemical and pharmacological studies are strongly recommended to scientifically validate its traditional medicinal uses, isolate and characterize bioactive constituents, and assess its potential for the development of novel therapeutic agents in the future. These scientific assessments, combined with conservation-focused utilisation, are crucial for ensuring the long-term preservation and sustainable use of this valuable ethnomedicinal species.

Keywords: Conservation, *Eremostachys superba*, gajar moola, ornamental plant, threatened species, veterinary, women infertility.

Saar: Maujooda adhyayan Parat de Jammu–Kashmir rajya de Samba te Udhampur zilyan de Shiwalik kshetra ch gambhir roop kanne sankatgrast bute *Phlomoides superba* (Royle ex Benth.) Kamelin & Makhm. di chaar navi khoji gayina aabadiyan baare jaankaari dinda ae. Eh prajati dangarein di bimariyan aaste mahatva rakhdian ae, khaaskar isdiyan jarran, jinde upyog paramparaagat taur te dangran ch mastitis di bimari theek karne tein doodh utpaadan vadhane lai kita jaanda ae. Par eh jarran da zarurat ton zyada istemaal (82.4%) tain aakramak jari *Lantana camara* L. kane mukabla (14.7%) is prajati di prakritik aabadi ch tez giraavat da kaaran banea ae. Ina khatryan gi gataane aaste soochna-daatyan ne *in-situ* sanrakshan upaay sujhaaye, jiyan ki *Lantana camara* di avadhi nu niyantrit karna tain jarr-kandan da seemit tain satat upyog apnaana. Navi aabadiyan di khoj na sirf *Phlomoides superba* de phailaav kshetra ge vadhaandi ae, balki aanuvanshik vividhta vadhaake tain vilupt hon de khatre nu ghataake is prajati de bachaav di sambhaavna nu majboot kar di ae. Aggoon, is de paramparaagat aushadhiya upyogan di vaigyaanik pushti karne, jaiv-sakriya ghatkan di pehchaan tain visheshta nirdharan, tain bhavikh ch navi davaiyan banane di sambhaavna jaanchne lai vistrit phytochemical tain pharmacological adhyayan zaroori manne gaye na. Eh vaigyaanik adhyayan, sanrakshan-kendrit upyog de naal milke, is keemti ethnomedicinal prajati de deerghkaalik sanrakshan tain satat upyog nu sunishchit karne lai bahut zaroori na.

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INTRODUCTION

Phlomoides superba (Royle ex Benth.) Kamelin & Makhm. (syn. *Eremostachys superba* Royle ex Benth.), is a significant perennial herb belonging to the tribe Phlomideae of the family Lamiaceae (Srivastava et al. 2017; Garg & Singh 2024). This species is commonly referred to as the Golden Himalayan Spike due to its striking appearance, whereas the vernacular names include 'Gajar moola' in Dogri and 'Ban mooli' in Hindi (Srivastava et al. 2017; Garg & Singh 2024). The plant grows upright and can reach a height of 1.5 m (Image 1). Roots are tuberous and vertical. Stem is hairy, either branched or unbranched. Leaves are simple, hairy, crenate, and have lobed or serrated margins. Leaf petiole is up to 10 cm and lamina is 9.5–19.5 cm in length and 4.5–9.5 cm wide. The plant bears bright yellow flowers arranged in verticillaster spikes with 8–12 flowers at each node. Bracts are oval-shaped. Corolla is yellow and bi-lipped. Nutlets are trigonous and black in colour. Flowering takes place from March to May (Garg & Singh 2024).

Phlomoides superba is geographically distributed across the western Himalayan foothills, found in eastern Afghanistan, Pakistan, and the Indian states of Himachal Pradesh, Jammu & Kashmir, and Uttarakhand (Malik et al. 2014; Singh et al. 2022). The species naturally flourishes on the margins of forests in moist and loamy soil. However, agricultural expansion has resulted in the loss of natural habitats, confining *Phlomoides superba* to the edges of crop fields (Verma et al. 2003; Srivastava 2020). The species holds considerable medicinal, veterinary, and ornamental value. Its root tubers are traditionally used by local communities and tribes for treating mastitis and stimulating lactation in cattle, as well as for various human ailments like liver and stomach issues and gout (Malik et al. 2014; Srivastava et al. 2017; Garg & Singh 2024).

The species has grabbed the attention of numerous researchers because of its beautiful blooms, rarity, declining populations, and ethnobotanical applications (Srivastava et al. 2017). Its population has experienced alarming declines due to factors such as over-exploitation for medicinal purposes, extensive habitat loss due to agricultural expansion & widening of roads, and grazing by wild animals (Garg & Singh 2024). Furthermore, the species exhibits poor sexual reproduction, low seed set, and intrinsic seed dormancy under natural conditions, which exacerbates its low regeneration potential. This has led to inbreeding depression in small, isolated populations and a scarcity of pollinators (Garg & Rao 1997; Verma et al. 2003; Uniyal et al. 2012; Srivastava et al. 2017; Srivastava 2020). Recently, the *Helicoverpa armigera* Hübner has been identified as a significant pest, with its larvae feeding on seeds and causing 90–95% seed loss in highly infested wild populations (Srivastava & Sharma 2025). The present study was conducted to: (i) enlist the new sites where *Phlomoides superba* grows naturally, and (ii) document local methods for its conservation. Both the reporting of new sites and the documentation of local conservation practices for *Phlomoides superba* will contribute to the effective management of the species in the future.

Image 1. *Phlomoides superba* growing naturally at village Badla Denonion.

MATERIAL AND METHODS

Study site

The present study was conducted in Nand (32.587° N, 75.182° E), Badla Denonion (32.623° N, 75.068° E) and Gahani Alna (32.624° N, 75.058° E) villages of district Samba, and in Seral Chowa (32.686° N, 75.096° E) village of district Udhampur, union territory of Jammu & Kashmir (JKUT), India (Figure 1).

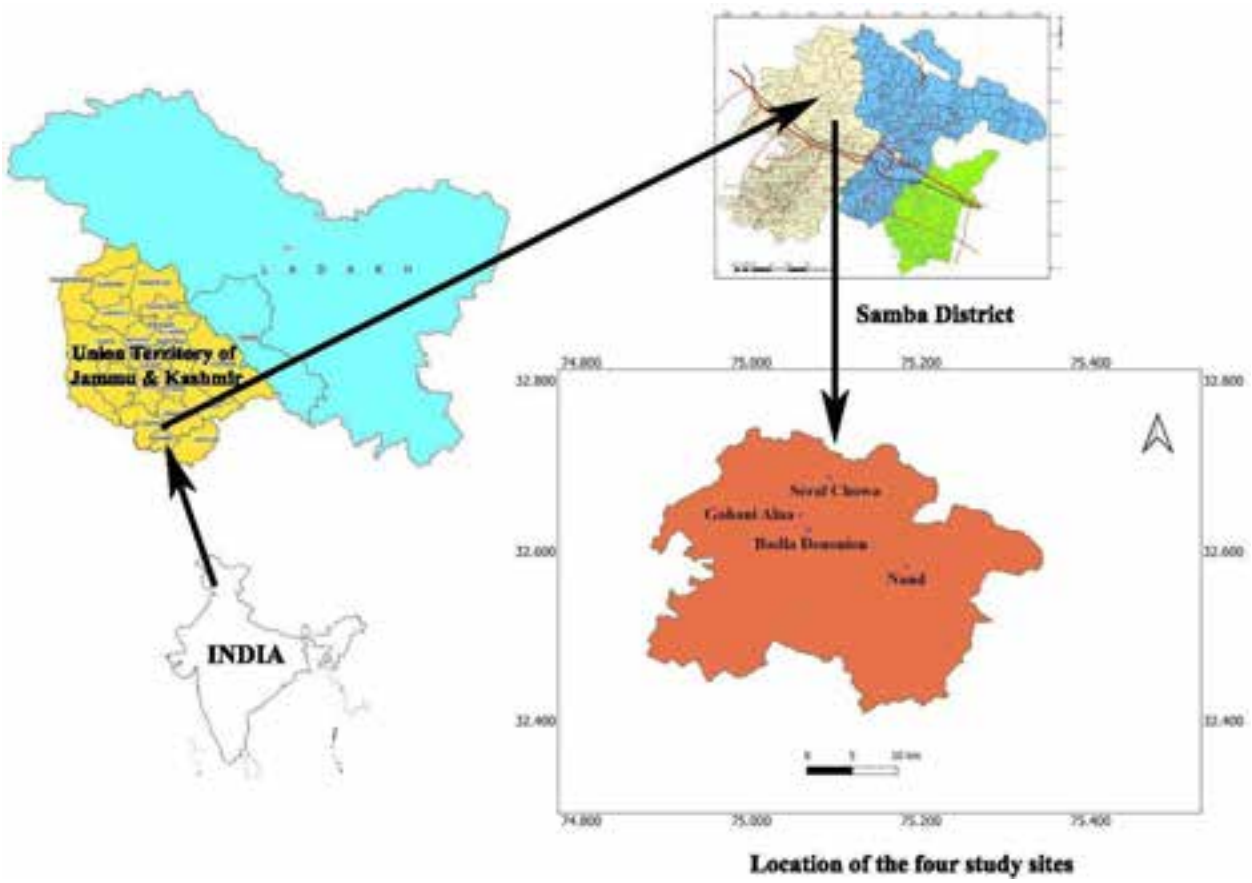

Figure 1. Location map of the study area.

Collection of data

The plant specimen was collected from the study site, preserved, mounted on the herbarium sheet, and submitted to the Herbarium of the Department of Botany, University of Jammu, Jammu, with an accession No. HBJU 17678. A total of 34 elderly people, above the age of 60 years, of the aforementioned villages were interviewed randomly for gathering the information related to *Phlomoides superba* as per a semi-structured questionnaire, and focused group discussions.

RESULTS AND DISCUSSION

Distribution

In the present study, the new population reports of *Phlomoides superba* are from Nand (112 individuals), Badla Denonion (24), Gahani Alna (71), and Seral Chowa (123), marking a total of 330 individuals. The species was found growing on the bunds of agricultural fields, along with wheat crop, in three villages, viz. Nand, Badla Denonion, and Gahani Alna, and from the edges of the forest of village Seral Chowa. These results are as per earlier studies (Verma et al. 2003; Srivastava et al. 2017; Srivastava 2020). Contrary to this, Srivastava et al. (2017) reported one population of *Phlomoides superba* from village Jallow of Udhampur District that grows alongside a small stream. In Seral Chowa Village, *Phlomoides superba* occurred along forest edges with species such as *Ageratum conyzoides* L., *Lamium amplexicaule* L., *Ajuga integrifolia* Buch. - Ham. ex D.Don, *Vicia sativa* L., *Justicia adhatoda* L., and *Carissa spinarum* L., but the site was heavily invaded by *Lantana camara*.

As per Srivastava et al. (2017), *Phlomoides superba* has so far been reported from 10 localities; seven sites from JKUT (Domel, Tara, Bal Shama, Suketor, Panj Grain, Jallow, and Pouni), two from Himachal Pradesh (Gujreda, Kundian), and one site from Uttarakhand (Mohand), distributed between 400 and 730 m altitude (Figure 2). The distribution (405–502 m) of *Phlomoides superba* in the present four sites is well within the range reported by earlier studies (Koul et al. 1997; Verma et al. 2007; Uniyal et al. 2012; Srivastava et al. 2017).

Speaking with the informants about the distribution of

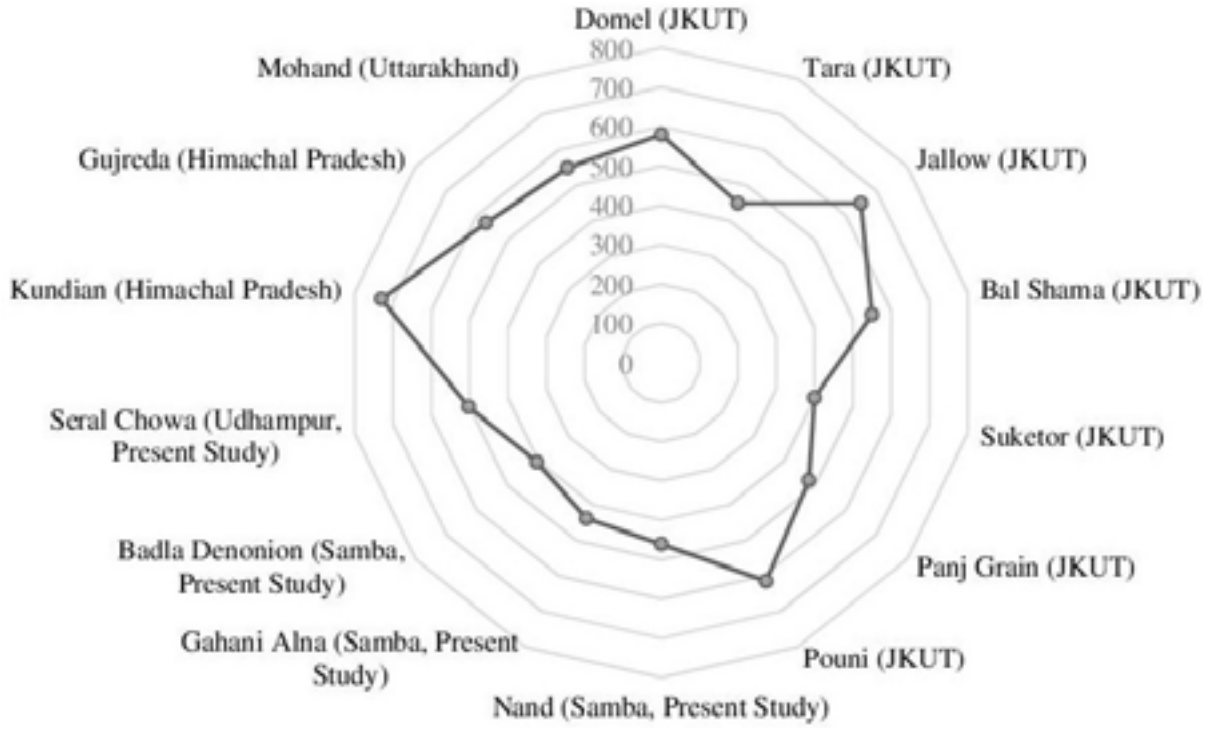

Figure 2. The distribution of *Phlomoides superba* in different altitudes (values in meter above mean sea level). JKUT—Union Territory of Jammu & Kashmir.

Phlomoides superba, it was discovered that the species was found in Labli and Najwal villages of the district Samba around 40–60 and 10–15 years ago, respectively. The first author then visited these locations, and did not find even a single plant growing over there which suggests a decline of the population of the said plant species. Similar observations of declining populations of *Phlomoides superba* from 2,192 to 982 individuals (i.e., 55%) have also been reported by Srivastava et al. (2017) from seven sites in a span of 4–20 yr.

Threat status

In the previous research, *Phlomoides superba* has been categorised in different threat status as 'Vulnerable' (Jain & Sastry 1980; Ved et al. 2003; Samant et al. 2007; Pant & Pant 2011), 'Endangered' (Jain & Sastry 1984; Garg & Rao 1997; Verma et al. 2007; Panwar & Srivastava 2015; Panwar et al. 2015; Pundir 2015), 'Critically Endangered' (Verma et al. 2007; Panwar 2014; Panwar et al. 2014), and 'near to extinction' (Som 1968; Rao & Garg 1994). *Phlomoides superba* is notified in the Gazette of India as a species on the verge of extinction in JKUT, Himachal Pradesh, and Uttarakhand as per Section 38 of the Biological Diversity Act, 2002 (Gowthami et al. 2021). The literature studies make it clear that a significant number of species in the genus *Eremostachys* are either extinct or very close to becoming so (Khan et al. 2022).

Ethnobotanical applications

In the present study, cattle are fed the root tubers to boost milk production and prevent mastitis and body swellings. The fresh tubers of the said species are dug from the ground, washed with water, cut into small pieces, mixed with the cattle feed, and fed to the cattle twice a day for three days. These uses are in accordance with the earlier studies conducted (Srivastava et al. 2017; Garg & Singh 2024). The locals also reported a unique ethnomedicinal use of the species, wherein the root tubers are consumed by women as a traditional remedy for infertility.

Causes of decline in *Phlomoides superba* population

In the present study site, the major cause (82.4%) of the decline in plant populations is the excessive use of root tubers for the treatment of mastitis, and as a galactagogue in livestock. The locals and other tribal groups dig out the root tubers of *Phlomoides superba*, mix it with cattle feed, and give it to the livestock. They also stated that invasion of *Lantana camara* (14.7%), and construction of roads (2.9%) in the natural habitats of *Phlomoides superba* as the associated reasons. These results are in accordance with earlier studies (Uniyal

et al. 2012; Srivastava et al. 2017; Garg & Singh 2024). The other factors are: poor fruit and seed set, which is primarily caused by pollinator restrictions (Verma et al. 2003), and poor capacity for regeneration (Garg & Rao 1997; Uniyal et al. 2012). Due to its attractive flowers, *Phlomoides superba* is considered to have strong ornamental value. However, this aesthetic appeal has encouraged its collection and use beyond its natural habitat, contributing to increasing anthropogenic pressure on wild populations (Pundir 2015).

Conservation of *Phlomoides superba*

Numerous measures have been undertaken for the conservation of *Phlomoides superba* in view of its critically endangered status and the severity of threats it faces. Locals are making efforts to conserve *Phlomoides superba* by raising seedlings and cultivating it in their fields; however, these attempts have met with limited success due to poor seed set and low germination rates. Consequently, in situ conservation remains the primary strategy, with villagers actively removing the invasive weed *Lantana camara* and practicing sustainable utilisation of *Phlomoides superba* to support its survival in the wild.

The survival and viability of *Phlomoides superba* seeds remain topics of debate. Earlier studies reported limited or negligible viability; however, natural regeneration in the wild suggests otherwise (Srivastava 2020). According to Garg & Rao (1997), seeds remain viable for only one month, while Sunnichan & Shivanna (1998) and Verma (2001) reported viability periods of five and eight months, respectively. Furthermore, Panwar & Srivastava (2015) observed that seeds stored at low temperatures retained viability for up to 12 months, and Srivastava (2020) recorded enhanced germination rates under such conditions.

Successful conservation and cultivation of the species require the development of efficient propagation protocols. Although in vitro propagation attempts have been made, these methods have not yet been widely adopted (Sunnichan & Shivanna 1998; Panwar et al. 2015). Ex situ efforts by Verma et al. (2003) demonstrated the feasibility of raising plants and distributing seeds to universities and national institutes across India. The first author has also collected seeds of the species, germinated them, and distributed seedlings to Lovely Professional University, Phagwara, Punjab; Government Degree College for Women, Kathua; and Government Degree College for Women, Gandhinagar, Jammu, to promote ex situ conservation efforts. More recently, Srivastava (2020) achieved successful ex situ propagation using seeds treated with cold stratification and GA_3, resulting in 84% and 82% germination success, respectively.

CONCLUSION

The locals were well aware of traditional uses and dwindling populations of *Phlomoides superba*. Further surveys are required to document the population if any, from different locations and analyse its conservation status. Phytochemical analysis and pharmacological studies may also be conducted for the identification of chemicals responsible for the ethnomedicinal properties, and for the development of novel drugs. Additionally, this will aid in the preservation of this lovely plant that is in danger of going extinct.

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SHORT COMMUNICATION

A new bird record of Oriental Darter *Anhinga melanogaster* (Suliformes: Anhingidae) in Bhutan: range expansion and plastic entanglement mortality

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Abstract: The Oriental Darter *Anhinga melanogaster*, ranges from Pakistan to Indonesia and the Philippines. Although it occurs in adjacent India, it has not been recorded in Bhutan. The first observation was of a live bird in a novel habitat, and the second a carcass, which indicates a potential threat from plastic pollution, as the cause of mortality was entanglement in plastic trash. We recommend that biologists and others carefully observe the newly created lakes supporting hydroelectric production in Bhutan because they may be creating novel habitats for species in Bhutan, as well as fostering range expansion of species into Bhutan.

Keywords: Darter, new record, novel habitat, observation, plastic pollution, population decline, threat, wetland habitat.

The Oriental Darter *Anhinga melanogaster* is distributed across southern and southeastern Asia ranging from Pakistan to Indonesia and the Philippine Islands (Orta et al. 2014). It is classified as a species of 'Least Concern' with an increasing population trend (Birdlife International 2024). Its status is enigmatic because it has been classified in the past as 'Near Threatened' owing to potential threats from habitat loss, pollution, competition with humans for prey, and has shown unexplained regional population declines with only minor expansions (Orta et al. 2014). We document the first confirmed record of this species in Bhutan, comprising a live individual in a novel habitat, and a carcass demonstrating mortality from plastic entanglement. We also add possible alternative explanations for this potential incipient range expansion.

First record of an Oriental Darter in Bhutan

On the morning of 20 April 2025, four of us (KD, KS, KG, & RJG) stopped alongside the Wangdue-Tsirang Highway (27.322^0 N, 89.941^0 E), overlooking a lake newly created by a recently constructed PunaTsangChu Hydroelectric Project dam (PunaTsangChu II) on the Puna Tsang Chu River in central Bhutan (Image 1) (Note: this lake was not yet depicted on Google Earth as of 30 September 2025, although the downstream dam site was visible). There, we observed and photographed an adult Oriental Darter. The only other waterbird we

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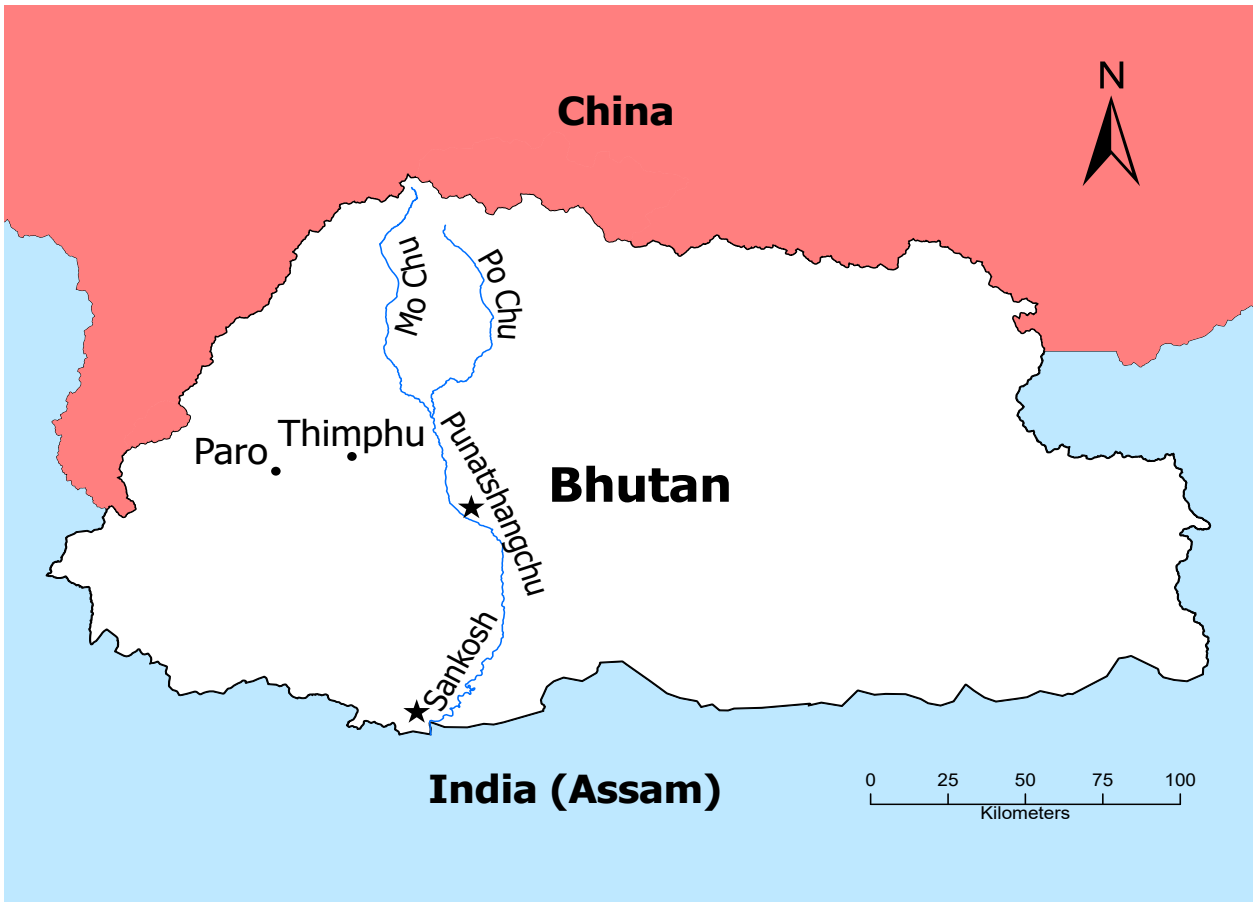

Image 1. Locations (stars) in Bhutan of living Oriental Darter *Anhinga melanogaster* observed on 20 April 2025 on the PunaTsangChu River, and of the Oriental Darter found dead on 13 May 2021 in the Sankosh River, Bhutan. This is the same river, only the name changes when it enters a different political district.

observed was a Great Cormorant *Phalacrocorax carbo*. Two of the authors (KD & RJG) simultaneously identified the darter using a spotting scope (Leica APO-Televid variable power) and binoculars (Swarovski EL 10 x 42), while others used binoculars. The darter was 200–400 m away on the far side of the lake. It was initially perched on an exposed branch of a fallen dead tree at the edge of the lake (Image 2). The darter then flew about 10 m to a small live tree or large shrub that was partially submerged in the water, approximately 7–10 m from the shore (Image 3). Although it is not clear if the bird moved in response to us because we were on a skyline above it, albeit distantly, it appeared to be aware of us because it made frequent intentional movements and ducked its head under the live vegetation. This is the first documented sighting of a live Oriental Darter in Bhutan.

Two of the authors (RG & KG) were most familiar with identifying Oriental Darters in the field, having seen them in India, Malaysia (Sabah), Thailand, and the Philippines, as well as observing the similar African Darter *Anhinga rufa*, Anhinga *Anhinga anhinga*, and Australasian Anhinga *Anhinga novaehollandiae*. This reservoir represents a newly available lacustrine habitat.

Past observation of a dead Oriental Darter in Bhutan

Subsequent to our sightings, KD alerted birders of the Oriental Darter observation in Bhutan through one of their social media networks. We were informed of a dead Oriental Darter found on 13 May 2021 at Lhamoizhingkha, Dagana, Bhutan (26.741^0 N, 89.867^0 E), which is approximately 0.5 km from the border with Assam, a state of India adjacent to Bhutan's southern border (Images 1 & 4). This dead bird with plastic entangling its beak was found by PD floating in the Sunkosh River while he was on a forest patrol. Although the proximate cause of death (e.g., starvation, drowning, suffocation) cannot be determined retrospectively, the ultimate cause was likely the plastic entanglement as it would have impeded foraging, caused stress, and impacted the bird in other ways (e.g., Sigler 2014;

Image 2. Oriental Darter *Anhinga melanogaster* perched in a dead tree in newly created lake in central Bhutan on 20 April 2025.

Image 3. Oriental Darter *Anhinga melanogaster* perched in a partially submerged live shrub/small tree in a newly created lake in central Bhutan on 20 April 2025.

Sazima & D'Angelo 2015; Ryan 2018).

The discovery of this dead bird does not prove it arrived alive in Bhutan on its own, especially because it was so close to India where it naturally occurs (Inskipp et al. 2012; Orta et al. 2014), but a natural arrival is far more likely than it being brought into Bhutan (alive or dead) illegally or by a predator given the plastic entanglement. Hence, this bird found dead may represent the first record of an Oriental Darter in Bhutan.

Discussion

Extralimital observations of birds are a topic of interest among birders and scientists – amongst the former due to the excitement of finding 'vagrants', and the latter because the phenomenon of vagrancy is not fully understood; new location records could portend something more important – range expansion (Veit et al. 2022). In our case, there are three potential alternatives to explain the live darter's appearance in Bhutan: 1. 'traditional' explanations (e.g., genetic maladaptation, behavioural incompetence, or stochastic events (like storms)) (Byju & Raveendran 2022; Veit et al. 2022); 2. climate change/anthropogenic change resulting in development of suitable climate in a new location (or the opposite – climate changes driving dispersal), changes in food supply, and human induced habitat change (e.g., after visiting Bhutan, RJG and KG visited Krabi, Thailand, where they observed an Oriental Darter in a mangrove forest, and were told by a local long-time bird guide (Surasit Khueawan, pers. comm. 12 May 2025) that Oriental Darters had only appeared in the area in the past two years, which may be related either to food supply or anthropogenic changes); and 3. Population dynamics (increases in population leading to population expansion via normal dispersal), driving range expansion and colonization of new areas or novel habitats – such as this newly created lake (Zawadzki 2019; Veit et al. 2022).

In this case, the construction of new hydroelectric dams in the foothills of Bhutan may be creating novel habitats for darters and other birds to colonize that were previously not, or not widely, available in Bhutan. The dammed river sustains a fish population that supports birds that prey on fish. The adjacent forest provides potential nest sites for fish-eating birds such as darters and herons (Ardeidae). The rising waters of an impoundment lake will likely inundate adjacent trees, kill them, and those dead trees will provide suitable perching and roosting sites for darters, as shown in Images 2 and 3. Thus, a suitable prey base, suitable nest sites, and roost sites, coupled with the change from a flowing stream to a placid lake, provide key features associated with Oriental Darters (Orta et al. 2014). Of course, determining the response of Oriental Darters to anthropogenic change and population dynamics in terms of dispersal into Bhutan requires more information than we have, but many non-migratory vagrant birds are found near the edge of their ranges, which may be the case here.

Hydroelectric development often has deleterious conservation impacts owing to the potential environmental damage it causes (e.g., loss of terrestrial habitat, disruption to fish migrations, disruption of natural hydrological cycles (Baxter 1977)). That said, depending on how lakes develop behind dams, they

Image 4. Oriental Darter *Anhinga melanogaster* found dead floating in the Sankosh River on 13 May 2021 approximately 0.5 km due north of Bhutan's southern border with the state of Assam, India.

may provide future habitat for some waterbirds, and as in this case, for bird species that occur in adjacent India that are also impacted by climate change or other stressors. Therefore, we recommend that biologists, conservationists, and birders consider newly created impoundments in the Himalaya Mountains as potential novel lake habitats that could be colonized by both resident and extralimital bird species rather than assuming they are 'bird-sterile environments'. In our case, this particular Puna Tsang Chu River system may be an important area for colonization by Oriental Darters in Bhutan, given that it flows into India, which has a known population of Oriental Darters, both darters we reported here were found on this river, and the river now has novel habitats owing to hydroelectric development.

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NOTE

The first distribution record of semelparous plant Thottukurinji *Strobilanthes integrifolia* (Dalzell) Kuntze (family Acanthaceae) for Gujarat, India

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The genus *Strobilanthes* Blume consists of about 465 species, in India represented by 154 species (Albertson & Venu 2024) and it is the second-largest genus in the family Acanthaceae, which is distributed mainly in the wet-non-deciduous forests of the Western Ghats and Himalaya (Karthikeyan et al. 2010). Despite the level of diversity and the ecological importance of the genus, as some species are locally abundant, even subdominant in the shrub layer of hill forest, species delimitation remains problematic, essentially because many species are poorly known and rarely collected, mainly because of their 'plietesial' flowering pattern. it is distributed in southern & southeastern Asia and Melanesia (Wood & Scotland 2009; Mabberley 2017; Wood et al. 2022).

The Girnar Hills situated between the parallels of latitude 21.530^0 N and meridians of longitude 70.530^0 E (Figure 1; Image 1). From the 10 biogeographic zones of India, Girnar Wildlife Sanctuary is classified as the semi-arid zone (Wainer 2015). During field work in the month of December 2024, the authors observed an interesting species of *Strobilanthes* in both flowering and fruiting stages at high elevations of Datar Hills, Girnar Wildlife Sanctuary, and Dudhvada range, Tapi. Upon further investigation of morphological characteristics, it is identified as *Strobilanthes integrifolia* (Dalzell) Kuntze. It has not been recorded from the Gujarat State (Patel 1971; Shah 1978; Albertson & Venu 2024). The species, *S. integrifolia* is previously known only from peninsular India (Venu 2006). The detailed photographs are presented in Images 2, 3 and 4. The voucher specimens (BKNMU412 & BKNMU413) are deposited at the Department of Life Sciences, Bhakta Kavi Narsinh Mehta University, Junagadh, Gujarat.

Taxonomic treatment

Strobilanthes integrifolia (Dalzell) Kuntze, Revis. Gen. Pl. 2: 499. 1891. Gamble, Fl. Madras: 1043. 1924; Venu, Strobilanthes Penins. India: 117, f. 24, 24a. 2006 (as "*integrifolius*"); Karthik. & al., Fl. Pl. India 1: 51. 2009; J. Bhattacharya & al. in Flow. Pl. India Annotat. Checkl. (Dicot.) 2: 309. 2020; W.D. Albertson & Venu in Fl. India 21: 664. 2024.

Synonyms: *Endopogon integrifolius* Dalzell, *Leptacanthus alatus* Wight., *Leptacanthus integrifolius*

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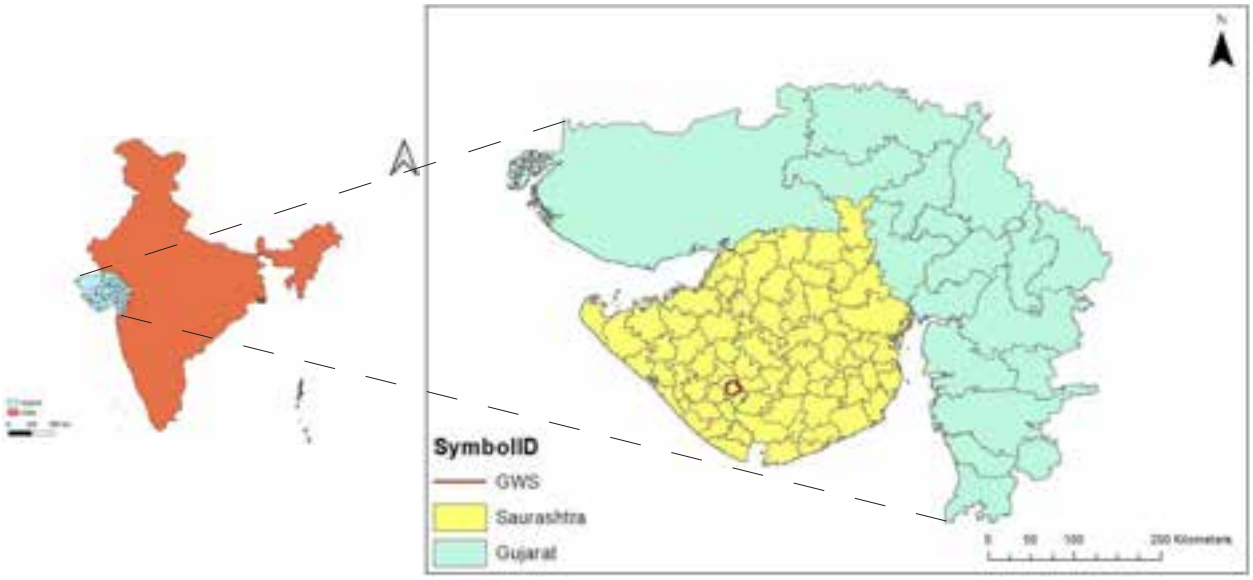

Figure 1. Gujarat state map: GWS—Girnar Wildlife Sanctuary.

(Dalzell) M.R.Almeida., *Mackenziea integrifolia* (Dalzell) Bremek., *Strobilanthes perfoliata* T.Anderson.

1–2 m tall shrub. Leaves opposite, elliptic-lanceolate, 5–10 cm long and 2–5 cm wide, acuminate at apex, tapering at base, margins entire, with winged petiole. Flowers occur in terminal spikes, 5–12 cm long, flowers with strong pleasant fragrance, bilipped, 3–4 cm long and tubular at base, sessile. Rachis tetragonal, viscous hairy; peduncles usually short. Bracts and bracteoles are glandular. Calyx 0.9–1.0 cm long, divided nearly to base; segments linear, subacute, one longer than the other four; corolla dark blue, glabrous outside, hairy inside, 2.8–3 cm long, with five lobes; stamens in didynamous (2 long and 2 short stamens), filaments of long stamens are hairy, filaments of shorts stamens are glabrous. Pollens 63–71 µm polar axis and 37–50 µm equatorial diameter. Capsules 0.5–1.0 cm, 2-seeded, compressed; seeds small, ovoid.

Common name: Entire-Leaf Coneflower

Etymology: *Strobilanthes* come from Greek word ‘strobilos’ (pine cone) and ‘anthos’ (flower), referring to cone-like inflorescences. *Integrifolia* comes from Latin ‘integer’ (whole, entire) and ‘folius’ (leaf), referring to the undivided leaves.

Flowering & Fruiting: December to March.

Note: Flowering once in every 7 years.

Specimens examined: India, Gujarat, Junagadh District: Datar Hills (21.498^0 N, 70.501^0 E) and Girnar hills (21.533^0 N, 70.525^0 E), Girnar Wildlife Sanctuary; 929 m elevation, *Rasik Sojitra* and *Snehal Gamit*, BKNMU412 & BKNMU413.

Image 1. Map showing area of Girnar Wildlife Sanctuary, Junagadh, Gujarat.

Distribution: Goa, Gujarat (present report), Karnataka, Kerala, and Maharashtra. Endemic to India.

Ecology: This small shrub, found in dry deciduous forests, nearby moist and rocky habitat, in the forest undergrowth. It is associated with *Carissa spinarum* L. and *Jasmine officinale* L.

Threats: The species is threatened by pilgrim activities at the Upla Datar, road-widening, and grazing pressure from cattle, leading to habitat degradation and reduced regeneration.

Conservation status: Not assessed.

Image 2. *Strobilanthes integrifolia*. © Rasik Sojitra and Snehal Gamit.

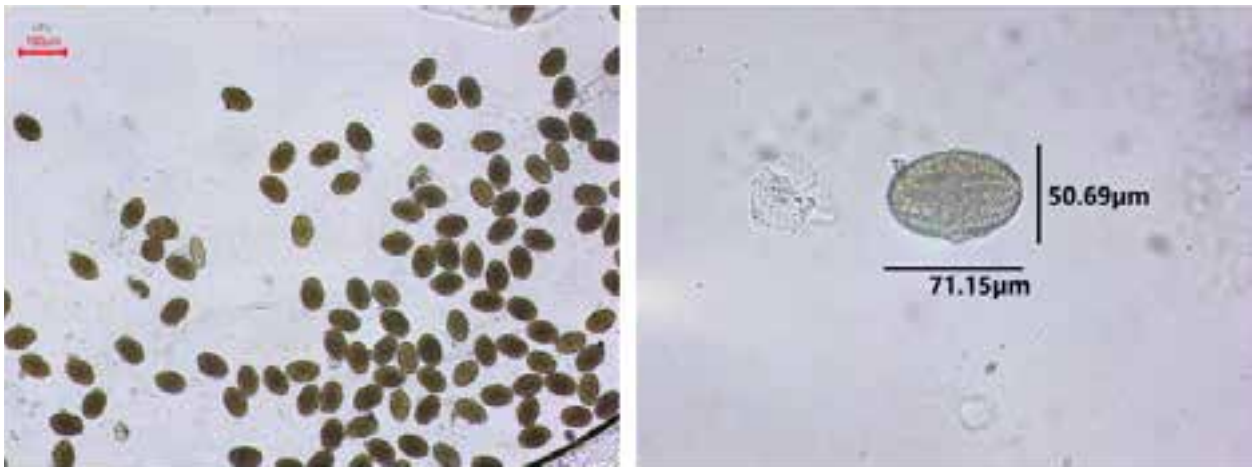

Image 3. Pollens of *Strobilanthes integrifolia*. © Rasik Sojitra and Snehal Gamit.

Key to the *Strobilanthes* species in Gujarat

1a. Flowers bright rosy-purple ..... *S. urens*
1b. Flowers pale blue to dark blue 2

2a. Leaf margins entire 3
2b. Leaf margins serrate 5

3a. Inflorescence terminal; bracts imbricate; flowers sessile ..... *S. integrifolia*
3b. Inflorescence axillary; bracts not imbricate; flowers pedicellate 4

4a. Leaves coriaceous, glabrous ..... *S. callosa*
4b. Leaves membranous to chartaceous, pubescent ..... *S. ixiocephalus*

5a. Prostrate herb..... *S. hirta*
5b. Erect herb ..... *S. pavala*

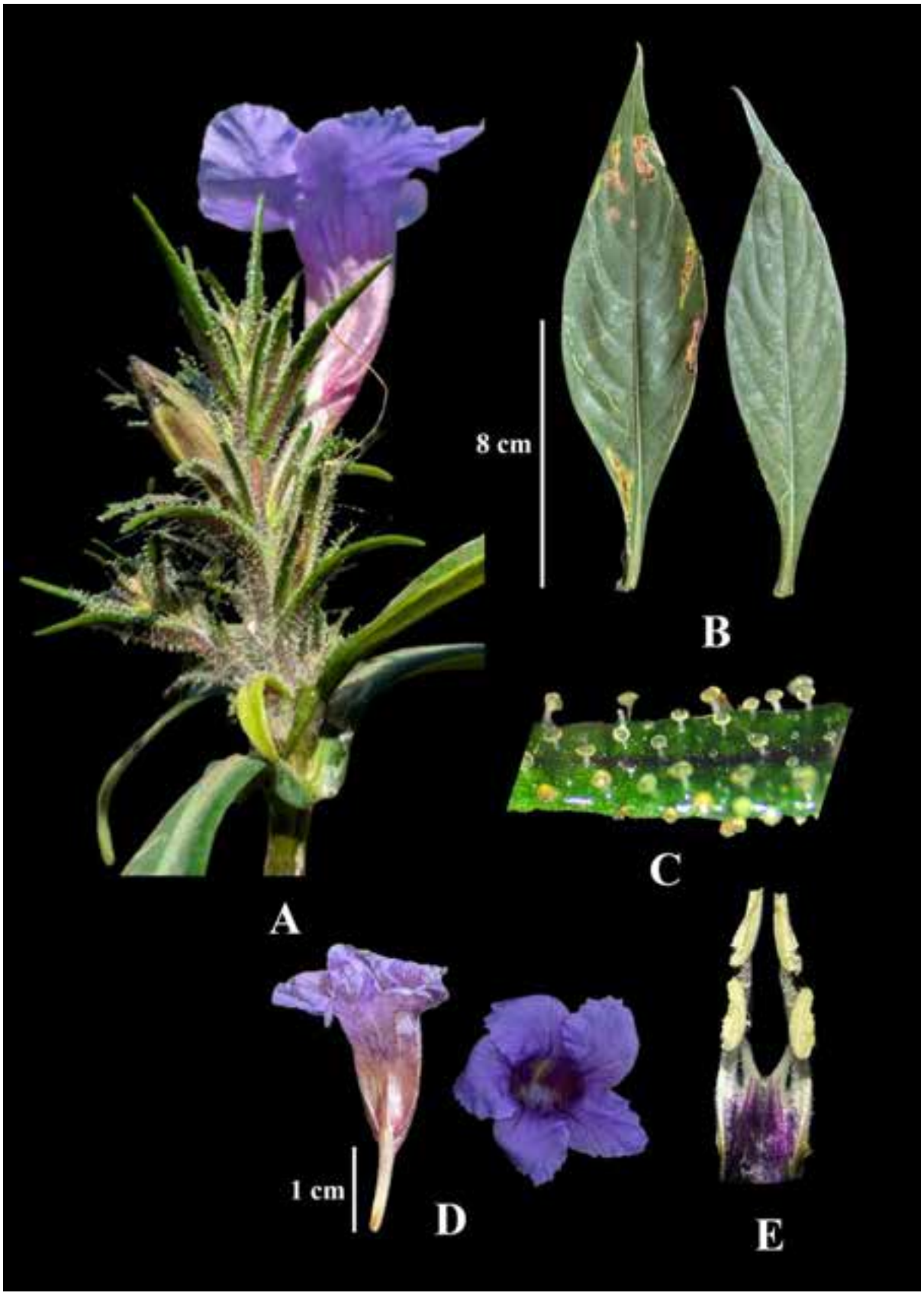

Image 4. *Strobilanthes integrifolia*: A—Inflorescence | B—Leaves | C—Glandular bract | D—Corolla | E—Didynamous stamens. © Rasik Sojitra and Snehal Gamit.

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NOTE

Cardamine fragariifolia O.E.Schulz (Brassicaceae): a new addition to the flora of Sikkim, India

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India is recognized as one of the 12 mega-biodiversity countries of the world with approximately 47,000 plant species and is rich in threatened and endemic plants (Singh et al. 2013). The eastern Himalaya span approximately 1,500 km^2 across the Indian states of Sikkim, West Bengal, Arunachal Pradesh, and Nagaland (Chettri et al. 2012). Sikkim is a small state covering an area of 7,096 km^2 with a unique habitat that supports a variety of rich flora and fauna throughout the region. The genus *Cardamine* L., belongs to the family Brassicaceae. It is a cosmopolitan genus with over 280 species (Marhold et al. 2021), mainly distributed in the temperate regions. The genus *Cardamine* is a taxonomically problematic, widespread genus with over 200 arctic, alpine, and boreal taxa, and is one of the largest genera of the family in terms of number of species (Hewson 1982; Al-Shehbaz 1988; Webb et al. 1988; Al-Shehbaz et al. 2006; Carlsen et al. 2009). In India, the genus comprises about 14 species (Sharma & Balakrishnan 1993), of which 12 are reported from Western Ghats (Nayar et al. 2014) and later three species from Maharashtra (Dalavi et al. 2019). Therefore, total 15 taxa are reported from India so far. The genus harbours 12 taxa of *Cardamine* from Sikkim Himalaya (Gogoi et al. 2021).

During the routine field survey of Maenam Wildlife Sanctuary (MWS), South Sikkim, specimens of *Cardamine* were collected in this subtropical forest. Upon a thorough examination of the collected specimens, including type specimens from BM, E, IBSC, K, KUN, GH, W, WU and additional specimens from BSHC, CAL, L and KUN, ARUN, and comparative analysis with present literature (Hooker & Anderson 1875; Smith 1913; Hara 1966; Grierson 1984; Polunin & Stainton 1984; Singh et al. 2019; Gogoi et al. 2021), the species has been identified as *Cardamine fragariifolia* O.E.Schulz. In India, while literature records indicate the presence of *Cardamine fragariifolia* in Arunachal Pradesh (Hajra & Chowdhery 1993; Hajra et al. 1996), a critical examination of specimens has not been observed till date (Al-Shehbaz & Guang 1998). Therefore the present collection from MWS Ravangla, South Sikkim marks the addition of a new record to state flora. Herbarium specimens were prepared using standard procedures following Jain & Rao (1977), and Bridson & Forman (1998). Voucher specimens are deposited in the Department of Botany, Sikkim University, Gangtok Sikkim.

Taxonomic description

Cardamine fragariifolia O.E.Schulz, Bot. Jahrb. Syst. 32(4): 446. 1903. Type: China: Hubei, 1885–88, A. Henry

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5803 [K: K000697727 digital image! Holotype; GH: Isotype]. *Cardamine scoriarum* W.W.Sm., Notes Roy. Bot. Gard. Edinburgh 11: 203. 1920. Type: China: Yunnan: flank of volcanic mountain to Northwest of Ten-yueh, 25° N, 7,000 ft, vi.1912, G. Forrest 8201 [E: E0015541 digital image! Holotype; K: K000697741 image! Isotype]. *Cardamine smithiana* Biswas, J. Bot. 76: 22. 1938. Type: China. Tibet (Xizang): Cong La, 2,900 m, 25.vii.1933, F. Ludlow & G. Sherriff 324 [BM: 000536045 digital image! Holotype]. *Cochlearia alatipes* Handel-Mazzetti, Symb. Sin. Pt. vii: 370. 1931. Type: China. South West Hunan. In monte Yiin- schan prope urbem Wukang, 1,000 m, 12.vi.1918, Handel-Mazzetti 12097 [WU: 024357 digital image! Holotype; E: E00386079 digital image! WU: 024348 digital image! Isotypes] (Image 1 & 2).

Spreading perennial herbs up to 120–130 cm high. Rhizomes 2–5 × 0.2–0.8 cm, sometimes stoloniferous. Stems prostrate or decumbent, simple at base or branched above, often stout or slender, sometimes rooting from proximal nodes, usually glabrous or sparsely puberulent. Basal leaves wither after flowering. Cauline leaves 10–20 × 7–12 cm, petiolate, usually lowermost trifoliolate or sometimes lowermost leaves with 4–5 leaflets, articulated at base; petiolules 6–11 mm long, leaflets subequal 3–8 × 1–4 cm, terminal leaflet slightly larger, ovate to lanceolate, 5–10 × 2–5 cm, base of terminal leaflet cuneate to obtuse, base of sub-leaflets oblique, margin coarsely or minutely serrate to crenate, apex usually acute to acuminate, rarely caudate-acuminate, glabrous to sparsely appressed. Inflorescence ebracteate, 40–60-flowered corymb; pedicel slender, divaricate up to 13 cm long, usually glabrous or sparsely puberulent. Sepals greenish-white, with dark brown to purplish tips sometimes, oblong, 0.2–0.4 × 0.1–0.2 cm, erect, glabrous or sometimes with few glandular hairs. Petals obovate or obovate-oblong, 0.6–0.8 × 0.4–0.5 cm, purple, lavender or pink, rarely white, apex rounded, claw 0.1–0.2 cm. Stamens

Image 1. *Cardamine fragariifolia* O.E.Schulz: A—Plant habit in its natural habitat | B—Flowering plant in its natural habitat | C & D—Proximal rooting of plants from the nodes | E—Herbarium specimen of *Cardamine fragariifolia* prepared and deposited at Department of Botany, Sikkim University (Accession no: 793). © Srijana Mangar.

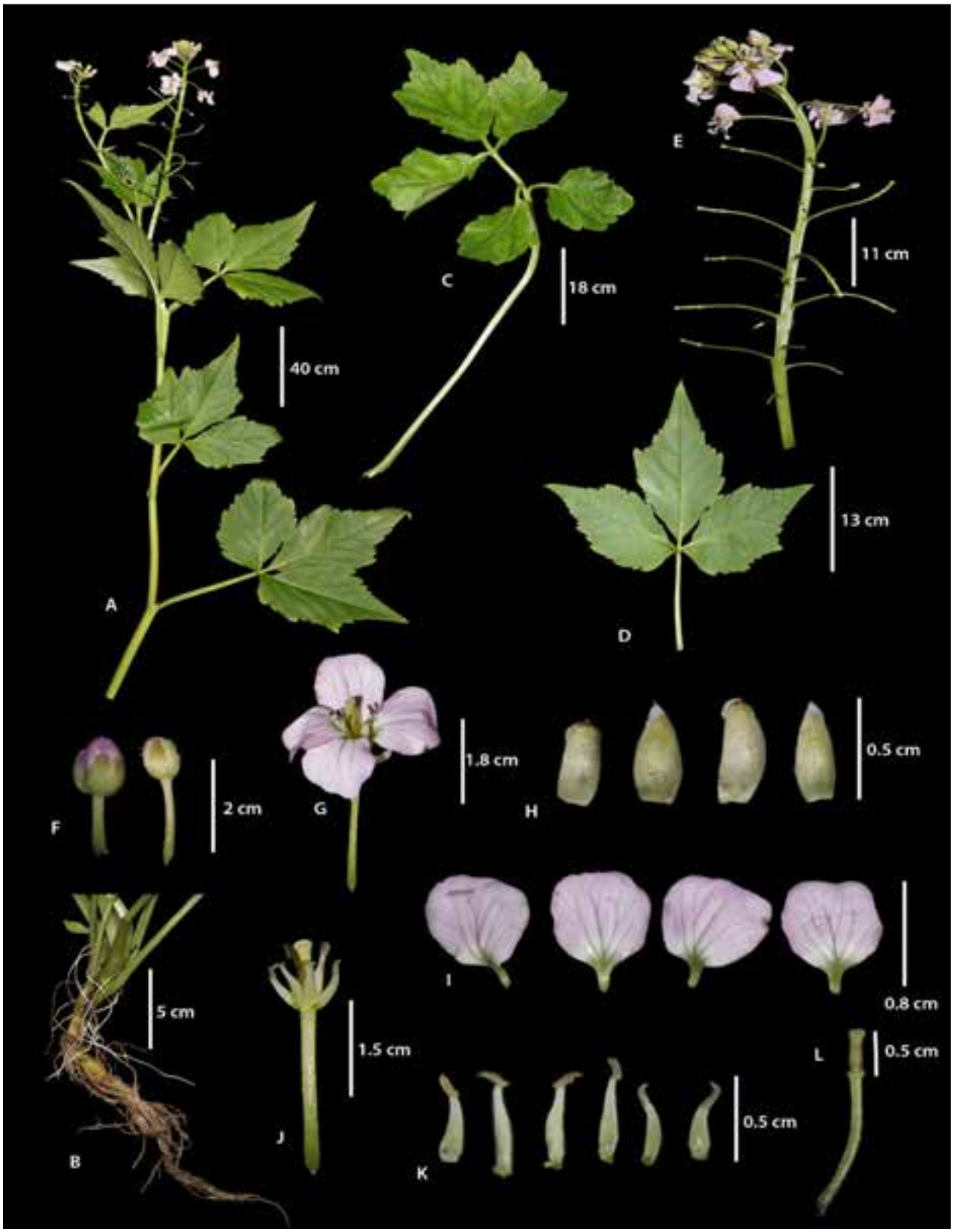

Image 2. ***Cardamine fragariifolia*** **O.E.Schulz: Dissected flower parts: A—Flowering twig | B—Rhizome | C—Basal leaves | D—Upper trifoliate leaves | E—Inflorescences | F—Flower buds | G—Single flower | H—Sepals | I—Petals | J—Stamens arrangement on pistil | K—Stamens | L—Pistil. © Srijana Mangar.**

six, tetradynamous; filaments white, median filaments 4–5 mm long, lateral filaments 3–4 mm long; anthers oblong, up to 2 mm long. Pistil glabrous; style slender, 5 mm long; siliques linear.

Phenology: Flowering during July to September; fruits not seen

Specimen examined: INDIA, Sikkim, South Sikkim, Ravangla, 22.406º N, 088.393º E, 2,323 m, 14.viii.2024, S. Mangar, 00507 (Sikkim University Herbarium, Accession No. 793).

Distribution: India: Sikkim (South Sikkim, Ravangla: Maenam Wildlife Sanctuary, Arunachal Pradesh), Bhutan, China, and northern Myanmar.

Notes: The specimens are usually found in the wet areas near streams of broad-leaved temperate forests. It is associated with *Rohdea nepalensis* (Raf.) N.Tanaka, *Codonopsis gracilis* Hook.f. & Thomson, *Chamabainia cuspidata* Wight, *Pilea umbrosa* Wedd. ex Blume, *Impatiens uncipetala* C.B.Clarke ex Hook.f., *Chrysosplenium nepalense* D.Don, *Elatostema nasutum* Hook.f., *Hydrocotyle himalaica* P.K.Mukh., *Begonia cathcartii* Hook.f. & Thomson, and *Galium asperifolium* Wall. Locally, it is referred as "*Kanchi saag*" and its young tender leaves are consumed as vegetables and considered a local delicacy.

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NOTE

Passiflora vesicaria var. *vesicaria* (Passifloraceae) - a new record for the flora of West Bengal, India

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The genus *Passiflora* L. (Passifloraceae), native to the New World, tropical, and subtropical Asia to southwestern Pacific, and naturalized in many countries beyond their native ranges, is comprised of 603 species (POWO 2025). The species are mainly herbaceous or woody perennial vines, rarely shrubs or trees. The vines climb with the help of tendrils and are notable for several unique traits such as extrafloral or sometimes petiole-based nectaries, bracts with glandular tips, a raised androgynophore, and a corona composed of one to seven filamentous rows. Many species also bear flowers with five-parted calyces and corollas, three united carpels, and five stamens (Ulmer & Macdougal 2004). As noted by Killip (1938), the genus displays exceptional variability in leaf form, surpassing most other plant groups in morphological diversity.

In India, the genus *Passiflora* is represented by 23 species (Santapau & Henry 1973) and very recently Undirwade & Bhuktar (2025) recorded another species, viz., *P. vesicaria* L. var. *vesicaria* in India, collected from Maharashtra. In West Bengal, it is represented by six species *P. edulis* Sims, *P. foetida* L., *P. napalensis* Wall., *P. quadrangularis* L., *P. suberosa* L. and *P. subpeltata* Ortega (Das 2015).

During a recent floristic survey in North 24-Parganas District of West Bengal, a few scattered natural populations of *Passiflora* species have been spotted and collected from different localities. The plant specimen was photographed using a Nikon D7500, 1400mm lens DSLR camera and dissection was done under Gemstar stereo zoom microscope. Herbarium specimens have been prepared by standard herbarium methods (Jain & Rao 1977) and deposited at Central National Herbarium, Botanical Survey of India (CAL). On a detailed morphological study with the help of protologue and description by Killip (1938), Feuillet & MacDougal (2003), Vanderplank (2013), and Undirwade & Bhuktar (2025), it has been identified as *Passiflora vesicaria* L. var. *vesicaria*, a native of South America.

Taxonomic Treatment

***Passiflora vesicaria* L.** in Amoen. Acad. 5: 382.1760; Vanderplank in Curtis's Bot. Mag. 30(4): 349. 2013; Undirwade & Bhuktar in Rheedea 35(1): 28–32. 2025. *P. hispida* DC. ex Triana & Planch. in Ann. Sci. Nat. Bot., ser, 5. 17:172. 1873 (Image 1).

Type: Jamaica, without locality, *Patrick Brown* s.n. (Holotype annotated by Linnaeus, Registration no. 508-

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4074, now in the Swedish Museum of Natural History) (Vanderplank 2013).

Prostrate or climbing herbs with tendrils, tendrils up to 20 cm long, hairy. Stems herbaceous, climbing; hirsute, green but turns yellowish at maturity. Leaves alternate, simple, suborbicular to ovate in outline, base cordate, lamina 5–12 x 6–10 cm, shallowly 5-lobed, rarely 3-lobed, lobes ovate, apex acute, margins serrulate to serrate, both sides pubescent, dark green, venations actinodromous, multi-costate reticulate; petioles slender, 4.5–7 cm long, hirsute; stipules- pinnatified, glabrous, 6–8 mm long. Flowers axillary, solitary, sometimes two together, 2–4 cm in diameter; pedicels 2–6 cm long, hirsute; bracts 6–9 cm long, extending over the berry, pinnatified, persistent, terete, hairy. Calyx tube short, campanulate; sepals five, basally united, ovate-lanceolate, 1.3–2 x 0.4–0.6 cm. Petals five, oblong-lanceolate, white, 1–1.6 x 0.4–0.5 cm. Coronal filaments in 3–4 in series, inner series small, purple, 1–2 mm long, outer series 1.3–1.5 cm long, white with purple tinge. Operculum narrow, 2 mm long, glabrous, white. Androgynophore brownish-white, straight, glabrous, 6–10 mm. Anthers dorsifixed,

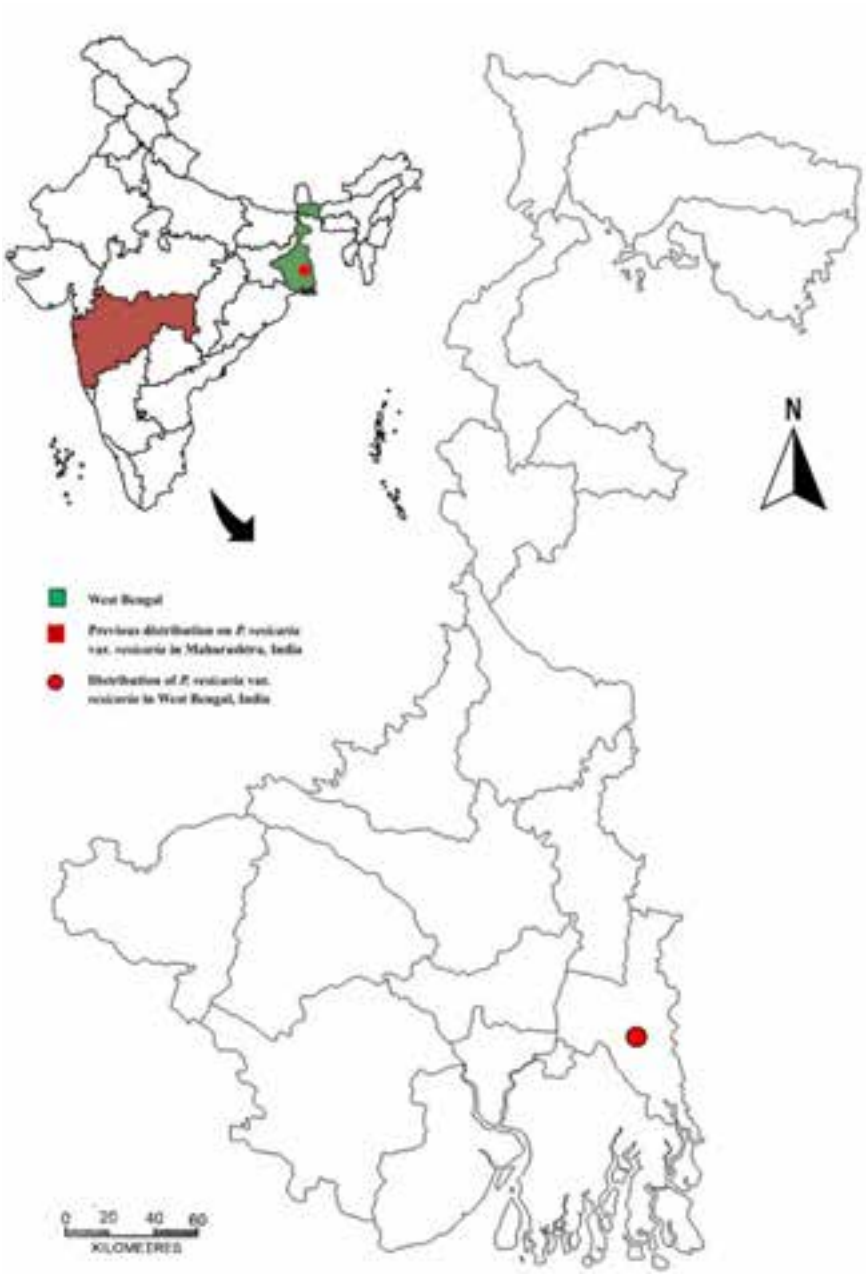

Figure 1. Distribution map of *Passiflora vesicaria* var. *vesicaria* L. in West Bengal, India.

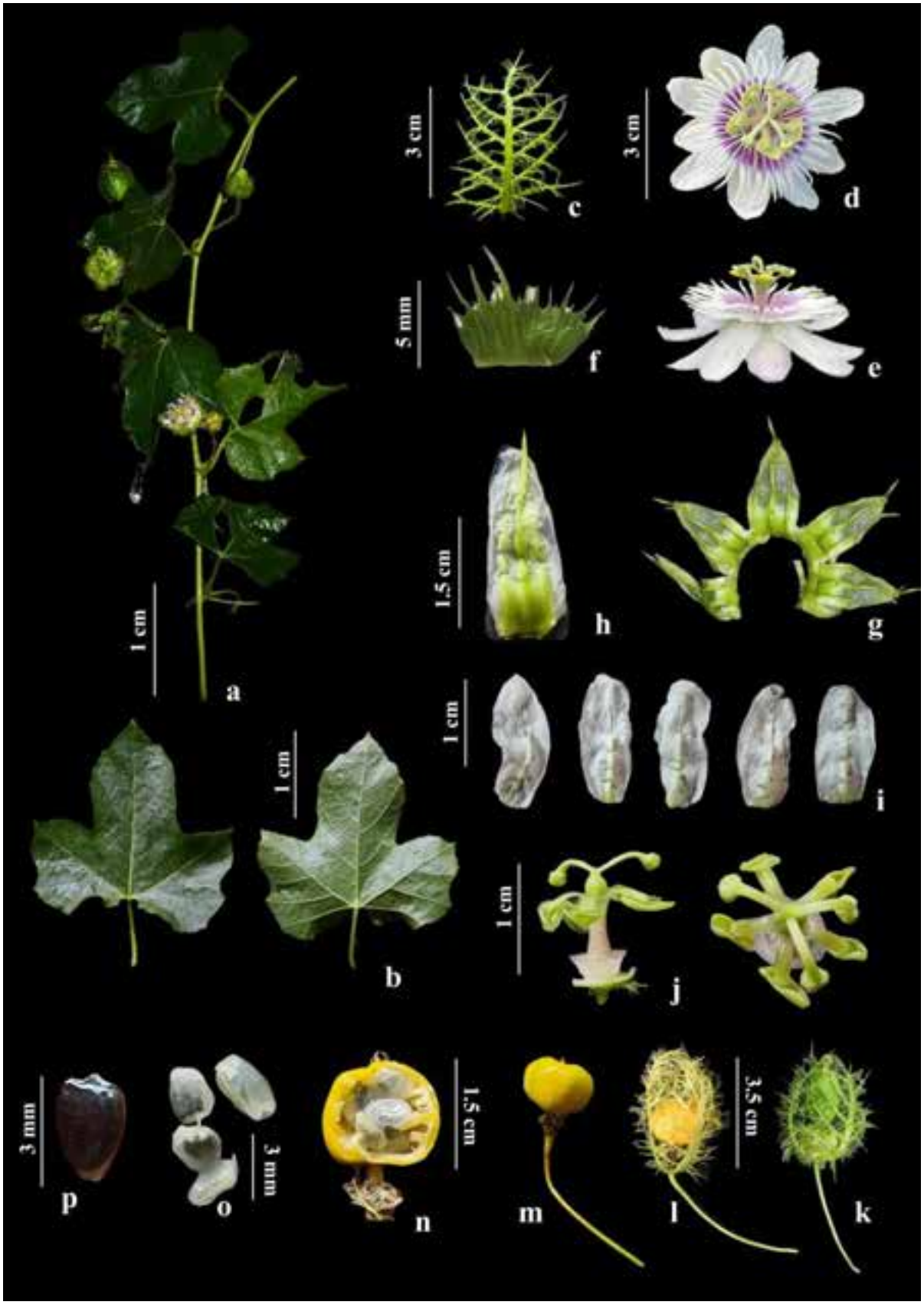

Image 1. ***Passiflora vesicaria*** **L. var.** ***vesicaria*****: a—Flowering branch | b—Leaves | c—Bract | d–e—Flower | f—Stipule | g—Calyx | h—Sepal | i—Petals | j—Androgynophore | k–l—Immature & matured fruit | m—Matured berry | n—L.S of berry | o—Seeds with aril | p—Seed. © S. Chowdhury.**

Table 1. Morphological difference between *Passiflora vesicaria* var. *vesicaria* & *Passiflora foetida* var. *foetida*.

P. vesicaria* var. *vesicaria	***P. foetida* var. *foetida***
Leaves mostly 5-lobed, rarely 3-lobed	Leaves shallowly or somewhat deeply 3-lobed
Stems hirsute	Stems mostly glabrous
Pedicels hirsute	Pedicels glabrous
Inner series of corona filaments purple, outer series white with purple tinge	Inner series of corona filaments white to pale cream, outer series pink to pale purple
Mature berries orange-yellow	Mature berries dark green

greenish-yellow, 2–3 mm long. Ovary subglobose, 1–2 mm in diameter, glabrous, carpels three, pale green to yellow; styles three, 4–5 mm long, pubescent near base; stigmas three, capitate. Berries ovoid to globose, 1.5–2 x 0.8–1 cm, glabrous, enclosed inside bracts, green, turns orange-yellow at maturity. Seeds oblong to ovate, 3–4 x 1.5–2 mm, dark brown-black, aril semi-transparent juicy, 0.5 mm in thickness.

Flowering & Fruiting**:** December to April.

Habitat: Growing in roadside, fallow fields, and among scrub jungles.

Distribution: India: Maharashtra, West Bengal (reported here) (Figure 1); Native of tropical America and West Indies, introduced in many old-world tropical countries.

Specimen examined: INDIA: West Bengal, North 24 Parganas District, Bamunmura, 22.70º N 88.51º E, 20.iv.2025, *S. Chowdhury* 20 (CAL); N. 24 Parganas, Badu, 22.93º E 88.42º N, 24.iv.2025, S. Chowdhury 21 (CAL); Kamduni, 22.64º N 88.52º E, 04.v.2025, S. Gupta 22 (CAL); Kharibari, 22.56º E 88.36º N, D. Mondal 23 (CAL).

Notes: *Passiflora vesicaria* L. var. *vesicaria* belongs to the subgenus *Passiflora* section *Dysosmia* DC. (Fullet & MacDougal 2004). This species is a very close relative of *P. foetida* L. which is widely distributed in most parts of India. *Passiflora vesicaria* var. *vesicaria* can easily be identified by having 5-lobed leaves and matured berry orange-yellow in colour, while its allied species *Passiflora foetida* var. *foetida* has strongly 3-lobed leaves and a mature berry green in colour.

Passiflora vesicaria L. var. *vesicaria* differs from *P. foetida* L. by the following characters tabulated in Table 1.

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NOTE

Monocarpic plietesial behaviour in *Lepidagathis* Willd. (Acanthaceae)

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Lepidagathis clavata Dalzell is a Critically Endangered B1ab(iii) endemic species growing on exposed rocky surfaces of the lateritic plateaus in the northern Western Ghats (Dalzell 1850; Kolte & Prabhukhanolkar 2023). In January 2016, during our botanical exploration to the lateritic plateaus of Chaukul from the Sindhudurg District of Maharashtra, we noticed a small patch with few individuals of this species flowering. Based on these live specimens, we published an article with updated description, lectotypification, and colour photo plate (Kolte et al. 2016). Subsequently, at the end of May 2016, we observed that all those flowered individuals dried off after setting seeds and decayed entirely in the monsoon. This field observation kindled our interest to constantly monitor different populations of this species to uncover the probability of a monocarpic pattern of life-cycle. Afterwards, we regularly conducted field trips to the lateritic plateaus (Chaukul from the Sindhudurg District of Maharashtra, Sada, and Chorla [type locality] from the Belgaum District of Karnataka) where this species was reported to be distributed earlier, primarily to understand its phenology.

The gregarious flowering of the entire Chaukul plateaus population was observed in November 2016 for a fortnight (Image 1A,B), followed by a mass setting of seeds and dried off by the end of May 2017 (Image 1C). Further, it was noticed that by the end of the southwest monsoon, all the old stumps had decayed (Image 1D) and seeds began to germinate. A critical observation of the germination of seeds revealed that this species adopts a vivipary mechanism, which is not hitherto reported in the genus (Image 1D). Whilst, at around the same time, the populations at Chorla and Sada plateaus were predominantly in a vegetative stage

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Image 1. (A to E) Different stages of *Lepidagathis clavata* during January 2016 to November 2024: A—Peak flowering in November 2016 | B—Flowering individual in peak flowering season, i.e. in November (inset: close-up of inflorescence) | C—Dried individual during April-May (inset: close-up of inflorescence) | D—Decaying individual during monsoon (inset: close-up of inflorescence) | E—During vegetative growth. © Rutuja R. Kolte.

with a sporadic flowering in some patches. However, we could observe a synchronized flowering of the Chorla and Sada populations in November 2020. Later, those populations died, decayed, and seeds germinated in the next monsoon in June 2021.

The flowering periodicity of *L. clavata* was not known until November 2024, when the entire Chaukul population flowered again gregariously after a gap of seven years, which germinated from mass seeding during the 2017 monsoon. Between two gregarious flowerings, every year individuals were growing vegetative in the prostrate form to support their growth on the rocky plateau (Image 1E). As years passed, branch tips started growing erect on the plateau floor. We could also notice the stray flowering in a few individuals. All the above observations about the phenology of this endemic species confirm that it is a plietesial monocarpic species. This is reported here for the first time in the genus *Lepidagathis* Willd. The next gregarious flowering of the Chorla and Sada populations is expected in November 2028.

Besides, in the protologues of some of the recently described species such as *Lepidagathis mahakassapae* S.More et al. and *L. ushae* Borude et al. found growing on the rocky plateaus have been reported as monocarpic without detailed notes (Borude et al. 2020; More et al. 2022). However, a long-term monitoring of these species including all other *Lepidagathis* species growing on the lateritic plateaus is essential to understand their phenology as they are the most probable candidates exhibiting monocarpic plietesial behaviour.

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