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continued on the back inside cover

Cover: Emperor Tamarin *Saguinus imperator*: a look into a better world through the mustache lens – mixed media illustration. © Maya Santhanakrishnan.

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ARTICLE

Measuring people's attitude towards conservation of Leopard *Panthera pardus* (Mammalia: Carnivora) in the foothills of Himalayan region

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Abstract: Measuring people's attitudes about the large carnivores involved in human-wildlife interface, also termed conflict or interaction, is an essential aspect of developing effective conservation and management planning for human-carnivore coexistence. Human-leopard (*Panthera pardus*) interaction is widespread and one of the most pressing conservation issues within the global range of leopards. However, there is a scarcity of information on local people's opinions and attitudes concerning carnivores in human-dominated areas. Our current study focused on understanding the human dimensions of human-leopard interactions in the multi-purpose landscape situated in the foothills of Shiwalik Himalaya, Uttarakhand, India. Between January and May 2022, we conducted a semi-structured questionnaire survey (N = 266) to understand how socio-demographic factors impact the attitudes of local people toward leopard conservation in the Rajaji Tiger Reserve, Uttarakhand, India. Overall, 61.7% of respondents had positive attitudes toward leopards and supported leopard conservation, primarily attributed to the aesthetic value of leopards. Using ordinal logistic regression models, we found that male respondents and individuals with higher education had a positive attitude towards leopard conservation. The majority of respondents who conveyed positive attitudes towards leopard conservation belonged to the more educated socio-demographic groups. As a follow-up, specific studies need to be conducted on local people's attitude about compensation or compassionate payments, often disbursed as compassionate payments, the response of the forest department to prevailing conflict, and current awareness programs. These can be crucial factors towards shaping the attitude of local respondents and promote human-leopard coexistence.

Keywords: Coexistence, economic loss, felid-conservation, human-leopard conflict, human-leopard interaction, human-leopard interface, people's attitude, socio-demographic factors, Uttarakhand.

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Author contributions: Conceptualization: Megha Rani, Sujeet Kumar Singh, Randeep Singh; Writing - original draft preparation: Megha Rani; Methodology: Megha Rani, Sujeet Kumar Singh, Randeep Singh; Formal analysis and investigation: Megha Rani; Writing - review and editing: Megha Rani, Sujeet Kumar Singh, Randeep Singh, Maximilian L. Allen, Puneet Pandey; Funding acquisition: NA; Supervision: Sujeet Kumar Singh, Randeep Singh

Ethics declaration: We obtained permission to conduct the survey from the principal chief conservator of forest, Uttarakhand Forest Department, (letter no. 2380/5-6 dated 9-2-2021, letter no 2949/5-6, date 17-05-2022,). We obtained verbal consent from the respondents who were interviewed, and they were briefed about the purpose of collecting the information. Additionally, informed consent was obtained from all individual participants included in the study before conducting the surveys, and all respondent information was protected to ensure that the right to privacy was not violated.

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INTRODUCTION

Humans have had an impact on the terrestrial ecosystem for millennia by converting a large portion of the earth's surface to anthropogenic land usage (Barnosky et al. 2012; Ellis et al. 2013). An increasing number of large carnivore species have been forced to coexist with humans in altered landscapes as a result of landscape change (Galán-Acedo et al. 2019). This habitat sharing at the human-wildlife interface has led to a greater number of conflicts between large carnivores and people in many areas, with negative effects on both local people's livelihoods and biodiversity conservation (Biset et al. 2019; Lamb et al. 2020). Across the world, approximately 82% of the total distributional ranges of carnivores fall outside of protected areas and are threatened by different human activity all over the world (Braczkowski et al. 2023). These threats are mostly related to competition with humans for habitat, prey, and livestock (Graham et al. 2005; Treves et al. 2006; Wang & Macdonald 2006). This is important because habitat loss, prey depletion, and the illegal killing of carnivores are the main causes of the decline of carnivore populations globally (Ripple et al. 2014).

Over the past few decades, tigers *Panthera tigris* and leopards have been among the species involved in human-wildlife conflict, associated with increased incidence of attacks on people and livestock in India (Naha et al. 2018). Among both predators, leopards are quite often seen in the human-wildlife interface (outside of protected areas on the outskirts of human settlements), where the transition between people and forest areas makes them more prone to interaction with humans (Rahalkar 2008; Athreya et al. 2013; Naha et al. 2018). Globally, human-leopard interaction revolves around livestock depredation (Ogada et al. 2003; Katel et al. 2014; Pena Mondragon et al. 2017) or attacks on humans (Athreya et al. 2011; Kshettry et al. 2017; Packer et al. 2019). As a result, leopards are often killed in retaliation, placing them at greater risk and increasing the vulnerability of their populations (Mishra et al. 2003; Treves & Karanth 2003; Nyhus & Tilson 2004), as mortalities from human-wildlife interaction can contribute to declines in carnivore populations (Fuller 2001; Nowell & Jackson 1996; Butchart et al. 2010). Leopard numbers are decreasing globally because of habitat degradation, decline in prey base, retaliatory killing, and poaching for body parts (Jacobson et al. 2016; Stein et al. 2020). The International Union for the Conservation of Nature recently changed the classification of the leopard from 'Near Threatened' to 'Vulnerable' in 2016 due to exploitation, a decrease in its habitat, and loss of prey base (Stein et al. 2020). The leopard is the most adaptive and widely dispersed large carnivore in both Asia and Africa (Jacobson et al. 2016), distributed across many ecosystems ranging from tropical forests, desert savannah, and alpine ranges (Nowell & Jackson 1996) to the outskirts of cities (Odden et al. 2014).

Human-leopard negative interaction is a serious management and conservation issue because of opposition to and intolerance for large carnivores by people in human-dominated landscapes (MacLennan et al. 2009). Identification of interface areas can help to develop management strategies to reduce negative interactions, but it is crucial to have the support of local communities for any conservation efforts (Pooley et al. 2021). During the past several decades, India's population has increased by more than double, leading to increased interactions between humans and leopards who live close to protected areas (Jhala et al. 2020). As a result, leopards have attacked and killed people in different areas throughout India, and leopards were also killed in retaliation (Mishra et al. 2003; Treves & Karanth 2003; Nyhus & Tilson 2004; Chauhan et al. 2000; Badola et al. 2021; Ahmed & Khan 2022). Due to attacks and fear, conservation measures to protect apex predators can be contentious and may face opposition from local communities (Graham et al. 2005). In response to these emerging threats and due to the ecological importance of species, different strategies have been implemented to promote human-leopard coexistence. These include establishing conservation incentives (Woodroffe et al. 2005; Dickman et al. 2011), livestock insurance schemes (Morrison et al. 2009; Mishra et al. 2016), and incorporating local people in conservation governance.

Understanding human attitudes toward leopards is an essential aspect of human-leopard coexistence in shared landscapes (Marchini 2014; Verdade et al. 2014). Recent studies have highlighted many factors with respect to sociocultural and socioeconomic aspects, such as local community identity and values, social positioning, political influence, and cultural viewpoints (Manfredo et al. 2009; Dickman et al. 2013; Pooley et al. 2017) influencing people's attitude towards large carnivore conservation in shared landscapes, for example, age, gender, education levels, and family size (Yosef 2015; Mekonen 2020; Merkebu & Yazezew 2021; Penjor et al. 2021), livestock depredation, husbandry practices (Biru et al. 2017; Mkonyi et al. 2017; Teixeira et al. 2021), type of human-carnivore interaction, diversity of livelihoods, size of the land owned, and the number of livestock owned (Gebresenbet et al. 2018; Biset et

al. 2019; Western et al. 2019). It is evident that social, political, and cultural variables influence big carnivore persistence (Aiyadurai 2016; Redpath et al. 2017; Athreya et al. 2018). One such example associated with cultural viewpoint was presented in the study conducted by Ghosal (2013) which reported that in Maharashtra large carnivores like tigers and leopards are worshiped as 'Waghoba/Waghya dev', for both fear and respect. In the political aspect, one such reason is the lack of lethal control of carnivore populations in India, which may have contributed to opinionated perception of the shared landscapes (Majgaonkar et al. 2019). Unfortunately, the cultural and socio-political aspects of people-carnivore interactions cannot be measured in the same way that ecological evaluations can (Karanth et al. 2009). In India, the conservation of large carnivores, particularly occurring outside of protected areas, is still challenging. Leopards have coexisted with humans in multiple-use landscapes for centuries (Athreya et al. 2015), but studies on factors influencing their coexistence mechanism like the people's attitude towards leopard conservation are scarce.

Our current study focused on understanding the human dimensions of human-leopard interactions in the multiuse landscape situated in the foothills of Shiwalik Himalaya, Uttarakhand India. The purpose of this study was to identify the components that account for human attitude toward leopards, their conservation, and the motivations for these attitudes. This includes (1) examining local people's attitudes toward leopard conservation and (2) identifying the determinants (demographic, socioeconomic, and previous encounters with leopards such as attacks on humans and/or livestock) influencing local people's attitudes toward leopard conservation in the vicinity of Rajaji Tiger Reserve. We formulated three hypotheses to address the study objectives: (1) Men would more likely support leopard conservation as women are less exposed to carnivores than males, and they are less tolerant of them (Røskaft et al. 2003; Mir et al. 2015); (2) Educational status would affect the attitude toward leopard conservation. Highly educated people being more favourable towards leopard conservation, education can improve carnivore tolerance by rationalizing attitudes (Woodroffe et al. 2005) and enhancing people's perspectives on predator conservation, and shaping their attitudes (Espinosa & Jacobson 2012); and (3) People who lost humans and/or livestock to wildlife in the past were expected to have negative attitudes towards such animals (Mir et al. 2015), and that past leopard experience would negatively affect the attitude towards leopard conservation.

MATERIALS AND METHODS

Study area

We conducted the household survey in two ranges (Motichur range and Shyampur range) of Rajaji Tiger Reserve (Figure 1). We selected two study sites based on high density of leopard (16.90 ±1.44/100 km^2; Jhala et al. 2021), (45 leopard (35–36 95% HPD level) /100 km^2; Yadav et al. 2019) and a human-leopard negative interaction hotspot region (Harihar et al. 2011). The Motichur and Shyampur range of the Rajaji Tiger Reserve (820 km^2), covers an area of 113 km^2 and 101 km^2 (Figure 1). The Rajaji Tiger Reserve (RTR) is situated in the lesser Himalayan zone and the upper Gangetic plains biogeographic zone (Rodgers & Panwar 1988). The climate is subtropical type with three distinct seasons winter, summer, and rainy with a temperature range that varies 23–46 °C in summer and a minimum of 5 °C during winter. The annual rainfall varies 1,200–1,500 mm. Within a 5-km radius of RTR, there are over 100 settlements, but our study area consists of 13 villages with a total population of 28,449 with 13,170 male and 15,279 female (Uttarakhand Population census 2011), and many of the population rely on adjacent forest resources such as fuelwood, fodder, grass, livestock foraging ground, and locally available non-timber forest products (Badola 1997; Chandola et al. 2007). The vegetation consists of northern tropical moist and dry deciduous forests with species such as *Shorea robusta, Mallotus philippensis, Kydia calycina, Dalbergia sissoo, Acacia catechu, Ougeinia oojeinensis*, and *Terminalia* spp. The dominant vegetation of the area is comprised of Sal *Shorea robusta*, Rohini *Mallotus philippensis*, Khair *Acacia catechu*, Haldu *Adina cordifolia*, Bahera *Terminalia bellirica*, Bargad *Ficus benghalensis*, and Shisham *Dalbergia sissoo*. Prime mammalian fauna of the park consists of tiger, leopard, Sloth Bear *Melursus ursinus*, Striped Hyaena *Hyaena hyaena*, Barking Deer *Muntiacus muntjak*, Goral *Nemorhaedus goral*, Chital *Axis axis*, Sambar *Cervus unicolor*, Wild Boar *Sus scrofa*, and among reptilian fauna the Mugger Crocodile *Crocodylus palustris* and King Cobra *Ophiophagus hannah* (Joshi 2016). Motichur and Shyampur ranges were chosen based on the recommendations of forest department employees and local key informants, who reported a high prevalence of conflict in these two ranges. Most of the communities in this area are (1) Garhwalis and Kumaonis, hill inhabitants who are marginal farmers and also engaged in private jobs, and (2) Gujjars, the transhumance pastoralists who live inside the forest and breed cattle.

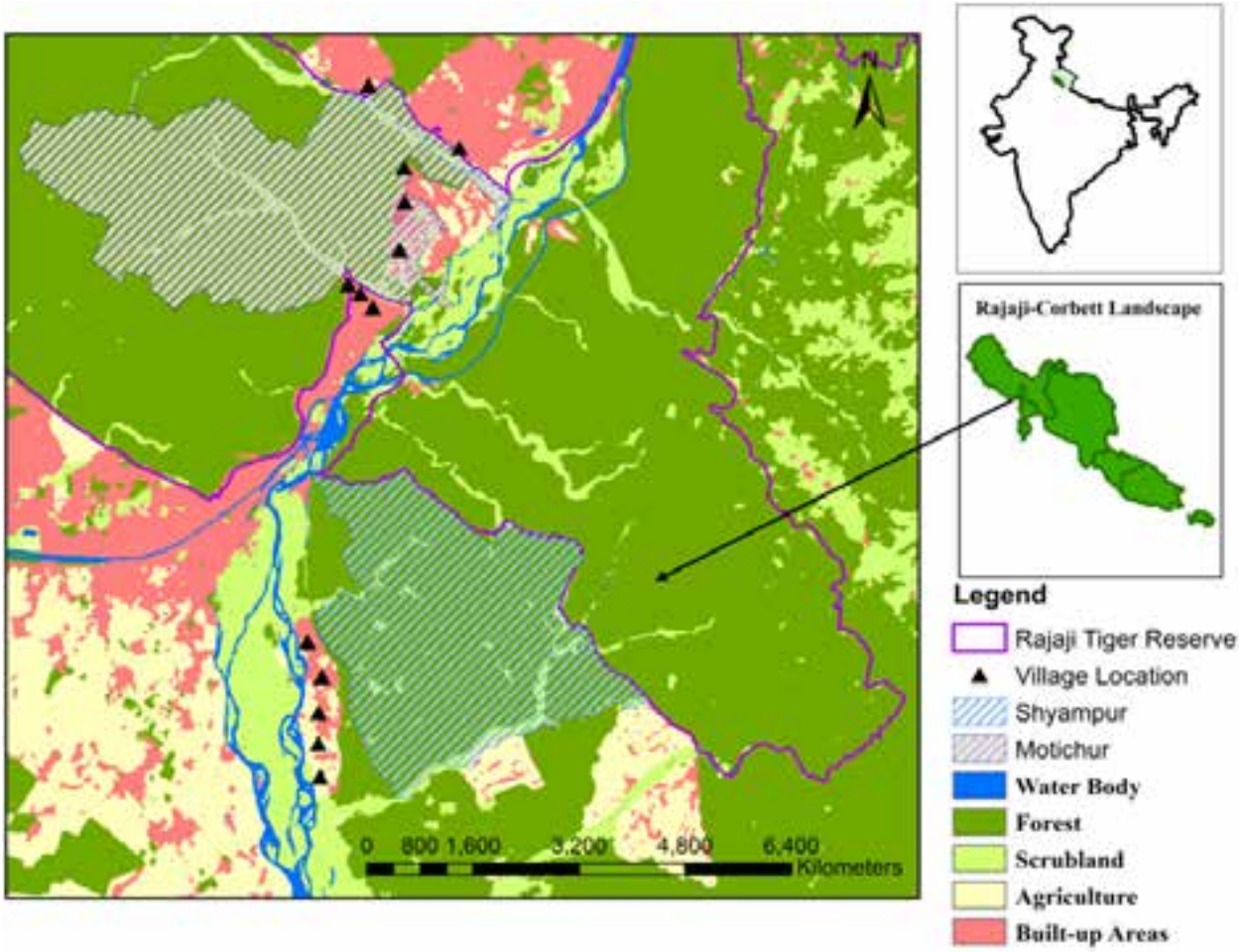

Figure 1. Study area location with the location of surveyed villages in Rajaji Tiger Reserve, Uttarakhand, India from January 2022 to May 2022 (N = 266).

Data collection

We first collected the reported conflict incidents involving livestock predation and human casualties by leopards from the year 2010 to 2021 from the Uttarakhand Forest Department and our survey (for the details regarding methodology see Supplementary Material Text S1). Thereafter, we collected the resident's attitudes on human-leopard negative interaction along with their response to the conservation of leopards in the RTR. The literature analysis helped to construct the questionnaire for the survey (Naha et al. 2018; Yadav et al. 2019) (Appendix 1). The questionnaire was pre-tested with 30 respondents before being surveyed. A local forest guard was present initially at the start of each interview for a formal introduction about the subject matter and to increase the community acceptance. Prior informed consent was obtained verbally from all participants. Their responses were later translated into English during analysis. Each interview lasted for 40–45 minutes. A total of 266 randomly selected households were interviewed during a survey from 13 villages in both study sites (Motichur and Shyampur range) of RTR between January to May 2022 using a semi-structured questionnaire (a standard set of questions that included both open and close-ended questions) in the local language (Hindi), with a systematic sample of 10% of families per village and maintaining an average distance of 500-800m between each residence in the corresponding village. The questionnaire comprised three sections: (i) sociodemographic (gender, age, family size, education, occupation, income, livestock head) and experience of the respondent with leopards (any human casualties or livestock depredation by these animals in respondents' family in the last 10 years); (ii) question on attitude toward leopard conservation – to what extent do you agree that leopard conservation is important? The latter qualitative questions were recorded on a five-point Likert scale as strongly disagree (-2), disagree (-1), neutral (0), agree (1),

and strongly agree (2), while the prior questions were recorded on nominal scales (Supplementary Material Table S1). Thereafter, we identified a total of eight predictor variables (Table 1), chosen from attitude-based studies done in the past on wildlife conservation (Krester et al. 2009; Mkonyi et al. 2017).

Data analysis

We quantified and analyzed all eight predictor variables that could potentially impact people's attitudes toward the conservation of leopards. We checked the independent variables for multicollinearity and found all the variables had generalized variance inflation factor (GVIF) <5 (Fox & Monette 1992), indicating the absence of collinearity among the predictor variables (Supplementary Material Table S2). We used Ordinal Logistic Regression (OLR) to model ordinal dependent variables as a function of continuous or categorical predictor variables (Warner 2008; Adejumo & Adetunji, 2013) using the 'MASS' package with 'polr' function against all independent variables (Eboli & Mazzulla 2009; Mutanga et al. 2016; Auster et al. 2019; Liang et al. 2020). We used this initial global model to understand the importance and significance of each variable. Thereafter, we formulated 12 potential models using the 'AICcmodavg' package using all eight predictor variables (Johnson & Omland 2004) to understand drivers of attitudes. We used the Akaike information criterion corrected for small sample sizes (AICc) to select the most plausible models (ΔAICc <2) to describe the people's attitude toward leopard conservation (Burnham & Anderson 2004). We computed the measure of association between different explanatory variables and outcomes using the odds ratio (Auster et al. 2019). We performed all statistical analysis for data collected on different parameters of human-leopard negative interactions in R v. 4.2.1 (R Development Core Team 2022) and the statistical software IBM SPSS Statistics 26.0 (IBM SPSS 2019).

RESULTS

Socio-economic condition of locals

Out of all respondents (N = 266), 62% were male (N = 165) (Figure 2). Most of the people had primary education (42%; N = 112), followed by secondary education, graduation, and illiterate status (Figure 2). Based on the questionnaire survey, 44% of people were mid-d (41–60 years age class), with an average age of 47 (±SE 0.9) (Figure 2). Out of all occupations, service and daily wage labour were the two major occupations, employing nearly 74% (N = 196) of the people (Figure 2). Out of all the respondents, 41% (N = 110) of annual income ranged between INR 100,000–500,000 (Figure 2). The average livestock owned per household was 3.45 (±SE 0.34). The average landholding size per household was 0.03 (±SE 0.005 ha). The average family size was found to be 6.36 (±SE 0.19). Approximately, 58% (N = 154) of households reported being dependent on forest resources for their livelihood (i.e., for fuelwood, non-timber forest product (NTFPs), and grass). Out of all the respondents 44% (N = 117) were dependent on fuelwood as well as alternate fuel; 26% (N = 68) alone were dependent on fuelwood and 29% (N = 78) were dependent on commercial fuel. Most of the respondents (70%, N = 186) owned livestock which included cattle (74%), goats (18%), and poultry (8%).

The overall attitude towards conservation

From the survey, significantly most of the respondents had positive attitudes towards leopards (61.7%), then

Table 1. Variables at the village level used in regression models to predict the attitude of people towards leopard conservation in Rajaji Tiger Reserve, Uttarakhand.

Theme	Variable (Abbreviation)	Description	Data scale
Socio-economic	Gender (Gen)	Gender of the respondent. Two levels: Male and Female.	Nominal
	Employment (Emp)	Occupation of the respondents.	Nominal
	Past leopard experience (PLE)	Experience of losses incurred due to leopards such as human casualty (attack/death), and livestock depredation. Two levels: Yes or No	Nominal
	Annual income (INR)	Dependence of respondents on income-generating activities. Four levels: <50,000, 50,000–100,000, 100,000–500,000, >500,000	Nominal
	Age in years	The age group of the respondent. Three levels: 18–40, 41–60, >60.	Nominal
	Family Size (Fs)	Number of family members in a household. Three levels: 0–3, 4–6, >6	Nominal
	Livestock-head (LH)	Number of livestock in each respondent household. Four levels: 0–5, 6–10, 11–15, >15	Nominal
	Education (Edu)	Education received at the time of the interview. Four levels: Illiterate, Primary School (1–10), Secondary (10–12), Graduate and above.	Nominal

neutral (20.7%) or negative (17.7%) attitudes ($\chi2 = 19.75$, df = 2, p <0.005) (Figure 3). There was also a significant difference in degree to which respondents agreed on the conservation of leopards ($\chi2 = 17.76$, df = 4, p <0.005). Out of all the respondents, 33% (N = 88) strongly agreed with conserving leopards in the surrounding landscape, while 26% (N = 69) strongly disagreed (mean = 0.3, ± SE 0.09) (Figure 4). The positive attitude of local communities towards leopard presence in their surrounding environment indicated that respondents found leopards to be important in the environment. Out of all the respondents who had faced livestock death (10%) due to predation along with human injury and death (5%) had a marginal negative attitude towards leopards which accounted for (4%), and thought that leopard predation on livestock occurred due to the easy availability in the surrounding vicinity. Out of all the reported human casualties, most of these occurred inside PAs while collecting fuelwood. Sixty-one percent of the people in the study area were not aware of the role of leopards, 25% believed their primary role was to kill livestock whereas 9% stated that they helped maintain ecological balance (Supplementary Material Figure S1). Fifty-nine percent of respondents believed that availability of domestic prey, i.e., livestock attracted leopards towards human habitation and 26% of respondents stated that the decline of wild prey was the primary reason for leopard predation (Supplementary Material Figure S2).

Socio-economic drivers of people's attitude towards leopards and their conservation

The ordinal logistic regression resulted that, the persons having a positive attitude toward the importance of leopard conservation were positively related to gender (male) (ß = 0.75, p = 0.004) and high literacy (ß = 0.82, p = 0.06) (Table 2). Thereafter, people with very few livestock-head (ß = −0.27) and moderate annual income (ß = −0.17) had a negative influence but did not significantly affect the people's attitude toward inference on the importance of leopard conservation (Table 2). However, employment (ß = 0.97), and households experiencing livestock predation or human casualties (ß = 0.17) were found to have a positive but non-significant influence on the support of leopard conservation.

In our model comparison analyses predicting the socio-economic drivers of leopard conservation, we obtained three top models based on ΔAICc values (ΔAICc <2) (Table 3; Supplementary Material Table S3). The first top model signified that the predictor variables including gender (ß = 0.40), age (ß = 0.05), and education of people (ß = 0.26) influenced the attitude of people on leopard conservation (ΔAICc = 0.00, *w* = 0.28; Table 3). While in the second top model, gender (ß = 0.43), family size (ß = -0.10), livestock head (ß = 0.18), and education (ß

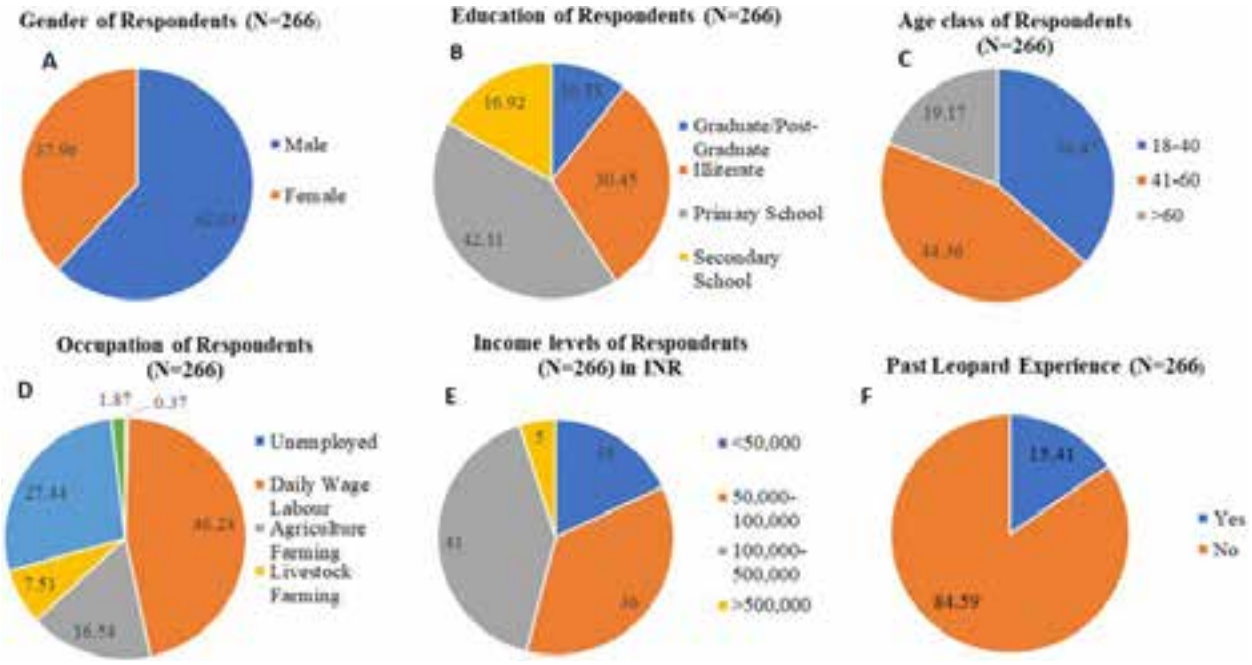

Figure 2. Socio-demographic attributes (gender, education, age, occupation, and income) and past leopard experience of respondents (N = 266) in Rajaji Tiger Reserve, Uttarakhand.

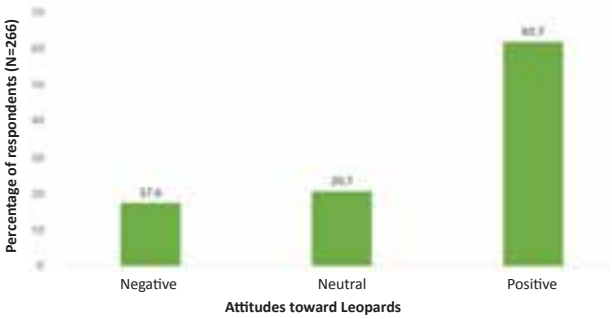

Figure 3. Attitude of people (N = 266) towards leopards in Rajaji Tiger Reserve, Uttarakhand.

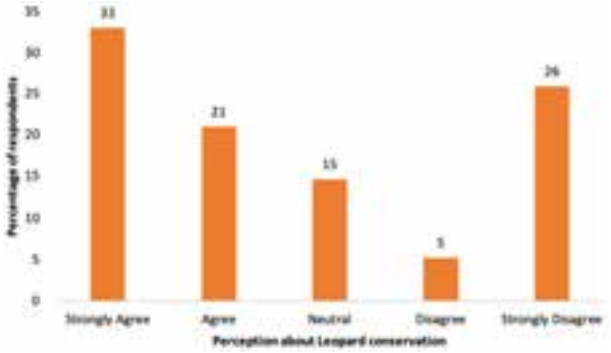

Figure 4. Attitude of people (N = 266) towards leopard conservation in Rajaji Tiger Reserve, Uttarakhand.

= 0.26) were the predictors of people's attitude toward leopard conservation (ΔAICc = 0.26, *w* = 0.25; Table 3). In the third top model, gender (ß = 0.39), age (ß = 0.06), employment (ß = 0.03), and education (ß = 0.28) were the best predictors of people's attitude toward leopard conservation (ΔAICc = 1.94, *w* = 0.11; Table 3).

DISCUSSION

Conflicts between people and large felids (including tigers and leopards) are common, especially where people reside in proximity to forests in human-dominated landscapes (Inskip & Zimmermann 2009; Malviya & Ramesh 2015). An excellent example of this is the Rajaji-Corbett landscape, where there have been many human-feline conflicts in and around the parks, with disputes being recorded by numerous households, villages, and Gujjar communities (Malviya & Ramesh 2015). Our study highlights the factors (i.e., the gender and education of respondents) that play a significant role in the attitude of local people toward leopards' conservation in the Rajaji landscape. Specifically, we found males were more likely to support leopard conservation, and the person with higher education (i.e., graduate and post-graduate people) at the household level was more likely to influence support toward leopard conservation. These factors play an important role in influencing the attitudes of local people and the success of human-felid coexistence.

The attitude of local people is an important consideration for the conservation of leopards (Kshettry et al. 2017). The majority of respondents in our study area were in favour of leopard conservation. One possible explanation for our findings, as expressed by the local community, was that the habitat would get conserved to assist protection and existence of the species. Permanent human habitation is connected with increasing exposure to large carnivores. Ericsson & Heberlein (2003) proposed this to explain public attitudes towards mesopredators, which was later demonstrated by Røskaft et al. (2003) for the people exposed to large carnivores in Norway. Our study highlighted that the respondents had differentiated opinions positive (61.7%) as well as negative attitudes (17.7%) about leopards. Most of the respondents generally had a positive attitude towards leopards, which may be attributed to the financial incentives dispensed to locals following human/livestock loss due to leopard predation (Badola et al. 2021); in some cases, financial incentives may even promote coexistence (Mishra et al. 2003; Dickman et al. 2011). However, programmes whose primary goal is to provide large compensation payouts typically fail to build tolerance towards predators (Bautista et al. 2019) which may be reflected in our study area as some people had a negative attitude toward leopards.

Our results are consistent with research on conflicts with wild animals (Davenport et al. 2010; Thornton & Quinn 2010) that show a mix of attitudes toward coexistence with wildlife (Szinovatz 1997; Gidey et al. 2011). After the recovery of tigers in the Rajaji Tiger Reserve, leopards shifted their distribution and diet, indicating that leopards were forced to inhabit the peripheral habitats along the park boundary since livestock are only available in the villages located in the surrounding forested areas (Harihar et al. 2011). Therefore, a significant increase in the occurrence of domestic prey in the diet of leopards from 7% to 32% over the four years (Harihar et al. 2011) reflects the shift in dietary habits of leopards. It appears that leopards started killing livestock and attacking people because of frequent visits near to human settlements. This may have led to some negative human-leopard interactions and negative attitudes among local people. Similar studies

Table 2. Ordinal Logistic Regression analysis of variables affecting attitude towards leopard conservation, Rajaji Tiger Reserve, Uttarakhand. We note significant values as: *p <0.05, **p <0.01, and ***p <0.001.

						97.5% CI for odds ratio		
Independent variable	**Category**	**β**	**S.E.**	**t**	**Odds Ratio**	**Lower**	**Upper**	**P**
Gender	Male	0.75	0.27	2.82	2.12	1.25	3.56	0.004*
	Female (reference)	0.00						
Age	41–60	0.21	0.28	0.73	1.23	0.71	2.12	0.46
	>60	-0.003	0.35	-0.01	0.99	0.49	2	0.99
	18–40 (reference)	0.00						
Family Size	4–6	-0.142	0.49	-0.29	0.87	0.33	2.27	0.77
	>6	-0.14	0.51	-0.27	0.87	0.32	2.36	0.78
	0–3 (reference)	0.00						
Livestock-head	6–10	-0.27	0.38	-0.71	0.76	0.36	1.60	0.47
	11–15	-0.64	0.75	-0.86	0.52	0.11	2.28	0.38
	>15	0.12	0.65	0.18	1.13	0.31	4.09	0.84
	0–5(reference)	0.00						
Education	Primary	0.01	0.28	0.06	1.01	0.58	1.77	0.95
	Secondary	0.49	0.36	1.36	1.64	0.80	3.34	0.17
	Graduate and above	0.82	0.44	1.84	2.27	0.94	5.45	0.06·
	Illiterate (reference)	0.00						
Employment	Service	0.97	1.57	0.61	2.63	0.11	57.64	0.54
	Agriculture	0.41	1.54	0.26	1.50	0.07	31.08	0.79
	Daily wages	0.63	1.55	0.41	1.87	0.09	39.59	0.68
	Livestock farming	2.19	1.61	1.36	8.97	0.38	211.75	0.17
	Others	0.45	1.80	0.25	1.58	0.04	54.28	0.79
	No source of Income (reference)	0.00						
Past leopard experience	Yes	0.16	0.31	0.54	1.18	0.64	2.18	0.58
	No (reference)	0.00						
Income	50,000–100,000	-0.16	0.36	-0.47	0.84	0.41	1.70	0.64
	100,000–500,000	-0.18	0.36	-0.49	0.83	0.41	1.70	0.62
	>500,000	0.06	0.65	0.09	1.06	0.29	3.85	0.92
	<50,000 (reference)	0.00						

in Uttarakhand also reported that livestock predation by leopards tends to create a negative attitude (Naha et al. 2018; Mukeka et al. 2019). We observed that households having more livestock held positive attitudes toward leopard conservation but did not play a significant role in shaping conservation attitudes toward leopards. This is similar to other studies where people's attitude is positively associated with the number of livestock owned and negatively associated with livestock lost to predators (Naughton-Treves et al. 2003; Kideghesho et al. 2007).

Our results indicate that the employment status of people did not have any significant negative effect on leopard conservation. But in our study area, unemployed people with no or low formal education primarily depend on NTFPs (Non-timber forest products) from the forest in the form of fodder grasses, dry and fallen twigs and branches, leaf litter, and leaves, fiddlehead, locally known as lingda which has some medicinal properties and edible. This resource dependency is mainly due to free access to forest resources for the poor or low-income groups for their livelihood (Islam et al. 2015). Most of the respondents in the interview mentioned: 'Alternative fuels are expensive for me, and it has become a compulsion to visit the forest and collect fuelwood to

Table 3. Model comparison using Akaike information criterion corrected for small sample sizes (AICc) showing best top three models (ΔAICc <2) and β coefficient values to identify factors influencing the attitude of local people towards leopard conservation in Rajaji Tiger Reserve, Uttarakhand. We also report the number of parameters (k), the change in AICc scores (ΔAICc), the AIC weight (w), and the loglikelihood (LL). We note significant values as: *p <0.05, **p <0.01, and ***p <0.001.

Models	K	AIC_c	ΔAICc	w	LL	Adjusted R^2	Parameters	B	SE	P
Gender+Age+ Education	5	1001.00	0.00	0.28	-495.39	0.030	Intercept	-0.75	0.39	0.060
							Gender	0.40	0.20	0.052
							Age	0.05	0.14	0.686
							Education	0.26	0.10	0.011*
Gender+ Family Size+ Livestock Head+ Education	6	1001.26	0.26	0.25	-494.47	0.033	Intercept	-0.67	0.50	0.182
							Gender	0.43	0.20	0.030*
							Family Size	-0.10	0.16	0.510
							Livestock Head	0.18	0.14	0.204
							Education	0.26	0.10	0.009**
Gender+Age+ Employment+ Education	6	1002.95	1.95	0.11	-495.31	0.027	Intercept	-0.84	0.47	0.073
							Gender	0.39	0.21	0.065
							Age	0.06	0.14	0.642
							Employment	0.03	0.09	0.70
							Education	0.28	0.10	0.010*

meet my daily needs'. These factors tend to develop positive attitudes of people, who visit forests and collect non-timber forest products (Krishnakumar & Nagarajan 2020), toward leopard conservation.

Our results illustrated that men have a more positive attitude towards leopard conservation in our study area than women. In previous studies, gender also played a substantial role in predicting local people's perceptions of wildlife (Teixeira et al. 2021). Women are more involved in forest-based chores, so they are more prone to negative interaction with wildlife than men, as has been found in other studies (Mkonyi et al. 2017; Trajçe et al. 2019). Previous research studies around RTR (Wildlife Institute of India 2005) reported that the women's participation in the eco-development committees was low and they were more involved in accomplishing everyday chores (Chandola et al. 2007). The finding of our study has been consistent with other studies which showed the negative attitude of women due to greater fear of dangerous carnivores (Roskaft et al. 2003; Kaltenborn et al. 2010; Prokop & Tunnicliffe 2010). Possibly it is the result of less exposure to leopards than in men, who frequently confront them in defense of their families and livestock (Roskaft et al. 2003; Goldman et al. 2010).

Although it is believed that education broadens people's perspectives (Carter et al. 2012). Poverty, low literacy, and meagre money are also thought to contribute to negative perceptions of carnivores, such as the Sundarban Tiger (Inskip et al. 2013). Education and awareness about predators can sometimes ameliorate negative attitudes (Bruskotter & Wilson 2014; Lyngdoh et al. 2017) and mitigate conflict due to improved knowledge of the risks and drivers of conflict (Treves & Karanth 2003). Our results showed that respondents with formal education (i.e., graduates and post-graduates) expressed a more positive attitude toward leopard conservation than those without any formal education. Our finding confirms those of previous studies that showed that formal education can improve attitudes and increase tolerance levels for large carnivores (Lindsey et al. 2005; Woodroffe et al. 2005; Parker et al. 2014). We did not find any significant association between age and family size with an attitude of locals toward leopards' conservation.

We acknowledge some limitations of our study. Our study only focused on the sociodemographic, and economic factors affecting people's attitude toward the conservation of leopards. But we did not quantify the wildlife values, interest in animals, empathy, norms, habits, and other ecological variables in our analysis. Other limitations were representativeness. It is especially in relation to accessibility to victims' households related to human casualties by leopards, gender biases, and our constraints with manpower time. In spite of these limitations, our study highlights the effectiveness of coexistence among the local community in mitigating human-leopard conflicts in and around RTR. This study could be further used for future research on leopards and also on the management and conservation of

leopards in the area. Since the conservation of leopards involves and affects the local population of RTR, the factors that foster such positive perceptions of leopards should be acknowledged and linked ecologically for further research on mitigating leopard-human negative interaction. In our study area 47% of the respondents proposed solar fencing as an effective mitigating tool leading to coexistence (Supplementary Material Figure S3).

CONCLUSIONS AND RECOMMENDATIONS

Our findings have implications for leopard conservation in and around Rajaji Tiger Reserve. Despite attacks on humans and livestock, our research findings demonstrate that there is crucial local support for leopard conservation, which could aid in the survival of leopard populations. However, the villagers who expressed prejudice toward leopards (26%) should not be ignored because it may lead to retaliatory killing. Women and people with low education levels have been reported to have negative attitudes toward leopards' conservation; this cohort should be recognized and offered a particular conservation programme. A specific study based on local perception about compensation payments and the response of the forest department to a prevailing conflict should also be conducted as it can be a crucial factor in shaping the attitude of local respondents. Awareness programs should focus more on people who are less positive, less educated, and less knowledgeable about wildlife. These measures would improve people's attitudes toward wildlife in general and increase community awareness of wildlife conservation (Lindsey et al., 2005). Park management should put effort towards refuting the existing perception and better foster ties between the park and the community. Multiple strategies could be used to target impacted communities, and deciding the ones that are most suited should be done together with the participation of concerned communities so that they represent their cultural environment and are more likely to draw community support.

The finding of our study suggests that the local communities play a vital role as major stakeholders in effective conservation of leopards, and they promote coexistence with carnivore together with the support of government officials. These partnerships can not only help shape an individual attitude towards species conservation but also can increase community engagement towards awareness programs for knowledge of leopard importance. Sensitizing the local community about the need to conserve wildlife can help develop tolerance towards carnivores (Woodroffe et al. 2005), but it is sometimes difficult to develop a positive attitude among the community who are intolerant towards large carnivores due to lacking interest (Kaczensky 2003). Therefore, it is recommended that to address the negative as well as positive attitude, there be widespread community awareness, the development of alternative livelihood options that lessen the pressure on wildlife, and the development of efficient HWC mitigation measures in designated areas of RTR. The Forest department at RTR has installed solar power fencing at some places along village boundaries. It serves as an effective measure to reduce HWC incidents (Krishnaswamy et al. 2022) and minimise encroachment on forest land until management authorities take necessary action. Such conservation and management inputs need to be further installed and repaired, as most of the time fencing is damaged due to the frequent movement of elephants at places where no boundary is demarcated between villages and PAs (Jasmine et al. 2015).

Data availability

The data used in this study are provided in Supplementary Information.

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Supplementary Information: Text S1. Methodology

Data used in the present study is a mix of primary and secondary data. Primary data was collected during the survey and by field visits between January–May 2022 in the study area. Whereas secondary data used in the present study were collected from the Uttarakhand Forest Department. We collected official year-wise summary records of total compensation or compassionate grants paid out to individual households from the Uttarakhand Forest Department, suffering livestock loss and human casualties by leopards in the Rajaji Tiger Reserve (RTR) for the past 11 years (2010–2021) to better understand the nature and extent of human-leopard negative interactions. Secondary data was verified via onsite verification of the incident occurrence place in the study area. We recorded information such as livestock predation and human casualties by leopards based on spatial location. Duplicate incidents were removed from the combined primary and secondary survey to obtain the maximum efficacy.

Result: From the year 2010–2021, data were a total number of (N = 84) conflict incidents with leopards. Most incidents involved livestock predation 59% (N = 50) and the remaining involved attacks on humans 41% (N = 34). We found that 48% (N = 24) of attacks by leopards on livestock were on calves, followed by 24% on adult cows (N = 12), and 22% on goats (N = 11). Only 2% of attacks were attributed to sheep and 1% to buffalo. Among attacks by leopards on humans, 62% (N = 21) resulted in a loss of life, with the remaining 38% (N = 13) suffering a major wound.

Table S1. Each predictor variable co-categories were assigned a numerical value and were recoded into categorical variables.

Predictor Variable	Category	Recorded Numeric Output
1. Gender	Male	2
	Female	1
2. Family Size	0–3	1
	4–6	2
	>6	3
3. Livestock head	0–5	1
	6–10	2
	11–15	3
	>15	4
4. Education	Illiterate	0
	Primary	1
	Secondary	2
	Graduate and above	3
5. Employment	Service	1
	Agriculture	2
	Daily wages	3
	Livestock farming	4
	Others	5
	No source of income	0
6. Past leopard experience	No	1
	Yes	2
7. Income	<50,000	1
	50,000–100,000	2
	100,000–500,000	3
	>500,000	4
8. Age	18–40	1
	41–60	2
	>60	3

Table S2. Generalized Variance Inflation Factor (GVIF) to check multicollinearity among the 8 predictor variables.

Variables	GVIF	Explanation for list of explanatory variables included for performing ordinal logistic regression
Gender	1.16	Gender plays a significant role in predicting local people's perception of wildlife (Teixeira et al. 2021). Carnivores were encountered sporadically by women than by men. This is supported by previous research that compared men and women (Mkonyi et al. 2017; Trajçe et al. 2019). This could be due to the fact that men are at the forefront of outdoor activities such as encountering predators to defend their cattle as well as their life. Women are in charge of indoor activities.
Family size	1.06	Families with multiple members require more natural resources such as fuelwood (for domestic energy needs), non-timber forest produce (NTFPs), and livestock grazing, requiring them to spend more time in protected areas and come into contact with carnivores Abukari & Mwalyosi (2018).
Livestock-head	1.08	Support for conservation models appears to be affected by livestock numbers. The number of livestock in a community is a crucial determinant of the interaction between local communities and carnivore conservation. Those with more livestock might suffer more livestock damage and have a negative attitude toward carnivore conservation than those with fewer livestock (Biru et al. 2017; Gebresenbet et al. 2018).
Education	1.06	Respondents with less education are more likely to work in agriculture and rely on native environments for a living. It is well known that a higher degree of education enables alternative livelihoods such as employment possibilities (Lozano et al. 2019; Young et al. 2020). Such alternative activities tend to prevent agricultural-related habitat loss and local people's encroachment on native wildlife habitat, encouraging human-carnivore cohabitation (Lozano et al. 2019).
Employment	1.1	Various occupations/employment can have different attitudes toward wildlife conservation (Dandy et al. 2012).
Past leopard experience	1.09	Those who have had a conflict with predators are less likely to base their views and future actions regarding wildlife conservation on objective facts or information, as these experiences might lead to emotional prejudice and subjectivity (Inskip & Zimmerman 2009; Slagle et al. 2012).
Income	1.1	Persons with higher incomes had a stronger affection for leopard and their conservation. This could be because high-income households are less affected by wildlife than poor families (Dhungana et al. 2016). Better access to conservation awareness, educational benefits, as well as compensation payments, increases the capacity to deal with the potential cost of leopard conservation. Another explanation could be having more livestock may indicate a wealthier family; losing a few livestock from a wealthy family may have little impact, whereas losing the same number of livestock from a poor family can be traumatic (Bhattarai & Fischer, 2014), and thus the potential predator may be perceived as a greater threat to a poor family. Second, an elite family may have more socio-political influence and better accessibility of compensation for predator losses, which may gradually neutralize their negative attitude toward leopards.
Age	1.11	Younger individuals have more positive attitudes toward carnivores (Casey et al. 2005; Suryawanshi et al. 2014) as they are less likely to encounter carnivores.

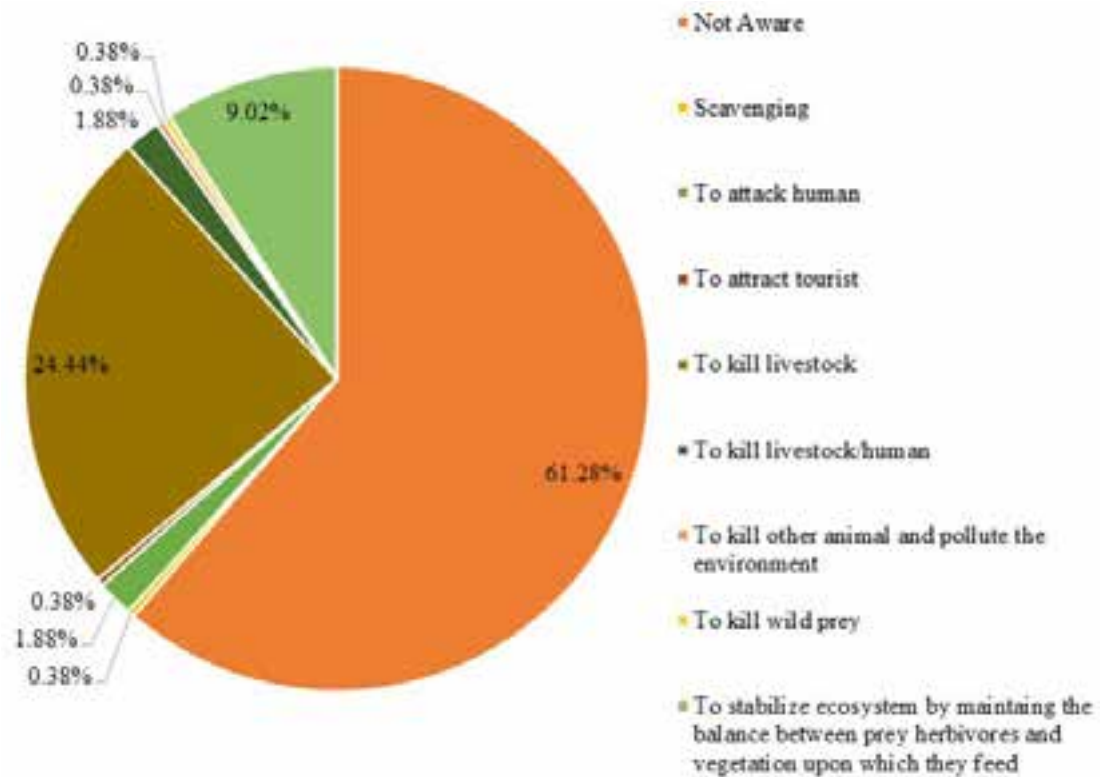

Figure S1. Respondents' perception towards the role of leopard in the RTR.

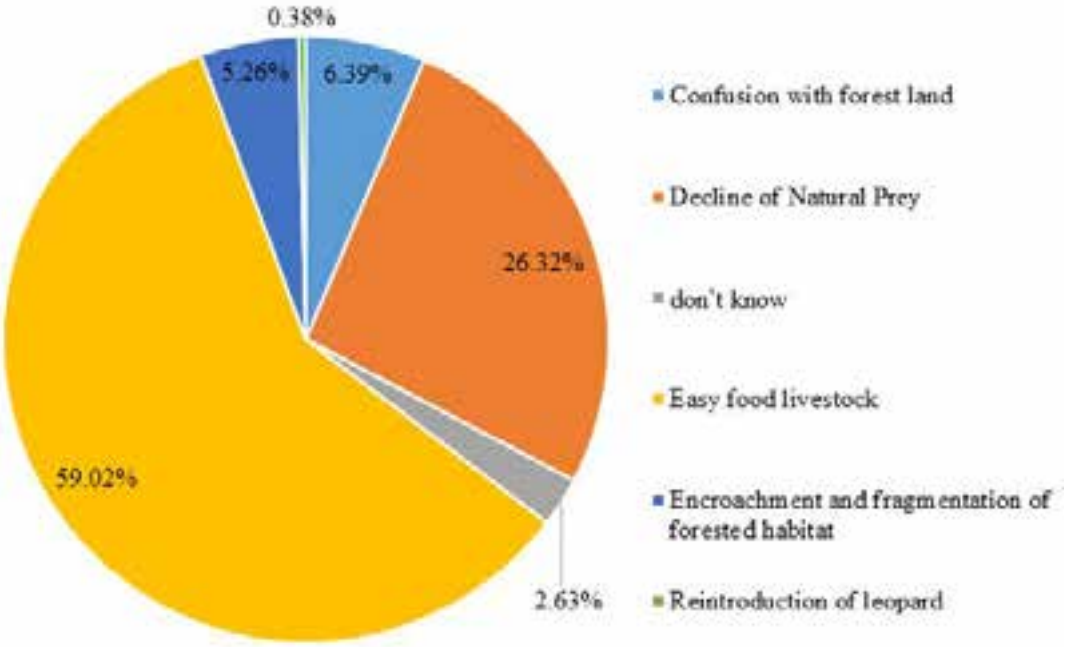

Figure S2. Respondents' perception about leopard predation in the RTR.

Table S3. A model comparison using the Akaike information criterion corrected for small sample sizes (AICc) of all 12 models to identify factors influencing the attitude of local people towards leopard conservation in Motichur and Shyampur range of RTR, Uttarakhand. We also report the number of parameters (k), the change in AICc scores (ΔAICc), the AIC weight (w), and the loglikelihood (LL).

Models	K	AICc	ΔAICc	*w*	LL
Gender + Age + Education	5	1001.00	0.00	0.28	-495.39
Gender + Family size + Livestock head + Education	6	1001.26	0.26	0.25	-494.47
Gender + Age + Employment + Education	6	1002.95	1.94	0.11	-495.31
Gender + Family size + Livestock head + Education + Employment	7	1003.37	2.37	0.09	-494.47
Gender + Family size + Livestock head + Education + Employment + Past leopard experience	8	1003.59	2.58	0.08	-493.51
Gender + Livestock head + Past leopard experience	5	1004.32	3.32	0.05	-497.04
Gender + Family size	4	1005.05	4.05	0.04	-498.45
Gender + Age	4	1005.49	4.49	0.03	-498.67
Gender + Family size + Livestock head + Education + Employment + Past leopard experience + Income	9	1005. 64	4.64	0.03	-493.47
Gender + Family size + Livestock head	5	1006.02	5.02	0.02	-497.89
Gender + Age + Employment	6	1007.49	6.49	0.01	-498.63
Gender + Family size + Livestock head+ Education + Employment + Past leopard experience + Income + Age	10	1007.65	6.65	0.01	-493.39

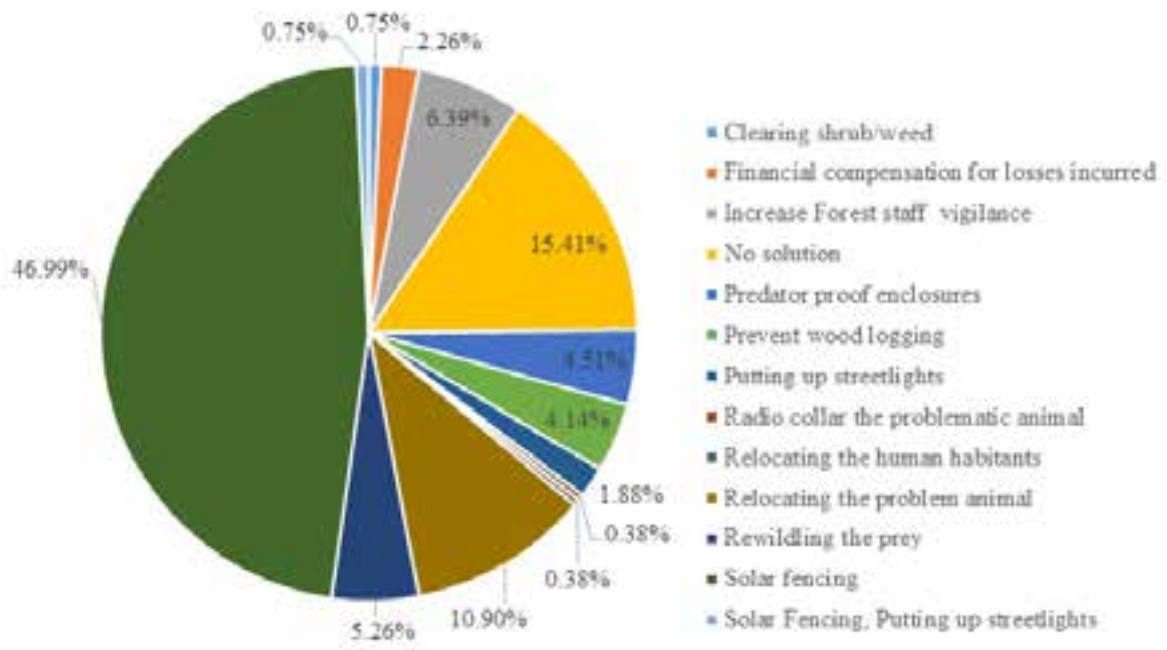

Figure S3. Mitigation measures suggested by residents of Motichur and Shyampur range, RTR.

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ARTICLE

Empirical evidence of Tiger *Panthera tigris* (Mammalia: Carnivora: Felidae) dispersal towards south from Similipal Tiger Reserve to Kuldiha Wildlife Sanctuary: potential implications for its conservation in the Greater Similipal Landscape

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Abstract: India has achieved a rare global conservation success by doubling its Tiger *Panthera tigris* number since 2006. However, in India's east-central states of Odisha, Chhattisgarh, and Jharkhand the tiger numbers are declining. The tiger population in Odisha is largely confined to Similipal Tiger Reserve which represents the only known breeding population of a genetically unique wild melanistic form. We report a first empirically confirmed tiger dispersal event towards the south between Similipal Tiger Reserve and adjacent Kuldiha Wildlife Sanctuary as part of our intensive monitoring exercise conducted from 2019–2022. This evidence-based dispersal event confirms tiger presence in Kuldiha after 11 recent years and urges strong support for tiger conservation in the Greater Similipal Landscape. In order to ensure long-term tiger presence in this landscape, we suggest more rigorous management interventions like habitat restoration and management, prey recovery, intensive protection measures, conflict management, and creation of inviolate space.

Keywords: Eastern Ghats Landscape, east-central tiger population, functional corridor, habitat integrity, Hadgarh Wildlife Sanctuary, human-tiger conflict mitigation, melanistic tiger population, metapopulation dynamics, prey recovery, systematic camera-trapping

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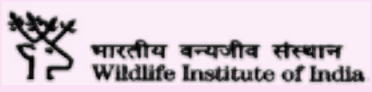

INTRODUCTION

The Tiger *Panthera tigris* is an endangered large carnivore (Goodrich et al. 2022) that exemplifies conservation efforts worldwide. India has achieved a rare conservation achievement by implementing a strong 50-year conservation program (MoEF&CC 2023). The tiger numbers got more than doubled from a population estimate of 1411 (1165–1675) in 2006 to 3682 (3439–3925) in 2022 (Jhala et al. 2008; Qureshi et al. 2023). However, the future of these tiger populations depends on careful management of the remaining forested habitats, where they are expected to face challenges from rapid urbanisation, increasing human density, expanding agriculture and associated infrastructure development and economic growth (Gubbi et al. 2016). In the Indian scenario, it is even more important as majority of the extant protected areas (PAs) are fragmented and all the tiger landscapes of the country have not experienced similar levels of population recovery. For example, the Central-India and Eastern Ghat landscapes currently retains ~40% of India's wild tiger population inside largely fragmented wildlife habitats (Jhala et al. 2020). This landscape has experienced substantial increase in tiger abundance from 2014 to 2022, except in the east-central states of Odisha, Chhattisgarh, and Jharkhand (Jhala et al. 2021; Qureshi et al. 2023). The small, isolated tiger populations of this landscape currently face various ecological, demographic, and genetic challenges (Seidensticker 2016).

The tiger population in Odisha, in particular, is of specific conservation interest as they represent a genetically unique lineage of melanistic form in the wild (Singh 1999; Kolipakam et al. 2019; Sagar et al. 2021). Similipal Tiger Reserve (STR- 2750 km^2 area) in Odisha currently reports the only known breeding population of the melanistic wild tigers globally (Rathore et al. 2021) and has been identified as one of the 42 source populations of tigers in Asia (Walston et al. 2010). Historically, tigers were found across STR along with surrounding PA's of Kuldiha Wildlife Sanctuary (KWS- 272.75 km^2 area), Hadagarh Wildlife Sanctuary (HWS- 191.40 km^2 area) and in Satkosia Tiger Reserve (SkTR- 963 km^2 area). However, the tigers have gone locally extinct from KWS (the last Tiger died in 2009- Panda 2019), HWS (the last Tiger died in 2014), and SkTR (Qureshi et al. 2023). An intensive camera-trap based study conducted over a duration of eight months in 2013 failed to report tiger presence in KWS (Debata & Swain 2018), making STR as the only hope for this unique population as well as in the east-central landscape.

Such recent events of local extinctions and declining tiger occupancy (between 2006–2022) (Qureshi et al. 2023) demands appropriate long-term conservation strategies through landscape-level approaches to ensure future tiger survival. The expansion of tiger occupancy along with ensured connectivity between the remnant habitats is critical for their future persistence in this landscape. Here, we present empirical evidence of a tiger dispersal from STR to KWS and discuss potential measures to be undertaken for increasing tiger occupancy in Greater Similipal (Similipal-Hadagarh-Kuldiha) Landscape.

MATERIAL AND METHODS

Study Area

The study was conducted across STR and KWS, located within the Deccan Peninsula Biogeographic Zone (Rodgers & Panwar 1988). Both areas feature tropical moist deciduous, tropical dry deciduous, and tropical semi-evergreen forest types (Champion & Seth 1968). The major large carnivores include Tigers, Leopards *Panthera pardus*, Indian Wolves *Canis lupus*, Asiatic Wild Dogs *Cuon alpinus*, Sloth Bears *Melursus ursinus*, and Striped Hyenas *Hyaena hyaena*. The ungulate prey community consists of Chital *Axis axis*, Sambar *Rusa unicolor*, Gaur *Bos gaurus*, Northern Red Muntjac *Muntiacus vaginalis*, Indian Chevrotain *Moschiola indica*, Four-horned Antelope *Tetracerus quadricornis*, and Wild Boar *Sus scrofa*. The Asiatic Elephant *Elephas maximus* is also present in both protected areas (Nayak 2014; Panda 2019).

STR and KWS are connected by two corridors along the northern and southern parts of the Salandi reservoir (Nayak 2014; Menon et al. 2017; Figure 1). The Similipal-Kuldiha corridor traverses the northern part of the Salandi reservoir along HWS and connects to a thin strip of reserve forest (ranging 0.3–2 km in width). This region is part of a proposed elephant corridor and contains six densely populated villages (Nayak 2014; Menon et al. 2017) and 97 temporarily defunct stone quarries. The forest has experienced encroachment pressures from nearby villages, posing a significant conservation challenge (Menon et al. 2017; Panda 2019)

Camera Trapping

As part of an ongoing tiger assessment program, 1,526 motion sensor camera-trap stations were placed and systematically monitored in STR from 2019 to

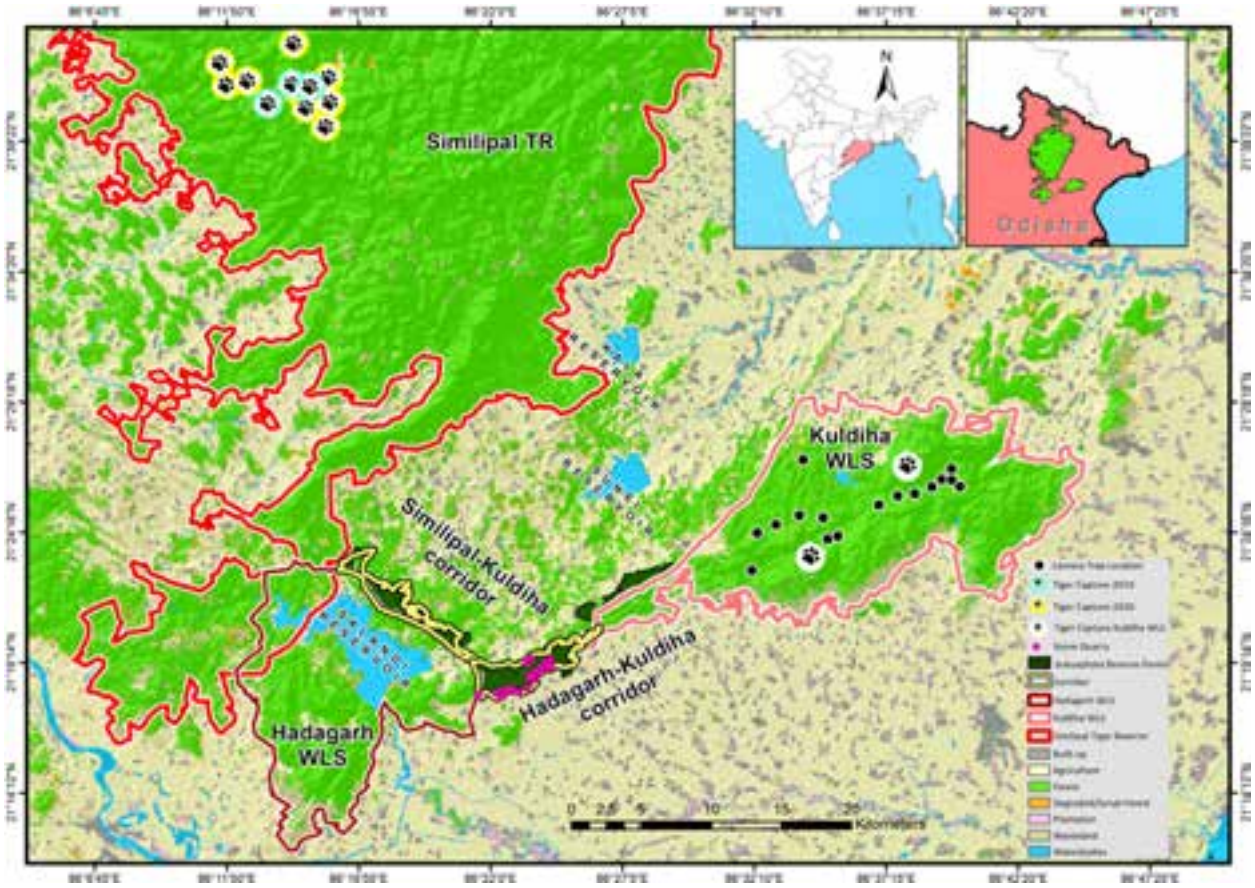

Figure 1. Map of Similipal-Hadagarh-Kuldiha protected area complex along with the biological corridors and the Tiger (T21) photo-capture locations in the years 2019, and 2020 in STR and 2021–2022 in KWS.

2022. Camera trapping was conducted in the entire core of STR following the national guideline of a 2 km^2 grid design to cover the intensive study area (NTCA-WII 2018). All the digitally stamped (with date and time of capture inforamtion) tiger photographs were identified and seperated out from the entire data set. The individual tiger identification was performed by using the software ExtractCompare (Hiby et al. 2009). Genetalia and secondary sexual characters (such as nipples for females) were used to ascertain the gender of the individual tigers in the four-year dataset.

Initially, KWS was not part of this monitoring effort, as no tiger signs were recorded here over last decade (Panda 2019). During December 2021, local department officials reported presence of possible tiger pugmarks in KWS and immediately a monitoring exercise was planned. An intensive large carnivore sign survey was conducted across KWS based on the reports from the ground staff members. Eighteen sites (forest roads, animal trails and trail junctions etc.) were selected with high potential of tiger presence for deploying camera-traps. Subsequently, single-sided camera traps were placed in all these sites from 22 December 2021 to 27 January 2022. The cameras were kept active throughout the day and regularly monitored. The tiger photos captured in these cameras were compared with the available tiger photograph repository from STR (Rathore et al. 2021) using ExtractCompare (Hiby et al. 2009). The results were further validated by three independent trained personnel. The age-class category assessments was conducted by using all earlier camera-trap records of the individual following Sadhu et al. (2017).

RESULTS

Two tiger images were obtained from all the camera traps deployed in KWS (Image 1c,d). The images were captured on 24 December 2021 and 8 January 2022, respectively. Both images were ascertained to be from one young-adult male tiger, which later matched with a cub (named as T21, Image 1a) earlier photographed

Image 1. Images of tiger (T21): a—photo-captured as a cub in 2019 | b—juvenile in 2020 in STR | c—Right flank | d—and left flank of T21 photo-captured in KWS in 2021–2022.

in UBK range of STR in 2019. T21 was photographed till September 2020 in the same range (Image 1b) before finally photo-captured in KWS in 2021. This dispersal event confirmed tiger presence in KWS after 11 years and indicates the possibility of an active corridor between these two PAs, where STR can be considered as the source and KWS as a sink habitat.

DISCUSSION

The STR tiger population has experienced a recent population increase from 12 ± 1 individuals in 2018 (Jhala et al. 2020) to 20 ± 2.47 individuals in 2022 (Qureshi et al. 2023). We feel that the recent tiger dispersal is possibly driven by the displacement of young individuals from STR to KWS as a result of the increase in tiger numbers. It is important to point out that although the growth of human habitation and mining activities in this space has ecologically separated Kuldiha from Similipal, but tiger movement link exists through Hadgarh WS. Our results provide empirical evidence of tiger dispersal to this protected area, which was earlier suggested by Singh (2021). If such a rise is continued then more such events can be anticipated across the Greater Similipal Landscape, and therefore appropriate steps towards managing this region need to be planned.

PAs connected through corridors in a metapopulation framework are currently the foundation for contemporary tiger conservation initiatives (Seidensticker 2016). Considering the evolutionary importance of the STR Tiger population, their demographic and genetic challenges, and isolated habitats, maintaining the integrity of the larger Similipal-Hadagarh-Kuldiha complex will be extremely critical. Firstly, urgent management attention is warranted toward habitat restoration of both the Similipal-Kuldiha and Hadagarh-Kuldiha corridors. One of the most effective ways to achieve this would be to include HWS, KWS, and the reserve forests (RF) in this corridor within a potential revised STR boundary, where the added areas could become part of the extended buffer area of STR, where a synchronized management

plan can be implemented. Further, adequate attention towards prey recovery throughout the entire region is required, where habitat management efforts aimed at increasing large ungulate densities would be beneficial for potential tiger recovery as the relative abundance of prey species is very low in KWS (Debata & Swain 2018) and HWS (Palei et al. 2021). The prey density estimation exercises should be conducted regularly in KWS and HWS to track ungulate biomass availability. Illegal hunting/poaching of ungulate prey has been reported in KWS (Panda 2019) and thus intensive monitoring of their population and protection measures will be crucial for tiger recovery. In this regard, implementation of regular anti-poaching patrolling using MSTriPES (Monitoring System of Tigers- Intensive Protection and Ecological Status; https://www.project-tiger.in/) would be essential. Similarly, government-supported incentivized voluntary human settlement relocation programs will improve the habitat productivity for ungulates and would play a vital role in successful tiger repopulation in KWS and HWS. Further, attention and necessary planning towards addressing potential human-tiger negative interactions is also needed. There are 12 villages within KWS with a human population of 17,000 and a large population of livestock (Panda 2019). Considering the fragmented nature of this area and such high human presence surrounding the PAs, increasing human-tiger interactions can be expected in the near future. Tigers are known to traverse through agricultural landscapes (Habib et al. 2021), often leading to such conflict situations. For conflict mitigation, active management efforts like timely compensation plans, participatory management efforts, etc., need to be in place to reduce any chances of retaliatory tiger deaths.

It is important to point out that our data is suggestive of this active corridor between STR and KWS, as no direct evidence was available to prove tiger use of these corridors. We suggest regular monitoring and assessment programs through intensive field surveys and camera-trapping approaches to assess the prey diversity, density, habitat use, and movement patterns across KWS, HWS, and the corridor regions.

The tiger populations in the east-central region of the central-India and Eastern Ghat landscape are facing adverse impacts from various human interventions across their habitats. The STR tigers are showing encouraging dispersal signatures with surrounding habitats. We believe that the dispersal event presented in this paper should be used to prepare an appropriate and focused management plan aiming at maintaining the source-sink population dynamics thereby assisting in long-term persistence of this evolutionary unique tiger lineage in Kuldiha and Hadgarh sanctuaries.

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OPEN ACCESS

ARTICLE

Philippine Warty Pig *Sus philippensis* Nehring, 1886: level of awareness and conservation practices in Datal Bad, West Lamidan, Don Marcelino, Davao Occidental, Philippines

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Abstract: The Philippines is a biodiversity hotspot with four endemic wild pig species. The Philippine Warty Pig is a medium to large size mammal that is usually solitary. They commonly exhibit crop raiding behavior, and hunting by farmers and poachers decreases populations of this species, which is listed as 'Vulnerable' in the IUCN Red List of Threatened Species. This study was conducted to determine the level of awareness of Philippine Warty Pig conservation practices among locals in sitio Datal Bad, West Lamidan, Don Marcelino Davao Occidental, Philippines. Responses (N = 50) were gathered by a survey questionnaire. Respondents were highly aware of Philippine Warty Pigs and policies toward wildlife conservation. They reported hunting pigs using air guns 'sorit', bow and arrow 'papana', harpoon 'bangkaw', and snare 'lit-ag'. The respondents added that they performed religious rituals and farming that may pose threats to Philippine Warty Pigs. They also manifested a willingness to work with government and academic institutions to enhance knowledge about conservation of pigs and other wildlife in their locality.

Keywords: Biodiversity, bow and arrow, conservation, endemic, harpoon, hunting, indigenous people, snare, threats, wildlife.

Filipino: Ang Pilipinas ay isang biodiversity hotspot na may apat na endemikong uri ng baboy sa gubat. Ang Philippine Warty Pig ay isang hayop na karaniwang malaki ang sukat na kadalasang nag-iisa. Karaniwan silang nangunguna sa pagnanakaw sa pananim, at ang pangangaso ng mga magsasaka at mangangaso ay nagpapababa sa populasyon ng uri na ito, na nasa listahan bilang 'Vulnerable' sa IUCN Red List ng mga Nanganganib na Uri. Isinagawa ang pag-aaral na ito upang matukoy ang antas ng kamalayan sa mga patakaran ng konservasyon ng Philippine Warty Pig sa mga lokal sa sitio Datal Bad, West Lamidan, Don Marcelino Davao Occidental, Pilipinas. Ang mga Tugon (N = 50) ay nakuha sa pamamagitan ng isang survey questionnaire. Ang mga respondente ay lubos na may kamalayan sa mga Philippine Warty Pigs at sa mga patakaran patungkol sa konservasyon ng wildlife. Nag-ulat sila ng pangangaso ng mga baboy gamit ang mga baril na 'sorit', pana at panaan na 'papana', harpoon na 'bangkaw', at bitag na 'lit-ag'. Nagdagdag ang mga respondente na kanilang isinasagawa ang relihiyosong ritwal at pagsasaka na maaaring magdulot ng panganib sa mga Philippine Warty Pigs. Nagpahayag din sila ng kagustuhang makipagtulungan sa pamahalaan at mga akademikong institusyon upang mapalawak ang kaalaman tungkol sa konservasyon ng mga baboy at iba pang wildlife sa kanilang lugar.

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INTRODUCTION

The Philippines is one of the world's biodiversity hotspots, with four endemic wild pig species: three warty pigs and one bearded pig (Cariño 1998; Meijaard & Melletti 2017). As mentioned in the study of Villegas et al. (2022), the warty pigs *Sus cebifrons* (Heude, 1888), *Sus oliveri* (Groves, 1997), *Sus philippensis* (Nehring, 1886), and the Palawan Bearded Pig *Sus ahoenobarbus* (Huet, 1888) can be found in the islands of Luzon, Visayas, Palawan, and Mindanao. *S. philippensis* morphological characteristics comprise of commonly black with grey colored fur and a pale snout band. They also have long full crown tuft and nuchal mane extended along the back of a male Philippine warty pigs with pairs of warts and gonial tufts (Meijaard & Melletti 2017; Cabanas et al. 2022;). This large to medium sized mammal is usually found in solitary or with their young in areas where there is an open canopy, near clearings like plantations, trees with smaller DBH, areas with abundance of fruits, and adjacent to streams which the warty pigs can access easily (Cabanas et al. 2022; Villegas et al. 2022; Gamalo et al. 2023).

The warty pigs is known to raid crops, and farmers tend to hunt them which drives the population of this species to decrease (Cabanas et al. 2022). Aside from hunting and poaching, some threats to Philippine warty pigs that contributed to its decline are habitat destruction, pathogens (African Swine Fever Virus), and hybridization (Blouch 1995; Villegas et al. 2022; Gamalo et al. 2023). With these risks, the Philippine Red List Committee (PRLC) and the International Union for Conservation of Nature (IUCN) Red List for Threatened Species have categorized *S. philippensis* as 'Vulnerable' (Meijaard & Melletti 2017; DENR-BMB 2020). In the report of Oliver (1995), wild pig populations in Davao Region are declining and very rarely seen in Mt. Apo. In the surrounding areas of Mt. Apo, various ethnicity exists with high potential for hunting warty pigs is observed as they only know that hunting is illegal only for charismatic species such as Philippine Eagle. Accordingly, RA 8371 or the Indigenous Peoples Right Act and RA 9147 or the Wildlife Resources Conservation and Protection Act clearly stated that utilization of wild animals for tradition and culture is permitted. But in the case of the warty pigs which is already considered as vulnerable, RA 9147 does not allow the use of vulnerable animals like the warty pigs to be utilized in any traditional or cultural practices to protect its declining population. However, hunting as tradition and lack of awareness as to the status of the warty pigs is one of the leading causes of population decline in the region (Tanalgo 2017).

Field investigation into specific environmental requirement, population structure, reactions to hunting strain, and commercial logging, are the some of the key factors that played an important role in the conservation of warty pigs (Blouch 1995). Highlighting in this paper is the Philippine Warty Pig *S. philippensis* which is reported to have sightings in Datal Bad West Lamidan, Don Marcelino, Davao Occidental especially in cultivated areas where vegetables and root crops were planted (P. Avenido pers. comm., March 8, 2023). Accordingly, a study by Cosico et al. (2017) stated that Philippine Warty Pig's main diet is composed of root crops, vegetables, fruits, and invertebrates which explains the sightings of warty pigs in West Lamidan. Given its occurrence in the area, no study related to its protection and conservation were done though communities mentioned that they safeguarded this species as it is said to be a natural resource in their land. To address this gap, this current paper aimed to determine the level of awareness and identify local conservation practices of the locals in Datal Bad West Lamidan, Don Marcelino, Davao Occidental about the Philippine Warty Pig.

METHODS

Study area

This study was conducted in Datal Bad, West Lamidan, Don Marcelino, Davao Occidental (Figure 1). Datal Bad is situated approximately along 6.092578 N and 125.654225 E. The areas have an estimated elevation of 1,448.5 m (4,752.2 ft). Its population as of 2022 was 113 individuals comprising two indigenous groups namely the B'laan & Manobo, living and sharing the same culture. The study site is approximately 3.3 km from the barangay proper of West Lamidan and about 4.8 km from Don Marcelino. The main source of livelihood among the tribes is farming. They cultivate crops like corn, cassava, bananas, and abaca. The crops they produce are mainly for consumption while some are sold to merchants at the barangay site including the fiber produced from abaca. Datal Bad nested along the side of the forest and is not accessible to any mode of transportation, even horses. In marketing the farm produce, the tribes used to carry them along the slopes of the mountains to the barangay site passing through the fast-flowing river.

Research Design and Instrument

This study utilized a qualitative research design to examine the current state of Philippine Warty Pig conservation practices among the tribes in Datal Bad, West Lamidan. Descriptive research design was used to analyze the data from the survey questionnaire (Sedlock 2010) relative to the main purpose of the study. An adopted questionnaire formulated by Sedlock (2010) was used to gather information in the study site. The respondents considered in the study are residents of Datal Bad. Information collected includes respondents' demographic profile, hunting preferences, number of people who went to hunt, hunting methods, reasons of hunting, level of awareness, and conservation practices. The benchmark statements on the level of awareness on Philippine warty pig conservation among the residents in the study were rated using the Likert scale (Table 1).

The common human activities related to Philippine warty pig, the scale below was used to interpret the

Table 1. Scoring guide in the analysis of the response for the level of awareness on Philippine Warty Pig.

Range of Means	Scale	Description	Interpretation
3.3–4.0	4	Highly Aware	Indicators relating to the level of awareness on Philippine warty pig conservation practices are always employed. The level of awareness is fully manifested.
2.5–3.2	3	Aware	Indicators relating to the level of awareness on Philippine warty pig conservation practices are oftentimes employed. The level of awareness is manifested.
1.8–2.4	2	Unaware	Indicators relating to the level of awareness on Philippine warty pig conservation practices are moderately employed. The level of awareness is sometimes manifested.
1.0–1.7	1	Highly Unaware	Indicators relating to the level of awareness on Philippine warty pig conservation practices are seldom employed. The level of awareness is somehow manifested.

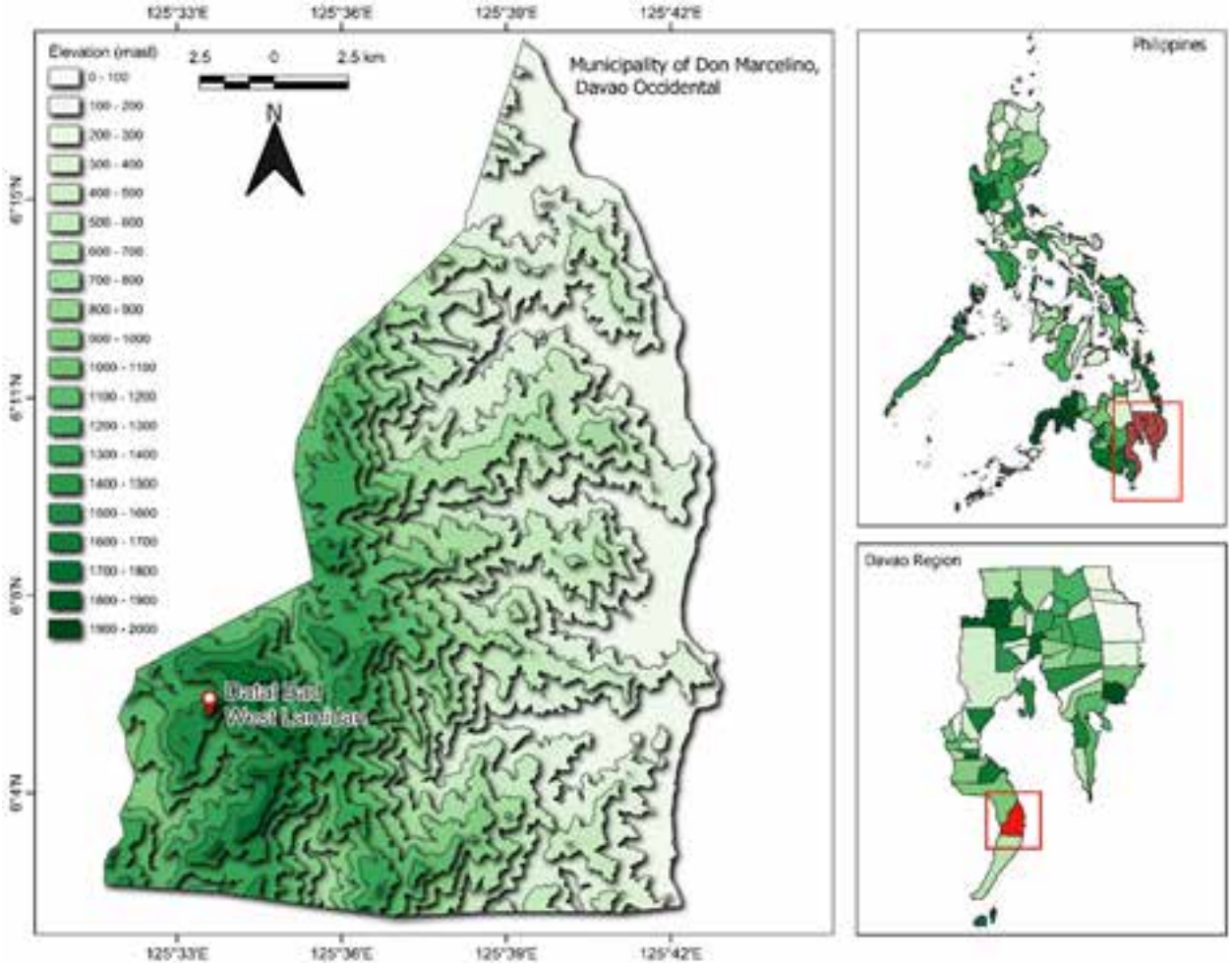

Figure 1. Digital elevation map of Don Marcelino, Davao Occidental.

responses of the respondents.

Respondents of the Study

An opportunistic randomly selected residents of the study site were surveyed. Simple random technique was used to identify respondents of the study out of the total population of Datal Bad (more than 10% of the entire population of the study area). Respondents were 15 years old and above. No sex preference as long as they reside in Datal Bad and have knowledge on Philippine warty pigs.

Data Analysis and Ethical Consideration

The data collected were analyzed using descriptive statistics such as frequency count, percentage, and mean. Mean is the measure of center or average and the most recognized type of descriptive statistics. It was used to repurpose hard-to-understand quantitative insights across a large data set into bite-sized descriptions. Mean was used to determine the average of quantitative data. It was calculated by adding all the figures within the data set and then dividing by the number of figures within the set.

The responsibility of the researcher in this study was to ensure that the respondents are well cared for during and after the conduct of the study. Therefore, the researcher made coordination with the tribal and indigenous leaders prior to the entry and survey proper. The researcher explained and elaborated to respondents the objectives of the study and the purpose of the visit. This helped ensure the researcher would bring no harm or danger to the respondents, their place, and community. This etiquette followed a set of ethical consideration to protect the participants (British Psychological Society 2000).

RESULTS AND DISCUSSION

Socio-Demographic and Socio-Economic Characteristics of Respondents

The socio-demographic and socio-economic variables may influence awareness on hunting Philippine warty pig and its conservation practices. In addition, the extent of awareness of these practices and attitudes towards them are significantly affected by age, gender, and level of education. Increasing knowledge is associated with more positive attitudes toward conservation. This conforms to the findings of Prokop (2009) that males showed greater knowledge of wildlife than women. Likewise, knowledge of wildlife conservation issues appears to be more extensive among men who are household heads and among people who own more livestock and, therefore, have higher economic status in the community.

Based on the interview, some indigenous group in the area are non-law abiders but they are the most knowledgeable about the wildlife. Poverty and lack of permanent job drives indigenous communities to hunt wildlife and exploiting possible resources that the environment could offer.

Demographic Characteristics of Respondents

The demographic profile of the respondents in the study is presented in (Figure 2). In terms of age, respondents at the age bracket of 29–37 years old dominated which accounted 38% followed by 20–28 years of age (22.0%). The age group with lowest percentage was observed in the age bracket of 65–73 years old at 6.0% (Fig. 2A). With regards to gender, the male respondents dominated over female respondents with 68.0% and 32.0%, respectively (Figure 2B). This result revealed that male is more knowledgeable and aware in the existence and status of Philippine warty pig, with this, the result of the survey is more accurate. However, the information generated from women are still valid and acceptable since they also have knowledge on the Philippine warty pig in the area. Male are more engaged into hunting as they are responsible for supporting their families' necessities such as food and income while female is commonly supporting their husband doing the routinary household chores. On the other hand, with respect to the number of siblings among the respondents, it was evident that each household has siblings ranged from 1–9 per household. Most respondents belonged to a household consist of nine individuals which is very common in a Filipino family despite its economic status (Figure 2C). Moreover, as to the educational attainment of the respondents (Figure 2D), there are 37 of them who are in the elementary level (74.0%) while 22.0% have graduated elementary. Furthermore, among the respondents, only one have reached high school (2.0%), and have finished high school (2.0%), respectively.

Figure 3 depicted the employment of the respondents. Results demonstrated that most of the respondents were farmers which accounted 68.0% while some of them earned a living being a paid laborer (14.0%). There were female respondents who earned as vendor whereas the lowest value was attributed to the carpenter with 2.0%. In terms of the monthly income of the respondents (Figure 4), Majority of the respondents

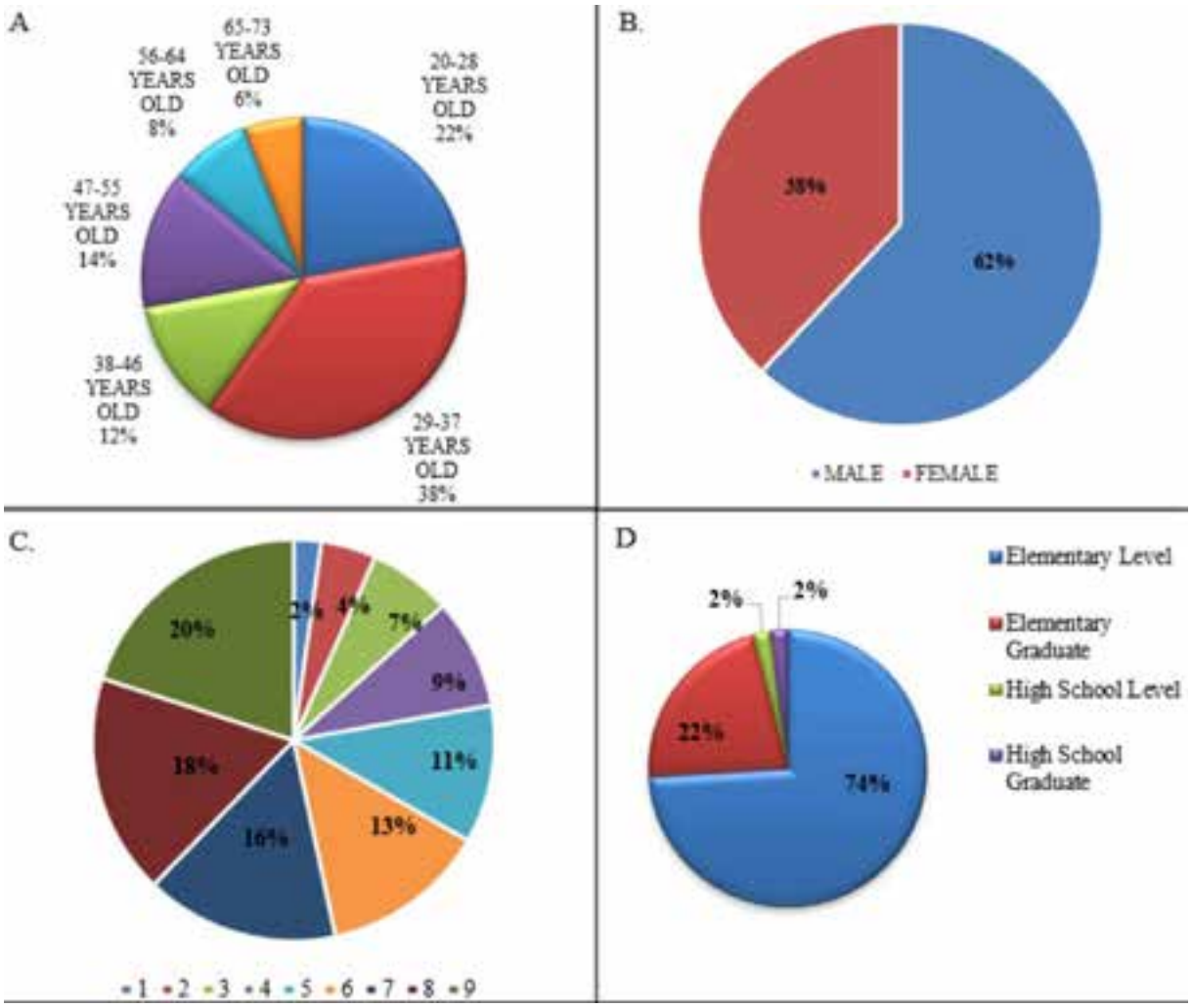

Figure 2. A—Age | B—gender | C—number of siblings | D—level of education of the respondents.

(60%) have a monthly income of below PHP 3,000.00 followed by those who earned PHP 3,001.00–PhP 7,000.00 (36.0%) monthly, whereas 4.0% had an income of PHP 7,001–11,000 per month. Moreover, none of the respondents in Datal Bad earned more 11,000 pesos a month.

Common activities of the locals in Datal Bad

The several activities of the locals in Datal Bad in relation to Philippine warty pig is presented in Table 3. Respondents confirmed that they are doing activities that posed threat to Philippine Warty Pig. They always hunt for food, medicine or even as pet. As part of the tradition and local belief of the respondents, having the Philippine warty pig as pet will make them famous as these animals were very rare. Although, they already knew laws of the government in protecting wildlife, but they don't follow the policies and did not practice on how to conserve Philippine Warty Pig. Due to poverty and their need for food, some of them lead to hunt wildlife resources present in the area and even sometimes they leave waste inside the forest. These may be because of no strong existing policy or ordinance in local adapting national laws in protecting wildlife. The respondent's involvement in hunting and disregarding the policies set by the National Wildlife Conservation clearly demonstrate that the local community lacks effective wildlife conservation practices.

According to the community the diversity indices of wildlife of Datal Bad are high. In spite of this, possible threat and disturbances due to human activities might hamper Philippine warty pig population and diversity of the area in general. Some practices such as military visits, excessive & unregulated tourism, and hunting might affect its population. Also, the application of chemicals to minimize the population insect pest for

Figure 3. The socio-economic characteristics of the respondents in terms of their occupation.

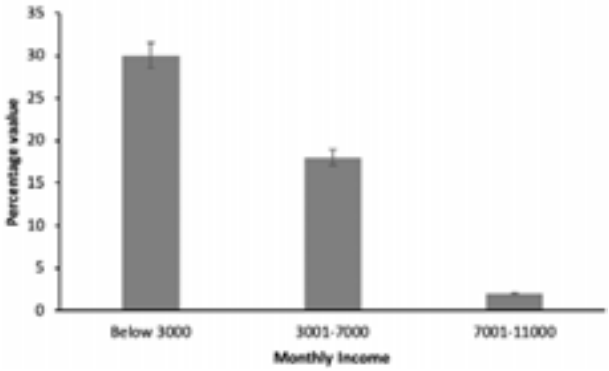

Figure 4. The socio-economic characteristics of the respondents in terms of their monthly income.

farming are likely to affect the current population and species composition in the forest of Datal Bad.

The researcher interviewed 50 respondents and 94.0% of them said that they were willing to work with Municipal Environmental and Natural Resources Office (MENRO), researchers, and academic institutions to manage well, protect, and to conserve warty pigs in the area and 4.0% are not willing. Also, only 2.0% was undecided to work with MENRO. In consonance to this, the respondents needed the government support, concrete road, policy enhancement, and the support from the community to make local conservation practices towards Philippine Warty Pig to be sustainable and to stop it from extinction. The locals' practices and reported disturbances might be an implication for future conservation plans in the area. Indeed, there is a need to further educate all locals and work with local barangay officials to ideally stop, or at least reduce the level of disturbance in the forest.

Knowledge and Awareness of the Locals on Philippine Warty Pig

Table 4 shows the knowledge and awareness of the respondents about Philippine Warty Pig in the area.

Table 2. Scoring guide in the analysis of the responses of respondent's common activities relating to Philippine Warty Pig.

Range of means	Scale	Description	Interpretation
3.3–4.0	4	Always	Indicators relating to common activities on Philippine warty pig are always observed.
2.5–3.2	3	Most of the time	Indicators relating to common activities on Philippine warty pig are oftentimes observed.
1.8–2.4	2	Sometimes	Indicators relating to common activities on Philippine warty pig are moderately observed.
1.0–1.7	1	Never	Indicators relating to common activities on Philippine warty pig have never been observed.

Respondents were highly aware of Philippine Warty Pig in the area. On the other hand, respondents were aware on associated conservation policies formulated by MENRO and the Barangay Council, services and benefits of Philippine Warty Pig , local conservation practices, and prohibitions. They were also aware of human activities that pose threats on Philippine Warty Pig . The results contrasted with the findings in the study conducted by Hassan et al. (2015) wherein respondents, especially farmers are unaware of the ecological services rendered by Philippine Warty Pig and reflected a negative attitude towards them. However, a greater percentage of the respondents in the same study positively responded to the policies and recommendations towards conservation. This linked to the idea of Hassan et al. (2015) that lack of ecological awareness seems to be the major impediment in wildlife conservation and results to a mass persecution of wildlife especially Philippine Warty Pig that may lead towards local extinction of these organisms in the future, and as well as the educational background and ecological literacy of an individual (Kellert & Westervelt 1984). Prior to the widespread of wildlife conservation education and awareness program, a vast majority of people also had similar beliefs about wildlife.

These beliefs on Philippine Warty Pig were, however, less prevalent. The educational attainment of the respondents indicates that conservation education can further convey awareness among the people, promotion of non- consumptive wildlife-oriented tourism and can serve as tool to halt mass persecution of Philippine Warty Pig.

Conservation Threats

The human activities in Datal Bad which may cause threats and disturbance to Philippine warty pig is

Table 3. Common activities of the locals in Datal Bad, West Lamidan, Don Marcelino, Davao Occidental.

Benchmark statement	Mean response	Mode	Qualitative description
1. Went to the forest	2.92	3	Most of the time
2. Hunt Philippine Warty Pig in the forest	2.90	3	Most of the time
3. Sold Philippine Warty Pig in the market	2.82	3	Most of the time
4. Hunting or persecution of Philippine Warty Pig	2.60	3	Most of the time
5. Hunting Philippine Warty Pig for pleasure	2.36	2	Sometimes
6. Make Philippine Warty Pig as food	3.42	4	Always
7. Make Philippine Warty Pig as medicine	2.66	3	Most of the time
8. Sold Philippine Warty Pig in the market	2.84	3	Most of the time
9. Make Philippine Warty Pig as a pet	2.62	3	Most of the time
10. Destruct Philippine Warty Pig habitat	2.68	3	Most of the time
11. Making or creating noise inside/beside the forest	2.70	3	Most of the time
12. Leave waste inside the forest	2.08	2	Sometimes
13. Follow wildlife protection policy	2.78	3	Most of the time
Overall mean	2.72	3	Most of the time

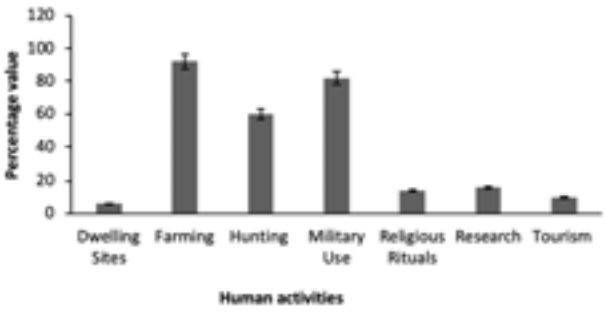

Figure 5. Human activities which may cause possible threats and disturbances to Philippine Warty Pig .

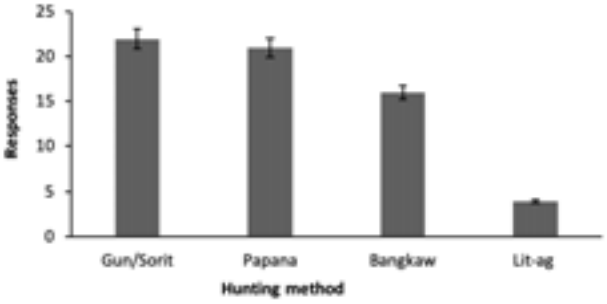

Figure 6. Philippine warty pig hunting method practiced by the locals.

presented in Figure 5. It depicted that, most of the time, forest was used by the community for farming which accounted 92.0%. On the other hand, the forest was used by the military as dwelling place (82.0%). Although policies and fines were already in place for wildlife protection, hunting and retaliation (60.0%) are still happened and with the number of wildlife present in the area, researchers were conducting studies using the forest as their sampling site. Other activities included religious rituals and other activities (14.0%) while tourism and recreations accounted 10.0%. These activities were done inside or near the habitat of Philippine wart pigs which may directly or indirectly disturb and may be considered threats to the Philippine Warty Pig population.

Concordance to the findings of Cardiff et al. (2012), farming, military, and tourist can pose a threat to Wildlife population as they can disrupt Philippine Warty Pig activities. Philippine Warty Pig avoid human which could reduce their feeding time and avoidance of prime feeding areas that are used by human can have a negative effect on their energy balance (Buckley 2004). Even if the goal of conducting research is good, it brings harm to Philippine Warty Pig in the sampling area in some ways. Research activities like staying overnight for specimen collection, using of flashlights, and creating noise like religious activity can cause disturbance to the Philippine Warty Pig in the area. Hunting and retaliation of Philippine Warty Pig species and consumption also occurred in the area.

Based on the survey, one of the respondents said that some group of people, indigenous groups, usually hunt Philippine Warty Pig in the area and they sell it at a price of 200 pesos per kg. This conformed to the findings of Mildenstein (2002) who reported that some indigenous tribes in the Philippines believed that

Table 4. Knowledge and awareness of the locals in Datal Bad on Philippine Warty Pig.

Variables	Mean response	Mode	Description
1. I am aware that there are Philippine Warty Pigs in our area.	3.62	4	Highly aware
2. I am aware that there are Philippine Warty Pigs near our barangay that we are not allowed to hunt.	3.24	3	Aware
3. I have received information about Philippine Warty Pig conservation.	3.32	4	Highly aware
4. I am aware how to conserve Philippine Warty Pigs.	3.38	4	Highly aware
5. I am aware that there are efforts from the local government to conserve Philippine Warty Pigs.	3.30	4	Highly aware
6. I am aware on an act protecting the Philippine Warty Pig passed by the government.	3.22	4	Highly aware
7. I am aware of MENRO and Barangay policy about Philippine Warty Pig conservation.	3.22	3	Aware
8. I am aware that human activities have significant impact on Philippine Warty Pig population.	3.12	3	Aware
9. I am aware about the services and benefits that rendered by the Philippine Warty Pig.	3.02	3	Aware
10. I am aware on the different program about Philippine Warty Pig conservation.	3.06	3	Aware
Overall Mean	3.25	3	Aware

Philippine Warty Pig meat is a good source of protein. In Carolina Islands of the Federated States of Micronesia, wild boar species are part of a high valued delicacy, traditionally eaten during celebrations. It is commonly hunted opportunistically as a novel supplemental food source (Food and Agriculture Organization of the United Nations 2011).

Extensive farming in the area poses a great threat and disturbance in warty pig fauna. In addition, worldwide, agriculture a major impact on many habitats. The increasing human population has meant ever increasing demands on agriculture to produce more food. In many countries, this has led to a change from traditional to more intensive agricultural techniques, with greater use of artificial chemicals as fertilizers & pesticides and many habitats have been lost through expanding and developing more efficient agricultural systems (Esselstyn et al. 2004). Racey (2003) stated that the increasing use of land for agriculture have been associated with extensive loss and fragmentation of natural habitats and, frequently, the degradation of remaining habitats. Major threats to Philippine Warty Pig populations worldwide are the loss of natural habitats which resulted from modification and fragmentation due to agricultural development.

Most of the results were merely similar to the findings of (Villegas et al. 2023) that most of the threats on wildlife in the Philippines are due to lack of strong policies or protection, increased demand for recreational sites, treasure hunting, mining, pollution, illegal collection of cave resources, and rapid urbanization.

Hunting Method

The mode of Philippine Warty Pig hunting in the locality includes the following: solitary, by pair or in group. Most of the respondents went Philippine Warty Pig hunting in groups. According to them, group hunting was much more ideal compared to solo or by pair since there are more individual who can help in sighting possible Philippine Warty Pig . Additionally, they prefer group hunting because this group hunters were commonly relatives or a member of a single family. The family members tend to hunt during their most convenient time and if there was a report of Philippine Warty Pig sightings in the area. This result was in consonance with the study of Stegeman (1938) who reported that hunters do not follow fixed hunting schedule but hunted when convenient. Although, some hunting trips are carried out for cultural or ritualistic reasons may follow a schedule, for example during village festivals and functions. Some hunters are doing this trip because they are craving as it their viand.

In Figure 6, the multiple response of respondents relative to hunting activities they used is presented such as gun/sorit (22 responses) as their tool in hunting and is the mostly used, followed by papana (21 responses) whereas bangkaw and lit-ag have 16 and four responses, respectively. These different hunting methods are also practiced in other areas for hunting wildlife (Aiyadurai et al. 2010). Trapping methods were also practiced including bows and arrows and spears but not blowguns. The indigenous methods documented were stone-fall, trigger-and release, canopy, spring-pole, gun, metal noose, hanging stone, pitfall, box, log-fall, and rodent traps. Also, in the results gathered by the study of Johnson (2005) found out that guns were the most common method reported for capturing most wildlife, other tools for hunting include snares and bows. More

than half of total responses for hunting methods across all animals were guns, followed by papana, bangkaw, and lit-ag.

Wildlife Use and Consumption

It was found out that hunted Philippine Warty Pig were commonly consumed for food, fairly used as pet, and rarely practiced for trading due to the awareness of law in protecting wildlife. This finding revealed wildlife specifically the Philippine Warty Pig and fish made up an average of 66% of protein source. Interviewers observed that relatively small amounts of meat were consumed per individual per meal, but that meat was often present. Also, as stated by Bennett & Robinson (2000) human population density is high. Population depends on wildlife for its major source of protein. In relation to this, the study conducted by Rao et al. (2005) wild fish appeared to be the most prevalent source of animal protein relative to wild or domestic meat (livestock). Proteins are considered as part of the dietary components of hunters as they consumed.

Mostly in the study sites, Philippine Warty Pig was used in tradition, for medicine, and rarely used in religion and others. Stegeman (1938), explained the preference for wild meat was reportedly based on taste. People believed that wild meat is not contaminated like the meat of domestic animals that villagers refuse to eat. Majority of the respondents hunted Philippine Warty Pig for personal consumption, while others hunted for recreation, trade, and retaliation. Such findings are like the study of Stegeman (1938) which reported in Arunachal Pradesh, northeastern India Mishmi, Myers (2000) reported food as the main reason for hunting, followed by money, rituals/customs, and interest in hunting and retaliatory killing of crop-raiding animals. Cash income was an important reason for hunting by Myers (2000). Also, according to Nijhawan & Mihu (2020) (22 responses) reported ritual as the main inspiration for hunting.

CONCLUSION

Majority of respondents are in the age bracket of 29–37 years old and males are more aware in Philippine Warty Pig in the area. Poverty and lack of permanent jobs are the major drivers for illegal hunting of the Philippine warty pig in the vicinity. Several indigenous people in the community were observed to be violators of national and local policies. Meanwhile, the community are aware of the highly diverse wildlife and the presence of the Philippine Warty Pig in their locality. Though there are national policies to address the declining number of Philippine Warty Pig and other wildlife, there are various local practices, cultural beliefs, and tradition that possess threats and disturbances to the already vulnerable Philippine warty pig population in Datal Bad. Further, continuous occurrence of various local threats and disturbances in Datal Bad can lead to the local extinction of the said species. Therefore, a strong information drive campaign and the establishment of local policies that was specific to the conservation of Philippine Warty Pig is necessary. In addition, community-based wildlife conservation management is also important to directly involved local communities in the preservation and protection of the vulnerable Philippine Warty Pig. These actions are very essential since the community in Datal Bad specifically those who hunt Philippine Warty Pig are very open and willing to be involved in conservation, protection, and research activities which could positively impacts Philippine Warty Pig population.

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Appendix I. Survey questionnare (Modified from: Sedlock (2010).

PHILIPPINE WARTY PIG AWARENESS AND CONSERVATION PRACTICES IN SITIO DATAL BAD, WEST LAMIDAN

A. Socio-demographic Profile of the Respondents

Name (optional): _____ Age: _____
Number of Siblings: _____ Gender: _____
Educational Attainment:

( ) Elementary Level
( ) Elementary Graduate
( ) High School Level
( ) High School Graduate
( ) College Level
( ) College Graduate
( ) Vocational Graduate

Occupation/Sources of Income

( ) Farmer
( ) Paid laborer
( ) Vendor
( ) None
( ) Other Sources: _____

Monthly Income/Month: _____

B. Knowledge on Philippine warty pig

Please indicate how much you aware or unaware with the following statements about Philippine warty pig conservation by tick (√) one box on each row.

4: Highly aware 3: Aware
2: Unaware 1: Highly Unaware

Particulars		Highly Aware	Aware	Unaware	Highly unaware
		4	3	2	1
1	Are you aware of Philippine warty pig in your area?				
2	Are there Philippine warty pig near your barangay that you are not allowed to hunt?				
3	Have you received information about Philippine warty pig conservation?				
4	I am aware about on how to conserve Philippine warty pig?				
5	I am aware that there are efforts from the local government to conserve Philippine warty pig?				
6	I am aware on an Act Protecting the Philippine warty pig /Wildlife passed by the government?				
7	I am aware of MENRO and Barangay policy about Philippine warty pig Conservation.				
8	Human activities have significant impact on Philippine warty pig Conservation				
9	I am aware about the services and benefits that rendered by the Philippine warty pig				
10	I am aware on the different program about Philippine warty pig conservation.				

C. Awareness on Philippine warty pig

1. How many Philippine warty pigs are there in your area? Please Specify_____
2. Is there Philippine warty pig near your barangay that you are not allowed to touch?
   ( ) Yes
   ( ) No
   Why_____
3. How many Philippine warty pigs did you see in the forest when you visited?
   ( ) None
   ( ) Few (less than 50; individuals were scattered throughout the forest)
   ( ) Many (hundreds of Philippine warty pig)
   ( ) A lot (thousands of Philippine warty pig)
4. What is the largest number of Philippine warty pig you have seen in a forest?
   ( ) No forest experience
   ( ) 0–10
   ( ) 10–100
   ( ) 100–1,000
   ( ) 1,000–10,000
   ( ) 10,000+

5. How does this number of Philippine warty pig compare to what you saw in the forest during the Ramos presidency (between 992–1998)?
   ( ) I/we did not visit the cave then
   ( ) Less
   ( ) Same
   ( ) More
   ( ) Not applicable (e.g., too young)
6. Do you think the community should do anything to regulate Philippine warty pig hunting?
   ( ) Yes
   ( ) No
   How? _____
7. Did you follow these recommendations?
   ( ) Yes
   ( ) No
8. Did you follow the community management guidelines?
   ( ) Yes
   ( ) No
9. Philippine warty pig in your area.
   ( ) Still abundant
   ( ) Decreased

D. Common activities of the locals in Datal Bad, West Lamidan, Don Marcelino, Davao Occidental

The following are the list of activities that you may do, for each one that you do regularly. Please tick (√) one box on each row.

4: Always 3: Most of the time
2: Sometimes 1: Never

		Highly Aware	Aware	Unaware	Highly unaware
		4	**3**	**2**	**1**
1	Did you perform activities in forest?				
2	Hunt Philippine warty pig in the forest				
3	Sold Philippine warty pig in the market				
4	Hunting or persecution of Philippine warty pig				
5	Hunting Philippine warty pig for pleasure				
6	Make Philippine warty pig as food				
7	Make Philippine warty pig as medicine				
8	Sold Philippine warty pig in the market				
9	Make Philippine warty pig as a pet				
10	Destruction of Philippine warty pig habitat				
11	Making or creating noise inside/ beside the forest				
12	Leave waste inside the forest				
13	Follow Wildlife protection policy				

1. How you do you use the forest?
   ( ) Tourism and Recreation
   ( ) Religious purposes/rituals
   ( ) Collecting Philippine warty pig for food
   ( ) Others: _____
2. In the last six (6) months (In a typical six months), how often did you visit the forest for other purposes?
   ( ) Never
   ( ) Once
   ( ) Weekly
   ( ) Monthly Other: _____
4. Philippine warty pig Use/Perception/Beliefs
   ( ) Medicine
   ( ) Tradition
   ( ) Religion
   ( ) Philippine warty pig as pest
   ( ) Other use_____
5. Would you be willing to work with researchers and MENRO personnel to help manage Philippine warty pig in your area?
   ( ) Yes
   ( ) No

6. What would you need to manage the forest in a reliable fashion?

D. Local Threats and Disturbances to Philippine warty pig

1. Activity near the forest site.
   ( ) Quarrying
   ( ) Kaingin or charcoal mining
   ( ) Farming
   ( ) Construction
   ( ) Waste disposal or other land fill
   ( ) War
   ( ) Others_____
2. Entry to forest and other utilization.
   ( ) Military use
   ( ) Religious observances
   ( ) Dwelling sites
   ( ) Farming
   ( ) Hunting or retaliation
   ( ) Research
   ( ) Tourism and recreation
   ( ) Others_____
3. What hunting method do/did you use? _____

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ARTICLE

Understanding Human-Nilgai negative interactions in India: a systematic review through print media report analysis

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Abstract: Despite being one of the most conflict-prone species in India, the Nilgai antelope *Boselaphus tragocamelus* has received little scientific attention. In this study, we address this knowledge gap by conducting an analysis of secondary data extracted from print media reports on Human-Nilgai negative interactions at the regional scale (tehsils and districts) across different states of India. Our findings revealed notable variations in conflict levels among different states, with Bihar emerging as the most affected (86 tehsils and 22 districts), followed by Madhya Pradesh (34 tehsils; 21 districts) and Uttar Pradesh (33 tehsils; 20 districts). Within Bihar, Muzaffarpur and East Champaran districts stand out for their high conflict levels. Crop raiding by different populations of Nilgai is identified as the primary cause of the negative interaction, with a relative frequency of occurrence of 98%. Attacks on humans by nilgai, although rare, accounted for a relative frequency of occurrence of only 1.2%. Additionally, newspapers reported retaliatory killings, with a relative frequency of occurrence of 0.84%. Between 2018 and 2022, nilgai populations were documented raiding 45 distinct crop types. Analysis of these raids revealed varying frequencies across different crop categories, with vegetables being the most heavily targeted (31%), followed by pulses (22%) and cereals (20%). Our study identifies priority tehsils and districts across different states in the country where studies aiming at nilgai-crop interactions, population dynamics, and movement ecology can be carried out to devise effective mitigation measures.

Keywords: Attacks on humans, Blue Bull, crop raiding, crop types, farmers, human-wildlife conflict, retaliatory killings.

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INTRODUCTION

Human-wildlife negative interactions (HWNI) refers to the challenges that arise when the existence or actions of wildlife present a tangible or perceived threat to humans and/or their interests. This results in disputes among various groups of individuals, causing adverse effects on both humans and wildlife (IUCN SSC HWCTF 2020). As the global population expands and urbanization progresses, wildlife habitats are increasingly endangered by degradation, loss, and fragmentation. The lines separating human settlements from natural habitats are fading, intensifying interactions between humans and wildlife. These negative interactions frequently lead to the loss of crops, livestock & property, and to personal injuries (Karanth & Kudalkar 2017; Holland et al. 2018). These negative interactions also have indirect consequences that are challenging to measure, including declines in psychological well-being and impacts on livelihoods & food security (Barua et al. 2013; Yang et al. 2020). Developing regions of the world, such as southern and southeastern Asia, are particularly vulnerable to this issue (Anand & Radhakrishna 2017).

Wild ungulates have been found to be increasingly involved in raiding crops, damaging properties, attacks on humans, vehicle collisions, and competition with & transmission of diseases to livestock, causing human-ungulate negative interactions across the globe (Chauhan et al. 2009; Kuemmerle et al. 2011; Acevedo et al. 2014; Duarte et al. 2015; Colino-rabanal et al. 2018; Gross et al. 2018). The introduction of the Wildlife Protection Act (1972) and its associated management actions, coupled with incompatible land use practices, have made human-ungulate negative interactions frequent in India (Chauhan & Singh 1990; Chauhan et al. 2009; Bajwa & Chauhan 2019).

Nilgai, also known as Blue Bull *Boselaphus tragocamelus* Pallas, 1766, is an interaction-prone ungulate species in India (Sekhar 1998; Chhangani et al. 2008; Kumar et al. 2017; Bajwa & Chauhan 2019). Although widely distributed (Karanth et al. 2009), there is a scarcity of knowledge on interaction distribution range, and few studies have attempted to address this issue (Chauhan et al. 2010; Chauhan 2011). The species has been found to be increasingly involved in road mishaps, human-human conflicts over their population management practices, and attacks on humans (Dharaiya 2012; Vishnoi 2016; Khan et al. 2019; Gulati et al. 2021; Gorchiya et al. 2022). However, a comprehensive study of the interactions of different populations with humans across their range has not been assessed. The species is well-known as a crop pest in India (Chauhan & Singh 1990; Goyal & Rajpurohit 2000). Despite this, we have a limited understanding of nilgai-crop interactions, notably it is not known whether some crop types influence human-nilgai negative interactions more than others. In this review, we attempted to address these questions through a systematic survey and analysis of newspaper reports. We first identified different types of human-nilgai negative interactions and their relative frequency of occurrences in India. Similarly, we estimated the relative frequencies of different crop types raided by nilgai in India. The conflict hotspot was identified and mapped at a smaller administrative level based on the reported location and conflict intensity, estimated from various news sources.

Study Area

The present study focuses on analysing print media coverage of human-nilgai negative interactions. The research spans various sub-districts in Indian states where nilgai populations are prevalent, including Andhra Pradesh, Bihar, Chhattisgarh, Gujarat, Haryana, Himachal Pradesh, Jharkhand, Madhya Pradesh, Maharashtra, Odisha, Punjab, Rajasthan, Telangana, Uttarakhand, Uttar Pradesh, and West Bengal (Johnsingh & Manjrekar 2016; Jhala et al. 2019).

These states can be broadly classified based on their geological zones and geographical locations. The classifications include the Shivalik Hills landscape (Himachal Pradesh, Punjab, Haryana, Uttarakhand, and Uttar Pradesh), Gangetic Plains landscape (Uttarakhand, Uttar Pradesh, Bihar), western Indian landscape (Rajasthan and Gujarat), central Indian landscape (Madhya Pradesh, Maharashtra, Chhattisgarh, Jharkhand, and Odisha), Eastern Ghats landscape (Andhra Pradesh, Telangana, and Odisha), and northeastern hills (West Bengal).

The area encompasses diverse biogeographic zones, ranging from the western Himalaya, Punjab, and Gangetic Plains in the north to the desert and semi-arid areas in the west, Deccan Peninsula in the south, and eastern highlands in the east (Menon 2014). The landscapes of these states harbour a unique and rich assemblage of flora and fauna in their protected areas (Jhala et al. 2019).

Certain states in the study area harbour abundant nilgai populations, prevalent not only within designated protected areas but also thriving outside their confines.

MATERIAL AND METHODS

Data collection and analysis

The secondary data on human-nilgai negative interactions in India was obtained through a systematic survey of news articles from 2018–2022, for a total duration of five years (Alexander & Quinn 2008; Athreya et al. 2015). Mainly considering English and Hindi language-based newspapers for data collection, we conducted a literature survey in the news section of the Google search engine using English and Hindi keywords such as 'crop', 'damage', 'loss', 'menace', 'attack', 'farm', and 'farmer' in combination with 'nilgai' or 'blue bull'. Additionally, we included vernacular names of the species that Hindi newspapers might use, such as 'Ghodroj', 'Ghodparas', 'Roz', 'Rojda', and 'Vanroz' as identified in previous references (Chauhan et al. 2010; Menon 2014; The Guardian 2014). The literature survey extended through the last tab.

In the administrative structure of an Indian state, a district serves as a fundamental division, encompassing sub-districts known as tehsils or taluks. A tehsil, in turn, is an administrative unit within the district, constituting an area of land with a central city or town acting as its administrative centre. This region may include additional towns and commonly comprises several villages (https://darpg.gov.in/).

We extracted details on the location of negative interactions as reported in the newspaper, including villages and towns, and subsequently identified and listed the corresponding tehsils for these interaction-affected areas. This process was undertaken by examining reports in newspapers, and further verification and identification were conducted by visiting the official websites of the corresponding districts in the state. Additionally, we utilized the resources available on (https://grammanchitra.gov.in/GM3/) to ensure comprehensive and accurate information on interaction-affected tehsils. In reports where we could obtain information at the district level only, the district name was searched along with the combinations of previous keywords.

Special attention was paid to categorising the conflict. We defined human-nilgai negative interactions here as incidents of crop raids, damage to property, attacks on humans by nilgai, and retaliation against these actions by people (IUCN SSC HWCTF 2020). Crop raiding was defined as damage to standing crops by feeding and trampling (Hill 2017). During this literature survey, we also encountered news reports of nilgai vehicle collisions in the form of either road accidents or railway accidents. Given the definition of human-wildlife negative interactions (IUCN SSC HWCTF 2020), we considered them as accidents and did not include these reports in our study.

We recorded the crop types affected by nilgai populations in a binary fashion: '1' indicates a raid and '0' no raids. Crops were categorized into five categories: cereals, pulses, vegetables, oil yielding crops, and other cash crops. In instances where nilgai raided multiple crops in different villages within a tehsil, we entered each case separately with corresponding village or town names. For situations where the news article did not specify the crop name or category, we assigned them to an unspecified category.

The relative frequency of each affected crop type was estimated as a percentage by summing up the total raid cases for that specific crop type and dividing it by the total cases for all crop types affected. The result was then multiplied by 100 to obtain the relative frequency in percentage (Table 1). Similarly, the relative frequency for each interaction category was also estimated.

For spatial mapping of negative interactions, district-level information was used. We obtained the Survey of India website (https://www.surveyofindia.gov.in/) GIS database at the district level for Indian states. The mapping was conducted at two scales: firstly, at the district level for the most affected state, and secondly, at the country level for our study area. A hot spot map at the district level was created for the most affected state by estimating the crop raiding frequency (CRF) across its various tehsils (Hoare 1999). Here CRF represents the total number of crop raiding incidents or events across various tehsils of a district throughout the entire study period. To prevent the over-reporting of the same incident by different newspapers, we maintained a minimum interval of 11 days between reports from the same tehsil.

At the country level, spatial mapping was conducted by summing the number of interaction-affected tehsils in the corresponding states.

There are two advantages of using this approach. First, it provides a snapshot sample of the spatial distribution of human-nilgai interaction in both inside as well as outside protected area networks across a relatively large geographic area. Second, in India, states such as Gujarat, Rajasthan, Haryana, and Punjab have no compensation scheme for crop raids by ungulates and hence the interaction records (Karanth et al. 2018; Bajwa & Chauhan 2019). In this way, data were extracted and analysed from online editions of 13 publications, including 10 Hindi and three English-language newspapers.

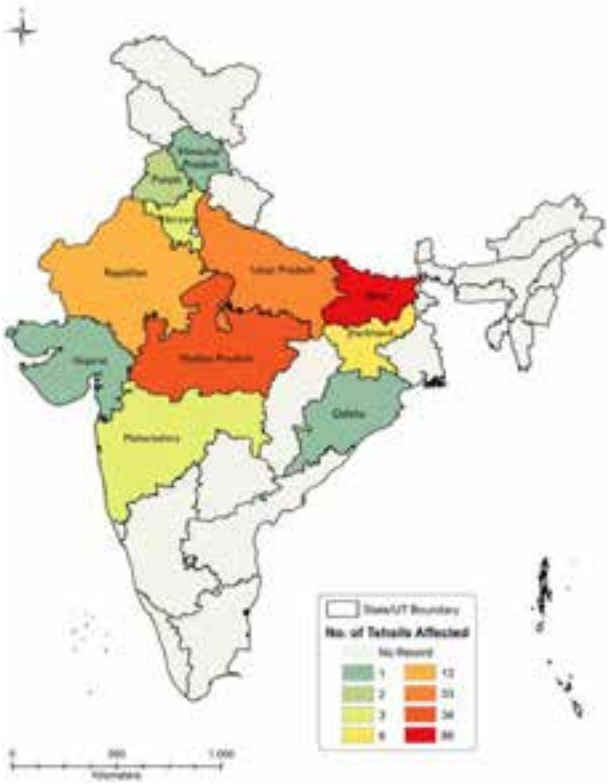

Figure 1. Distribution of human-nilgai negative interaction cases across Indian states based on the number of tehsils affected.

RESULTS

Spatial distribution of interactions in the country

Different newspapers reported a total of 597 interaction cases in India, spanning 73 districts, encompassing 183 tehsils across 11 states within the timeframe of 2018–2022. However, the number of conflict cases in each of these tehsils and states suggests that its severity is different across them.

As depicted in Figure (1) and Table (2), Bihar emerged as the most frequently affected state, with 22 of 38 districts affected, constituting approximately 58% of all districts. 86 tehsils were affected, or approximately 47% of the total (183) affected in the country. Madhya Pradesh and Uttar Pradesh ranked second and third in the list of affected states.

Madhya Pradesh state has been witnessing the impact across 21 out of its 53 districts, affecting a total of 34 tehsils. Similarly, Uttar Pradesh is facing challenges, with 20 out of 75 districts, encompassing 33 affected tehsils within the state. Further details about the situation in other states are outlined in Table (2).

We assessed the intensity of conflict by calculating the CRF for various districts in Indian states (Table 2). Given that Bihar has the highest number of affected

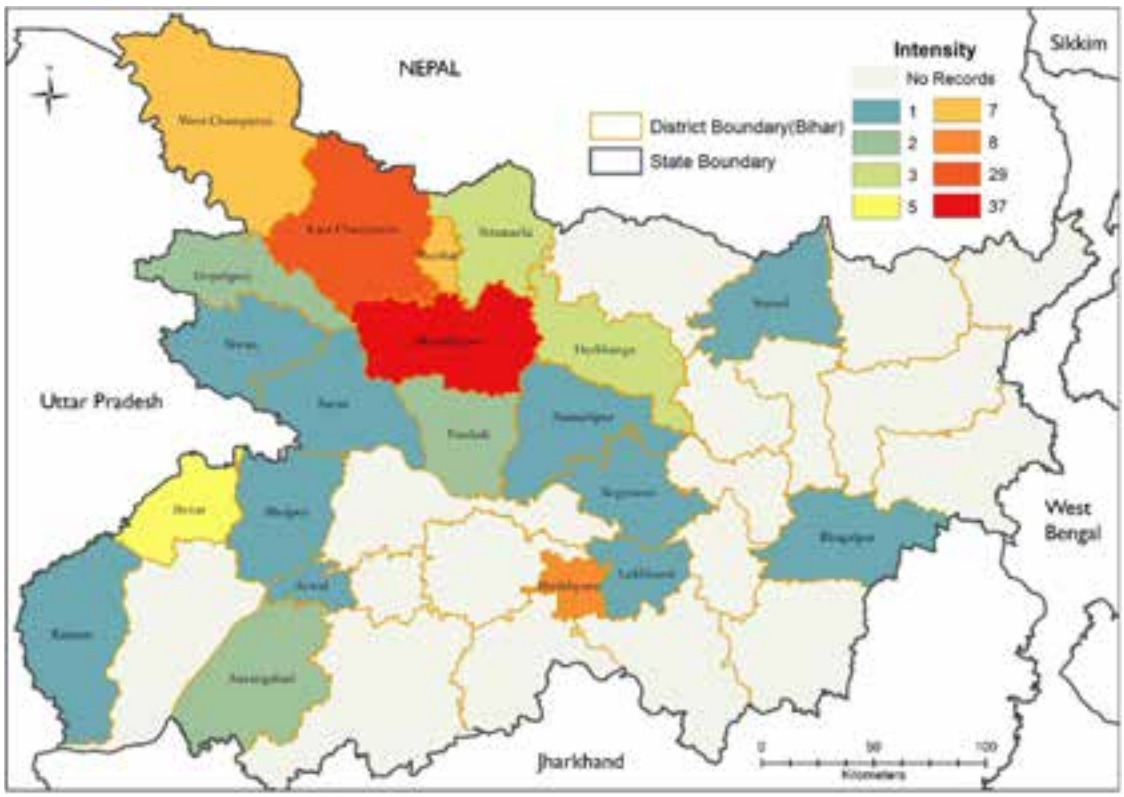

Figure 2. Crop raiding frequency (Intensity) of nilgai across different districts of Bihar state.

Table 1. Various crops raided by nilgai with their relative frequencies of raid.

Crop categories	Crop types affected	Relative frequencies of raid (%)
Vegetables	Unspecified vegetables	7.55
	Potato	6.21
	Cauliflower	2.72
	Tomato	2.11
	Brinjal	1.85
	Coriander	1.85
	Onion	1.80
	Cabbage	1.39
	Ash gourd	1.13
	Bitter gourd	1.13
	Fenugreek	0.92
	Garlic	0.62
	Sweet potato	0.56
	Chilli	0.56
	Pointed gourd	0.41
	Turmeric	0.26
	Okra	0.05
	Ridge gourd	0.05
Pulses	Chickpea	7.40
	Pigeon pea	4.42
	Pea	3.80
	Red lentil	2.72
	Unspecified pulses	1.90
	Green gram	0.72
	Lobia pulse	0.46
	Grass pea	0.41
Cereals	Wheat	10.73
	Maize	5.34
	Paddy	3.24
	Sorghum	0.31
	Pearl millet	0.31
Unspecified	Unspecified Crops	10.84
Other cash crops	Banana	1.64
	Mango plants	1.54
	Sugarcane	1.39
	Opium	1.23
	Cotton	1.23
	Guava	1.18
	Papaya	0.36
	Lychee plants	0.05
Oil yielding crops	Mustard	4.88
	Soyabean	1.23
	Unspecified oilseeds	0.67
	Linseed	0.62
	Ground nut	0.21
		SUM = 100%

tehsils, we generated a hot spot map using the CRF values assigned to its districts (Figure 2). Our finding revealed that both Muzaffarpur and eastern Champaran have been experiencing a higher intensity of conflict compared to other districts in Bihar, with all of their tehsils affected.

Relative frequency of different conflict categories

Out of 597 conflict cases reported in India, 98% (585 cases) were attributed to crop raids by nilgai. Attacks on humans accounted for 1.2% (seven cases), while 0.84% (five cases) involved the retaliatory killing of nilgai by humans (Figure 3). Notably, our survey did not uncover any news reports of property damage caused by nilgai during the specified period.

Relative frequency of different crops raided by nilgai

We found that different nilgai populations have damaged 45 crop types in India. To gain a deeper understanding of this impact, we categorized these crop types into specific crop categories. Among these crop categories, vegetables had the highest relative frequency of raid (32%) by nilgai (Figure 4). A total of 18 crop types were damaged in this category, with relatively frequent damage observed in two crop types: unspecified vegetables (7.6%) and potato crops (6.2%) (Table 1).

After vegetables, pulses were the second most frequently raided (22%) category. Although eight crop types were damaged in this category, Chickpea, Pigeon Pea, and Pea were the three crop types particularly vulnerable to nilgai raids. Cereals ranked third (20%) in the most affected crop category, with wheat and maize being crop types frequently sustained nilgai raids.

Oil yielding crops were least raided category, accounting for only 7.6%. Further details on other crop categories and their types affected are given in Table 1.

Attacks on humans by nilgai

We found only seven news reports of nilgai attacks on humans during our study period, showing the rarity of such attacks. Five people died, and three were injured in these attacks. The victims were farmers. Most of them were working on the farm, while one victim was guarding the crops at night. These news reports did not specify whether the attack was intentional or in self-defence, leaving uncertainty about the motivations behind these rare occurrences.

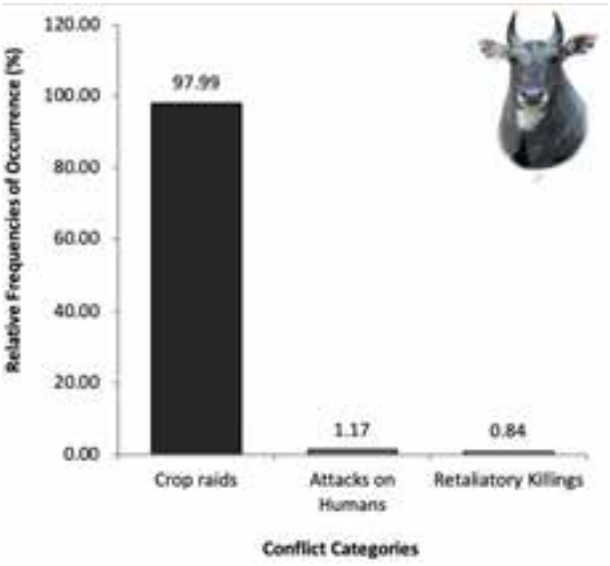

Figure 3. Relative frequency of occurrence (%) of different conflict categories.

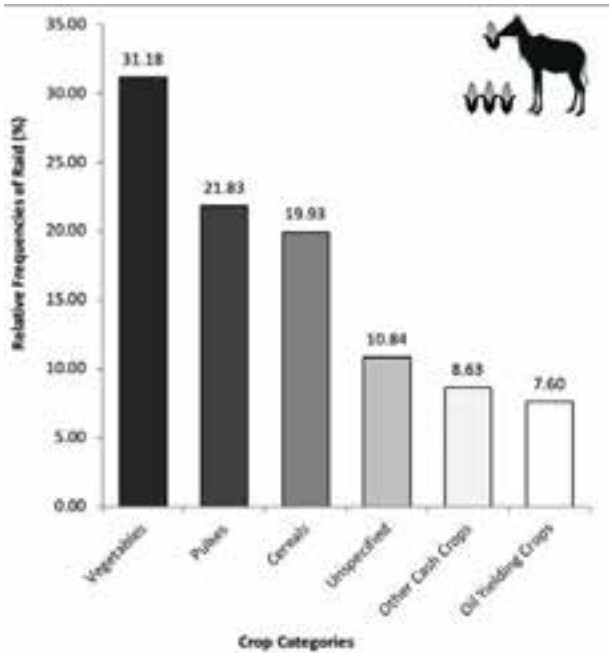

Figure 4. Relative frequency (%) of all crop categories raided by Nilgai.

Retaliatory killing of nilgai by humans

Newspapers reported five incidents of retaliatory killing of the species by humans. Farmers retaliated against frequent crop raids by fencing their farms with high-tension electric wires or by shooting the animal while raiding crops, which led to nilgai deaths.

DISCUSSION

This was the first attempt to map and assess the spatial distribution of human-nilgai negative interactions in India at the district and smaller administrative scales. Our findings revealed that, as compared to other states in India, Bihar has faced relatively severe human-nilgai conflict, with most of its districts and tehsils being affected. This finding was not surprising, because due to the severity of this issue the state culled 4,729 nilgais during 2016–2019 (Khan 2021). Madhya Pradesh and Uttar Pradesh ranked second and third, respectively. A total of 3,278 cases of crop raids by nilgai were reported during 2009–2013 in Madhya Pradesh, and the state government had to pay 1.2 crore Indian Rupees (US$ 146,568) as compensation to victims (Babbar et al. 2022). Previous studies suggest that Uttar Pradesh has the largest population of nilgai (2,54,449) in India (Chauhan 2011). This state has been facing crop raiding by nilgai since the 1990s (Qureshi 1991). In 1995 and 1996, considering the severity of crop damage by nilgai, the government issued a permission letter and eliminated 270 individuals in the Etah district of the state (Chauhan et al. 2010).

The non-existence of studies on the nilgai population trend coupled with land use land cover dynamics in these three states has hampered our understanding of why these states have been facing a relatively higher intensity of conflict. Interestingly states such as Rajasthan, Punjab, and Haryana had fewer cases of conflict, despite previous studies suggesting otherwise (Chopra & Rai 2009; Meena et al. 2014; Johnson et al. 2018; Bajwa & Chauhan 2019; Kumar et al. 2022). One possible explanation could be that these states are dominated by the Bishnoi community, who tend to tolerate nilgai raids rather than reporting them, due to their cultural and religious sentiments (Sankar & Goyal 2004). Another factor could be under-reporting of conflict by print media, attributed to the lack of public interest in incidents of crop and property damage caused by wildlife (Neupane et al. 2013). Even in the case of Bihar state, the frequency of crop raids by nilgai in different districts is almost negligible compared to findings in previous studies (Bayani et al. 2016; Bayani & Watve 2016). In many parts of India, crop raiding by nilgai has become so frequent that print media rarely cover all incidents unless they become topics of debate among politicians or provoke mass protests by victims (Vishnoi 2016; Times of India 2024).

Under-reporting by print media has already been documented in previous studies (Neupane et al. 2013; Paudel et al. 2022). Our results suggest that crop raiding

Table 2. List of affected districts across Indian states, as reported by newspapers, along with its corresponding crop raiding frequency estimates (CRF).

State	District	CRF
Bihar	Arwal	1
Bihar	Aurangabad	2
Bihar	Begusarai	1
Bihar	Bhagalpur	1
Bihar	Bhojpur	1
Bihar	Buxar	5
Bihar	Darbhanga	3
Bihar	East Champaran	29
Bihar	Gopalganj	2
Bihar	Kaimur	1
Bihar	Lakhisarai	1
Bihar	Muzaffarpur	37
Bihar	Samastipur	1
Bihar	Saran	1
Bihar	Sheikhpura	8
Bihar	Sheohar	7
Bihar	Sitamarhi	3
Bihar	Siwan	1
Bihar	Supaul	1
Bihar	Vaishali	2
Bihar	West Champaran	7
Madhya Pradesh	Dhar	5
Madhya Pradesh	Gwalior	3
Madhya Pradesh	Sheopur	7
Madhya Pradesh	Raisen	1
Madhya Pradesh	Ratlam	7
Madhya Pradesh	Ujjain	2
Madhya Pradesh	Sagar	1
Madhya Pradesh	Damoh	1
Madhya Pradesh	Indore	1
Madhya Pradesh	Neemuch	3
Madhya Pradesh	Dewas	1
Madhya Pradesh	Shivpuri	1
Madhya Pradesh	Mandsaur	3
Madhya Pradesh	Tikamgarh	1
Madhya Pradesh	Jhabua	2
Madhya Pradesh	Shajapur	1
Madhya Pradesh	Rewa	1
Uttar Pradesh	Deoria	1
Uttar Pradesh	Azamgarh	8
Uttar Pradesh	Saharanpur	3
Uttar Pradesh	Gorakhpur	2
Uttar Pradesh	Basti	1
Uttar Pradesh	Kannauj	1
Uttar Pradesh	Bhadohi	2
Uttar Pradesh	Prayagraj	4
Uttar Pradesh	Moradabad	3
Uttar Pradesh	Aligarh	1
Uttar Pradesh	Lalitpur	2
Uttar Pradesh	Meerut	1
Uttar Pradesh	Maharajganj	2
Uttar Pradesh	Unnao	1
Uttar Pradesh	Hathras	1
Uttar Pradesh	Ghazipur	1
Rajasthan	Bhilwara	4
Rajasthan	Chittorgarh	2
Rajasthan	Jalore	1
Rajasthan	Pratapgarh	2
Rajasthan	Nagaur	1
Rajasthan	Jhalawar	1
Jharkhand	Palamu	2
Jharkhand	Garhwa	3
Jharkhand	Koderma	1
Maharashtra	Wardha	1
Maharashtra	Akola	1
Maharashtra	Chandrapur	1
Haryana	Palwal	2
Haryana	Fatehabad	1
Punjab	Pathankot	1
Punjab	Rupnagar/Ropar	1
Odisha	Sundargarh	1
Gujarat	Surendranagar	1

by nilgai is a primary cause of negative interaction with humans across its distribution range, which corresponds to previous findings (Sekhar 1998; Chhangani et al 2008; Kumar et al. 2017; Bajwa & Chauhan 2019). Given India's status as an agrarian country, this issue presents a significant threat to the livelihoods of farmers and to the food security of subsistence farmers in these affected states (Barua et al. 2013; Rathi et al. 2020). It was found that in the study area, nilgai raided 45 types of crops in a time frame of five years. Nilgai, being a mixed feeder (Hines 2016) weighing over 250 kg (Sheffield et al. 1983), is capable of causing extensive damage to

standing crops and orchards by selective feeding and trampling. However, vegetables, pulses, and cereals were raided the most among different crop categories. These results correspond to the previous findings where nilgai demonstrated preferences towards vegetable, pulse, and cereal crops (Aryal 2007; Kumar et al. 2017, 2022; Khanal et al. 2018). One possible explanation could be that due to their higher nutritional value and palatability, these crops may have preferentially foraged over others (Biru & Bekele 2012).

During our literature survey, we found that many newspapers reported escalating nilgai raids, leading farmers in severely affected areas to increasingly avoid cultivating vegetables and pulses, highlighting a pressing need for effective management. Our results indicate that attacks on humans by nilgai are rare, probably due to their timid nature. Farmers are particularly vulnerable to such attacks while guarding their crops or driving away the animal due to its sheer size and agility. Our study revealed instances of retaliatory killing of nilgai through methods such as electrocution and shooting. This finding corresponds to a previous study where villagers poisoned nilgais to protect their crops (Qureshi 1991).

Although this approach to studying human-nilgai conflict is advantageous in quickly covering a relatively large area and obtaining data from areas without records, it has limitations. Due to the incomplete media coverage, we could not obtain any data on some other crucial aspects of this conflict, such as population estimates of nilgai in affected areas, their phenological preferences for different crop types, sex associated with crop raiding, temporal patterns of crop raids, extent of damage inflicted on different crop types and the motivations behind their attacks on humans. Our findings have revealed that there is an urgent need to conduct studies on the population dynamics of nilgai in different affected tehsils of Bihar, Madhya Pradesh, and Uttar Pradesh states. Based on the intensity of negative interactions (CRF), focal districts and its corresponding tehsils can be chosen from the list we have provided in this article (see supplementary Table 1 for details). Studies addressing nilgai-crop interactions would be critical in identifying high-risk crops and formulating appropriate mitigation measures. Lastly, Studies on their habitat and movement ecology in these affected tehsils using radio telemetry will enable pinpointing high-risk zones, understanding habitat preferences, and developing targeted strategies for mitigation, promoting coexistence through proactive management based on real-time insights.

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Supplementary Table 1. List of human-nilgai negative interaction affected tehsils and its corresponding locations across Indian states.

State	Tehsil (Village/Town if Any)
Bihar	Ariyari (Chandi)
Bihar	Barbigha (Maldah)
Bihar	Barauli (Diara)
Bihar	Aurai
Bihar	Bandra
Bihar	Bochahan
Bihar	Benipur (Mahinam)
Bihar	Alinagar (Motipur)
Bihar	Bhagwanpur (Mahdauli)
Bihar	Bettiah (Gobardhana)
Bihar	Bagaha (Bagaha-2/Tharuhat)
Bihar	Chanan/Bannu Bagicha (Bhalui)
Bihar	Buxar (Gobindapur)
Bihar	Bhagwanpur
Bihar	Aurangabad (Nima)
Bihar	Bhitaha (Bhitaha)
Bihar	Areraj
Bihar	Adapur
Bihar	Chakia
Bihar	Bankatwa
Bihar	Banjaria
Bihar	Bidupur (Saidpur Ganesh)
Bihar	Chand
Bihar	Chauradano
Bihar	Chewara (Karande)
Bihar	Chiraiya
Bihar	Deo (Belsara)
Bihar	Dhaka
Bihar	Dumraon
Bihar	Gaighat
Bihar	Gaunaha (Parsauni)
Bihar	Ghat Kushumbha (Gagaur)
Bihar	Ghorasahan
Bihar	Gopalganj (Kararia)
Bihar	Harsidhi
Bihar	Hasanpura
Bihar	Jagdishpur
Bihar	Jale (Jale)
Bihar	Kahalgaon/colgong (Kasdi)
Bihar	Kaler (Sohsa)

State	Tehsil (Village/Town if Any)
Bihar	Kalyanpur
Bihar	Kanti
Bihar	Katra
Bihar	Kesaria
Bihar	Kesath (Kesath)
Bihar	Khanpur (Khairi)
Bihar	Kotwa
Bihar	Kurhani
Bihar	Madhuban (Rupani)
Bihar	Marwan
Bihar	Mehsi
Bihar	Minapur
Bihar	Motihari
Bihar	Motipur
Bihar	Muraul
Bihar	Mushahari
Bihar	Nawanagar (Devpura tola)
Bihar	Paharpur
Bihar	Pakaridayal
Bihar	Paroo
Bihar	Patahi
Bihar	Phenhara (Marpa Mohan)
Bihar	Piprahi
Bihar	Piprakothi
Bihar	Pupri (Chainpur)
Bihar	Purnahiya (Bedaul)
Bihar	Ramgarhwa
Bihar	Ramnagar (Bhaval)
Bihar	Raxaul
Bihar	Riga
Bihar	Runnisaidpur (Madhaul)
Bihar	Sahebganj
Bihar	Sakra
Bihar	Sangrampur
Bihar	Saraiya
Bihar	Sheikhpura (Purena)
Bihar	Shekhopur Sarai (Nimi)
Bihar	Simri (Dumri)
Bihar	Sonepur (Milli)
Bihar	Sugauli

State	Tehsil (Village/Town if Any)
Bihar	Supaul (Lourdh)
Bihar	Tariyani
Bihar	Tetaria
Bihar	Thakraha (Thakraha)
Bihar	Turkaulia
Bihar	Beldaur (Bahiyar)
Madhya Pradesh	Badnawar (Bangda)
Madhya Pradesh	Bhitarwar (Ladhwaya)
Madhya Pradesh	Baroda (Baroda)
Madhya Pradesh	Begumganj (Madhiya Gusain)
Madhya Pradesh	Alot
Madhya Pradesh	Badnagar
Madhya Pradesh	Dabra (Kalyani)
Madhya Pradesh	Deori (Dongar Salaiya)
Madhya Pradesh	Dhar (Anarad)
Madhya Pradesh	Ghatigaon (Ghatigaon)
Madhya Pradesh	Hatta (Chauraiya)
Madhya Pradesh	Indore (Pipalda)
Madhya Pradesh	Jaora
Madhya Pradesh	Jawad (Kesarpura)
Madhya Pradesh	Kannod (Sundrel)
Madhya Pradesh	Karahal (Hirapur)
Madhya Pradesh	Karera (Jujhai)
Madhya Pradesh	Malhargarh
Madhya Pradesh	Manasa (Chukni)
Madhya Pradesh	Nagda-Khachrod (Pipaliya Molu)
Madhya Pradesh	Palera (Jewra Maura)
Madhya Pradesh	Petlawad (Jhakanwada)
Madhya Pradesh	Pipaloda (Machun)
Madhya Pradesh	Ratlam Rural
Madhya Pradesh	Sailana
Madhya Pradesh	Sardarpur (Piparni)
Madhya Pradesh	Shajapur (Shajapur)
Madhya Pradesh	Sheopur (Manpur)
Madhya Pradesh	Singoli (Jaat)
Madhya Pradesh	Teonthar (Chakghat)
Madhya Pradesh	Vijaypur (Ochha)
Madhya Pradesh	Chhatarpur (Bandhi Salaiya)
Madhya Pradesh	Jaura/Joura (Chanchul)
Madhya Pradesh	Shyampur (Lodhipura)
Uttar Pradesh	Barhaj (Bhulaipur)
Uttar Pradesh	Azamgarh (Sathiaon)

State	Tehsil (Village/Town if Any)
Uttar Pradesh	Budhanpur (Atraulia)
Uttar Pradesh	Behat (Naugawan)
Uttar Pradesh	Bansgaon (Gagaha)
Uttar Pradesh	Campierganj (Pipiganj)
Uttar Pradesh	Basti (Kanaila)
Uttar Pradesh	Chibramau (Chachiyapur)
Uttar Pradesh	Gyanpur (Babusarai)
Uttar Pradesh	Handia (Tela)
Uttar Pradesh	Kanth (Kanth)
Uttar Pradesh	Karchhana (Panasa)
Uttar Pradesh	Koil (Vijaigarh)
Uttar Pradesh	Madawra/Mandawara (Patna)
Uttar Pradesh	Meerut (Janikhurd)
Uttar Pradesh	Mehnagar (Mehnagar)
Uttar Pradesh	Mehrauni/Mahroni (Dongra Khurd)
Uttar Pradesh	Moradabad (Mundapandey)
Uttar Pradesh	Nakur (Nasrullagarh)
Uttar Pradesh	Nautanwa (Parsamalik)
Uttar Pradesh	Nizamabad (Tahbarpur)
Uttar Pradesh	Phulpur (Sahajipur)
Uttar Pradesh	Purwa (Purwa)
Uttar Pradesh	Rampur Maniharan (Dalheri)
Uttar Pradesh	Sadabad (Bisawar)
Uttar Pradesh	Sagri (Bilariaganj)
Uttar Pradesh	Seorai (Kutubpur)
Uttar Pradesh	Soraon (Shringverpur)
Uttar Pradesh	Thakurdwara (Thakurdwara)
Uttar Pradesh	Garh Mukteshwar (Paswada)
Uttar Pradesh	Kaimganj(Khargapur)
Uttar Pradesh	Hamirpur (Bharua Sumerpur)
Uttar Pradesh	Bhogaon (Dikhatmai)
Rajasthan	Bijoliya
Rajasthan	Begun
Rajasthan	Ahore (Paota)
Rajasthan	Chhotisadri
Rajasthan	Jahazpur
Rajasthan	Kotri
Rajasthan	Mandalgarh
Rajasthan	Nawa (Chosla)
Rajasthan	Pachpahar (Bhavanimandi)
Rajasthan	Pratapgarh
Rajasthan	Rawatbhata

State	Tehsil (Village/Town if Any)
Rajasthan	Jahazpur (Laalkakheda)
Rajasthan	Kaman (Lewara)
Jharkhand	Bishrampur (Ketat Kalan)
Jharkhand	Garhwa
Jharkhand	Hussainabad (Hata)
Jharkhand	Jainagar (Rebhnadih)
Jharkhand	Majhiaon
Jharkhand	Meral
Maharashtra	Ashti (Salora)
Maharashtra	Akot (Punda)
Maharashtra	Chimur (Sonegaon)
Haryana	Hodal (Aurangabad)
Haryana	Palwal (Nangal Brahman)
Haryana	Ratia (Rattangarh)
Punjab	Dhar Kalan (Hardosaran)
Punjab	Rupnagar (Katli)
Odisha	Nuagaon (Chaubahal)
Gujarat	Wadhwan (Memka)
Himachal Pradesh	Bilaspur (Barmana)

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ARTICLE

Harmonizing ecology and society: an integrated analysis of vulture conservation in the Nilgiri Biosphere Reserve, India

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Abstract: The Nilgiri Biosphere Reserve (NBR) in southern India is home to several critically endangered vulture species. This study in Mudumalai Tiger Reserve and Sathyamangalam Tiger Reserve of NBR presents an integrated analysis of vulture conservation efforts focusing on harmonizing ecosystem preservation and community engagement. We assessed the current status of all four vulture species in the NBR using the road transect method, covering 2,040 km with 24 replications (January–December 2021). We undertook covert surveys in 82 veterinary pharmacies across four districts of Tamil Nadu to determine the availability of non-steroidal anti-inflammatory drugs (NSAIDs), considering the 100-km vulture safe zone that included vulture nesting and foraging areas. As practical conservation efforts require active local community participation, our assessments include the perception study of local communities in 20 villages (eight tribal and 12 non-tribal) near vulture habitats. We focused on NSAID usage, considering the impact of numerous socio-economic factors on vulture conservation efforts. We surveyed 540 respondents using detailed questionnaires for these evaluations. The study underlined the need for a comprehensive vulture management plan that balances ecological concerns with the well-being and means of subsistence of surrounding communities. This study is helpful for future conservation efforts in other areas with comparable problems at the nexus of ecology and society.

Keywords: Community engagement, ecological balance, NSAID prevalence, road transect method, southern India, vulture habitats, welfare and livelihoods, wildlife conservation.

Tamil: தென்னிந்தியாவில் உள்ள நீலகிரி உயிர்க்கோளக் காப்பகம் (NBR) பல அழியும் தருவாயில் உள்ள பெருங்கழுகு இனங்களின் தாயகமாக உள்ளது. இந்த ஆய்வு NBR இன் முதுமலை மற்றும் மற்றும் சத்தியமங்கலம் புலிகள் காப்பகம் ஆகியவை கழுகு பாதுகாப்பு முயற்சிகளின் ஒருங்கிணைந்த பகுப்பாய்வை முன்வைக்கின்றன. சுற்றுச்சூழல் பாதுகாப்பு மற்றும் சமூக ஈடுபாட்டை ஒத்திசைப்பதில் கவனம் செலுத்துகிறது. NBR இல் சாலை மார்பகமாக கணக்கெடுப்பு முறையைப் பயன்படுத்தி, 24 முறை 2,040 கி.மீ. (ஜனவரி-டிசம்பர் 2021) கணக்கீடு செய்து, நான்கு கழுகு இனங்களின் தற்போதைய நிலையை மதிப்பீடு செய்தோம். மேலும் 100-கிமீ பெருங்கழுகு பாதுகாப்பான மண்டலத்தை கருத்தில் கொண்டு, கழுகு கூடு கட்டுதல் மற்றும் உணவு தேடும் பகுதிகலில் NSAIDs உள்ளதா என்பதை நாங்கள் இரகசியமாக ஆய்வு மேற்கொண்டோம். அதன்படி தமிழ்நாட்டின் நான்கு மாவட்டங்களில் உள்ள 82 கால்நடை மருந்தகங்களில் NSAIDs உள்ளதா என்பதை கண்டறியும் ஆய்வுகளை நடத்தினோம் . நடைமுறை பெருங்கழுகு பாதுகாப்பு முயற்சிக்கு உள்ளூர் சமூகப் பங்கேற்பு தேவை, எனவே பெருங்கழுகு வாழ்விடங்களுக்கு அருகில் உள்ள 20 கிராமங்களில் (8 பழங்குடியினர் மற்றும் 12 பழங்குடியினர் அல்லாதவர்கள்) உள்ளூர் சமூகங்களின் கருத்து ஆய்வு நடத்தினோம். பெருங்கழுகு பாதுகாப்பு முயற்சிகாக பல சமூக-பொருளாதார காரணிகளின் தாக்கத்தை கருத்தில் கொண்டு, NSAID பயன்பாட்டில் கவனம் செலுத்தினோம். இந்த மதிப்பீடுகளுக்கு விரிவான கேள்வித்தாள்களைப் பயன்படுத்தி 540 பதிலளித்தவர்களிடம் நாங்கள் ஆய்வு செய்தோம். ஆய்வு அடிக்கோடிட்டுக் காட்டியது சுற்றியுள்ள சமூகங்களுக்கு ஒரு விரிவான பெருங்கழுகு மேலாண்மை திட்டம் தேவை. இந்த ஆய்வு எதிர்கால பாதுகாப்பு முயற்சிகளுக்கு மற்ற பகுதிகளில் தூழலியல் மற்றும் சமூகம் ஒப்பிடக்கூடிய சிக்கல்களுடன் தொடர்புடையதாக உள்ளது.

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INTRODUCTION

Nine species of vultures are recorded from India, of which five belong to the genus *Gyps* (Prakash 1999). Seven species of vultures are known to exist in southern India. The four residents are White-rumped Vulture (WRV) *Gyps bengalensis,* Egyptian Vulture (EV) *Neophron percnopterus*, Red-headed Vulture (RHV) *Sarcogyps calvus,* and Long-billed Vulture (LBV) *Gyps indicus.* The three migrants are the Cinereous Vulture *Aegypius monachus,* the Himalayan Griffon Vulture *Gyps himalayensis,* and the Eurasian Griffon Vulture *Gyps fulvus* (Bowden 2018). Vulture populations across southern Asia have drastically declined due to the veterinary use of nonsteroidal anti-inflammatory drugs (NSAIDs) (Pain et al. 2008; Ogada et al. 2012) in farm animals (Ogada et al. 2012; McClure et al. 2018; Buechley et al. 2019). In the 1990s, three species of *Gyps* vultures experienced 95% catastrophic declines as a result of diclofenac administration to cattle (Prakash 1999; Prakash et al. 2003, 2012; Oaks et al. 2004). In India, the use of the drug diclofenac for veterinary purposes was outlawed in 2006 (Prakash et al. 2007). Other NSAIDs, such as nimesulide, flunixin, aceclofenac, and ketoprofen, are also harmful to vultures (Zorrilla et al. 2014; Galligan et al. 2016; Naidoo et al. 2018).

Diclofenac is still being used illegally for veterinary purposes in southern Asia (Cuthbert et al. 2011a,b; Botha et al. 2017). Less than 1% of animal carcasses contaminated with diclofenac could have caused the disaster observed during the Asian vulture crisis, according to Green et al. (2004). Thus, creating vulture protection zones, raising awareness, and teaching the local populace are among the top conservation priorities. These measures, combined with laws and policies about the toxicity of NSAIDs, are the most important conservation needs for Old World vultures (McClure et al. 2018). These drugs remain available in the proposed vulture safe zone in the Nilgiri Biosphere Reserve (NBR) area of southern India (Manigandan et al. 2023b). Inadvertent poisoning is another serious risk to vultures that has not gotten much attention from scientific research. The intentional poisoning of carcasses as retaliation (Harris 2013) and the construction of electrical infrastructure that can electrocute birds (Manigandan et al. 2021) have resulted in a notable loss of vultures.

Given vulture prevalence in human-influenced environments and their critical endangerment, prioritizing social science research is imperative. Vultures play a crucial role in ecosystems by efficiently scavenging carrion and meat waste, thereby aiding in the cleaning of the environment (Thiollay 2017). Their presence in humanized settings, particularly in areas with inadequate solid waste management, can help mitigate the risk of disease outbreaks by reducing the population of mammalian scavengers such as dogs and rodents known to transmit diseases to humans (Ogada et al. 2012), thereby potentially decreasing the transmission of diseases. For instance, the decline of vulture populations in India led to a surge in feral dog populations scavenging carcasses in urban areas, contributing to disease transmission (Guerrero et al. 2012). Hence, the absence of vultures in humanized environments may exacerbate the proliferation of mammalian scavengers and the associated health risks. This study elucidates local community attitudes and actions, pivotal for both positive and negative impacts on vulture survival (Dhakal et al. 2022). Human activities significantly affect vulture conservation efforts, making empirical data on social and ecological aspects vital for effective interventions (Heberlein 2012; Reimer et al. 2013; Henriques et al. 2018). Understanding local perceptions, especially in key breeding areas like NBR in southern India, is crucial for conservation strategies, considering the intersection of economic development and anthropogenic stress (Manigandan et al. 2023a). Such insights inform conservation policies recognizing the role vultures play in ecosystems (Dhakal et al. 2022).

The objectives of the current study are:

1. To estimate the present population of different species of vultures within the study area, with emphasis on the four species currently threatened to be extinct.

2. To assess the level of perceived threat associated with the sale and availability of NSAIDs through direct assessments from the pharmacies of the nearby districts near the vulture nesting and foraging areas of NBR.

3. To evaluate the socio-economic status of the public and their awareness and attitudes regarding vulture conservation within the NBR. This study will contribute to formulating a site-specific management plan for NBR. This strategy will take into account the species status, existing threats, and local people's knowledge and perspectives, thereby updating the current conservation plan for vultures.

METHODS

Study area

In NBR, both Mudumalai Tiger Reserve (MTR) and Sathyamangalam Tiger Reserve (STR) are located in the

southern state of Tamil Nadu and adjoin each other as the study area (Figure 1). MTR Latitude: 11.587627°, Longitude; 76.710485°), covering 688 sq km, is bound by Bandipur Tiger Reserve (BTR) of Karnataka State to the north, Wayanad Forest Division of Kerala State to the west, Nilgiri South Forest Division to the south, and STR to the east. STR , Latitude: 11.586740°, Longitud: 77.157586° , a 1,410 km^2 area bordered to the north by the Biligiri Rangan Hills Tiger Reserve (BTR), to the west by the BTR, to the south by the MTR and Sigur plateau, and to the east by the Bargur Reserve Forest. Tropical evergreen, tropical moist, tropical dry, and scrub and thorny forests are the different types of forests found in STR and MTR. The watershed of the Moyar River includes both MTR and STR. WRVs are prevalent in the extensive area of Moyar Gorge, particularly within the riverine forests dominated by *Terminalia arjuna* trees, which serve as their primary nesting sites. LBVs find good roosting and nesting habitats along the area's numerous cliffs and escarpments.

Estimating the population of vultures

Road-transect methods were used to assess the vulture population at the study site (Venkitachalam & Senthilnathan 2016; Manigandan et al. 2023a). Five transects were chosen based on the nearest accessible tarred and metal roads to the villages as well as the presence of a vulture nesting colony in the protected areas of NBR. The transects (T) are: T1: Bhavanisagar to Thengumarahada; T2: Siriyur to Vazhaithottam; T3: Vazhaithottam to Masinagudi; T4: Masinagudi to Moyar; and T5: Masinagudi to Theppakadu (Figure 1).

The transects were driven between 0800 h and 1100 h, and 1500 h to 1800 h IST at 20–30 kmph by a four-wheeler over a total transect length of 85 km. These transect surveys were conducted twice a month, from January to December 2021. A total of 2,040 km of road were surveyed throughout the study during 24 replications. Whenever we observe the vultures, the vehicle was stopped, and the geo-coordinates noted, species identified, and numbers are recorded using a binocular (Nikon Monarch M5 12x42) from about 100 m to minimize disturbance. These were used for the preparation of maps using QGIS 3.28 (Manigandan et al. 2023a). We did not count the birds that were too far away to be identified.

To assess the accessibility of NSAIDs toxic to vultures we conducted covert surveys at 82 veterinary pharmacies across four districts in Tamil Nadu part of the vulture safe Zone: Nilgiris, Erode, Tiruppur, and Coimbatore, in January and February 2021. The sample comprised pharmacies managed by licensed pharmacists. We initiated contact with each pharmacy through local individuals or livestock owners seeking treatment for sick cows or buffaloes, using expired medication boxes containing diclofenac, ketoprofen, aceclofenac, flunixin, and nimesulide. The initial survey recorded pharmacy names, addresses, and sometimes geographic coordinates. Subsequent surveys located the same pharmacies using this information (Cuthbert et al. 2011a; Manigandan et al. 2023b). Building on the preliminary survey data, we employed the same approach to identify medications intended for human and animal use, commonly sold in the NBR region. Data on the type of compound (defined by active NSAIDs), brands, whether the drug was injectable or in bolus form, and manufacturing date and price were recorded. This enabled us to ascertain the presence of vulture-toxic drugs in the market (Manigandan et al. 2023b).

Local community perception survey

The questionnaire survey encompassed both tribal and non-tribal populations residing near vulture habitats within MTR and STR, where tribal communities are allowed to collect non-timber forest produce (NTFP) and graze cattle. Conducted from November to December 2021 across 20 settlements, eight of which were tribal (Irulas, Betta Kurumbas, Then Kurumbas, and Baniyas), and the rest non-tribal (Phuyal et al. 2016; Dhakal et al. 2022). Figure 1 outlines information on the 12 villages in MTR and eight villages in STR. Perceptions on vulture conservation were gathered from 540 randomly selected respondents, comprising 279 tribal and 261 non-tribal individuals. The random selection process involved drawing household numbers from various study villages as primary targets (Milano et al. 2018). While household heads were the primary respondents, resident adults aged 18 or older within households were also invited to participate (Gandiwa et al. 2013). Interviews were conducted with the aid of a Kannada translator to facilitate open communication as most spoke this language than the local Tamil language, with each interview lasting 20–30 minutes at the respondent's residence. Most questions utilized a 'precise and closed' format (Manigandan et al. 2023b) to effectively capture villagers' perceptions, although this format was not the primary focus (Gandiwa et al. 2013). The questionnaire, largely based on Reson (2012), covered socio-economic factors and local people's knowledge and perceptions regarding vultures and their ecological significance, ensuring clarity and alignment with study objectives. Uniform presentation of questions prevented bias

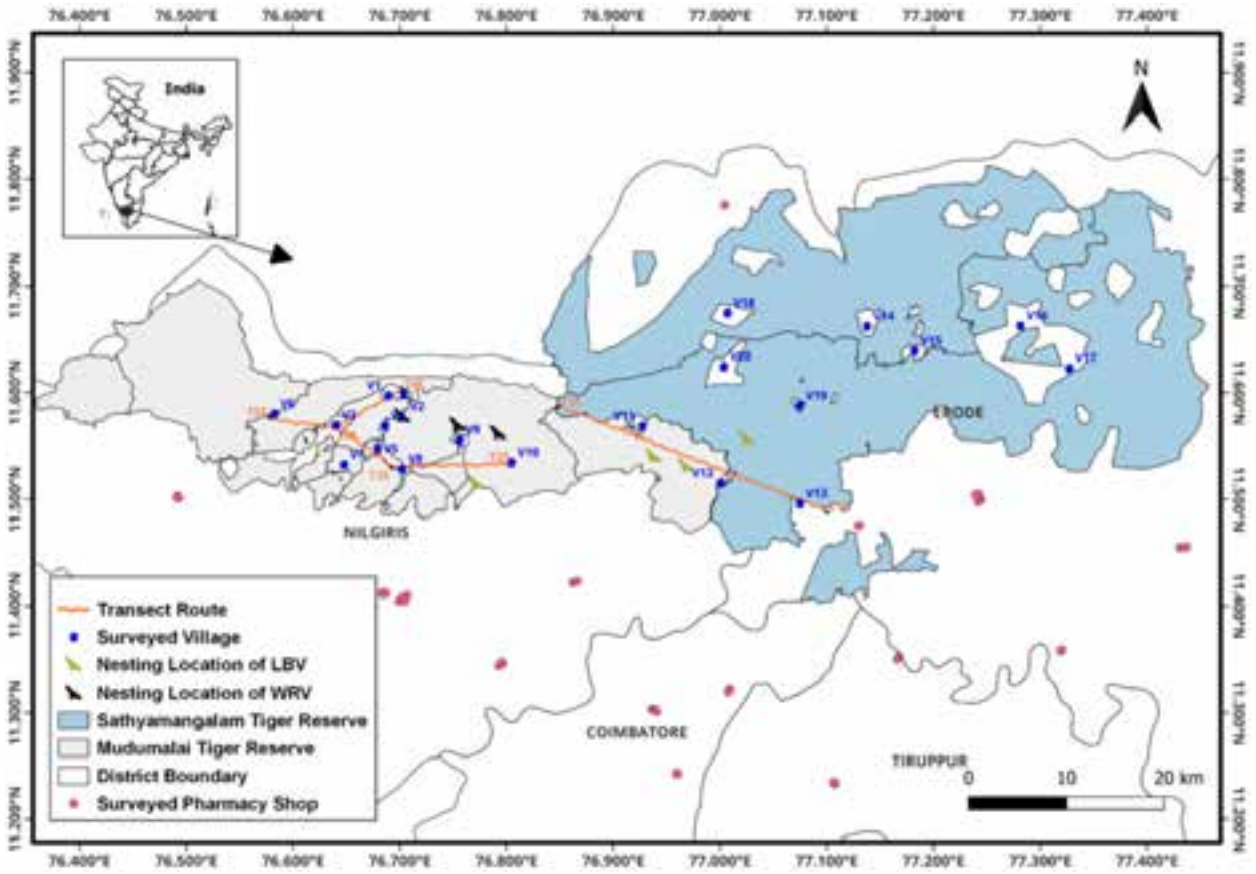

Figure 1. The study area of Mudumalai and Sathyamangalam tiger reserves with the road transect; nesting locations of WRV and LBV; locations of pharmacy shops in nearby districts; and locations of villages.

and ensured consistent responses (Kasunic 2005). Additionally, the questionnaire was pre-tested in a nearby community, and adjustments were made for clarity as needed. Post-survey cross-checking and editing were conducted to minimize data discrepancies and inconsistencies.

Statistical analysis

Basic statistics such as the arithmetic mean and standard error were calculated using (Microsoft Excel and SPSS 23. We also conducted a seasonal evaluation of vulture populations, distinguishing between summer (April–July), monsoon (August–November), and post-monsoon (December–March) periods by the Kruskal-Wallis ANOVA test (Venkitachalam & Senthilnathan 2006). We also examined the relationship between variables on differences between sex, education, gender, age, caste, and economic status regarding awareness of vultures, and their conservation, comparing the groups using the non-parametric test, the chi-square test. To explore the relationship between variables, we used the Pearson correlation coefficient, positive correlation (+1) negative correlation (-1) using the statistical software Origin Lab 2024.

RESULTS

Vulture population estimation

In our survey, we identified four vulture species: WRV, LBV, RHV, and EV. The WRV had the highest recorded numbers, with 1,570 individuals (M±SE, 65.4±2.4), and an encounter rate of 0.85 individual/km. Following this, LBVs were recorded at 151 individuals (M±SE 6.1±2), with an encounter rate of 0.08 individual/km, while RHVs numbered 118 (M±SE 4.9±0.25), with an encounter rate of 0.06 individual/km. The EV had the lowest count throughout the survey, with only 18 individuals (Figure 2). The mean population of WRV was highest during summer, followed by post-monsoon, and then monsoon. However, there was no significant difference between the samples (a). Conversely, the population of LBV did not vary significantly across seasons (B). Similarly, the mean population of RHV showed no seasonal variance

(c), nor did that of EVs (d) (Figure 4 a–d).

NSAID surveys

In a comprehensive covert survey conducted across four districts, a total of 19 different bolus brands and 14 injectable brands of NSAIDs were identified as available for purchase to treat livestock. The survey revealed a diverse array of 11 distinct types of NSAIDs offered for sale: aceclofenac, analgin (also known as metamizole), diclofenac, flunixin, meglumine, ibuprofen, ketoprofen, mefenamic acid, meloxicam, nimesulide, paracetamol (also known as acetaminophen), phenylbutazone, and piroxicam. Interestingly, many of the NSAIDs available for purchase were found to contain more than one active ingredient. Paracetamol was included as a secondary ingredient in 57.5% of bolus formulations and 42.5% of injectable formulations. Notably, paracetamol was commonly combined with bolus forms of nimesulide, as well as both injectable and bolus forms of meloxicam and bolus forms of diclofenac. Additionally, we identified two brands of diclofenac, either alone or in combination with paracetamol. It is worth noting that the two injectable brands of diclofenac, originally manufactured for human use, were being sold for veterinary treatment (Table 1).

Among the four districts, meloxicam (n = 19) had the most prevalence in pharmacy shops, followed by ketoprofen and aceclofenac (n = 2 each); flunixin, and nimesulide (n = 1 each) in Nilgiris. Meloxicam (n = 17) had the highest availability in pharmacies in the Erode district, followed by nimesulide and ketoprofen (n = 3 each), flunixin (n = 2), and aceclofenac (n = 1). Meloxicam (n = 4) was the most widely available in pharmacy shops in the Tiruppur district, followed by aceclofenac (n = 2), ketoprofen, flunixin, nimesulide, and ketoprofen (n = 1 each). Finally, in the Coimbatore district, meloxicam was the most widely available in pharmacy shops (n = 18), followed by aceclofenac (n = 3), flunixin and nimesulide (n = 2 each), and ketoprofen (n = 1) (Figure 3).

Table 1. Analysis of injectable and bolus NSAID formulations in four districts, with a focus on paracetamol-related co-active ingredients (brand names are indicated in parenthesis).

Active ingredient	Bolus	Injectable	Total
Tolfenamic acid		1(1)	1(1)
Meloxicam	4(2)	6(2)	10(4)
Diclofenac	3(1)	2(1)	5(2)
Ketoprofen		1	1
Aceclofenac	1(1)		1(1)
Flunixin		1	1
Ibuprofen	3(2)		3(2)
Nimesulide	6(1)	1	7(1)
Paracetamol		1	1
Analgin	2(1)	1(1)	3(2)
Phenylbutazone butazone2		1(1)	1(1)
Total with paracetamol as a secondary compound	19(8)	14(6)	33(14)

Perception surveys

In the present study, a detailed analysis of the surveyed respondents' socio-economic characteristics revealed the following key findings: The gender distribution was as follows: male respondents (53.1%, n = 287) outnumbered female respondents (46.8%, n = 253). The respondents' ages ranged from 18 to 80 years, with a median of 40 years. Notably, the majority of participants (34.6%) were of middle age (26–50 years; n = 187), closely followed by the young age group at 34.4% (18–25 years; n = 184). The older age group (51–80 years; n = 169) constituted 31% of the sampled population. The assessment of respondents' educational qualifications revealed a predominance of illiteracy, with 35.1% (n =

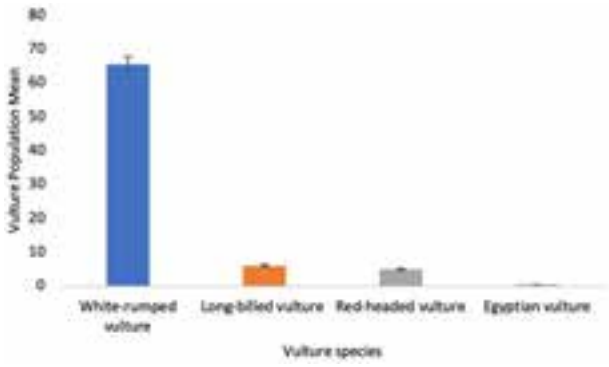

Figure 2. Population status of four vulture species of Mudumalai and Sathyamangalam tiger reserves in 2021.

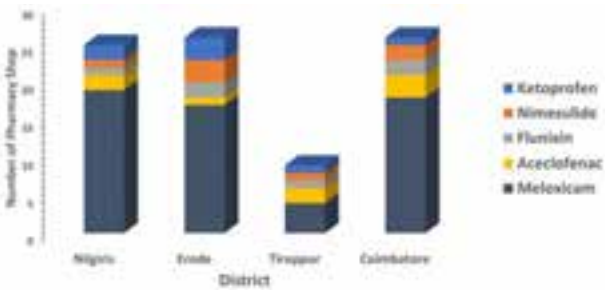

Figure 3. NSAIDs harmful to vultures are available in the Nilgiris Biosphere Reserve.

190) falling into this category. Following this, 22.4% (n = 121) had completed primary school, and an equal percentage (22.1%, n = 119) had completed secondary school. Additionally, 20.4% (n = 110) of participants possessed a college-level qualification.

In terms of source of income, agriculture was found to be the most common, accounting for 38.7% (n = 209) of the total sample, followed by livestock rearing at 30% (n = 162). Private employment accounted for 16.2% of the total (n = 88), while government employment accounted for 9.4% (n = 51). Entrepreneurial activities were less common, with 5.7% (n = 30) of the population involved in some form of business ownership. In addition, the study looked into the economic strata of households in the surveyed area. According to the findings, 32.7% (n = 177) of households were classified as lower-middle class, with 27.9% (n = 151) classified as very poor. The poor category comprised 21.4% (n = 116) of households, while the upper-middle class accounted for 11.4% (n = 62). The remaining 6.6% (n = 34) of households were categorized as affluent (Table 2).

The collective disposition towards vulture conservation was evaluated based on a summation of responses to 15 pertinent questions. Approximately, 66.6% (n = 360) of respondents believed that the vulture populations in the study area were declining. Moreover, a substantial 88.5% (n = 462) disagreed with reported incidents of mass vulture mortality in recent years. A significant majority of 87.4% (n = 472) felt that the availability of carrion, a primary vulture food source, was not increasing. Remarkably, 92.5% (n = 499) stated that they refrained from persecuting vultures. Another 85.7%

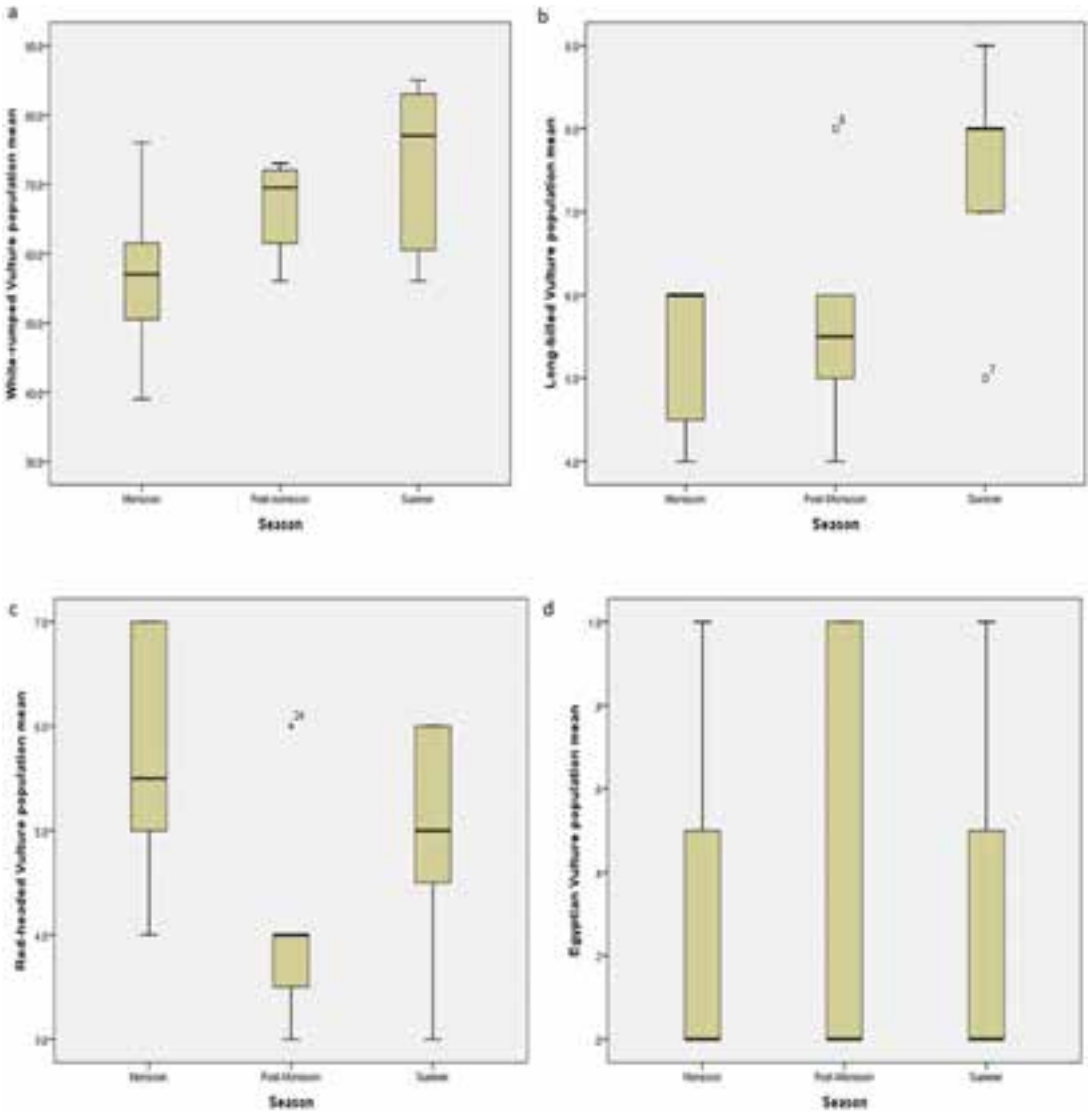

Figure 4. Vulture species population the season-wise in 2021.

Table 2. A comprehensive overview of the socioeconomic distribution of households in Nilgiri Biosphere Reserve.

Respondents' variables	Tribal	Non-tribal	Total
	respondents (%)	respondents (%)	
Gender			
Male	145 (51.9)	142 (54.4)	287 (53.1)
Female	134 (48.1)	119(45.6)	253 (46.8)
Age			
(Young) 18–25 years	82 (29.3)	102 (39)	184 (34.4)
(Middle) 26–50 years	103(36.9)	84 (32.1)	187 (34.6)
(Old) Above 51 years	94 (33.8)	75 (28.9)	169 (31)
Education			
Illiterate	135 (48.3)	55 (21)	190 (35.1)
Primary School	55 (19.7)	66 (25.2)	121 (22.4)
Secondary School	47 (16.8)	72 (27.5)	119 (22.1)
College Level	42 (15.2)	68 (26.3)	110 (20.4)
Source of livelihood			
Agriculture	97 (34.7)	112 (42.9)	209 (38.7)
Livestock rearing	107 (38.3)	55 (21)	162 (30)
Government sector	13 (4.6)	38 (14.5)	51(9.4)
Private sector	55 (19.7)	33 (12.6)	88 (16.2)
Own Business	7 (2.7)	23 (8)	30 (5.7)
Economic Status (Annual income)*			
Very poor (Below 25K)	139 (49.8)	12 (4.5)	151 (27.9)
Poor (26K to 50K)	88 (31.5)	28 (10.7)	116 (21.4)
Lower middle class (50K to 100K)	34 (12.1)	143 (54.7)	177 (32.7)
Upper middle class (100K to 500K)	18 (6.6)	44 (16.8)	62 (11.4)
Rich (Above 500K)	0	34 (13.7)	34 (6.6)

* Largely based on Reson (2012).

(n = 463) expressed the opinion that wildlife should have suitable habitats. A strong consensus of 93.1% (n = 503) recognized the need for increased awareness campaigns focused on vulture conservation. A notable 90.3% (n = 488) endorsed the necessity of safeguarding vultures for the well-being of future generations. A substantial 70% (n = 378) of respondents held vultures in high regard, similar to a deity. A 67.4% (n = 364) acknowledged the ecological benefits vultures provide to human communities. The majority (59.7%; n = 322) of respondents contested the idea of declining forest cover in their localities; 63.4% (n = 342) of respondents did not consider chemical fertilizers and pesticides as major contributors to vulture decline (Figure 5). The correlation coefficient between variables shows an asymmetric distribution with most of the participants having a relatively positive attitude toward vulture conservation, Among the respondents, Q-5,6,7,8,9,12,13,14 and 15 are positive attitudes (Figure 8).

A dichotomized scale was used to assess significant predictors influencing conservation attitudes among the surveyed population. There was a significant difference in conservation attitudes between male and female respondents. Females had a 52.5% (n = 187) positive attitude toward vulture conservation compared to males 47.5% (n = 169) which was statistically significant (χ^2 = 13.579, p <0.001). When we looked at the different age groups, we found that middle-aged participants were more interested in vulture conservation, with 37.4% having positive attitudes. Older and younger participants had slightly lower percentages, with 31.7% and 30.9%, respectively. However, these age differences did not show statistical significance (χ^2 = 5.406, p = 0.634). Among the communities, tribal participants showed a higher positive attitude (57.6%) towards vulture conservation compared to their non-tribal counterparts. However,

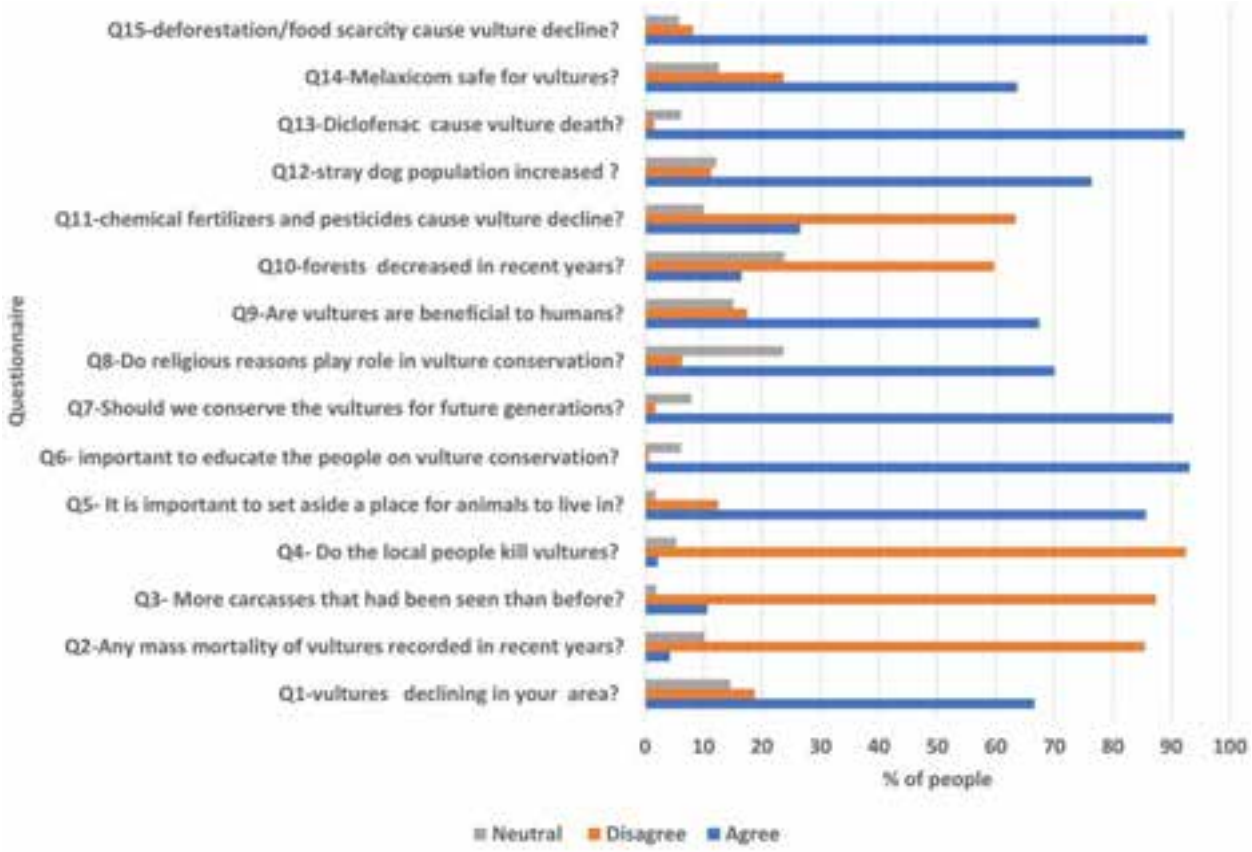

Figure 5. Societal perspectives on vulture conservation among tribal and non-tribal populations in Nilgiri Biosphere Reserve.

statistical analysis indicated no significant differentiation between the two groups (χ^2 = 14.651, p = 0.067).

Education-wise, among the younger respondents, those with college-level education (28.9%) exhibited significantly more positive attitudes towards vulture conservation. Respondents with secondary, primary, or no formal education had lower positive attitudes. This difference was statistically significant (χ^2 = 20.142, p <0.001). Regarding livelihood, livestock holders showed the highest inclination (33.7%) towards vulture conservation, which was statistically significant (χ^2 = 34.379, p <0.0001). Economically, among the low middle-class respondents, there was a positive attitude (36.8%) toward vulture conservation compared to others, but this difference was not statistically significant (χ^2= 8.256, p <0.083). For those living in the MTR, there was a significant positive attitude (64.6%) towards vulture conservation compared to those in STR (χ^2 = 3.73, p <0.053) (Figure 6).

In NBR, 12 village residents have a positive attitude as most of the tribal household has people working in the forest department as guards, anti-poaching watchers, and eight village residents have a negative attitude toward vulture conservation, In MTR, Moyar, Boothanatham, Masinagudi, Mavanallha, Theppakadu, Vazhaithottam, Anaikatty, Siriyur, and Kallampalayam are villages with positive attitudes toward vulture conservation, while Chemmanatham, Bokkapuram, and Thengumarahada are negative. Accordingly, in STR, only three villages have a positive attitude - Kadambur, Thalaimalai, and Ittarai. The remaining village respondents expressed a negative attitude towards vulture conservation (Figure 7). The correlation coefficient between variables shows an asymmetric distribution with most of the villages having a relatively negative attitude towards vulture conservation, among the respondents, villages who are living in the MTR (Village -1,2,3, 5,6,8,9, 10,12) have positive attitudes towards vulture conservation exception village- 4,7 and 11. As well as those who are living STR's negative attitude toward vulture conservation (Figure 9).

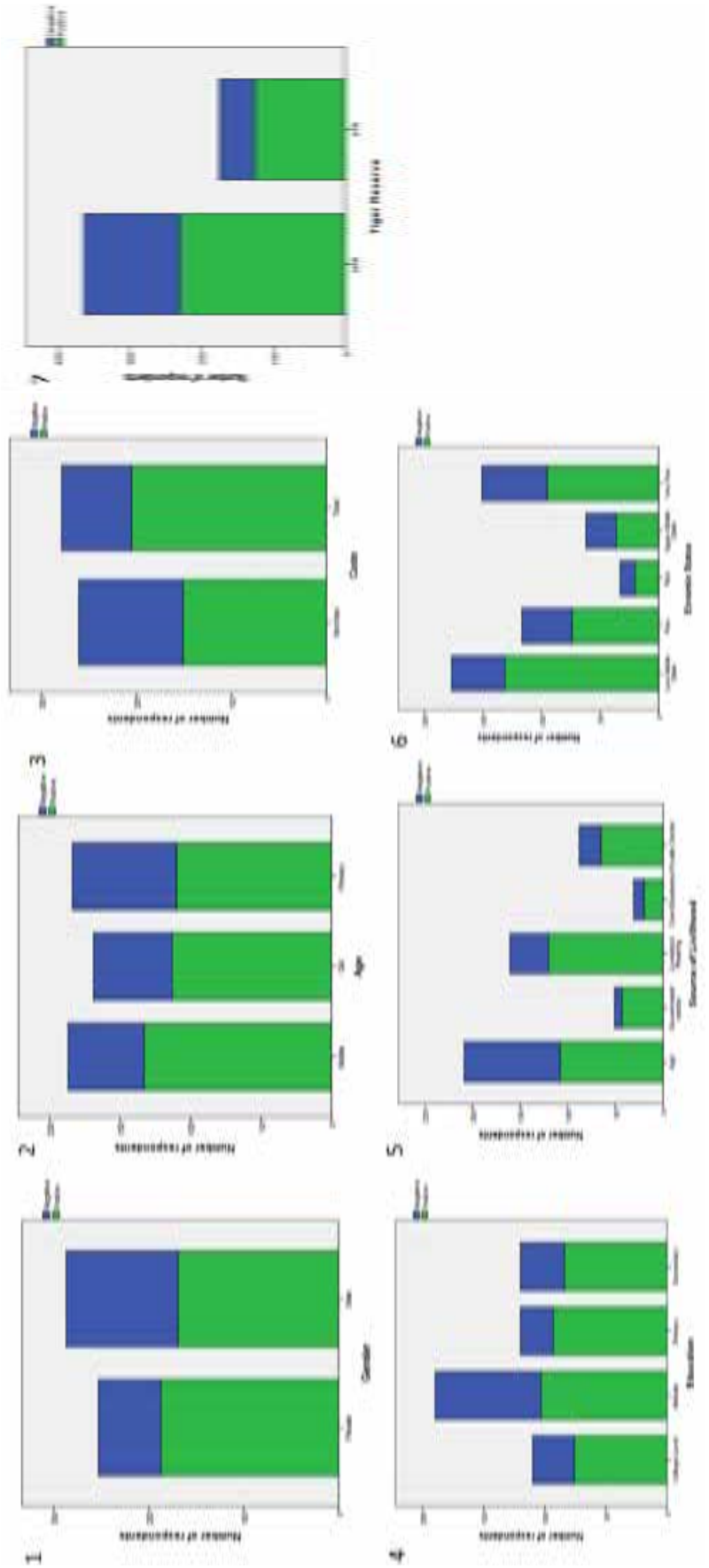

Figure 6. The relation between socioeconomic factors and conservation attitudes towards vulture conservation among local populations in the Nilgiri Biosphere Reserve.

DISCUSSION

Status of the Vulture population

We documented four vulture species, namely WRV, LBV, RHV, and EV. This study confirmed the present status of four vulture species in NBR and underscored the value of local knowledge regarding the threats faced by these species. Bhusal et al. (2019) and Galligan et al. (2019) have previously reported an increase in the vulture population following the ban on diclofenac in 2006. Even though in NBR, vultures faced new threats as forest fire and illegal tourism (Manigandan et al. 2024), our findings suggest that the population appears to be relatively stable (Manigandan et al. 2023a).

Our road-transect surveys of vulture sightings were compared to similar studies in the study area. Specifically, the encounter rates of WRV and LBV were 0.85 and 0.08, which aligns with earlier observations (Venkidachalam et al. 2016; Manigandan et al. 2023a).

Furthermore, we did seasonal comparisons of vulture populations. Venkitachalam & Senthilnathan (2016) had previously noted that WRV populations were higher in the post-monsoon season. In contrast, our study found that the populations of WRV were higher during the summer season. This difference may be attributed to the breeding seasons of these species, which commence in September and end in March, with nestlings gradually growing up by March. During this period, adult birds leave the nest to forage (Stotrambhashyam et al. 2015), resulting in increased vulture sightings from April to July. Notably, EVs, which were documented during the study period, were mostly juveniles, suggesting possible nesting of this species in NBR, consistent with earlier findings (Byju & Raveendran 2022).

Assessment of harmful drugs impacting vultures

Injectable formulations of diclofenac available in NBR were originally intended for human use, making their manufacturing and sales legal. However, these products were being offered for sale for veterinary use (Cuthbert et al. 2011a; Manigandan et al. 2023b), which is illegal. It is important to note that two bolus brands and one injectable brand of diclofenac were found to be manufactured after the ban on its veterinary use in 2006. On the other hand, meloxicam has been recognized as a safe drug for vultures (Swarup et al. 2007). While meloxicam is readily available in pharmacies, other potentially harmful drugs such as aceclofenac, ketoprofen, nimesulide, and flunixin are also widely available in pharmacy shops (Galligan et al. 2021; Manigandan et al. 2023b).

The presence of these harmful drugs on the market

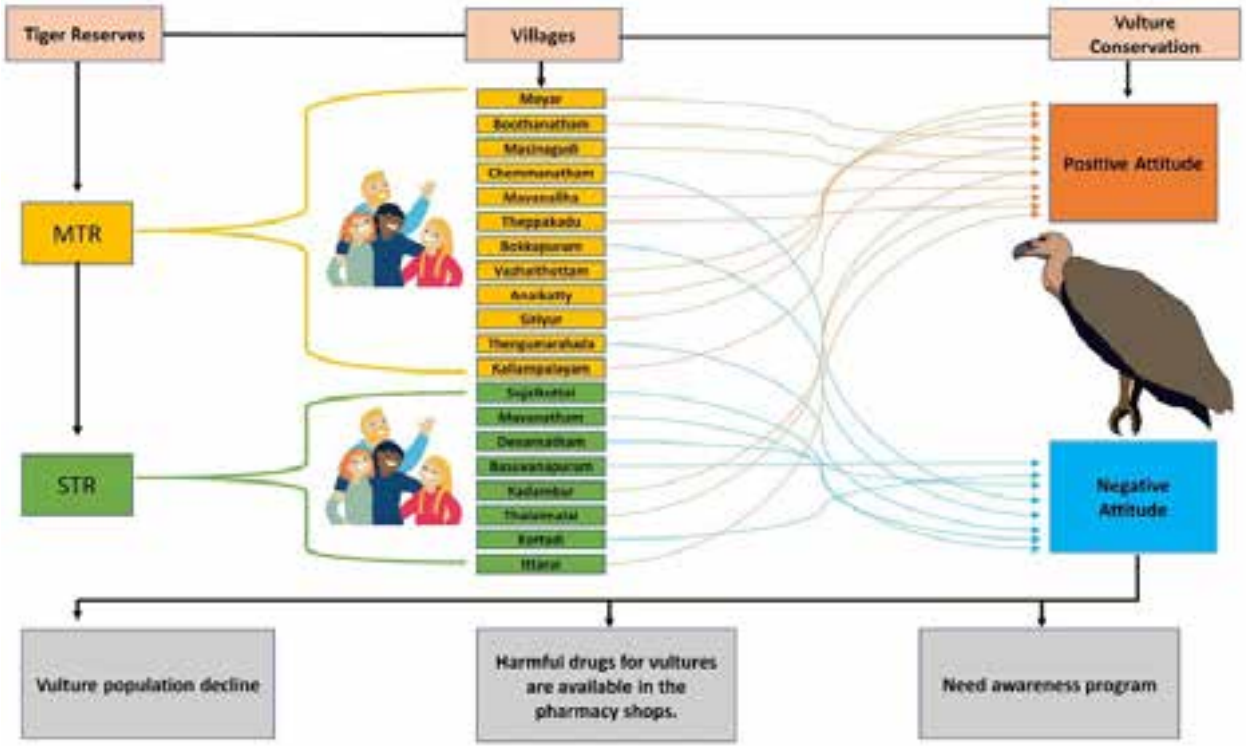

Figure 7. Village-wise attitudes of respondents toward vulture conservation in Nilgiri Biosphere Reserve.

poses a potential threat to vultures. In the MTR, where government veterinary doctors oversee cattle treatment, meloxicam is typically administered to cattle as a painkiller, ensuring the safety of vultures. However, in the case of STR, private veterinarians are responsible for treating livestock, raising concerns that they may use pain relief medications that could be harmful to vultures.

To safeguard vultures, vulture safe zones (VSZ) have been defined as areas within a radius of 100 km from the vulture nesting colony. The zone is divided into 50 km as the core zone and the next 50 km as the buffer zone (Mukherjee et al. 2014) from the nearest nesting colonies. Research has shown that 1% of lethal levels of diclofenac can lead to a significant decline in vulture populations (Green et al. 2004). Given the importance of protecting vultures and the presence of critically endangered species in the NBR, the Government of India has expressed interest in declaring it VSZ (MOEF 2020). However, this declaration must be made after thorough research and assessment to ensure the safety and preservation of vulture populations in the NBR.

Local community and knowledge of vulture conservation

We investigated the awareness and attitudes of local communities, specifically tribal groups, towards vulture conservation. Tribal communities often hold unique knowledge and perceptions about wildlife due to their cultural beliefs and practices. This research aligns with previous studies that emphasize the significance of local perceptions in garnering support for conservation efforts (Sharma et al. 2019; Katuwal et al. 2021; Byju et al. 2023). One interesting finding is that tribal people are more knowledgeable and aware of vultures than non-tribal people, which is likely due to their cultural reverence for vultures as god (Jha et al. 2023). Additionally, personal attitudes play a pivotal role in determining an individual's intentions to support vulture conservation (Byju & Raveendran 2022). Furthermore, our research reveals that various factors, such as ethnicity, age, education, gender, livestock ownership, participation in conservation activities, and perceived benefits, significantly influence conservation attitudes. Interestingly, unlike some indigenous communities in India that engage in hunting for sustenance, the tribal

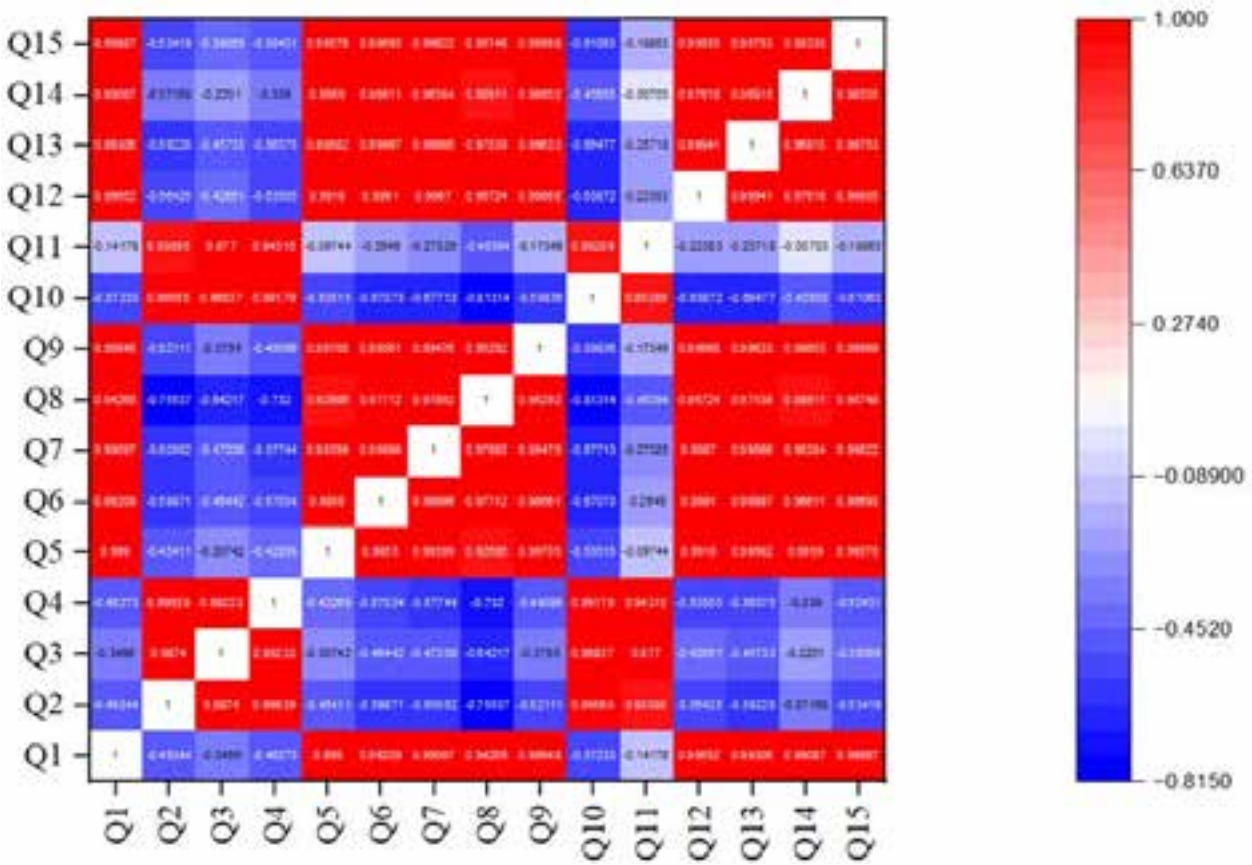

Figure 8. Correlation matrix among the 15 questionnaires with variables (Agree, disagree, and neutral) towards vulture conservation.

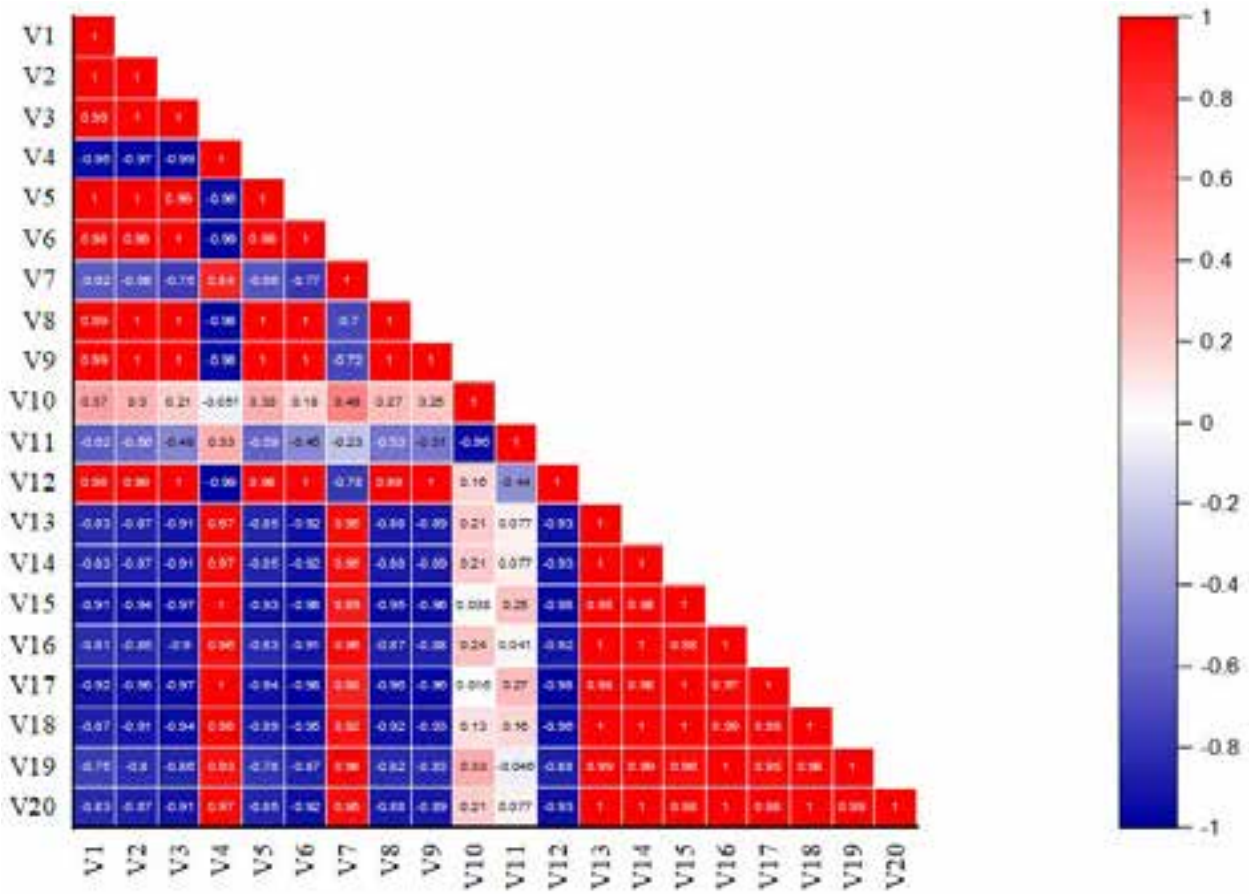

Figure 9. Correlation matrix among the 20 villages with the attitude (positive and negative).

communities in our study area do not hunt birds, including vultures (Jha et al. 2023). This distinction underscores the need for region-specific conservation strategies. Moreover, our study highlights the discrepancy in vulture awareness between the residents of MTR and STR. This difference can be attributed to the focused efforts of the forest department and NGOs on the MTR. As a result, future conservation endeavours should extend their attention to the STR to enhance vulture conservation efforts.

Improved access to primary and secondary education has contributed to an increase in community awareness. In terms of literacy, it was observed that illiterate individuals, especially among tribals, expressed relatively higher awareness of vulture protection compared to the non-tribal illiterate individuals. Furthermore, there were a higher proportion of male respondents, reflecting gender roles in Tamil society (Shumsher & Timilsina 2013). Despite reports of women's limited participation in discussions (Jha et al. 2023), the current study found that women had a more positive attitude toward vulture conservation, emphasizing the importance of vulture conservation education and awareness programs aimed at non-tribal communities and others. None of the disadvantaged groups, such as tribal communities, have a college-level education, emphasizing the importance of environmental education programs to engage them in conservation efforts. Previous research has shown that education can strongly influence conservation attitudes (Heinen 1998; Emtage 2004). The socioeconomic status of the local population, as measured by education, was a primary factor influencing attitudes toward vulture conservation. The data obtained in this study revealed a highly positive attitude among those who received higher secondary and college-level education (Shumsher & Timilsina 2013).

Subsistence agriculture and livestock rearing are the mainstay occupations in the study area, with a majority of households raising livestock. Contrary to the findings of Shumsher & Timilsina (2013) regarding lower caste and livestock producers, livestock owners showed a high level of interest in vulture conservation. Despite the ban on diclofenac in the country since 2006, informal discussions with veterinary personnel revealed

that local people still prefer to use diclofenac due to its cost-effectiveness and efficacy compared to other NSAIDs, posing a serious threat to vultures (Cuthbert et al. 2016). This highlights the need for ongoing efforts to discourage the illegal use of diclofenac for both veterinary and human purposes.

The disposal of carcasses in the region exhibited distinct practices based on the cause of animal death. Residents typically bury the carcasses of animals that died of diseases. Conversely, they prefer to discard carcasses in open fields in the case of natural death and wildlife attacks, facilitating vulture scavenging opportunities. The use of pesticides and chemical fertilizers, although not quantified, was a common practice among local farmers. Ghimire et al. (2013) noted that respondents disagreed with the statement that the "use of chemical fertilizers and pesticides causes vulture decline". Similarly, in the present study, a substantial number of respondents disagreed with the statement that the use of chemical fertilizers and pesticides contributes to vulture decline.

Regarding attitudes towards vulture conservation, the local population has a moderate level of concern. People acknowledged the significant benefits vultures brought to human societies through their ecosystem services, particularly in maintaining a clean and healthy environment by consuming carcasses (Byju & Raveendran 2022). However, for cultural reasons, the local populace did not hold vultures in high regard. Interestingly, the study discovered a higher level of awareness of the harm diclofenac causes to vultures than had previously been noted (Dhakal et al. 2020). Nevertheless, knowledge about other harmful NSAIDs remained limited among the respondents. These findings can contribute to the ongoing discussion on vulture conservation in the region.

Informal discussion with the respondents revealed a negative sentiment regarding vultures nesting in trees within their farmlands. People perceived vultures as pests due to the odour and the adverse effects of vulture droppings on their livestock and farms. To mitigate this, individuals would prune the branches hosting vulture nests near human settlements. This underscores the importance of ongoing awareness campaigns among local communities residing in proximity to vulture habitats (Phuyal et al. 2016; Milano et al. 2018).

CONCLUSION

To conclude, this study from NBR, the southernmost viable vulture breeding site, offers a comprehensive assessment of the status of vulture populations and highlights the critical role of local knowledge in understanding the threats these species face. Despite three of the vulture species being critically endangered, their numbers appear to be relatively stable. The presence of potentially harmful drugs in veterinary use raises concerns for vulture conservation, highlighting the importance of cautious consideration before designating vulture-safe zones. Furthermore, the study underscores the need for inclusive assessments that take into account factors such as education, gender, and socioeconomic status, particularly within tribal communities, as these elements play a significant role in influencing conservation attitudes. Recognizing the importance of awareness campaigns becomes crucial to addressing negative perceptions and mitigating human-vulture conflicts in local communities. Inclusivity and a multidimensional approach are essential for effective vulture conservation strategies.

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ARTICLE

Nesting habits of Baya Weaver *Ploceus philippinus* (Linnaeus, 1766) on power and television cables in the agricultural landscape of Kallakurichi district, Tamil Nadu, India

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Abstract: The nesting habits of Baya Weaver *Ploceus philippinus* with nesting site (e.g., power and television cables), source of nest materials, various developmental stages of nests, abnormal nests, number of individuals and their association with other bird species, and threats to their nests were studied between March and September 2021 in the agrarian landscapes of 42 villages in Kallakurichi District, Tamil Nadu. A total of 155 nest colonies containing 1,725 nests of various developmental stages and 1,993 adult birds were counted on power/television cables. The number of nests per colony found varied from one to 57. The average number of nests per colony was eleven. Baya Weaver had preferred power/television cables as nesting sites in the study area in spite of availability of potential nest-supporting trees, such as *Cocos nucifera* and *Borassus flabellifer* within 500 m radii from cables bearing nests. Birds used fibres of sugarcane leaves (*Saccharum officinarum*) for the construction of nests. Out of 778 helmet stage nests observed, 90% (n = 716) helmet stage nests had clay deposits on their inner walls and no clay deposits were found in the remaining 10% (n = 62) helmet stage nests. Eleven types of abnormal nests constituted 17% (n = 286) of the total nests. Sixteen other bird species (e.g., birds of order: Passeriformes, Coraciiformes, Piciformes, Cuculiformes and Columbiformes) were found associated with the individuals of Baya Weaver. These bird species strictly shared similar roosting and foraging grounds. The avian predators such as House Crow *Corvus splendens*, Large-billed Crow *Corvus macrorhynchos*, Black Drongo *Dicrurus macrocercus*, Rufous Treepie *Dendrocitta vagabunda*, Coucal *Centropus senegalensis*, and Shikra *Accipiter badius* had damaged the nests, eggs and chicks. The study revealed that about 1.1% nests (n = 197) were probably damaged by these avian predators. Power cables in the study sites had provided suitable nesting sites for Baya Weavers. The causes for utilization of power cables as nesting sites in larger geographical areas require further studies.

Keywords: Abnormal nests, associated birds, clay deposits, communal roosting, nest material, nest predation, threats.

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INTRODUCTION

Baya Weaver *Ploceus philippinus* (Linnaeus, 1766) (Aves: Passeriformes: Ploceidae) is a gregarious, social, polygamous, colonial nester and they are commonly distributed in the Indian subcontinent (Ali et al. 1956), Java, Malacca, and Sumatra (Blyth 1845; Wood 1926), Nepal, China, Indonesia, Laos, Myanmar, Singapore, Thailand, and Vietnam (BirdLife International 2016). Several authors have studied the breeding biology (Ali 1931; Ali et al. 1956; Ambedkar 1964; Mathew 1976) and abnormal nesting behaviours of this bird in India (Ambedkar 1964; Crook 1964; Sharma 1989; Pandian & Natarajan 2018; Pandian 2021). Baya Weavers used leaf fibres of Indian Date Palm *Phoenix sylvestris* and Sugarcane *Saccharum officinarum* as nest materials for construction of nests (Pandian 2021, 2023). Nests of Baya Weavers were found attached to telegraph wires running through sugarcane fields along the Chittoor-Chandragiri routes (Kirkpatrick 1952), Kumaon Terai region, Uttarakhand (Ambedkar 1969), Assam and Tamil Nadu (Davis 1976), and Mysore-Bangalore-Chennai regions (Subramanya 1982). Incidents of Rufous Treepie *Dendrocitta vagabunda* damaging nests and anthropogenic factors causing damages to nests and nest-supporting trees were recorded in Vellore and Viluppuram districts, Tamil Nadu (Pandian 2021, 2023). The IUCN Red List of Threatened Species has classified Baya Weaver under 'Least Concern' (LC) (Birdlife International 2016) category.

In this paper, I sought answers to questions relating to choice of power cables for nest construction by Baya Weaver with specific reference to Kallakurichi District, Tamil Nadu. The following were the objectives of the study: (1) extent and pattern of selection of cables for nesting, (2) preference of cables and proportions of selection of potential nest-supporting trees for construction of nests, (3) features of nest building including sources of nesting material, stages of nest developments, plastering of clay on inner walls, and abnormal nests with variations, (4) association with other bird species, and (5) threats faced by the nest colonies. Detailed studies on the constructions of nests on power cables in Tamil Nadu are still scarce. Hence the present study was carried out to fill this gap.

MATERIALS AND METHODS

Study Area

The present study was carried out in 42 villages in Ulundurpet and Kallakurichi taluks, Kallakkurichi District of northeastern Tamil Nadu. The district spreads over c. 3,530 km^2, with a human population of c. 13,40,000 (Census 2011) (Kallakurichi 2021). Agriculture is the primary occupation of the people. The major crops of the area are paddy *Oryza sativa*, sugarcane, followed by Jowar Sorghum *bicolor*, Pearl Millet *Pennisetum glaucum*, Finger Millet *Eleusine coracana*, Groundnut *Arachis hypogaea*, Green Gram *Vigna radiata*, and Tapioca *Mannihot utilisimma*. The practices of monoculture of Casuarina *Casuarina equisetifolia* are very common in the district. Flower and vegetable cultivations also occur. The maximum and minimum temperatures in the districts are 36°C and 20°C, respectively. The average annual rainfall is 1,060 mm (Kallakurichi 2021) (Figure 1).

Methods

With help from three field assistants, I identified 42 villages having definite nesting habitats of Baya Weaver on overhead power transmission cables in the cultivating lands in Kallakurichi District, Tamil Nadu. No particular sampling method was adopted, as I followed the entire area census covering all the arable lands in 42 villages in the district. The nests attached to the power cables and television cables between two poles and nests attached to service cables between electric poles and motor pump sets were considered a single nest colony. These nesting colonies were surveyed on daily basis covering six villages per day by each field assistant when the birds were found active from 0600 h to 1200 h and 1500 h to 1800 h between March and September 2021. Each nest colony was viewed daily continuously for one hour and recorded number of nests, progress on nest constructions (nesting developments), male birds plucking of fibres and carrying clay, and sighting of predators in the vicinity of nest colonies. The heights of the cables from the ground were ascertained from the data provided on power transmission poles while heights between overhanging nests and sugarcane crops, and the distance between the overhanging nests over the bunds were measured using a dried bamboo stick. Then the length was converted to standard scales of measurement. The sources of nesting materials was identified by observing the birds which plucked and carried fibres from nearby sugarcane leaves to the nesting sites and analysing six fallen and 15 damaged nests. The types of cultivating crops underneath the overhanging power cables were

recorded. The locations of all the cables that bore nest colonies were determined using GPS (Gramin Etrex 20x). The nests, their developmental stages, and deposits of clay on the inner walls of helmet stage nests were observed by using field binoculars (Super Zenith 20 x 50). In the completed nests, the clay deposits were studied by dissecting the fallen nests. The nest damages by avian predators and other factors were observed by binoculars. According to Sharma (1995), abnormal nest is defined as abnormality in structure of nest or any part of it due to duplication of part (s) or/and formation of additional part (s) or/and elaboration of nests or/and abolition of normal parts. All the abnormal nests built on power cables were photographed and classified based on the guidelines of Sharma (1995). Type of birds associated with Baya Weaver during perching/roosting, foraging, and nest predation by avian predators were observed by using binoculars, without disturbing nests

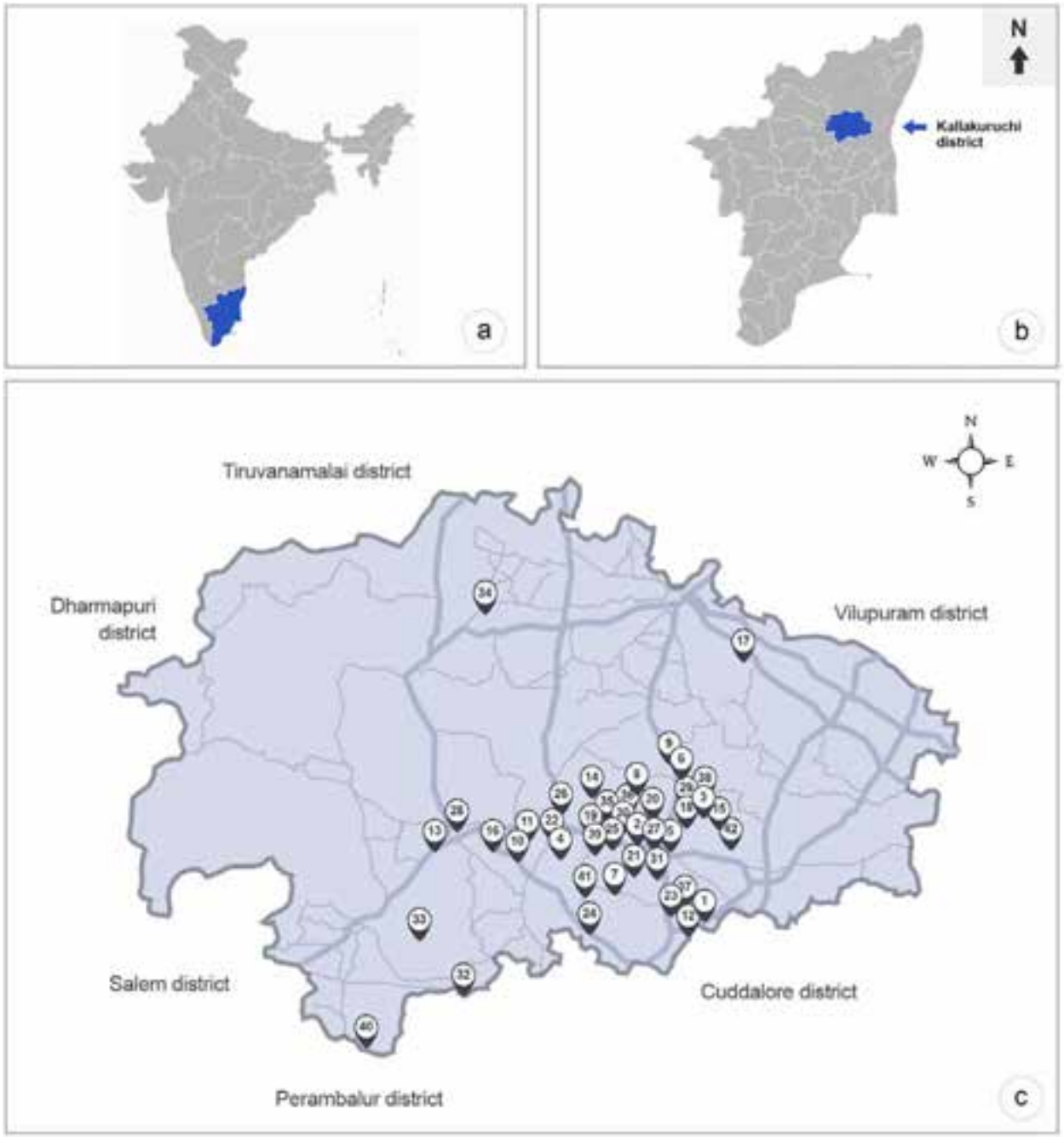

Figure 1. Study area map: a—India map showing Tamil Nadu | b—Tamil Nadu map showing Kallakurichi District | c—Kallakurichi District map showing locations of 42 villages containing nest colonies (Names of villages with GPS coordinates are furnished in Table 1).

and their residents. Each nest colony was observed uninterruptedly for 60 min and the maximum number of birds observed in that colony was counted. Two types of nest-supporting palms trees (*Cocos nucifera* and *Borassus flabellifer*) present in the area of 500 m radii around the cables containing nests were completely checked for the presence of nests. Out of the total such nest-supporting trees observed, the proportion of trees preferred by Baya Weaver for nesting and the proportion of trees that were not preferred by the birds for nesting was also taken into account. The distance between nest colonies and the nearest buildings/ human settlements and roads were measured using measurement tape. No nesting activities on these trees were studied in detail except enumerating the number of nesting and non-nesting trees. Utmost care was taken not to disturb the nests or birds and we maintained a minimum distance of c. 30 m during observations. Number of live nests, eggs, chicks and adult birds were neither disturbed nor handled during the study period. Nikon P 1000 digital camera was used for photography. Collected data were tabulated, analysed using SPSS (Statistical Package for Social Sciences) version 25.0 software and shown as graphical representation. The relationship between proximity of roads, buildings, human settlement and selection of cables by Baya Weavers for construction of nests were also analysed.

RESULTS

A group of males with breeding plumage started to carry fibres from sugarcane leaves and plaited knots on power/television cables during third week of May 2021 in the study sites. A total of 1,725 nests of various developmental stages and 1,993 adult birds were enumerated on 155 nest colonies attached to cables. The average number of nests in each colony ranged from one to 57. In all the sites (n = 155), the nesting cables were found overhanging sugarcane crops and no cable bearing nests was found overhanging other crops (Table 1).

Preference of power/ television cables for construction of nests

The study revealed that within 500 m radii from the cables bearing nest colonies, there were 2,919 potential nest-supporting trees, such as *Cocos nucifera* (n = 2541) and *Borassus flabellifer* (n = 378) in 42 villages. Individuals of Baya Weaver utilized only 1.5% (n = 41) of the total trees for construction of nests. That is, out of 2541 *C. nucifera* trees, the birds constructed nests on 25 trees and out of 378 *B. flabellifer* trees, the birds constructed nests on 20 trees alone. Proportionately, the birds preferred more number of *B. flabellifer* trees than *C. nucifera* trees for construction of nests. No nests of Baya Weavers were found on the remaining 98.5% of potential nest-supporting trees (n = 2874) of those two palm species (Arecaceae).

Type of nesting substrata

The study revealed that overhead power transmission aluminium cables bore 80% nests (n = 1,375) and 80% birds. Another 11% nests (n = 217) and 12% birds (n = 238) were reported on television cables passing over crop fields and the remaining 9% nests (n = 133) and 8% birds (n = 159) occurred on service cables connected between electric poles and motor pump sets. The study revealed that out of 1,375 nests enumerated on overhead power transmission aluminium cables, 17.8% nests (n = 245) were found attached to places/ junctures where aluminium cables and reel insulators were connected. In one instance, the birds plaited knots by joining aluminium cable and the stem of a climber *Cocculus carolinus* (Menispermaceae) in Emam village (11.729701°N & 79.242676°E) (Image 1a). The stalks of all the nests (n = 217) were found attached to the places where television cables and supporting strings/rings joined together. Similarly the stalks of all the nests (n = 133) enumerated on pump set service wires were found attached to multiple cables or at the junctures of cables and reel insulators (Image 1).

Preference of Baya Weaver in building nests on cables occurring close to human dwellings

The study also tested the relationship between proximity of roads, buildings, human settlement and selection of cables by Baya Weavers for construction of nests. Cables bore 62.5% nests (n = 1,078) occurred within 100 m radius from constructed structures such as cattle sheds, motor-pump sheds, isolated human dwellings or buildings in crop fields (Figure 2). Cables bore 61.4% nests (n = 1,059) occurred within 100 m distance from the nearest roads. The males select apparently those cables found adjacent to roads with busy vehicular traffic and movement of general public to build nests (Figure 3). Cables bore 32 % nests (n = 551) occurred within 200 m distance from human settlements and the birds even built nests on power cables occurring 20 m from human settlements (Figure 4).

Table 1. Details of villages, GPS coordinates, nest colonies, number of nests of Baya Weaver, developmental stages of nests, and number of birds in the study area (as on 2nd week of September 2021).

	Name of the village	GPS coordinates	Total no of nest colonies	Total no. of nests	Developmental stages of nests						Total no. of birds
					Wad stage	Ring stage	Helmet stage	Egg-chamber closed stage	Complete nests	Abnormal nests	
1	A. Mazhavarayanur	11.641323°N–79.207476°E	1	1	0	1	0	0	0	0	1
2	Alangiri	11.720209°N–79.143198°E	1	23	0	0	12	0	3	8	26
3	Anganur	11.742198°N–79.218901°E	3	46	2	2	26	7	4	5	55
4	Chithalur	11.675684°N–79.077867°E	1	24	0	1	12	0	10	1	30
5	Elavanasoorkottai	11.717443°N–79.174617°E	8	133	1	7	57	24	23	21	130
6	Eraiyur	11.775540°N–79.194864°E	1	6	0	0	6	0	0	0	6
7	Gudiyanallur	11.675005°N–79.115207°E	3	13	0	0	11	2	0	0	68
8	K.Kunjaram	11.763302°N–79.176961°E	4	108	12	0	53	9	16	18	101
9	Keezha palayam	11.702912°N–79.193709°E	2	53	0	0	28	3	16	6	64
10	Kurur	11.714977°N–79.035672°E	2	8	0	0	7	0	0	1	15
11	Madur	11.734778°N–79.015647°E	2	53	2	7	28	0	5	11	70
12	Mavidandhal	11.622296°N–79.219110°E	1	11	0	0	10	1	0	0	12
13	Moolasamudhiram	11.703817°N–79.266068°E	3	15	0	1	10	3	0	1	18
14	Mugamathiyarpettai	11.613614°N–79.126747°E	1	1	0	0	1	0	0	0	1
15	Nathakali	11.720346°N–79.242060°E	1	2	0	0	2	0	0	0	4
16	Niraimathi	11.727576°N–79.015314°E	2	24	1	4	9	0	0	10	22
17	P. Konalavadi	11.720749°N–79.266429°E	2	9	0	0	5	2	0	2	10
18	P. Malaiyanoor	11.689187°N–79.215930°E	1	23	0	1	19	0	0	3	38
19	Periyamambattu	11.730288°N–79.107724°E	3	26	0	1	19	4	2	0	30
20	Pinnalavadi	11.746075°N–79.140752°E	1	20	2	3	8	0	4	3	31
21	Poraiyur	11.694635°N–79.147242°E	10	149	1	0	79	7	22	40	153
22	Prithivimangalam	11.736117°N–79.062063°E	2	22	2	1	10	5	2	2	30
23	Pudhukeni	11.656788°N–79.178831°E	2	9	0	0	9	0	0	0	18
24	Pudu Uchimedu	11.627965°N–79.109939°E	2	45	0	0	8	6	24	7	63
25	Ravuthanayankuppam	11.684929°N–79.267855°E	3	13	0	0	8	2	2	1	17
26	Rottumangalam	11.71844°N–79.153619°E	1	8	0	0	4	2	0	2	6
27	Saalapakkam	11.723739°N–79.156647°E	4	19	2	1	15	0	0	1	18
28	Seevamangalam	11.660459°N–79.170434°E	3	86	0	1	65	3	7	10	23
29	Sembatta malayanoor	11.757158°N–79.218858°E	7	78	8	2	41	8	8	11	90
30	Sembimadevi	11.719075°N–79.160805°E	5	43	3	0	29	0	5	6	60
31	Sirunagalur	11.679898°N–79.157217°E	4	19	0	1	18	0	0	0	19
32	Sirupakkam	11.712586°N–79.225664°E	1	30	6	1	14	0	2	7	48
33	Siruvathur	11.678482°N–79.204069°E	4	20	0	0	17	0	0	3	20
34	Thakka	11.704111°N–79.267421°E	1	4	0	0	3	1	0	0	4
35	Thenerikuppam	11.145194°N–79.138345°E	9	65	4	3	38	0	9	11	64
36	Thimmalai	11.730138°N–79.123026°E	16	216	6	4	110	8	50	38	262
37	Tiruppeyar	11.648811°N–79.200328°E	2	4	0	0	4	0	0	0	5
38	Vadakurumboor	11.774587°N–79.213622°E	2	10	0	0	7	2	0	1	11
39	Vazhavandankuppam	11.724222°N–79.124699°E	8	69	0	1	46	8	4	10	94
40	Vellaiyur	11.722458°N–79.241880°E	22	198	6	1	99	18	29	45	237
41	Vengaivaadi	11.679030°N–79.095074°E	1	7	2	4	1	0	0	0	7
42	Emam	11.736110°N–79.243968°E	3	12	1	0	10	0	0	1	12
Total			**155**	**1725**	**61**	**48**	**958**	**125**	**247**	**286**	**1993**

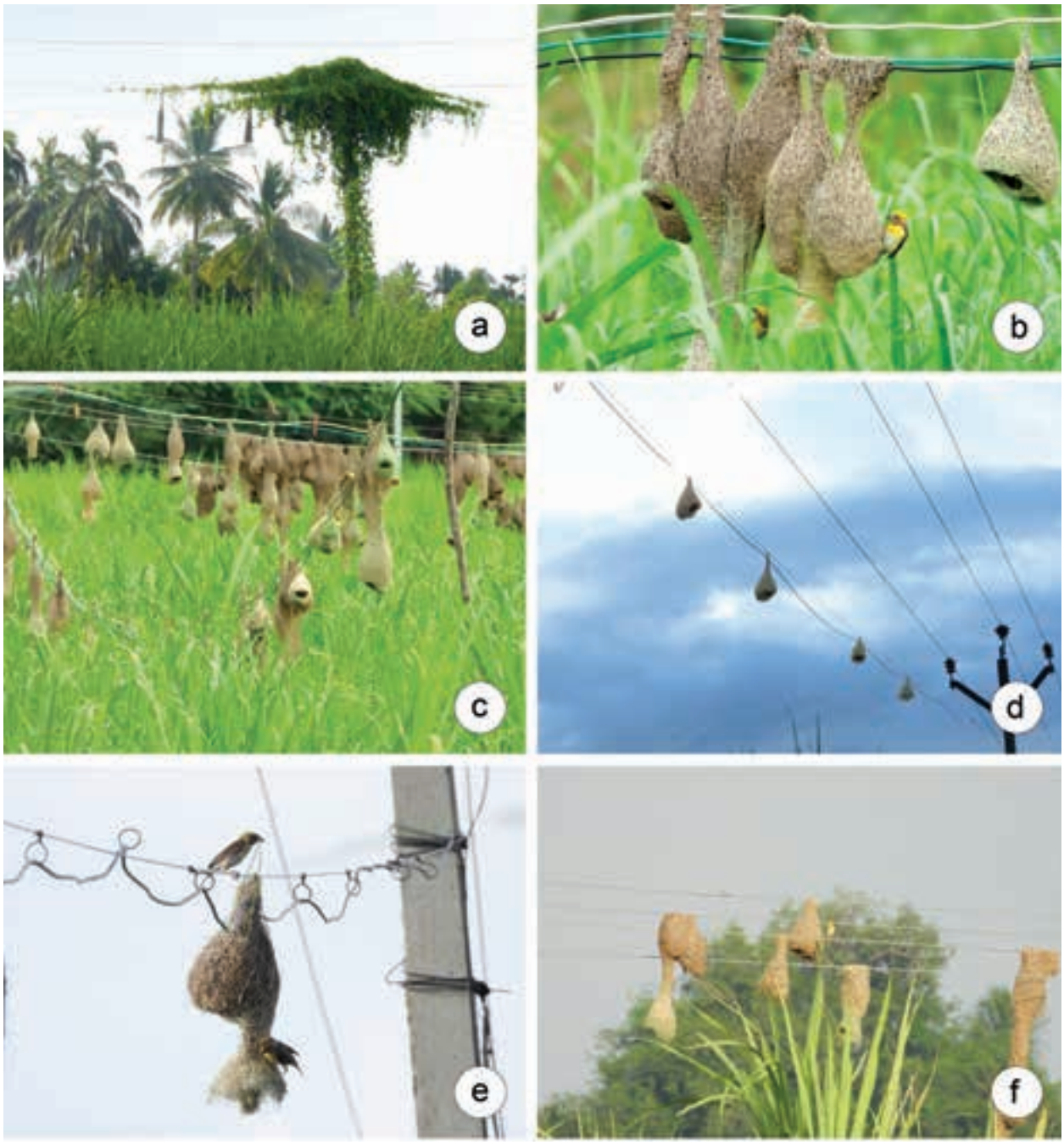

Image 1. Pictures showing overhanging nest colonies: a—Climber *Cocculus carolinus* spread over electric pole and cables and nests attached to power cable and climber | b—Nests attached to power cables overhanging harvested sugarcane field, (c) Nests attached to multiple service cables leading to motor pump sets | d—Nests attached at joints of television cable and supporting string | e—Nest attached to television cable and supporting string | f—Nests attached to joints of power cable and reel insulators. © M. Pandian.

Crops occurred close to nest colonies

Even though cables bearing nest colonies directly overhanging sugarcane crops, 63% nests (n = 1,086) and 67% birds (n = 1,276) occurred within 200 m distance from paddy crops. Another 37% nests (n = 639) and 33% birds (n = 640) occurred within 250 m distance from paddy and millet crops, such as pearl millet, finger millet, sorghum, and foxtail millet. Hence, all the cables bearing nests occurred within 250 m distance from grain and millet crops. It indicated that the Baya Weavers preferred their nesting sites close to grain crops.

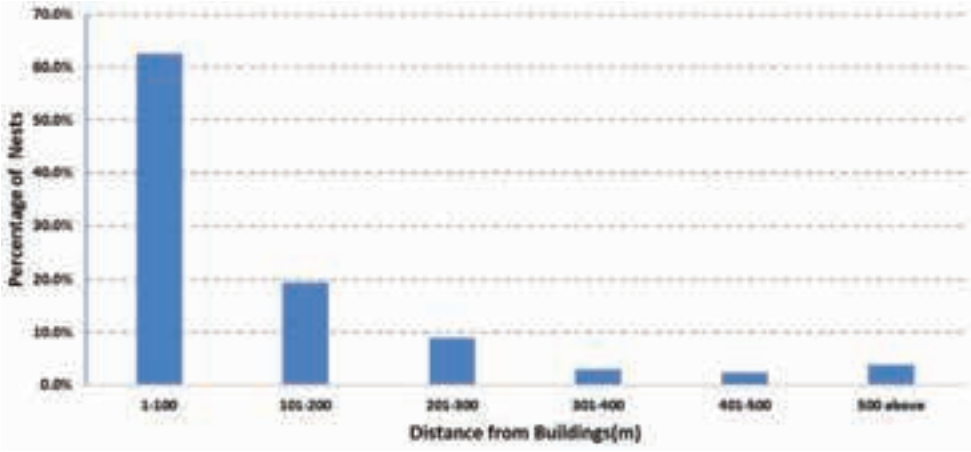

Figure 2. The distance between the nearest buildings and cables bearing nest colonies.

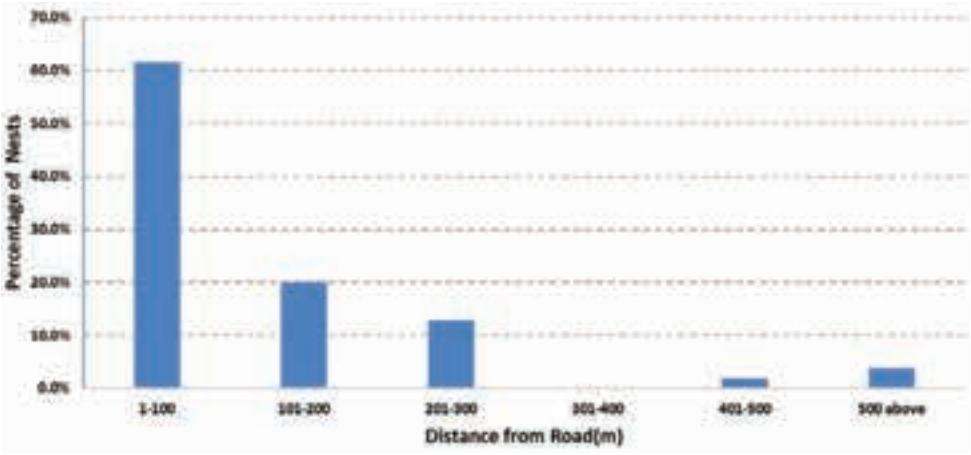

Figure 3. The distance between the nearest roads and cables bearing nest colonies.

Crop bunds

The study on the relationship between the distance of nest colonies (n = 155) with bunds in the crop fields were as follows: two nest colonies were found directly overhanging bunds; 21 colonies were found 1–2 m away from the bunds; 68 colonies at 3–4 m distance; 43 colonies at 5–6 m; 21 colonies at >6 m. The study revealed that only 1.3% nest colonies (n = 2) were found directly overhanging crop bunds and the remaining 98.7% nest colonies (n = 153) were found away from bunds and overhanging sugarcane crops.

Source of fibres

Study on the source of nest materials revealed that male Baya Weaver used leaves of Sugarcane *Saccharum officinarum* as nesting materials.

Stages of nest constructions

A total of 1,725 nests observed at the end of the breeding period (2nd week of November 2021) that included: wad stage nests–3.5% (n = 61), Ring stage–2.8% (n = 48), helmet stage nests–55.5% (n = 958), egg-chamber closed stage nests–7.2% (n = 125), complete nests–14.3% (n = 247), and abnormal nests–16.6% (n = 286). An average of 11 nests per colony was found in the study area (Figure 5).

Nest colonies

The number of nests in each nest colony varied: 63.8% of nest colonies (n = 99) bore nests ranged between 1–10. These include 13 nest colonies contained solitary nests, whereas 17.5% of nest colonies (n = 21) bore 11–20 nests, 10.3% nest colonies (n = 16) bore 21–30 nests, 5.2% (n = 8) colonies bore 31–40 nests. The remaining 3.2% nest colonies (n = 5) contained 41–57

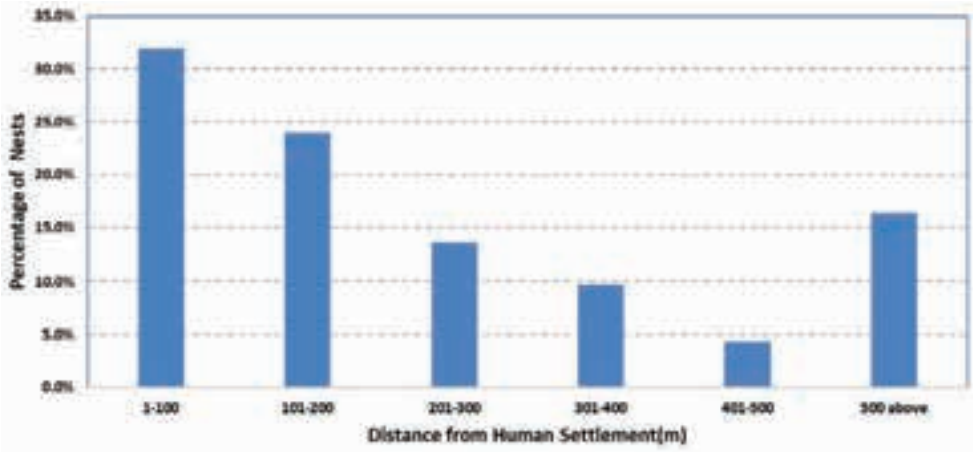

Figure 4. The distance between the nearest human settlement and cables bearing nest colonies.

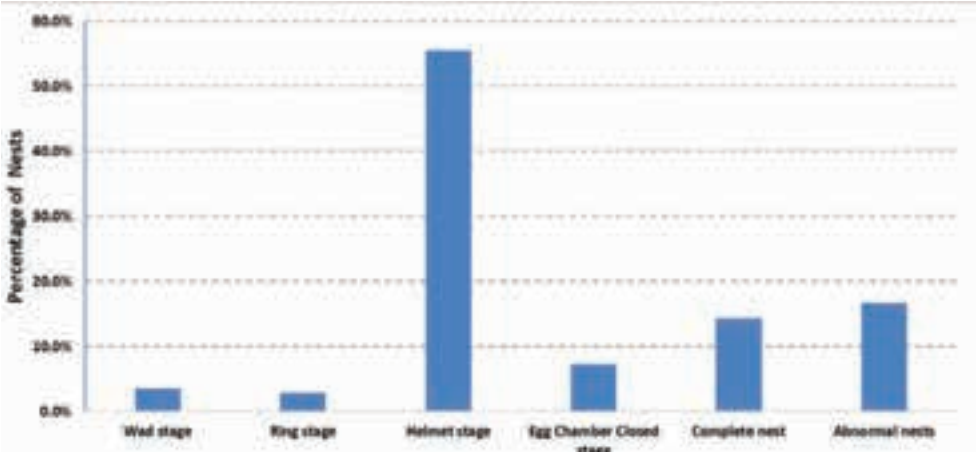

Figure 5. Details of various developmental stages of nests of Baya Weaver counted in the study area.

nests. The average number of nests per colony was 11. The heights between the overhanging nest colonies and the tip of sugarcane crops were found varied 1–2.5 m. However, nests of 27 colonies were found directly touching the sugarcane crops.

Abnormal nests

Abnormal nests constituted 17% (n = 286) of the total nests (n = 1,725) with 11 types of variations: 55% (n = 156) abnormal nests belonged to 1+1/2 storeyed type, followed by 16% (n = 46) mixed abnormal types, 8% (n = 23) 1+1 storeyed type, 7% (n = 21) chain storeyed type, 5% (n = 14) ½+½ storeyed, 5% (n = 14) fused nests, and 2% (n = 6) multi-stalked type. The remaining four nests (2%) constituted: two nests were bell-jar shaped and one was meshed type and another nest contained three openings.

Deposition of clay in the nests

The study on 778 helmet stage nests using binoculars revealed that clay deposits were found in 90% (n = 716) nests and no such clay deposit was observed in the remaining 10% helmet stage nests (n = 62). Exceptionally the birds plastered the entire outer walls of 42 completed nests with wet clay. The examination of six fallen nests of such category reveals that spaces between interwoven fibres were completely filled with clay and the nests resembled unfired wet clay pots (Image 3).

Associated birds

The study revealed that 16 other bird species were found associated with Baya Weaver during perching/roosting on power cables, sugarcane crops, *Prosopis juliflora* trees and while foraging on grain/millet crops. Of them only three other bird species have shared common foraging grounds. No antagonistic behaviours

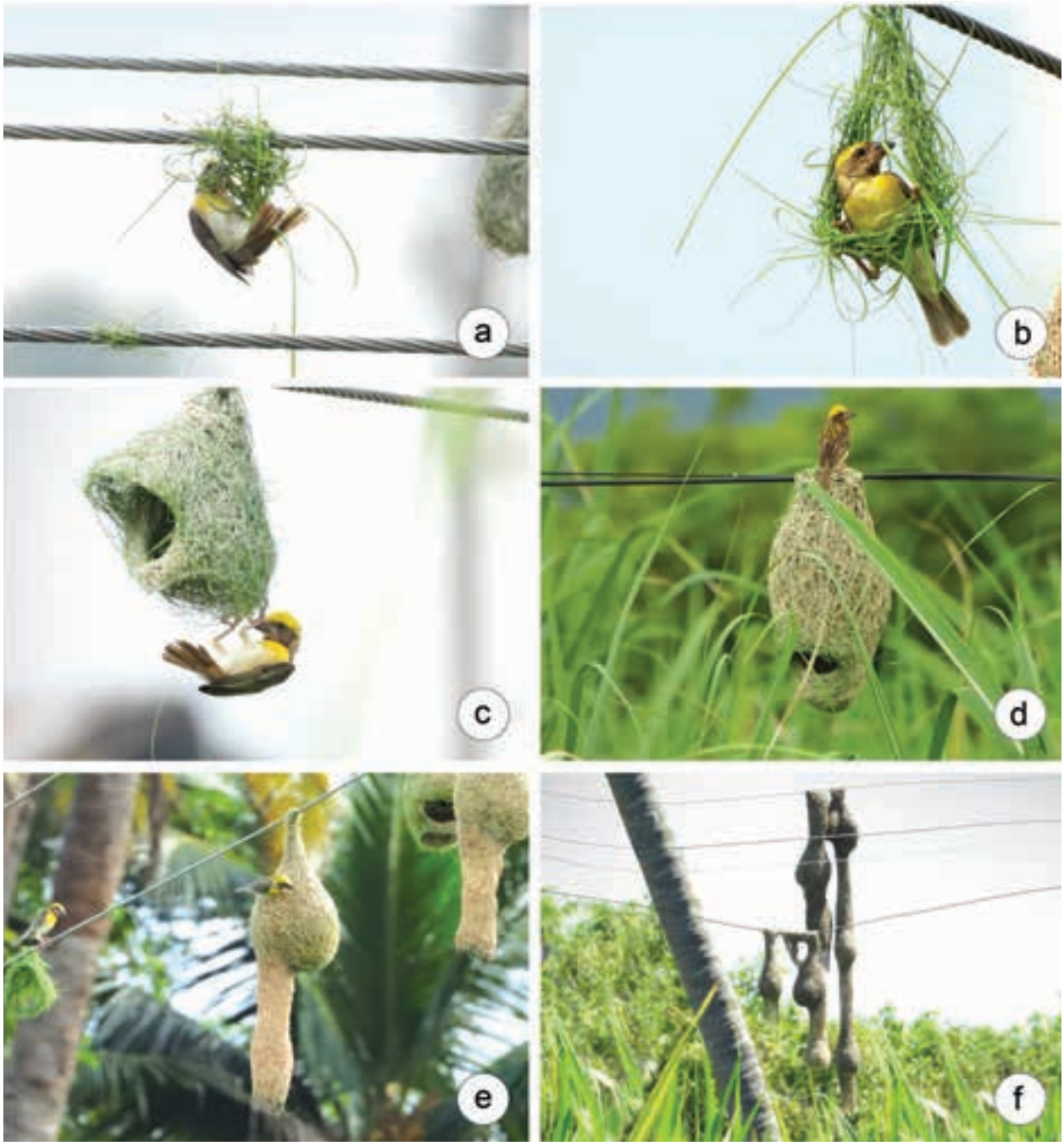

Image 2. Images showing various stages of nest developments: a—Wad stage nest | b—Ring stage nest | c—Helmet stage | d—Egg-chamber closed stage | e—Complete nest | f—Abnormal nests. © M. Pandian.

were observed between them over sharing of common perching/roosting and foraging sites. All the bird species had followed mixed communal roosting behaviours. Apart from that four pairs of Indian Silverbill *Euodice malabarica* had occupied complete nests (n = 4) of Baya Weaver, but it was not possible to ascertain whether they occupied the abandoned nests or usurped the nests of the latter (Table 2; Image 4).

Nest predation

Six avian predators were observed in the proximity of nesting colonies. Incidents of nest predation by Rufous Treepie *Dendrocitta vagabunda* (24) and Coucal *Centropus senegalensis* (12) were recorded. A total of 197 nests (egg-chamber closed stage 55; complete nests 82; and abnormal nests 60) were observed in a damaged condition by having circular holes near egg-chambers or

Table 2. Details of other bird species found associated with Baya Weaver during perching/roosting and foraging in the study area.

	Name/common name of the bird	Binomial	Total no. roosting with Baya Weaver	Total no. of foraging with Baya Weaver
1	Common Myna	*Acridotheres tristis* (Linnaeus, 1766)	35	0
2	Common Babbler	*Argya caudata* (Dumont, 1823)	26	02
3	Indian Silverbill	*Euodice malabarica* (Linnaeus,1758)	70	07
4	White-rumped Munia	*Lonchura striata* (Linnaeus, 1766)	63	13
5	Re-vented Bulbul	*Pycnonotus cafer* (Linnaeus, 1766)	11	0
6	Red-whiskered Bulbul	*Pycnonotus jacosus* (Linnaeus,1758)	08	0
7	Coppersmith Barbet	*Psilopogon haemacephalus* (Statius Muller, 1776)	13	0
8	Pied Bush Chat	*Saxicola caprata* (Linnaeus, 1766)	23	0
9	Grey-breasted Prinia	*Prinia hodgsonii* (Blyth, 1844)	42	0
10	Long-tailed Shrike	*Lanius schach* (Linnaeus, 1758)	06	0
11	Pied Cuckoo	*Clamator jacobinus* (Boddaert,1783)	17	0
12	Asian Green Bee-eater	*Merops orientalis* (Latham, 1801)	85	0
13	Spotted Dove	*Spilopelia chinensis* (Scopoli, 1768)	06	0
14	Black Drongo	*Dicrurus macrocercus* (Vieillot, 1817)	127	0
15	Common Kingfisher	*Alcedo atthis* (Linnaeus, 1758)	42	0
16	Indian Roller	*Coracias benghalensis* (Linnaeus,1758)	35	0
		Total	609	22

Table 3. Details of sightings of avian predators and their impact on the nesting colony in the study area.

	Name of the predator	Binomial	No. of sightings noted	Damages caused to nests
1	House Crow	*Corvus splendens* (Vieillot, 1817)	12	2
2	Large-billed Crow	*Corvus macrorhynchos* (Wagler, 1827)	8	1
3	Coucal	*Centropus senegalensis* (Linnaeus, 1766)	15	12
4	Black Drongo	*Dicrurus macrocercus* (Vieillot, 1817)	127	4
5	Shikra	*Accipiter badius* (Gmelin, 1788)	5	2
6	Rufous Treepie	*Dendrocitta vagabunda* (Latham, 1790)	34	26
	Total		201	47

torn the nests (Table 3; Image 5). The study revealed that out of 1,725 nests recorded, about 1.1% nests (n = 197) were probably damaged by the avian predators.

Nest damages by fire

In one of the nesting sites in Poraiyur village (11.6946^{0}N—79.1472^{0}E), an incident of c.300 sq.km area of sugarcane crop below the power cables bearing nests were gutted to fire probably due to scratching of moit nests after rainfall. In that fire accident, all the nests overhanging the sugarcane crop were burnt. It was not possible to ascertain the number of nests gutted to fire. The accidental fire occurred probably due to electrical short circuits.

DISCUSSION

Preference of cables for construction of nests

In the study areas, Baya Weavers had commonly built their nests on power cables. Baya Weavers constructing nests on telegraph and electric wires are common in India (Bhargava 2017), between Chitttoor and Chandragiri regions (Kirkpatrick 1952), Kumaon Terai region of Uttarakhand (Ambedkar 1969), Tamil Nadu and Assam (Davis 1976) and between Bangalore (Bengaluru) and Madras (Chennai) regions (Subramanya 1982). However in the present study, all the nesting colonies (n = 155) were found attached to cables overhanging sugarcane crops corroborate the findings

Image 3. Clay deposits in the nests: a—Inner wall of helmet stage nest contained a clay patch | c&d—Clay plastering on entire nest | d—Torn nest showing plastering of clay on entire inner walls. © M. Pandian.

of Ambedkar (1969), Kirkpatrick (1952), Davis (1976), and Subramanya (1982). However, no nest colonies were found overhanging paddy crops in the study areas.

Birds have been found to have made nests at odd places like electric transmission cables when other suitable nesting sites were scarce (Toland 1990; Chace & Walsh 2006). However, in the present study area, it was found that in spite of availability of sufficient number of potential nest-supporting palm trees (2,874) in a 500-m radii, Baya Weaver chose cables, indicating that in this instance, it is not the absence of traditional nesting sites that was reason to choose the cables as found by Toland (1990) and Chace & Walsh (2006).

Preference of Baya Weaver in building nests on cables occurring close to human dwellings

Baya Weavers built nests close to human settlement and foraging sites and also trying to coexist with humans (Ulman 2020). The study on the relationship between proximity of roads, buildings, and human settlement and selection of nesting sites, i.e., power/television cables revealed that the birds preferred to build nests on cables occurred close to areas, such as human dwellings, buildings like cattle shed and motor-pump sets, and roads as stated by Ulman (2020). The birds might have selected agricultural landscape due to the availability of nesting sites like power cables and palm trees and also the availability of grain crops close to nesting sites as Baya Weaver are granivorous.

Crop bunds

The preference of nesting sites on cables away from crop bunds indicate that the birds might have preferred power cables away from bunds/pathways probably to keep a distance/height from the reach of humans, and terrestrial predatory animals.

Source of fibres

Baya Weavers were found to have used fibres from palm fronds and grass leaves to construct nests in Sri Lanka (Wood 1926), coarse grass, paddy, and *Phoenix* spp., in Kolaba District, Maharashtra (Ali 1931), and

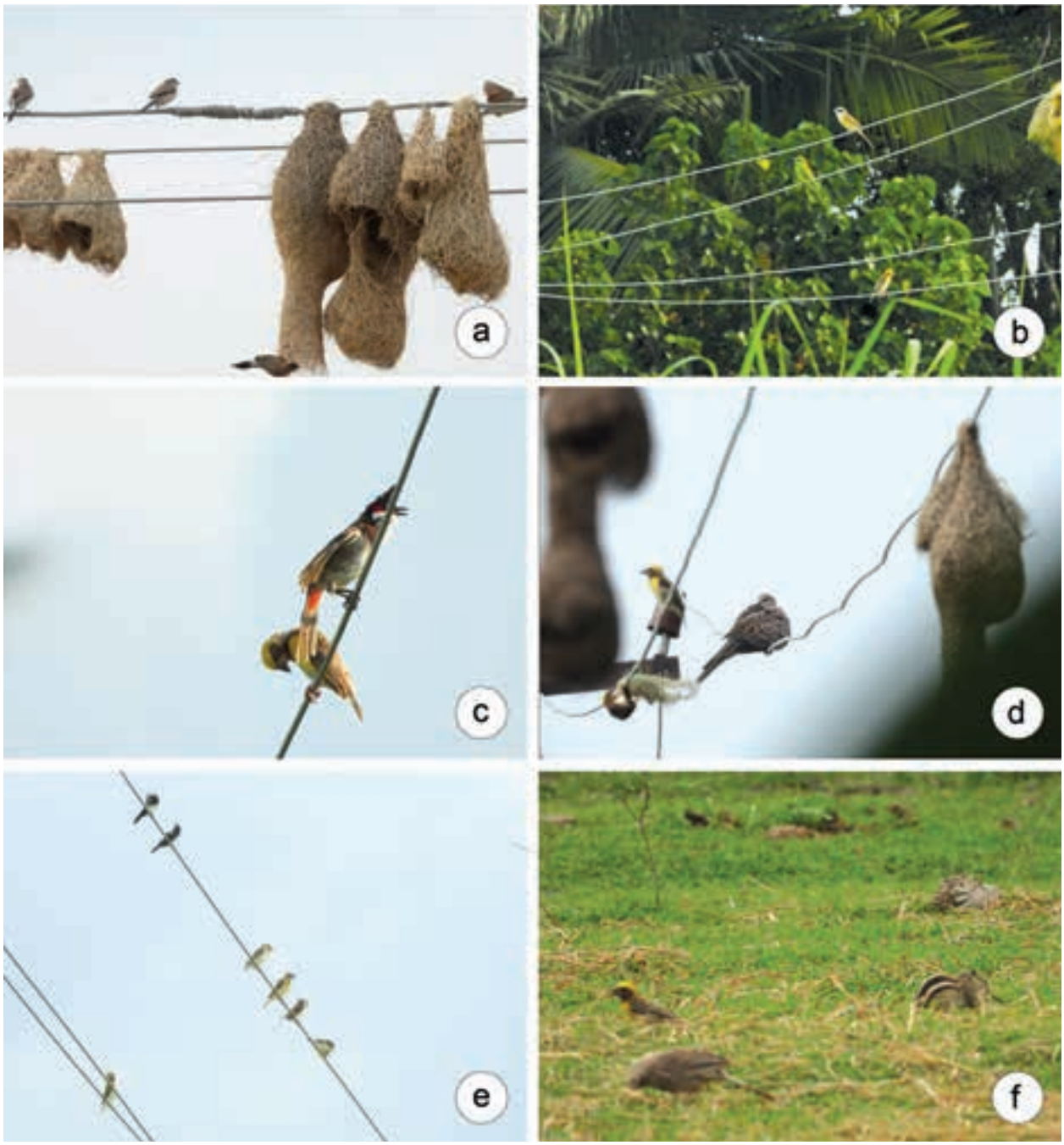

Image 4. Pictures showing associated birds with Baya Weaver: a—Indian Silverbill perching on cables and entering an occupied complete nest of Baya Weaver | b—Asian green bee-eater and Lon-tailed Shrike roosting with Baya Weaver | c—Baya Weaver roosting with Red-whiskered Bulbul | d—Spotted Dove roost near a nest of Baya Weaver | e—White-rumped Munia roosting with Baya Weaver | f—Common Babbler forages with Baya Weaver. © M. Pandian.

paddy, sugarcane, maize, guinea grass and palm fronds in Assam (Ulman 2020), whereas in this study, the birds used fibres from leaves of sugarcane alone. Since all the nests were found on cables overhanging sugarcane crops, the birds had preferred fibres of sugarcane leaves due to proximity of sugarcane crops than other palm trees.

Nest colonies

Baya Weaver is a colonial bird and hence lives in large colonies (Ulman 2020). Sharma (1989) had observed that each nest colony had consisted of 1–250 nests in Rajasthan, 5–24 nests in South Goa (Borkar & Komarpant 2003), 20–30 nests in Assam (Ulman 2020), and 1–61 nests in Vellore District, Tamil Nadu (Pandian 2021). In

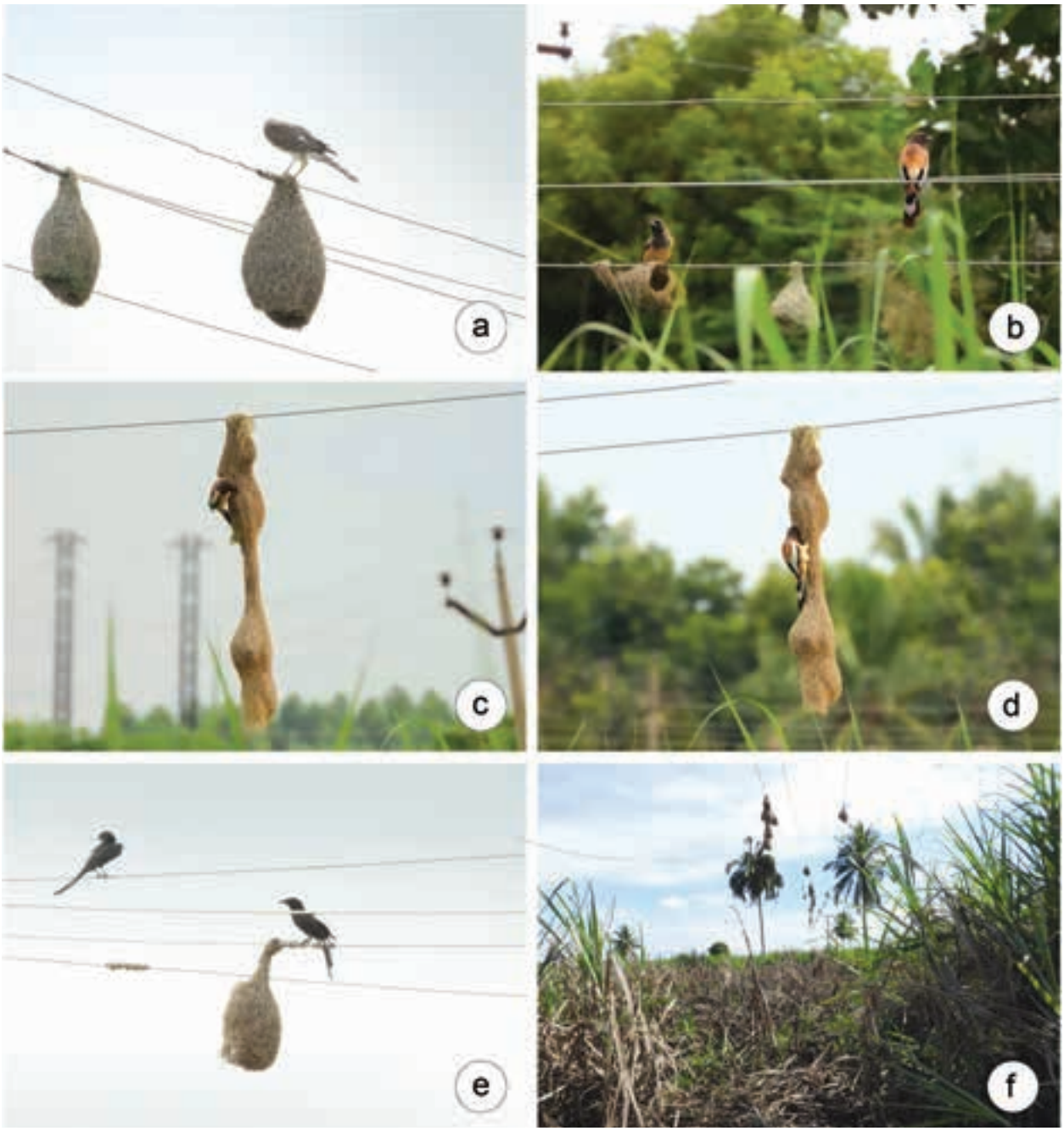

Image 5. Pictures showing probable threats to Baya Weaver: a—Shikra perching on the egg-chamber closed stage nest | b—Rufous Treepie pulled helmet stage nest to cause damage | c&d—Rufous Treepie made a hole and poked its head into an egg-chamber | e—Black Drongo plucked fibres from egg-chamber closed stage nest | f—Sugarcane crop gutted to fire due to short circuit in a wetted nest colony. © M. Pandian.

the present study, the number of nests per colony was found ranging from one to 57 nests.

Nesting substrata

Out of a total of 1,725 nests, 933 nests were found attached to more than one cable or attached at the joints of cables and reel insulators. But in the remaining 792 nests, the knot of one nest was found attached to the knot of adjacent nest and in this manner the knots of all nests were connected adjacently on the cable and formed a mesh like structure. Probably due to the slippery nature of aluminium power cables and smooth surface of service/television cables, the birds might have plaited knots using multiple cables or at the junctures of cables and insulators. Hence, it revealed that the birds required coarse surface or sufficient grip on the cables

for plaiting initial knots.

Abnormal nests

The behaviour of construction of abnormal nests also occurs in some other species of the family *Ploceidae*, such as Black-breasted Weaver *Ploceus benghalensis*, Spectacled Weaver *Ploceus ocularis*, African Black-headed Weaver *Ploceus cucullatus*, Streaked Weaver *Ploceus manyar*, and Sakalava Weaver *Ploceus sakalava* (Delacour 1947; Collias & Collias 1962; Maclean 1985; Mishra 2004). In India, the abnormal nests of Baya Weaver was studied by several authors like Ali et al. (1956), Ambedkar (1958), Sharma (1985, 1988, 1995), and Pandian (2018). The present observations of 11 types of abnormal nests in the study area corroborate the findings of the authors cited above.

Clay deposits

The habits of smudging of clay in the nests are common in three species of Asian weavers (*P. philippinus*, *P. manyar*, and *P. benghalensis*) and not found in African weaver (Crook 1963; Davis 1973). Plastering of inner walls of nest with wet clay is done when the nest construction reaches the helmet stage prior to pairing with females (Dewar 1909; Ali 1931; Ambedkar 1969; Borkar & Komarpant 2003). Hence, the present observations of clay deposits on the inner walls of helmet stage nests corroborate the findings of above authors.

Davis (1973) had recorded that 18.33% nests did not show presence of mud blobs on the inner walls of nests in South Goa. In the present study also 10% helmet stage nests did not show traces of clay and hence it matches with the observations of Davis (1973). As a peculiar feature, plastering of clay on the entire nest walls (n=42) were observed. Probably the birds might have plastered the entire nest walls with wet clay to reinforce the nest walls to protect the nests from avian predators. In this aspect, further detailed study is required.

Associated birds

The mixed communal roosting consisting of different species serves as centre for the instant exchange of information regarding the location of food sources and receives warning about the approach of any predators (Zahavi 1971; Gadgil 1972; Ward & Zahavi 1973; Gadgil & Ali 1975). In the present study also Baya Weaver was found associated with 16 other bird species and shares common roosting and foraging sites among them without any competitions and hence, it matches with the observations of Zahavi (1971); Gadgil (1972); Ward & Zahavi (1973); and Gadgil & Ali (1975)

Nest predation

Nest predation by House Crow, Large-billed Crow, and Rufous Treepie were reported by Ali et al. (1956) and Pandian (2021). In the present study also incidents of House Crow and Large-Billed Crow damaging nests of Baya Weaver were observed. Nest predations by piercing circular hole near egg-chamber by Rufous Treepie and Coucal were recorded. Instances of nest damages by Black Drongo were observed but no predation of eggs/chicks was noticed. It clearly indicates that these predators might have damaged the nests (n = 197) probably to predate eggs/chicks. Apart from nest predation, nests damage by electrical short circuit was also reported in one village. The impact of nest predation by avian predators and nest damages by short circuit on the breeding of Baya Weaver on larger geographical areas need further studies.

CONCLUSION

This is a first systematic study on the preference of Baya Weaver towards overhead power transmission cables, service cables connected between electricity poles and motor pump sheds, and television cables as nesting sites, stages of nests, abnormal nests, associated birds, and threats to the nests in the agrarian landscape of the study area. The survey revealed that Baya Weavers preferred and built nests on power cables/television cables and avoided readily available potential nest-supporting trees, such as *B. flabellifer* and *C. nucifera* for nesting in the study areas. The Baya Weavers had used only leaf fibres of sugarcane for building nests. They preferred power cables hanging over sugarcane crops as nesting sites and shared common roosting sites and foraging grounds with other associated birds. Increasing urbanization by conversion of cultivated lands into residential areas, industrialization, widening of roads along with indiscriminate felling of these principal nest-supporting trees that are vital for Baya Weaver will pose a threat to the populations of this bird in the landscape. Considerable damages to nests occurred due to avian predators. The practices of monoculture of *Casuarina*, sugarcane, vegetables, and flower crops by abandoning the traditional cultivation of cereals and millets crops in the study sites may cause shortage of food grains to adult birds. Though this bird falls in the least concern status of IUCN, it is better to start protecting the populations of this species and their habitats. Local communities,

particularly land holders, agricultural workers, and school students should be sensitized to understand the need to preserve the nesting habitats of this species.

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ARTICLE

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Factors influencing the occurrence of the House Sparrow *Passer domesticus* (Linnaeus, 1758) (Aves: Passeriformes: Passeridae) in Bhavnagar, Gujarat, India

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Abstract: The present study aims to understand key factors influencing the House Sparrow population across different habitat scales in Bhavnagar, Gujarat, India. Correspondingly, different variables such as changes in habitat composition, sound levels, and density of mobile phone base stations were considered with reference to the occurrence of the House Sparrows across the study area. During the study period (December 2016 to November 2018), the number of House Sparrows was recorded through point count without distance estimate method. Non-parametric tests were employed to assess variations in different variables and their correlation with the presence of House Sparrows, revealing that changes in local habitat composition significantly influence their occurrence. Shrubby vegetation, cowsheds, and old/traditional structures emerged as crucial predictors positively impacting House Sparrow's presence, particularly in urban areas where suitable habitat patches are scarce due to urbanization and modern lifestyles. The decline in these habitats has significantly impacted House Sparrow populations. To counter this decline, implementing strategies like providing artificial nest sites is being considered. However, it's crucial to ensure that there are adequate shelter and food resources available to effectively conserve the species.

Keywords: Bushy vegetation, cowsheds, electromagnetic radiation, green cover, habitat change, house sparrow density, mobile phone base station, nesting habitats, sound level, urbanization.

Gujarati: પ્રસ્તુત અભ્યાસનો ઉદ્દેશ્ય ભારતના ગુજરાત રાજ્યમાં આવેલ ભાવનગર શહેર ના વિવિધ પ્રકાર ના વસવાટો માં ઘર ચકલી ની વસ્તીને પ્રભાવિત કરતા મુખ્ય પરિબળોને સમજવાનો છે. જેને અનુરૂપ, સમગ્ર અભ્યાસ વિસ્તારમાં જોવા મળતી ઘર ચકલી ના સંદર્ભમાં વિવિધ ચલ જેમ કે વસવાટ-ની રચનામાં ફેરફાર, ધ્વનિ સ્તર અને મોબાઇલ ફોન બેઝ સ્ટેશનની ઘનતા ને અભ્યાસ દરમ્યાન ધ્યાનમાં લેવામાં આવી હતી. અભ્યાસ સમયગાળા દરમિયાન (ડિસેમ્બર ૨૦૧૬ થી નવેમ્બર ૨૦૧૮), ઘર ચકલી ની સંખ્યા અંતર અંદાજ પદ્ધતિ વિના પોઇન્ટ કાઉન્ટ દ્વારા નોંધવામાં આવી હતી. વિવિધ ચલોમાં ભિન્નતા અને ઘર ચકલી ની હાજરી સાથેના તેમના સહસંબંધનું મૂલ્યાંકન કરવા માટે બિન-પેરામેટ્રિક પરીક્ષણોનો ઉપયોગ કરવામાં આવ્યો હતો, જે દર્શાવે છે કે સ્થાનિક વસવાટની રચનામાં ફેરફાર તેમની ઘટનાને નોંધપાત્ર રીતે પ્રભાવિત કરે છે. ખાસ કરીને શહેરી વિસ્તારોમાં જ્યાં શહેરીકરણ અને આધુનિક જીવનશૈલીને કારણે યોગ્ય વસવાટની જગ્યાઓ દુર્લભ છે, ત્યાં ઝાડી-ઝાંખરા વાળી વનસ્પતિ, ગૌશાળા/પશુપાલન અને જૂની/પરંપરાગત બાંધકામ ની રચનાઓ ઘર ચકલી ની હાજરીને સકારાત્મક અસર કરતા પરિબળો તરીકે નોંધાયા છે. આ વસવાટોમાં થયેલા ઘટાડાએ ઘર ચકલી ની વસ્તીને નોંધપાત્ર રીતે અસર કરી છે. આ ઘટાડાનો સામનો કરવા માટે, કૃત્રિમ માળાઓ પ્રદાન કરવા જેવી વ્યૂહરચનાઓ ધ્યાનમાં લેવામાં આવી રહી છે. જો કે, પ્રજાતિઓને અસરકારક રીતે બચાવવા માટે પર્યાપ્ત આશ્રય અને ખાદ્ય સંસાધનો ઉપલબ્ધ છે તેની ખાતરી કરવી પણ મહત્વપૂર્ણ છે.

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INTRODUCTION

The House Sparrow *Passer domesticus* (Linnaeus, 1758) is an excellent urban exploiter species. Due to its sensitivity to changing urban environments, it can be considered as a model species for investigating the effects of urbanization (Manger 2008; Meillère et al. 2015a; Hanson et al. 2020; Mohring et al. 2021). Although the species has widespread distribution, alarming decline in the House Sparrow populations have been reported from different parts of the world (Crick et al. 2002; Summer-Smith 2003; Raven et al. 2005; Murgui & Maclas 2010; Summers-Smith et al. 2015). Studies in India have also shown a decline in the population of House Sparrows (Ghosh et al. 2010, Khera et al. 2010; Modak 2017). Besides, recent analyses suggest that changes in House Sparrow population show marked regional variation and are especially severe in urbanized habitats (Siriwardena et al. 2002; Chamberlain et al. 2005; Mohring et al. 2021). Many studies have noticed a pattern, where socioeconomically deprived areas harbour a large number of House Sparrows with a lower rate of population decline (Dröscher 1992; Bland 1998; Paston 2000; Robinson et al. 2005). Despite being an intriguing urban dweller, it appears that the heavily human modified urban environment has adverse effects on this urban sentinel species (Siriwardena et al. 1998; Balaji et al. 2014; Modak 2017; Meeran et al. 2021; Mohring et al. 2021).

Various hypotheses that negatively affect the House Sparrow population are proposed, including habitat change, specifically the loss of feeding, sheltering, or nesting sites (Vincent 2005; Anderson 2006; Shaw et al. 2008; Mouldrá et al. 2018). Additionally, the population decline may be attributed to the intensification of pollution sources such as traffic pollution (Summers-Smith 2003; Peach et al. 2008; Herrera-Dueñas et al. 2017), noise pollution (Bhattacharya et al. 2011; Meillère et al. 2015b), light pollution (Ghosh et al. 2010; Dominoni et al. 2013), air pollution (Summers-Smith 2003; Eeva et al. 2009), and electromagnetic radiation (Balmori & Hallberg 2007; Everaert et al. 2009). Additionally, these several stressors may interact and contribute cumulatively to the decline of House Sparrows (De Coster et al. 2015). However, conclusive evidence for any of these causes is still lacking.

There has been a great deal of research conducted in European countries concerning the decline of the House Sparrow population (Summers-Smith 2005; Wilkinson 2006; Chamberlain et al. 2007; Murgai & Maclas 2010; Peach et al. 2015; Ponce et al. 2018; Mohring et al. 2021). In India, the decline in the House Sparrow population has engendered deep public concern, particularly across Delhi, Haryana, Uttar Pradesh, and in West Bengal (Dandapat et al. 2010; Ghosh et al. 2010; Khera et al. 2010; Kumar et al. 2015; Patel & Dodia 2017); however, the proximate causes of this decline remain poorly understood. A relatively limited amount of information is currently available regarding the species' habitat associations within urbanized environments in India (Hussain et al. 2014). Besides, most of studies related to factors affecting House Sparrows' population has been conducted in southern India (Kurhade et al. 2013; Balaji et al. 2014; Pandian & Natarajan 2018; Maxmellion et al. 2020; Meeran et al. 2021; Pandian 2023; Veerá & Lanka 2023), in northern India (Hussain et al. 2014; Wani & Sahi 2018; Waldia & Bhatt 2022) and few from West Bengal (Ghosh et al. 2010; Modak 2017). However, a systematic account on factors influencing House Sparrow occurrence in Gujarat are lacking.

The present study pertains to examine the impact of different variables including habitat composition, sound levels, and density of mobile phone base stations on the occurrence of the House Sparrows across different habitat scale in Bhavnagar, Gujarat, India. The data set would be useful for identifying underlying environmental or anthropogenic factors negatively affecting the House Sparrow population. Moreover, understanding the factors contributing to the decline of the House Sparrow population will assist in developing effective conservation strategies.

MATERIALS AND METHODS

Study area

The present study was conducted in and around the coastal city of Bhavnagar in the Saurashtra region of Gujarat, India (Image 1). The area encompassed by the city of Bhavnagar is approximately 119 km^2, as reported by the Bhavnagar Municipal Corporation (2023). The Gulf of Khambhat lies on the west side of Bhavnagar. The outer region of the city is drained by Kansara, a small river that flows intermittently and is nonperennial in nature.

Throughout the year, Bhavnagar's climate remains fairly humid due to its proximity to the Gulf of Khambhat. There is a hot semi-arid climate with a hot dry summer, a wet monsoon, and a mild winter. Bhavnagar is a Class I Urban Agglomeration with a population density of 4,700 persons per km^2 (Bhavnagar Urban Region Population 2011 – 2024 (2022); Bhavnagar Municipal Corporation

(2023)). Due to the presence of the Bhavnagar Port, industrial growth has been catalysed in the city. As a result, Bhavnagar has become a hub for various industries, including diamond cutting and polishing units, salt and marine chemicals, plastics, shipbuilding, textiles, chemicals, and wood products. Major crops are Cotton, Groundnut, Bajra, Sesame, Jowar, Onion, while major horticultural crops include Mango, Citrus, Sapota (Chiku), and Banana (Jagdish 2022). Vegetation mostly dominated by deciduous plant species such as Gando Baval *Prosopis juliflora*, Desi Baval *Acacia nilotica*, Gorad Baval *Acacia senegal*, Khijado *Prosopis cineraria*, and Khati Amli *Tamarindus indica*.

Study design

In order to identify differential responses of the House Sparrow to distinct habitat scales, the study area has been divided into three gradients, namely: urban (URB) – dense residential area in the city; suburban (SUB) – area adjacent to the city or surrounding the main city (located at an approximate 2 km distance adjacent to the core city area); and rural (RUR) – open countryside outside the densely populated urban towns or city (approximate distance of 9–10 km from the core city area). Based on the primary survey, three potential sites (harbouring more than 100 House Sparrows) were selected from each gradient; hence, a total of nine sites were monitored throughout the study period. To avoid biases in the data collection due to the population mixture of different sample sites, it was ensured that each sample site was at least 2-km apart from each other. Hence, 2 × 2 km grids were created and superimposed over the study area with the help of Google Earth Pro v. 7.3.6.9345 (2022). From the urban gradient – Barsomahadev (URB1) (21.774N,72.139E), Bharatnagar (URB2) (21.744N, 72.160E), and Anandnagar (URB3) (21.788N, 72.157E) study sites were selected for data collection; while from the suburban gradient – VP Society (SUB1) (21.759N, 72.170E), Forest Colony (SUB2) (21.737N, 72.150E), and Fulsar (SUB3) (21.746N, 72.094E) study sites were selected for data collection; and from the rural area – Akwada (RUR1) (21.739N, 72.180E), Nari (RUR2) (21.783N, 72.077E), and Sidsar (RUR3) (21.721N, 72.110E) study sites were selected for the study.

Methods

The study period has been divided into four seasons,

Image 1. Google Earth satellite image showing nine different sampling sites within the study area (approx. grid line of 2 × 2 km).

i.e., winter (December–February), summer (March–May), monsoon (June–August), and post monsoon (September–November). Each site has been visited at least once a month. House Sparrows were counted by point count without distance estimate method from December 2016 to November 2018. The density of the House Sparrow was estimated by dividing the number of House Sparrows by monitoring sites. The survey area across each site was measured using Google Earth Pro program. Individuals of House Sparrows were observed by Nikon Aculon A211 8 x 42 binoculars. Besides, green cover was identified as an important component of habitat-influencing species occurrence at a local scale. Correspondingly, changes in green cover were monitored through Google Earth Pro program across different sampling sites. Besides, plant species used by the House sparrow for pre-roosting or roosting were also recorded by direct observation. In 2018, sound levels were measured at different study sites using an LT Biss digital Sound meter (range: 30–130 dB) with an accuracy of ± 1.5 dB. The minimum and maximum sound levels were recorded at 10-minute intervals during each field visit. In order to identify possible associations between mobile phone base stations and the presence of House Sparrow, the number of mobile phone base stations within 1-km radius of sample sites was considered using Tarang Sanchar Portal. Besides, basic information about electromagnetic fields (EMF), including potential effects, emission modes from towers, and radiation power thresholds from various telecom towers, was acquired through reference materials from the Tarang Sanchar Portal. During the study, numbers for each type of nest located within a 0.5 km radius of the roosting sites were also counted as indicative of nesting opportunities for House Sparrows at each site.

Statistical analysis

The data were analysed using IBM SPSS Statistics software (IBM SPSS Statistics for Windows, Version 22.0, Armonk, New York: IBM Corp. Software) after being exported from Microsoft Excel. We applied Kolmogorov-Smirnov and Shapiro-Wilk tests to assess the normality of the data. Given the non-normal distribution of the data, non-parametric tests were employed to determine variances (Hartvigsen 2021). We assessed variations in the percent density of House Sparrows, percent green cover, and sound levels across urban, suburban, and rural gradients using the non-parametric Kruskal-Wallis H test. Results are reported with asymptotic significances from two-sided tests, and significance levels were adjusted for multiple comparisons using the Bonferroni correction method. Due to insufficient point counts at the Akwada site (RUR1) in 2017, data from this location were excluded from the analysis for that year.

We explored the relationships between percent of green cover, sound levels, and the number of mobile phone base stations with the occurrences of House Sparrows using the Spearman's rank-order correlation coefficient test. A significance threshold was set at $P < 0.05$ for all statistical analyses. For each analysis, we report the degrees of freedom (df) and significance levels. Results are presented as means ± standard error (SE), and findings from post hoc analyses are reported using the compact letter display format.

RESULTS

The mean density of the House Sparrow was estimated based on a total of 204-point counts conducted at nine study sites across three gradients: urban, suburban, and rural during the study period. In 2017, the highest density of the House Sparrow was recorded at a rural gradient (0.0719 ± 0.0119/m^2), followed by suburban (0.0351 ± 0.0063/m^2) and urban (0.0275 ± 0.0042/m^2) respectively ($H(2) = 9.66$, $p < 0.05$) (Table 1, Figure 2). In 2018, the density of the House Sparrow decreased to 0.0366 ± 0.0089/m^2 in rural gradient followed by suburban (0.0247 ± 0.0066/m^2) and urban (0.0113 ± 0.0017/m^2) respectively ($H(2) = 3.35$, $P > 0.05$) (Table 1, Figure 2).

Vegetation cover plays a critical role in maintaining a healthy ecosystem on a local scale. In the current study, besides direct observations, changes in habitat composition were examined by analysing vegetation cover through Google Earth Pro. There was an average green cover of 29.08% of the total surveillance area across the urban gradient in 2017. Within the urban gradient, it was observed that green cover was primarily restricted to public gardens, private courtyards, roadside plantations, and green fields in certain locations. In 2018, green cover decreased to 24.52% across the urban gradient mainly due to the removal of vegetation from green fields (e.g., Bharatnagar (URB2), Image 2) or local regeneration efforts (e.g., Anandnagar (URB3)) (Figure 1).

In 2017, the suburban gradient boasted a green cover averaging 29.39% of the surveillance area, predominantly comprising green fields, private courtyards, and roadside plantations. However, by 2018, this green coverage diminished to 19.04% due to the deliberate removal of shrubby vegetation from

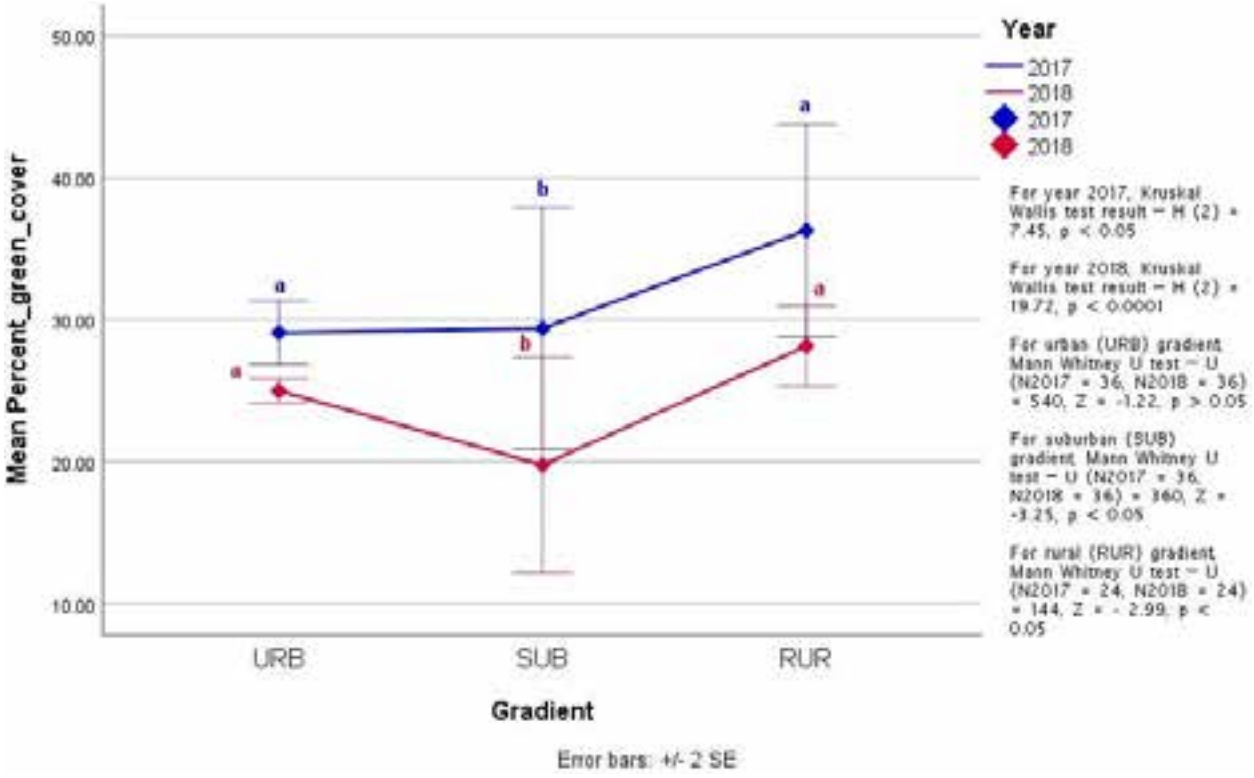

Figure 1. The mean percent green cover across urban (URB), suburban (SUB), and rural (RUR) gradients of Bhavnagar during the years 2017 and 2018.

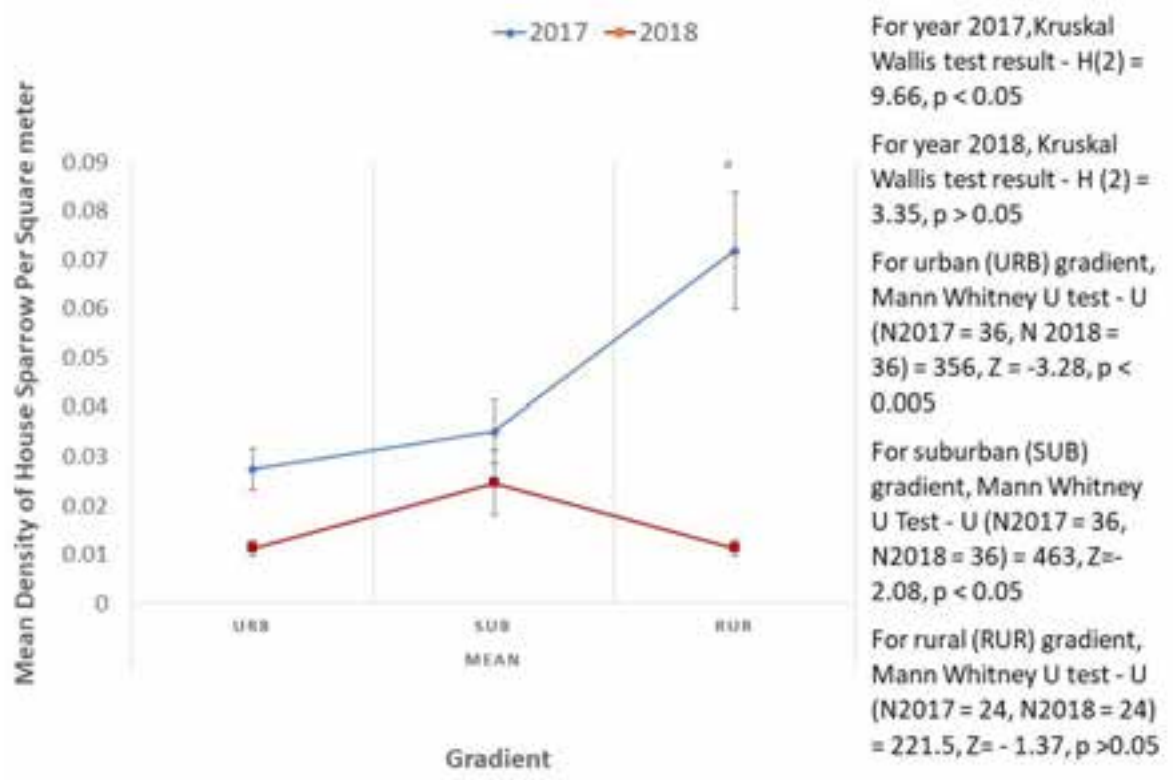

Figure 2. Mean density of House Sparrow across urban (URB), suburban (SUB), and rural (RUR) gradients of Bhavnagar during the years 2017 & 2018.

Table 1. The mean number of birds counted during point counts across the urban (URB), suburban (SUB), and rural (RUR) gradient during the study period from December 2016 to November 2018.

Year	Gradient	Mean Birds counted during point count
2016–17	Urban (URB)	1143.67 ± 197.456
	Suburban (SUB)	463.69 ± 72.797
	Rural (RUR)	309.29 ± 52.176
2017–18	Urban (URB)	447.06 ± 79.233
	Suburban (SUB)	204.75 ± 31.089
	Rural (RUR)	242.64 ± 37.861

Table 2. Spearman's rho correlations between the percent density of the House Sparrow and percent green cover across urban, suburban, and rural areas of Bhavnagar.

		Percent green cover		
		Urban (URB)	Suburban (SUB)	Rural (RUR)
Percent density of the House Sparrow	Correlation coefficient	0.547**	-0.517**	-0.577**
	Sig. (2-tailed)	0.000	0.000	0.000
	N	72	72	60

**Correlation is significant at the 0.01 (2 – tailed).

Image 2. Changes in habitat composition evidenced through Google Earth at Bharatnagar (A1, A2), VP Society (B1, B2), Forest colony (C1, C2), and Nari (D1, D2).

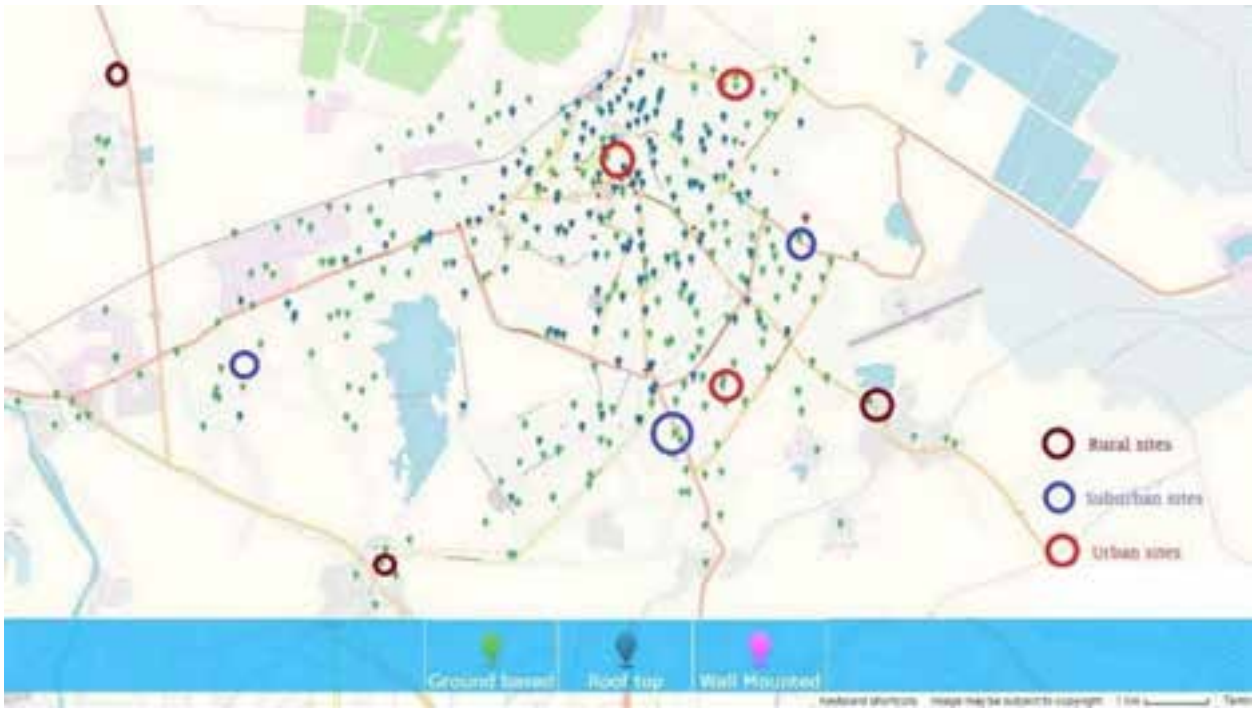

Image 3. Screenshot of Tarang Sanchar portal showing the density of mobile towers across urban, suburban, and rural gradients of Bhavnagar.

Table 3. Spearman's rho correlations between the percent density of the House Sparrow and different sound levels across the study area.

	Sound level			
		Sound level min	Sound level max	Sound level mean
Percent density of the House Sparrow	Correlation coefficient	0.085	-0.097	0.047
	Sig. (2-tailed)	0.382	0.320	0.632
	N	108	108	108

green fields for construction purposes, particularly evident at VP Society (SUB1). Concurrently, at Forest Colony (SUB2), a similar clearance of shrubby vegetation occurred for undisclosed reasons, presenting ambiguity regarding the rationale behind this action during field observations. Thus, while construction activities accounted for the decline in green cover in some areas, the precise motivation for vegetation removal at Forest Colony remained elusive throughout the study. (Figure 1, Image 2).

There was an average green cover of 34.47% of the total surveillance area across the rural gradient in 2017. Within the rural gradient, vegetation cover was mainly found in the form of farmland, green fields, private courtyards, and roadside plantations. In 2018, green cover decreased to 28.14% across the rural gradient mainly due to the removal of vegetation from green fields (e.g., Nari (RUR2)) for constructing a regional science centre) (Figure 1, Image 2).

During the study, there was a strong positive correlation found between the percent green cover and the mean density of the House Sparrow at urban gradient (r_s (70) = 0.547, p <0.0001) (Table 2). While strong negative correlation was found between the percent green cover and mean density of the House Sparrow at suburban (r_s (70) = - 0.517, p <0.0001) and rural gradient (r_s (58) = - 0.577, p <0.0001) (Table 2).

During the study, House Sparrows were mostly found to prefer shrubby vegetation for shelter, primarily composed of shrubby plant species such as *Prosopis juliflora*, *Ziziphus jujuba*, *Ziziphus xylopyrus* and *Acacia senegal* (Image 5B). In addition, often in the absence of aforementioned plant species, House Sparrow also used *Bambusa vulgaris*, *Punica granatum*, *Morus alba*, *Syzygium cumini*, *Ficus religiosa*, and *F. benghalensis* for roosting & pre-roosting purposes. In addition, it was also

noted with the presence of livestock/cowsheds near the monitoring sites of two urban sites (Barsomahadev (URB1); Anandnagar (URB3)), all three suburban sites (V P Society (SUB1), Forest colony (SUB2), Fulsar (SUB3)) and two rural sites (Akwada (RUR1), Sidsar (RUR3)). The Bharatnagar (URB2) site was characterized by dense residential areas with scattered wasteland patches. In contrast, the Nari (RUR2) site was surrounded by open farmland.

During the study, the highest sound level was recorded at urban gradient (Min.: 59.60 ± 1.14 dB; Max.: 77.26 ± 1.28 dB; Avg.: 68.43 ± 0.92 dB) followed by suburban (Min.: 59.30 ± 1.17 dB; Max.: 74.26 ± 0.71 dB; Avg.: 66.78 ± 0.76 dB) and rural (Min.: 55.55 ± 1.13 dB; Max.: 74.74 ± 1.63 dB; Avg.: 65.15 ± 1.11 dB), respectively (Figure 3). High sound levels across urban sites were due to the presence of large factories nearby and heavy vehicles passing from the roadside. In the present study, however, no such statistically significant relationship was established between the percent density of House Sparrow and different sound levels, i.e., minimum sound level (r_s (106) = 0.085, p >0.05), maximum sound level (r_s (106) = - 0.097, p >0.05) and mean sound level (r_s (106) = 0.047, p >0.05) (Table 3).

In the present study, compared to suburban and rural sites, urban sites typically had more mobile phone base stations (Image 3, Table 5). There was no significant correlation found between a number of mobile phone base stations and the occurrence of House Sparrows across the study area r_s (7) = 0.271, p >0.05 (Table 4). Similarly, no significant relation was found between several active nests of House Sparrows and the density of mobile towers, r_s (7) = 0.513, p >0.05 (Table 4). Hence, no mechanistic relationship was established between the densities of mobile phone base stations and occurrences of House Sparrows.

DISCUSSION

Green cover was found to be a critical habitat factor that influences House Sparrow occurrences directly or indirectly, notably serving as their preferred shelter for pre-roosting and roosting. The observed decline in density of the House sparrow could be partly linked to the removal of bushy vegetation, particularly in urban areas such as Bharatnagar (URB2) (Table 2). Wastelands or green fields with ruderal bushy vegetation were identified as vital shelters that support large communal gatherings of House Sparrows. For instance, in 2017, Bharatnagar (URB2) had dense bushy areas covering 16,934 m^2, hosting between 1,730 and 3,882 roosting House Sparrows (Foram Patel pers. obs. 26.iii.2017, 21.ix.2017) (Image 2A1, 4A). This bushy vegetation, along with nearby dunghills, provides essential foraging opportunities, corroborating findings from earlier studies that House Sparrows exhibit a preference for living near bushy vegetation (Summers-Smith 1963; Heij & Moeliker 1986; Wilkinson 2006; Weir 2015). In addition to offering shelter, these bushy areas are crucial for maintenance activities (Patel & Dodia 2021) and serve as a significant source of invertebrate prey, a vital component of the House Sparrow's diet during the nestling phase (Vincent 2005).

Furthermore, it was observed that traditional constructions provided better nesting opportunities compared to newer buildings, which lack suitable nooks for nesting (Shaw et al. 2008). Nonetheless, nesting opportunities for the House Sparrow were compensated by the artificial nest sites located throughout the study area. There were an average 90.43% of artificial nests in urban sites, 75.17% in suburban sites, and 79.67% in rural sites during the study. House Sparrows used a variety of artificial nests for nesting purposes, including wooden boxes, earthen pots, cardboard nests, and even empty detergent boxes and shoeboxes placed across the residential areas.

Except for Bharatnagar (URB2) and Nari (RUR2), cowsheds were commonly found within or nearby all other study sites (Image 5A). According to Cordero (1993), House Sparrows are more likely to be found around livestock or cowsheds, which are more frequent in rural locales than in suburbs with modern infrastructure. The litter and dunghills found in these cowsheds were significant sources of insects. Delgado et al. (2012) suggested that poultry manure has a positive effect on the abundance of invertebrates, which are essential components of the House Sparrow's diet, particularly during the breeding season (Vincent 2005; Peach et al. 2015). Many studies have reported similar observations where House sparrows rely heavily on seeds and invertebrates obtained from backyard poultry or dunghill at farmsteads (Balaji et al. 2014; Salek et al. 2015). Additionally, it was observed that House sparrows feed on household scraps or other supplementary foods or seeds in the courtyard. According to Hussain et al. (2014), the traditional lifestyle of seminomadic pastoralists (Van Gujjar) facilitates the availability of shelter and food for the House sparrows.

In the study, a notable absence of House Sparrows was observed in areas with a higher socioeconomic status, which were characterised by modern

Table 4. Correlation between number of mobile base stations and number of active nests of House Sparrow with abundance of the House Sparrow across the study area.

			Number of mobile towers	Abundance of House Sparrow	Active nests of House Sparrow
1	Number of mobile towers	Correlation Coefficient	1.000	0.271	0.513
		Sig. (2-tailed)	.	0.480	0.158
		N	9	9	9
2	Abundance of House Sparrow	Correlation Coefficient	0.271	1.000	0.504
		Sig. (2-tailed)	0.480	.	0.166
		N	9	9	9
3	Active nest of House Sparrow	Correlation Coefficient	0.513	0.504	1.000
		Sig. (2-tailed)	0.158	0.166	.
		N	9	9	9

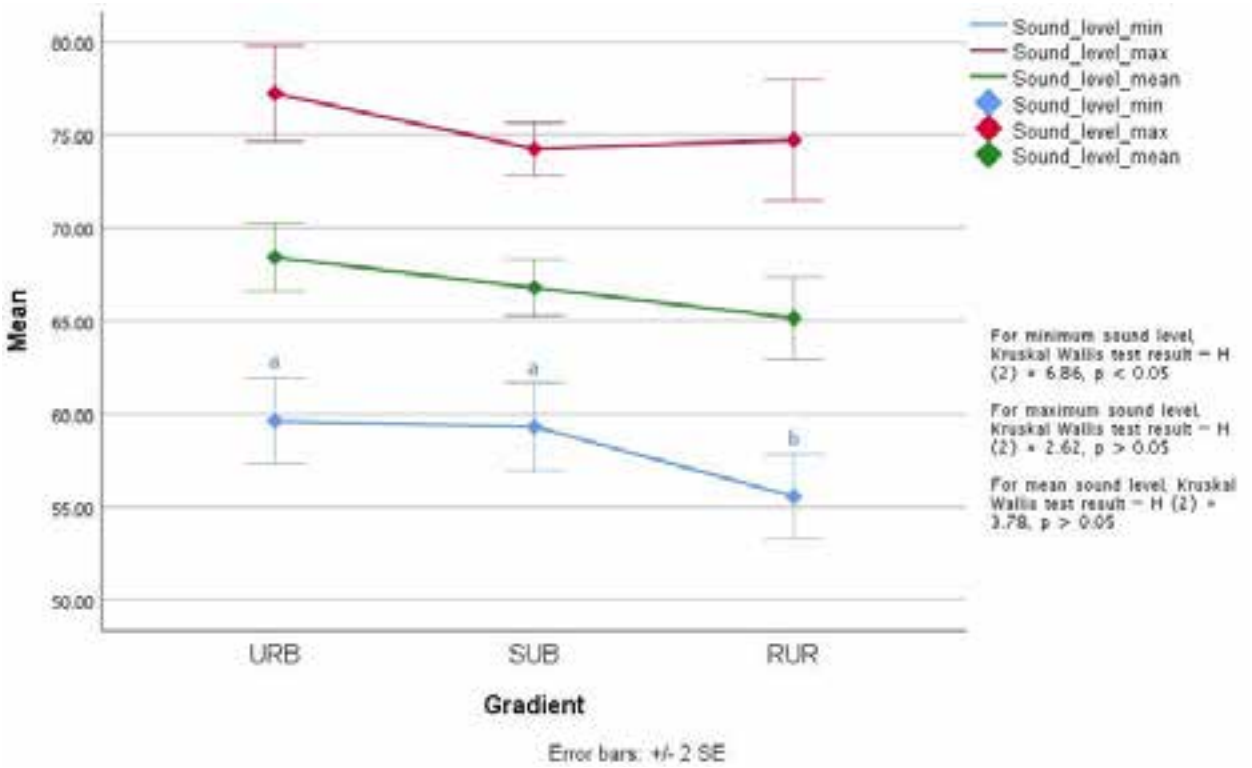

Figure 3. Variances in minimum, maximum, and mean sound levels across urban (URB), suburban (SUB), and rural (RUR) gradients of Bhavnagar in the year 2018.

infrastructure, paved surfaces, enhanced cleanliness, and ornamental landscaping. Conversely, House Sparrows were more commonly found in areas with older building structures, bushy vegetation, and the presence of cowsheds. This distribution pattern aligns with findings from various studies in urban settings, indicating that lower socioeconomic areas tend to have higher House Sparrow populations compared to affluent areas (Witt 2000, 2005; Pauleit et al. 2005; Shaw et al. 2008). Moreover, modern construction with improved hygiene, paved area and ornamental plantation has significantly reduced ideal foraging, nesting and roosting opportunities for the House Sparrow (Summers-smith 2003; Vincent 2005). Modak (2017) further supports this notion, highlighting the negative impact of urbanization on House Sparrow populations, particularly in planned urban regions like greater Kolkata.

During the study highest density of the House Sparrow was recorded at the Rural gradient. This finding aligns with numerous studies that have reported similarly high

densities of House Sparrows in rural areas (Robinson et al. 2005; Balaji et al. 2014). In rural gradient, bushy vegetation, cowsheds, and old/traditional constructions were common, harbouring a large number of House Sparrows (Figure 2). The extensive bushy vegetation found in suburban and rural areas offered ample opportunities for species dispersal. In contrast, the limited availability of suitable habitat patches resulted in a patchy distribution of House Sparrows in urban areas. The reduction in bushy vegetation due to commercial or residential development in urban and suburban sites could have a negative impact on the species, as indicated by observations from Vincent (2005) and Weir (2015).

Based on literature survey, high sound level was found to be another factor influencing House Sparrow populations (E.g., Bhattacharya et al. 2011). However, in our present study, we did not find any significant associations between various sound levels and the presence of House Sparrows. Furthermore, we observed active nests in study areas where high sound levels were recorded. Specifically, we noted high sound levels at three locations: Anandnagar (URB3) (maximum sound level: 80.58 ± 2.44 dB), VP Society (SUB1) (maximum sound level: 73.58 ± 1.26 dB), and Nari (RUR2) (maximum sound level: 85.97 ± 1.53 dB). During our study, we recorded 26 active nests in Anandnagar (URB3), 15 active nests in VP Society (SUB1), and 15 active nests in Nari (RUR2). In contrast to our findings, Bhattacharya et al. (2011) reported that nest boxes located in high-noise zones were inactive. However, in the present study House Sparrow found to be adaptive towards usual sound levels of civilised area. This aligns with the observations of Ghosh et al. (2010), who suggested that House Sparrows are accustomed to loud noises, and thus sound pollution is unlikely to significantly impact their population.

Our findings did not reveal any significant association between House Sparrow occurrence and the number of mobile phone base stations across the study area. Besides, we recorded active nests in locations with mobile phone base stations (Table 5). A similar study conducted by Meeran et al. (2021) found no correlation between mobile phone towers and the population of House Sparrows in Tamil Nadu, India. Furthermore, Pandian & Natarajan (2018) reported that House Sparrows breed in villages with mobile towers. Additionally, Nath et al. (2022) suggested that the low levels of electromagnetic radiation typical in urban environments do not induce thermal effects and thus have no discernible impact on sparrows and other urban avifauna.

As per information available on Tarang Sanchar Portal

Table 5. Number of mobile phone towers and active nests within a 0.5 km radius of the mobile phone tower in the year 2018.

Study sites	No. of mobile phone tower at the study site (within 1 km perimeter of the study site)	No. of active nests within a 0.5 km radius of the mobile phone tower
Barsomahadev (URB1)	4	30
Bharatnagar (URB2)	3	40
Anandnagar (URB3)	4	26
VP Society (SUB1)	1	15
Forest colony (SUB2)	2	16
Fulsar (SUB3)	0	17
Akwada (RUR1)	1	35
Nari (RUR2)	0	15
Sidsar (RUR3)	3	30

Image 4. A—Presence of a large patch of bushy vegetation in the form of a green field at the Bharatnagar (URB2) Site in 2017 | B—Commercial and residential development at Bharatnagar (URB2) Site in 2018. © A-B – K. R. Tadha.

Image 5. A—Presence of livestock/ cowsheds at the study site | B—Female House Sparrow sitting on bushy plant | C—Foraging House Sparrow. © A,C–F.P. Patel | B–K.R. Tadha.

- mobile phone base stations are located near mobile phone users and produce the lowest possible power, with the optimal network design. Due to the narrow vertical transmit pattern of the antennas and their wide horizontal spread, the radio signal intensity directly beneath them is very low (). Moreover, the transmitted power levels vary depending on the geographical area covered by the cell (Base stations and Health, 2022).

In contrast, according to Balmori (2021), the recent decline in the sparrow population is believed to be linked to the proliferation of mobile towers. Furthermore, studies conducted in India have reported a rapid decline in House Sparrow population as a result of contamination resulting from increased use of cell phones (Dandapat et al. 2010; Shende & Patil 2015). Moreover, Wotton et al. (2002) demonstrated that House Sparrows are particularly vulnerable to electromagnetic radiation due to their nesting behaviours, often selecting elevated locations like roof spaces where radiation from base stations may be more concentrated. Moller et al. (2011) reported instances of birds abandoning nests near mobile base stations within a week of construction, although such incidents were not observed in our study. Nonetheless, a basic correlation study between mobile phone towers and the presence of house sparrows does not establish a causal link.

Notably, our study did not assess the strength of electromagnetic radiation. While there's a lack of standardized baseline data on the direct impact of electromagnetic radiation emitted by base stations on birds, it remains uncertain whether radiation significantly contributes to the decline of House Sparrows. Therefore, a comprehensive analysis of the long-term effects of electromagnetic fields (EMF) on House Sparrows using standardized tools and protocols is essential to draw accurate conclusions.

CONCLUSION

Changes in habitat composition at a local scale had a significant impact on the presence of House Sparrows. Key factors positively influencing their occurrence included the presence of bushy vegetation, cowsheds, and old/traditional structures. Bushy vegetation served as an important shelter for the House Sparrows. Residential and commercial developments have reduced bushy vegetation patches in urban and suburban sites, resulting in fewer suitable foraging and roosting areas for the House Sparrow. Such small-scale changes in habitat composition could have significant negative effects on the abundance of the House Sparrow especially in urban areas**,** where suitable habitat patches are scarce**.**

In order to develop effective conservation strategies, it is essential to consider other aspects of the species' habitat requirements in addition to providing nesting opportunities through artificial nest sites. Effective green urban architectural planning and management are necessary to ensure heterogeneous green areas with suitable vegetative cover in order to provide a high availability of natural resources to the species. Besides, studies conducted at finer scale are important for defining management options that can be applied at a large scale.

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ARTICLE

Waterbird diversity of Saman Wetland Complex in Uttar Pradesh: a crucial site for the India's National Action Plan on migratory birds

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Abstract: The Saman Wetland Complex is formed by five major wetlands present in Etawah and Mainpuri districts of Uttar Pradesh. The habitat is majorly a wetland system with scrub vegetation along the edges and surrounded by agricultural fields; attracting a diverse group of bird species. These wetlands are an ideal habitat for Sarus Crane and are also Important Bird Areas. In the past two decades, the anthropogenic activities have deteriorated the habitat and wetlands no longer support the earlier congregation of birds. The study conducted during 2020–2021 provides baseline information on the present status of the Saman wetland complex, waterbird diversity, threats faced by the wetlands & waterbirds, and suggests future management/ conservation strategies.

Keywords: Bird species, Etawah, habitat, IBA, Saman Bird Sanctuary, Sarsai Nawar, Sarus Crane, wetlands.

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INTRODUCTION

Birds with nearly 10,787 species (252 families and 40 orders) are found on Earth, ranging from the poles to the equator (Praveen et al. 2020). Birds are an important component of any ecosystem that not only provide inestimable ecosystem functioning services like scavenging, preying, act as insects and pest control agents, plant pollinators, and seed dispersal but also as indicators for the evaluation of habitat quality of any particular area or region. Avifaunal diversity and documentation of any region are important in understanding the diversity and distribution of species over a certain area and time (Colin et al. 2000; Peterson et al. 2000).

There are a total of 1,306 bird species found in India that contribute to approximately 12.5% of the world's avifauna. India's biogeographic location, heterogeneity of physical features, and eco-climatic variations make it a rich biodiversity country (Praveen et al. 2018).

Uttar Pradesh (UP) is one of the largest states in India occupying an area of 2,40,972 km^2. Biologically, it is very rich and varied having 31 Important Bird Areas (IBAs; BirdLife International 2022) with more than 500 species being reported from the state. The state has six 'Critically Endangered', five 'Endangered', 16 'Vulnerable', and 23 'Near Threatened' bird species (Rahmani et al. 2016).

Out of the 31 IBAs in UP, 24 are wetlands ecosystems. Wetland ecosystems attract a high number of bird species providing adequate food supply and habitats in the form of aquatic vegetations, fishes, crustaceans, and reeds along the edges of the waterbodies respectively. Saman Jheel along with its satellite wetlands (Sauj, Sarsai Nawar, Kurra Zheel, and Kuddaiyya Marshland in Mainpuri and Etawah districts) makes a wetland complex that has been designated as IBAs (Image 1). The region attracts large congregations of waterbirds during the winter season besides having residential birds. According to Rahmani et al. (2016), more than 1,500 Common Teal *Anas crecca*, 6,000–10,000 Northern Pintail *Anas acuta*, 30,000 Lesser Whistling-duck *Dendrocygna javanica*, and 200 Great White Pelican *Pelecanus onocrotalus* were recorded in the area during a survey in January 2001. Many of these species occur in far greater numbers than their 1% biogeographic population threshold determined by Wetlands International (2012) and thus in 2019 the Saman Bird Sanctuary and Sarsai Nawar were declared Ramsar Sites. Saman wetland, and other jheels like Lakh-Bahosi used to be an important habitat for the Siberian Crane *Leucogeranus leucogeranus* in the state (Rahmani et al. 2016).

Being important as a wintering site for many migrants with more than 1% biogeographic population threshold, the area still lacks proper documentation of avifaunal diversity. Further, many anthropogenic activities have deteriorated the habitat in the last two decades. During the present study, we tried to record the current status of waterbird diversity, their population, and existing threats in the Saman Wetland Complex with special emphasis to create baseline data for the area.

Study Area

1. **Saman wetland** (27.0230 °N; 79.1900 °E) is located in the upper Gangetic Plains, near Saman village in the Mainpuri district of Uttar Pradesh. It was declared a Bird Sanctuary in 1990. The sanctuary is an oxbow lake, that depends completely upon rainfall for its water. The total area of the sanctuary is 525 ha and approximately 75% of the area is underwater. There is no representative forest type available but reeds along with scattered *Prosopis juliflora* are present within the sanctuary. Other hydrophytic vegetation includes *Nelumbo, Cyperus*, *Phragmites*, and *Typha*.
2. **Kurra Zheel** (27.0156 N; 79.0897 E) is located near Hajipura village in Kurra, Mainpuri district. Karhal-Kishni road divides the wetland into two parts.
3. **Sarsai Nawar Lake** (26.9659 °N; 79.2479 °E) is a monsoon-fed natural depression. The lake is important because it is the roosting area of Sarus Crane in the region.
4. **Sauj Lake** (27.027 °N; 79.1424 °E) lies beside the Karhal-Kishni main road, just before Saman Bird Sanctuary. The lake is a shallow depression in the landscape.
5. **Kudaiyya marshland** (26.9929 °N; 78.9924 °E) is situated along the Karhal-Kishni highway in the Mainpuri district. It is formed by the flooding of a natural depression (Rahmani et al. 2016).

The wetland complex experiences three distinct seasons, viz., summer (March–June), monsoon (July–October), and winter (November–February). The average rainfall in the area is 500–900 mm. The temperature varies 4–48 ^{0}C.

METHODS

Surveys were carried out in all the wetlands from January 2020–November 2021 to monitor the waterbird diversity, population status, and threats to the birds and their habitat. We covered three winters season ensuring two visits per season. Waterbirds were surveyed using

the total count method (Bibby et al. 1992). The number of birds in large flocks was generally estimated by mentally dividing the congregation into small groups of 5–100 depending upon the size of the flock. Birds were counted that were present within appx. 500 m distance from the observer. In the case of a large waterbody, simultaneous counts were taken with multiple observers. Landbirds were also recorded opportunistically whenever encountered in a wetland or flying over. No other standard methods or efforts were taken to count landbirds.

Birds were observed during mornings, beginning at sunrise and evening hours till sunset depending upon the high activity hours of roosting and foraging. Therefore, twice a day data was collected for the same sites to check the birds' movements and congregation. In the case of bird identification confirmation, Grimmett et al. (2011) was used. Threats and disturbances to the wetlands were recorded based on the observations during the survey as well as information obtained from the local people, bird watchers, and forest department staff.

Data analysis

A detailed checklist of recorded birds was made following BirdLife International (2021) nomenclature. All the recorded species were classified based on the conservation status provided in the IUCN Red List of Threatened Species (IUCN 2021).

We calculated species richness referring to the number of species in the wetland and Shannon-Wiener index which takes into account both species richness and their evenness (how evenly individuals are distributed among different species). We also calculated the relative diversity (RDi) of families using the following formula (Torre-Cuadros et al. 2007; Samson et al. 2018):

$$RDi = \frac{\text{Number of bird species in a family}}{\text{Total number of species}} \times 100$$

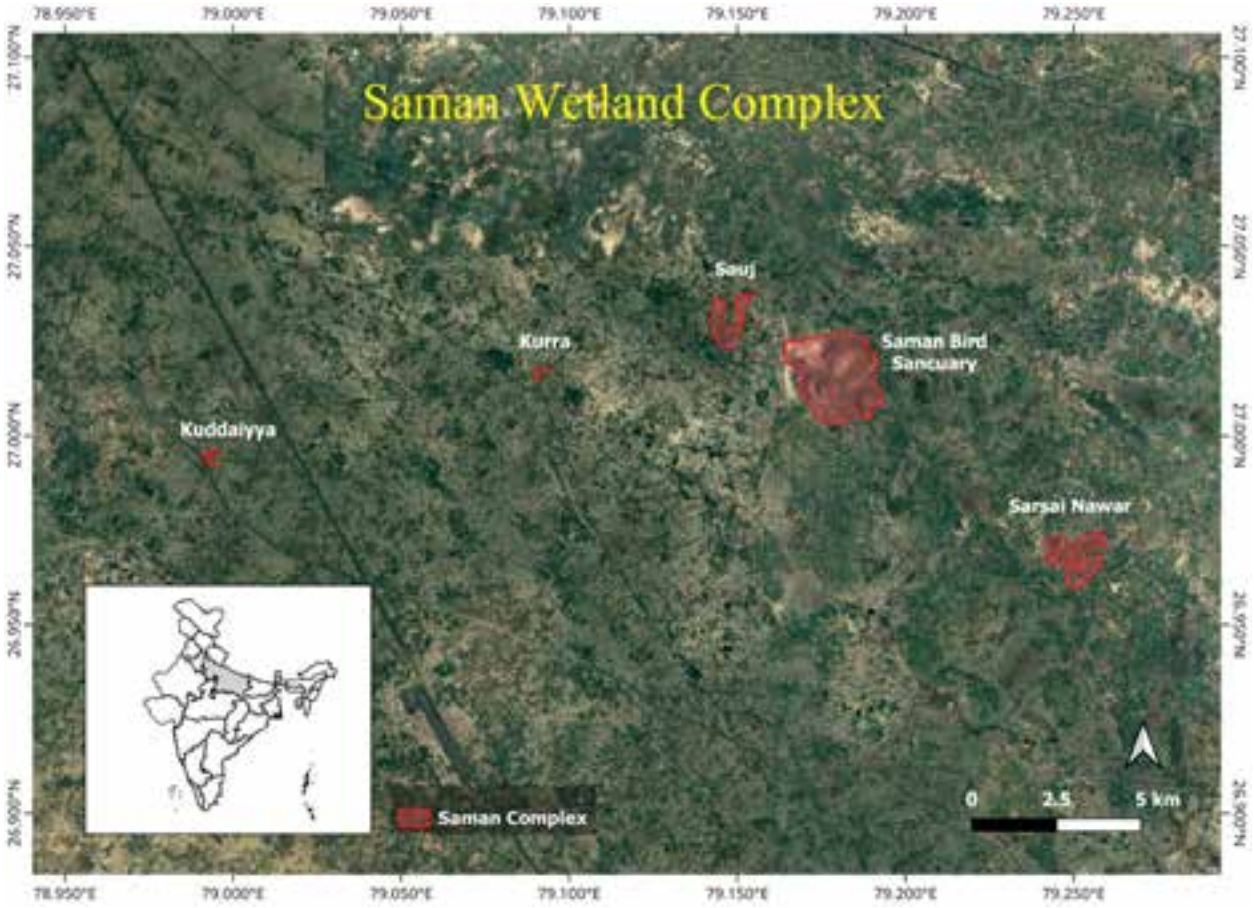

Image 1. Map of the of Saman Wetland Complex, Mainpuri district, Uttar Pradesh, India.

RESULTS

During the present study in Saman Wetland Complex, a total of 126 species of birds under 18 orders and 41 families were recorded (Annexure I). Out of the 126 species of birds, 70 species were waterbirds. Among these species, 34 were migratory waterbirds and 36 species were residents. Family Anatidae had a maximum number of species (n = 17) followed by Scolopacidae (n = 12). The maximum count of the waterbirds in a single day recorded at Saman Bird Sanctuary (Saman BS) was 8,210 birds in January 2020, followed by Sarsai Nawar (5,309 birds) in the same month. As globally order Passeriformes has a higher number of species than all others put together, this order represents the highest number of species (n = 34) in the study area, followed by Charadriiformes (n = 20 species) and Anseriforms (n = 17) (Figure 1). However, passeriforms are relatively scarce in the study areas.

Eighteen species belong to the various threatened categories of IUCN. Among the threatened waterbird species, two 'Vulnerable' species which are Common Pochard *Aythya ferina* & Sarus Crane, and eight 'Near Threatened' species were recorded during the study period (Table 1).

The maximum diversity of waterbirds was recorded at Sarsai Nawar (63 species) followed by Saman BS (52 species) and the lowest diversity was observed at Kuddaiyya Marshland with 30 species (Figure 2).

Among the landbirds, 58 species were recorded at Saman Wetland Complex. Maximum diversity was observed at Sarsai Nawar followed by Saman BS. Among them, Egyptian Vulture *Neophron percnopterus* and Steppe Eagle *Aquila nipalensis* are categorised as 'Endangered' according to IUCN while Greater Spotted Eagle *Clanga clanga*, Indian Spotted Eagle *Clanga hastata*, and Tawny Eagle are listed as 'Vulnerable'. Shannon Diversity Index was highest in the Kurra Jheel, which suggests that Kurra Jheel harbours a high diversity of species in a community and Saman BS the lowest (Table 2). Kurra is surrounded by villages and many birds that live around human settlements are present around the wetland and the congregation of waterbirds is very low. This might be the reason for the high diversity index of Kurra. The species richness index was found to be highest in Sarsai Nawar and lowest in Kuddaiya Marshland.

The family Anatidae had the highest RDi (13.49) with 17 species followed by Scolopacidae (9.52) with 12 species (Table 3).

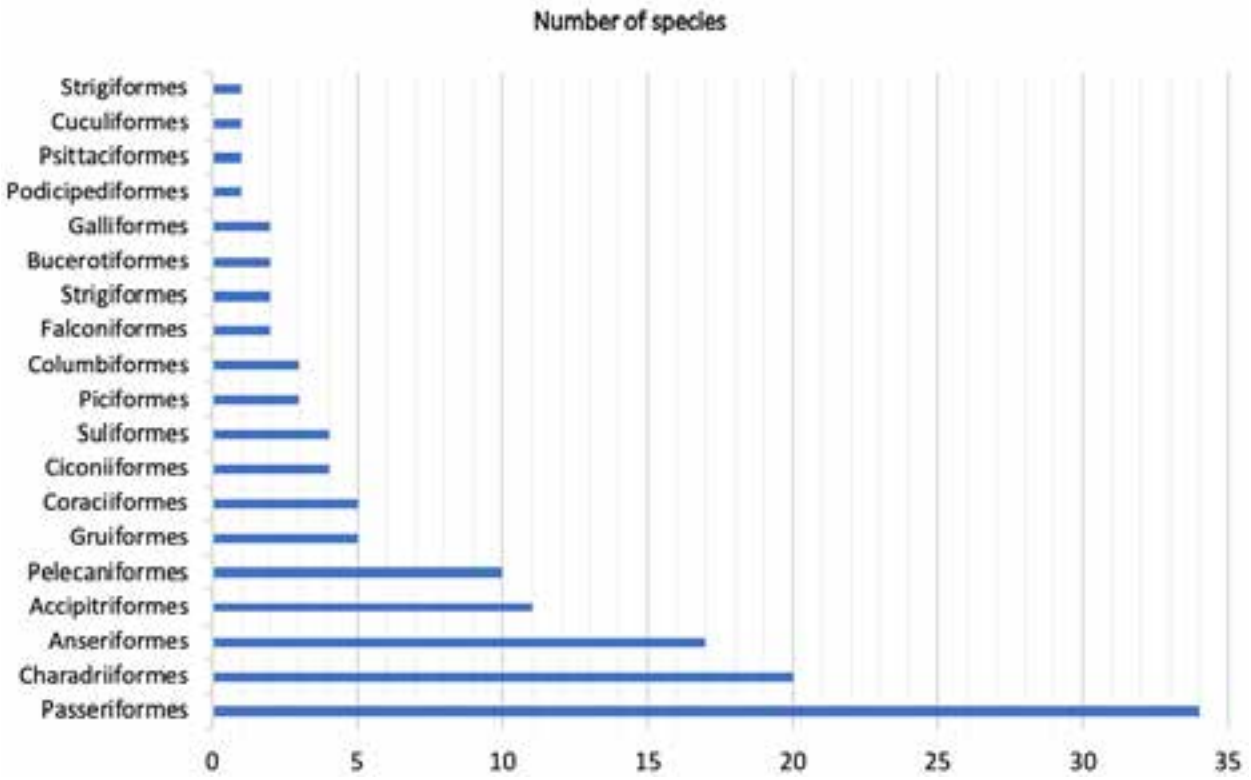

Figure 1. Order-wise count of bird species at Saman Wetland Complex.

Table 1. List of threatened bird species reported from Saman Wetland Complex.

	Common name	Scientific name	Family	IUCN status
1	Egyptian Vulture	*Neophron percnopterus*	Accipitridae	EN
2	Steppe Eagle	*Aquila nipalensis*	Accipitridae	EN
3	Common Pochard	*Aythya ferina*	Anatidae	VU
4	Sarus Crane	*Antigone antigone*	Gruidae	VU
5	Indian Spotted Eagle	*Clanga hastata*	Accipitridae	VU
6	Greater Spotted Eagle	*Clanga clanga*	Accipitridae	VU
7	Tawny Eagle	*Aquila rapax*	Accipitridae	VU
8	Red-necked Falcon	*Falco chicquera*	Falconidae	NT
9	Asian Woollyneck	*Ciconia episcopus*	Ciconiidae	NT
10	Black-headed Ibis	*Threskiornis melanocephalus*	Threskiornithidae	NT
11	Black-necked Stork	*Ephippiorhynchus asiaticus*	Ciconiidae	NT
12	Black-tailed Godwit	*Limosa limosa*	Scolopacidae	NT
13	Bonelli's Eagle	*Aquila fasciata*	Accipitridae	NT
14	Eurasian Curlew	*Numenius arquata*	Scolopacidae	NT
15	Ferruginous Duck	*Aythya nyroca*	Anatidae	NT
16	Indian Grey Hornbill	*Ocyceros birostris*	Bucerotidae	NT
17	Oriental Darter	*Anhinga melanogaster*	Anhingidae	NT
18	Painted Stork	*Mycteria leucocephala*	Ciconiidae	NT

Threats faced by the wetlands

During the survey, it was noticed that the Saman Wetland Complex is facing various problems due to anthropogenic activities around the wetlands and losing its ecological values. One of the major threats is an agricultural expansion on the edge of wetlands. As a result, wetlands are losing their area and thus, today unable to hold the large congregations as they used to. During summer as these wetlands become almost dry, villagers carry out agricultural practices in the wetland area. The use of chemical fertilisers and pesticides put nutrients load into the wetlands through agricultural runoff in addition to sewage from the adjoining villages. This causes water pollution and the growth of species like water hyacinth, *Ipomoea*, and *Typha*. Eutrophication in Kurra and Kuddaiyya is so high that hardly any open water surface is available for the waterbirds.

The interactions with the local people revealed other threats such as siltation which has reduced the water holding capacity of wetlands. People also responded positively about the bird capturing practices for meat purposes. This was also evident by the survey team at Saman BS. There is still dispute on the land compensation and therefore locals have a negative approach towards the Saman BS. Other threats and disturbances observed during the survey were the collection of lotus tubers and grasses from the wetland, grazing by livestock within the wetland area, free-ranging dogs, disposal of solid waste and construction debris in the wetland.

DISCUSSION

Saman Wetland Complex is included in the list of priority wetlands under India's National Action Plan for Conservation of Migratory Birds and their Habitats along Central Asian Flyway (CAF NAP). These wetlands are also defined as IBAs as they supported or were thought to support congregations of more than 20,000 waterbirds regularly. However, it is hardly the scene in the present date. In this region, wetlands are facing immense anthropological pressure. Major areas of the wetlands are reclaimed or destroyed for agricultural expansion and human settlements (Sundar 2006; Maurya & Kumar 2014). Pesticides and fertilizers are mixing into the wetland through agricultural runoff from the surrounding areas. Thus, all the wetlands are facing the threat of pesticide deposition, which may lead to the depletion of insects thereby leading to the disappearance of insectivorous birds.). All the wetlands are surrounded by villages which put grazing pressure on the areas near the wetlands. Grazing results in temporary modification of habitat and disturbance to birds (Jha 2015). Sundar & Choudhury (2005) documented the mortality of Sarus

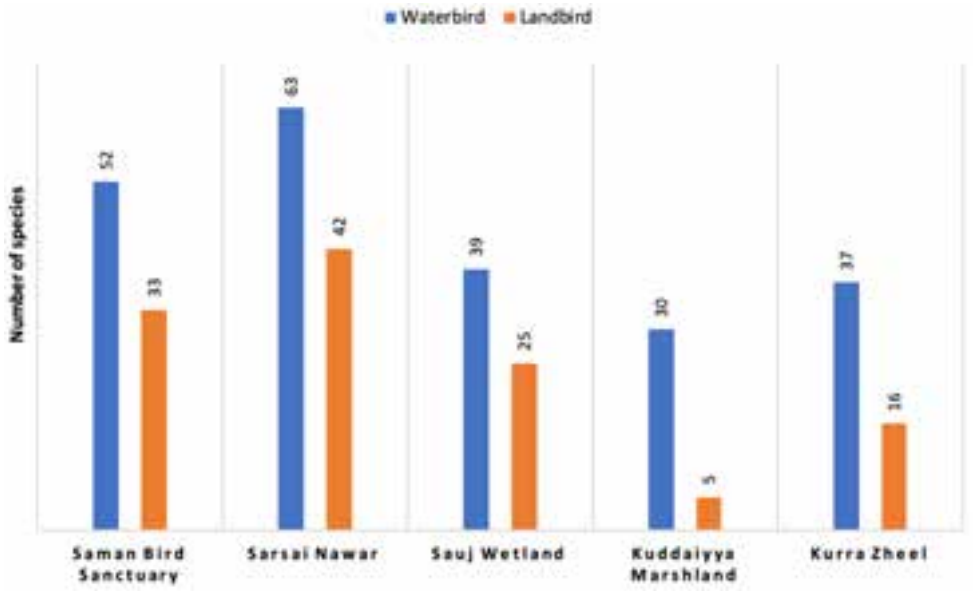

Figure 2. Avian diversity at Saman Wetland Complex.

Table 2. Shannon diversity index and species richness index of Saman Wetland Complex.

Wetland	Shannon diversity index	Species richness index
Sarsai Nawar	2.539	105
Saman BS	1.911	87
Sauj	2.012	64
Kurra	3.009	53
Kuddaiyya	2.591	35

Crane due to collision to high tension electric wires in the Saman wetland complex. As per the study, nearly 1% of the total population died because of electrocution each year. However, such a case was not recorded during the study period. Poaching is also reported in all the wetlands on a minor scale.

The present study recorded the presence of 126 species of birds from the Saman Wetland Complex. Out of the 126 reported species, seven species fall under the threatened categories by the IUCN Red List. The availability of varied habitat types of this region, like wetland shallow area, reed beds and agricultural fields attract many species of resident and migratory birds. Saman Wetland Complex is one of the ideal habitats for the Sarus Crane in India. About 73% of the Sarus population of Uttar Pradesh is found in four districts namely Mainpuri, Etawah, Etah, and Aligarh while Mainpuri has the highest number of counts (Maurya & Kumar 2014). Sarsai Nawar lake, a Ramsar site is a roosting site for the largest flock of Sarus Crane in India.

Based on earlier records, Kurra jheel was known to support more than 20,000 migratory waterbirds, but the current scenario is not the same. In a survey in 2008–2009 by BNHS, the count was not even 500 birds (Rahmani et al. 2016). In the present study, the maximum bird count was just 307 in November 2021. Thus, IBA status of Kurra is now questionable.

Notable observations

- In February 2020, a huge congregation of Wagtails, mainly Western Yellow Wagtail *Motacilla flava* and Citrine Wagtail *Motacilla citreola* were recorded during dusk. Most probably it was a roosting population that settled in the agricultural field near the wetland.

- Murmuration of Rosy Starling *Pastor roseus* was observed in November 2021 at Saman BS.

- An opportunistic sighting of four individuals of Steppe Eagle was recorded while passing through the Saman BS in February 2020.

- Two nests of Black-necked Stork in Saman BS and one in Sarsai Nawar were observed in November 2021

CONCLUSION

Kuddaiya marshlands and Kurra are highly degraded due to anthropogenic activities and beyond restoration. Both have lost huge wetland areas and what remains now is just ponds. On the other hand,

Table 3. Relative diversity (RDi) of bird families recorded during the survey in Saman Wetland Complex.

	Family	Number of species	RDi
1	Anatidae	17	13.49206349
2	Scolopacidae	12	9.523809524
3	Accipitridae	11	8.73015873
4	Ardeidae	8	6.349206349
5	Muscicapidae	7	5.555555556
6	Motacillidae	5	3.968253968
7	Ciconiidae	4	3.174603175
8	Charadriidae	4	3.174603175
9	Estrildidae	4	3.174603175
10	Rallidae	4	3.174603175
11	Phalacrocoracidae	3	2.380952381
12	Columbidae	3	2.380952381
13	Corvidae	3	2.380952381
14	Cisticolidae	3	2.380952381
15	Sturnidae	3	2.380952381
16	Alcedinidae	3	2.380952381
17	Falconidae	2	1.587301587
18	Threskiornithidae	2	1.587301587
19	Phasianidae	2	1.587301587
20	Jacanidae	2	1.587301587
21	Ramphastidae	2	1.587301587
22	Passeridae	2	1.587301587
23	Timaliidae	2	1.587301587
24	Anhingidae	1	0.793650794
25	Gruidae	1	0.793650794
26	Podicipedidae	1	0.793650794
27	Recurvirostridae	1	0.793650794
28	Glareolidae	1	0.793650794
29	Psittacidae	1	0.793650794
30	Cuculidae	1	0.793650794
31	Tytonidae	1	0.793650794
32	Upupidae	1	0.793650794
33	Coraciidae	1	0.793650794
34	Meropidae	1	0.793650794
35	Bucerotidae	1	0.793650794
36	Picidae	1	0.793650794
37	Dicruridae	1	0.793650794
38	Alaudidae	1	0.793650794
39	Pycnonotidae	1	0.793650794
40	Sylviidae	1	0.793650794
41	Ploceidae	1	0.793650794

Sauj still holds a considerable number of birds. Effective conservation efforts such as desilting of the lake, community conservation etc. can bring back the glory of this wetland. Saman BS and Sarsai Nawar are rich in diversity and support large congregations of migratory waterbirds. Both wetlands also support nesting habitats for resident birds including the threatened Sarus Crane and Black-necked Stork. Conservation measures are an absolute necessity to improve the habitat condition. With the coordinated efforts of local people and the forest department, bird tourism can flourish and will be helpful for the economic upliftment of people.

Based on the present study, it was felt that considerable detailed studies pertaining to various aspects of avian ecology in Saman Wetland Complex need to be conducted. Landscapes are facing habitat alterations due to urbanisation. Therefore, there is a need to conduct an intensive study to monitor the population dynamics of avifauna at the landscape level, dominated by human settlements and agricultural practices along with the drivers of habitat alteration. De-siltation of wetlands and removal of invasive aquatic plants are needed to be done with a scientific approach. The present study is expected to form baseline information for future studies on various aspects of avian ecology in the region and emphasizes the need of long-term qualitative and quantitative study in the area.

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Annexure I. List of species with its highest number recorded during the survey in Saman Wetland Complex along with its IUCN Red List status.

	Common name	Scientific name	IUCN Red List status	Saman Bird Sanctuary	Sarsai Nawar	Sauj Wetland	Kuddaiyya Marshland	Kurra Zheel
Order: Galliformes								
Family Phasianidae (Megapods, Partridges, Pheasants)								
1	Grey Francolin	*Francolinus pondicerianus*	LC	4	2	2	-	-
2	Indian Peafowl	*Pavo cristatus*	LC	-	2	-	-	5
Order: Anseriformes								
Family Anatidae (Whistling-Ducks, Swans, Geese and Ducks)								
3	Bar-headed Goose	*Anser indicus*	LC	-	4	-	-	-
4	Comb Duck	*Sarkidiornis melanotos*	LC	1	100	11	-	42
5	Common Pochard	*Aythya ferina*	VU	-	2000	-	-	-
6	Common Teal	*Anas crecca*	LC	70	34	-	10	-
7	Cotton Pygmy-goose	*Nettapus coromandelianus*	LC	1	-	-	-	-
8	Eurasian Wigeon	*Mareca penelope*	LC	4	50	-	8	-
9	Ferruginous Duck	*Aythya nyroca*	NT	19	10	-	14	-
10	Gadwall	*Mareca strepera*	LC	1000	300	-	35	-
11	Garganey	*Spatula querquedula*	LC	-	200	-	-	-
12	Greylag Goose	*Anser anser*	LC	60	64	1	-	-
13	Indian Spot-billed Duck	*Anas poecilorhyncha*	LC	-	1	-	-	-
14	Lesser Whistling-duck	*Dendrocygna javanica*	LC	500	150	100	117	150
15	Mallard	*Anas platyrhynchos*	LC	-	10	-	-	-
16	Northern Pintail	*Anas acuta*	LC	125	2000	200	2	-
17	Northern Shoveler	*Spatula clypeata*	LC	20	300	-	28	-
18	Tufted Duck	*Aythya fuligula*	LC	5	1	-	1	-
19	Red-crested Pochard	*Netta rufina*	LC	20	6	50	16	-
Order: Podicipediformes								
Family Podicipedidae (Grebes)								
20	Little Grebe	*Tachybaptus ruficollis*	LC	17	25	6	3	3
Order: Ciconiiformes								
Family Ciconiidae (Storks)								
21	Asian Woollyneck	*Ciconia episcopus*	NT	2	4	-	1	-
22	Black-necked Stork	*Ephippiorhynchus asiaticus*	NT	2	3	1	2	-
23	Painted Stork	*Mycteria leucocephala*	NT	5	16	4	-	6
24	Asian Openbill	*Anastomus oscitans*	LC	10	5	49	1	-
Order: Pelecaniformes								
Family Threskiornithidae (Ibises and spoonbills)								
25	Black-headed Ibis	*Threskiornis melanocephalus*	NT	60	68	5	-	8
26	Eurasian Spoonbill	*Platalea leucorodia*	LC	-	13	-	17	1
Family Ardeidae (Bitterns and Herons)								
27	Black-crowned Night-Heron	*Nycticorax nycticorax*	LC	-	-	1	-	1
28	Grey Heron	*Ardea cinerea*	LC	12	10	2	1	2
29	Indian Pond Heron	*Ardeola grayii*	LC	18	50	5	-	52
30	Purple Heron	*Ardea purpurea*	LC	6	5	3	1	9
31	Cattle Egret	*Bubulcus ibis*	LC	11	30	1	-	2
32	Great Egret	*Ardea alba*	LC	6	25	2	-	6

	Common name	Scientific name	IUCN Red List status	Saman Bird Sanctuary	Sarsai Nawar	Sauj Wetland	Kuddaiyya Marshland	Kurra Zheel
33	Intermediate Egret	*Ardea intermedia*	LC	4	15	2	-	9
34	Little Egret	*Egretta garzetta*	LC	4	6	1	-	35
Order: Suliformes								
Family Anhingidae (Anhingas)								
35	Oriental Darter	*Anhinga melanogaster*	NT	14	25	5	6	6
Family Phalacrocoracidae (Cormorants)								
36	Great Cormorant	*Phalacrocorax carbo*	LC	6	-	-	2	2
37	Indian Cormorant	*Phalacrocorax fuscicollis*	LC	22	2	-	-	5
38	Small Cormorant	*Microcarbo niger*	LC	62	50	25	17	24
Order: Falconiformes								
Family Falconidae (Falcons)								
39	Peregrine Falcon	*Falco peregrinus*	LC	-	1	-	-	-
40	Red-necked Falcon	*Falco chicquera*	NT	-	-	1	-	-
Order: Accipitriformes								
Family Accipitridae (Osprey, Hawks, Eagles, Harriers, Vultures)								
41	Bonelli's Eagle	*Aquila fasciata*	NT	2	3	-	-	-
42	Osprey	*Pandion haliaetus*	LC	-	1	-	-	-
43	Steppe Eagle	*Aquila nipalensis*	EN	-	1	-	-	-
44	Tawny Eagle	*Aquila rapax*	VU	-	1	-	-	-
45	Western Marsh Harrier	*Circus aeruginosus*	LC	5	2	-	1	2
46	Greater Spotted Eagle	*Clanga clanga*	VU	-	1	-	1	-
47	Indian Spotted Eagle	*Clanga hastata*	VU	-	1	1	-	-
48	Black Kite	*Milvus migrans*	LC	-	-	-	-	1
49	Black-winged Kite	*Elanus caeruleus*	LC	1	2	1	-	-
50	Long-legged Buzzard	*Buteo rufinus*	LC	-	-	1	-	-
51	Egyptian Vulture	*Neophron percnopterus*	EN	2	1	2	1	2
Order: Gruiformes								
Family Rallidae (Rails, Crakes, Gallinules and Coots)								
52	Common Coot	*Fulica atra*	LC	3000	500	40	12	20
53	Common Moorhen	*Gallinula chloropus*	LC	22	62	2	-	30
54	White-breasted Waterhen	*Amaurornis phoenicurus*	LC	17	2	1	-	2
55	Purple Swamphen	*Porphyrio porphyrio*	LC	19	39	7	7	50
Family Gruidae (Cranes)								
56	Sarus Crane	*Antigone antigone*	VU	22	232	16	8	5
Order: Charadriiformes								
Family Charadriidae (Plovers and Lapwings)								
57	White-tailed Lapwing	*Vanellus leucurus*	LC	7	10	8	3	-
58	Grey-headed Lapwing	*Vanellus cinereus*	LC	5	-	-	-	-
59	Red-wattled Lapwing	*Vanellus indicus*	LC	38	30	15	4	10
60	Little Ringed Plover	*Charadrius dubius*	LC	-	1	-	-	-
Family Recurvirostridae (Stilts and Avocets)								
61	Black-winged Stilt	*Himantopus himantopus*	LC	26	150	30	-	6
Family Jacanidae (Jacanas)								
62	Bronze-winged Jacana	*Metopidius indicus*	LC	17	40	7	-	40
63	Pheasant-tailed Jacana	*Hydrophasianus chirurgus*	LC	4	20	21	-	-

	Common name	Scientific name	IUCN Red List status	Saman Bird Sanctuary	Sarsai Nawar	Sauj Wetland	Kuddaiyya Marshland	Kurra Zheel
Family Scolopacidae (Snipes, Curlews and Sandpipers)								
64	Common Redshank	*Tringa totanus*	LC	30	50	8	3	2
65	Common Sandpiper	*Actitis hypoleucos*	LC	2	-	4	2	1
66	Common Snipe	*Gallinago gallinago*	LC	4	-	-	-	-
67	Green Sandpiper	*Tringa ochropus*	LC	1	5	7	3	-
68	Marsh Sandpiper	*Tringa stagnatilis*	LC	-	15	-	-	-
69	Wood sandpiper	*Tringa glareola*	LC	1	38	2	-	-
70	Eurasian Curlew	*Numenius arquata*	NT	5	-	-	-	-
71	Black-tailed Godwit	*Limosa limosa*	NT	-	25	-	-	-
72	Temminck's Stint	*Calidris temminckii*	LC	-	2	-	-	-
73	Ruff	*Calidris pugnax*	LC	239	23	-	-	-
74	Little Stint	*Calidris minuta*	LC	2	1	-	-	-
75	Common Greenshank	*Tringa nebularia*	LC	-	1	-	-	1
Family Glareolidae (Prantincoles and Coursers)								
76	Little Pratincole	*Glareola lactea*	LC	-	13	-	-	-
Order: Columbiformes								
Family Columbidae (Pigeons and Doves)								
77	Eurasian Collared Dove	*Streptopelia decaocto*	LC	5	4	2	-	-
78	Laughing Dove	*Streptopelia senegalensis*	LC	-	1	-	-	-
79	Rock Dove	*Columba livia*	LC	6	50	5	6	-
Order: Psittaciformes								
Family Psittacidae (Parrots and Hanging Parrots)								
80	Rose-ringed Parakeet	*Psittacula krameri*	LC	2	3	-	-	1
Order: Cuculiformes								
Family Cuculidae (Cuckoos, Malkohas and Coucals)								
81	Greater Coucal	*Centropus sinensis*	LC	1	1	1	-	1
Order: Strigiformes								
Family Tytonidae (Barn Owls); Strigidae (Typical Owls)								
82	Spotted Owlet	*Athene brama*	LC	3	-	-	-	-
Order: Bucerotiformes								
Family Upupidae (Hoopoes)								
83	Common Hoopoe	*Upupa epops*	LC	2	2	-	-	-
Family Bucerotidae (Hornbills)								
84	Indian Grey Hornbill	*Ocyceros birostris*	NT	1	2	-	-	-
Order: Coraciiformes								
Family Coraciidae (Rollers)								
85	Indian Roller	*Coracias benghalensis*	LC	1	-	2	-	1
Family Alcedinidae (Kingfisher)								
86	Common Kingfisher	*Alcedo atthis*	LC	1	2	1	-	-
87	Pied Kingfisher	*Ceryle rudis*	LC	-	2	2	2	-
88	White-breasted Kingfisher	*Halcyon smyrnensis*	LC	8	9	3	-	2
Family Meropidae (Bee-Eaters)								
89	Green Bee-eater	*Merops orientalis*	LC	1	2	-	-	-

	Common name	Scientific name	IUCN Red List status	Saman Bird Sanctuary	Sarsai Nawar	Sauj Wetland	Kuddaiyya Marshland	Kurra Zheel
Order: Piciformes								
Family Ramphastidae (Barbets)								
90	Brown-headed Barbet	*Psilopogon zeylanicus*	LC	1	-	-	-	-
91	Coppersmith Barbet	*Psilopogon haemacephalus*	LC	-	1	-	-	-
Family Picidae (Wryneck, Piculets and Woodpeckers)								
92	Eurasian Wryneck	*Jynx torquilla*	LC	-	1	1	-	-
Order: Passeriformes								
Family Dicruridae (Drongos)								
93	Black Drongo	*Dicrurus macrocercus*	LC	24	18	25	-	1
Family Corvidae (Crows)								
94	House Crow	*Corvus splendens*	LC	1	50	2	2	30
95	Large-billed Crow	*Corvus macrorhynchos*	LC	2	4	2	-	2
96	Rufous Treepie	*Dendrocitta vagabunda*	LC	1	2	-	-	-
Family Alaudidae (Larks)								
97	Oriental Skylark	*Alauda gulgula*	LC	-	1	-	-	-
Family Pycnonotidae (Bulbuls)								
98	Red-vented Bulbul	*Pycnonotus cafer*	LC	-	-	-	-	1
Family Cisticolidae (Cisticolas, Prinias and Allies)								
99	Ashy Prinia	*Prinia socialis*	LC	7	1	1	1	-
100	plain Prinia	*Prinia inornate*	LC	6	3	1	1	-
101	Common Tailorbird	*Orthotomus sutorius*	LC	2	-	-	-	-
Family Sylviidae (Warblers)								
102	Lesser Whitethroat	*Sylvia curruca*	LC	-	-	1	-	-
Family Timaliidae (Babblers)								
103	Jungle Babbler	*Turdoides striata*	LC	-	4	5	-	-
104	Large Grey Babbler	*Argya malcolmi*	LC	-	8	2	-	-
Family Sturnidae (Starlings and Mynas)								
105	Asian Pied Starling	*Gracupica contra*	LC	65	50	12	-	22
106	Common Myna	*Acridotheres tristis*	LC	1	2	3	-	4
107	Bank Myna	*Acridotheres ginginianus*	LC	1	-	-	-	-
Family Muscicapidae (Chats and Old World Flycatcher)								
108	Bluethroat	*Luscinia svecica*	LC	4	1	-	-	-
109	Brown Rockchat	*Oenanthe fusca*	LC	2	1	-	-	-
110	Common Stonechat	*Saxicola torquatus*	LC	-	1	-	-	-
111	Pied Bushchat	*Saxicola caprata*	LC	6	1	1	-	-
112	Indian Robin	*Saxicoloides fulicatus*	LC	1	1	2	-	-
113	Desert Wheatear	*Oenanthe deserti*	LC	-	1	-	-	-
114	Oriental magpie Robin	*Copsychus saularis*	LC	1	1	1	-	-
Family Passeridae (Sparrows, Petronias and Snowfinches)								
115	Chestnut-shouldered Bush-sparrow	*Gymnoris xanthocollis*	LC	-	-	2	-	1
116	House Sparrow	*Passer domesticus*	LC	-	-	-	-	30
Family Ploceidae (Weavers)								
117	Black-breasted Weaver	*Ploceus benghalensis*	LC	7	1	-	-	-

	Common name	Scientific name	IUCN Red List status	Saman Bird Sanctuary	Sarsai Nawar	Sauj Wetland	Kuddaiyya Marshland	Kurra Zheel
Family Estrildidae (Avadavats and Munias)								
118	Scaly-breasted Munia	*Lonchura punctulata*	LC	-	1	-	-	-
119	Tricoloured Munia	*Lonchura malacca*	LC	-	1	-	-	-
120	Red Avadavat	*Amandava amandava*	LC	3	1	-	-	-
121	Indian Silverbill	*Euodice malabarica*	LC	1	1	-	-	1
Family Motacillidae (Pipits and Wagtails)								
122	White-browed Wagtail	*Motacilla maderaspatensis*	LC	-	-	-	-	2
123	Western Yellow Wagtail	*Motacilla flava*	LC	1	15	1	-	10
124	White Wagtail	*Motacilla alba*	LC	-	-	-	-	6
125	Citrine Wagtail	*Motacilla citreola*	LC	2	3	22	-	1
126	Paddyfield Pipit	*Anthus rufulus*	LC	-	2	-	-	2

LC—Least Concern | NT—Near Threatened | VU—Vulnerable | EN—Endangered.

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ARTICLE

First record of two species of venomous snakes *Bungarus suzhenae* and *Ovophis zayuensis* (Serpentes: Elapidae, Viperidae) from India

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Abstract: We report *Bungarus suzhenae* Chen, Shi, Vogel, Ding & Shi, 2021 and *Ovophis zayuensis* (Jiang, 1977) for the first time from India. Specimens of *B. suzhenae* and *O. zayuensis* were collected during our field surveys in north (Arunachal Pradesh) and south (Nagaland-Manipur border) of the river Brahmaputra. Species identity was supported by partial cytochrome *b* (cyt *b*), and 16s mitochondrial gene. We provide a detailed morphological description and a key to the two genera of this region. This report extends the westernmost distribution of *B. suzhenae* by ca. 300 km from Myanmar, and the southernmost range of *O. zayuensis* by 170 km from Tibet. Until now eight species of *Bungarus* and only one *Ovophis* species have been reported from India. *Ovophis* species are recently reported to be medically important venomous snakes whose venom properties have not been investigated in depth.

Keywords: Krait, northeastern India, pit viper, range extension, taxonomy.

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Author details: Jason D. Gerard is a researcher with interest in taxonomy and ecology of reptiles. Bitupan Boruah is a PhD scholar whose interests are systematics and biogeography of lesser-known fauna such as amphibians and reptiles. V. Deepak is a researcher whose work predominantly focuses on the evolution and systematics of lizards, snakes and turtles in southern Asia. Abhijit Das is a scientist and faculty involved in teaching, training and research in Herpetology.

Author contributions: JDG and BB equally contributed to this work. BB, AD and JDG carried out field work for this study. JDG and BB examined the specimens. AD and BB conceptualized the study. BB and DV contributed to the phylogenetic analyses and data verification. All authors contributed equally to the writing and editing of this manuscript.

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INTRODUCTION

Northeastern India is part of the Indo-Burma biodiversity hotspot (Tripathi et al. 2016) and home to approximately 21 species of venomous snakes from the families Viperidae and Elapidae (Ahmed et al. 2009; Captain et al. 2019; Mirza et al. 2020; Rathee et al. 2022; Biakzuala et al. 2023 and 2024). Biodiversity explorations are continuing to reveal new information on snake diversity (Elangbam et al. 2023; Biakzuala et al. 2024). The Elapid genus *Bungarus* Daudin, 1803 consists of 18 species (Uetz et al. 2024), distributed from Iran and Pakistan eastwards to China and Indonesia (Chen et al. 2021). Eight species of *Bungarus* have been reported from India, namely, *B. andamanensis* Biswas & Sanyal, 1978, *B. caeruleus* Schneider, 1801, *B. sindanus* Boulenger, 1897, *B. walli* Wall, 1907, *B. lividus* Cantor, 1839, *B. fasciatus* Schneider, 1801, *B. niger* Wall, 1908, and *B. bungaroides* Cantor, 1839, of which the latter four are found in northeastern India (Ahmed et al. 2009; Das & Das 2017; Das 2018; Biakzuala et al. 2021). Recently, Chen et al. (2021) described *B. suzhenae* from China that is currently known from the type locality Yingjiang County, Yunnan Province, China, and the adjacent Kachin State of Myanmar.

There are eight species in the viperid genus *Ovophis* (Burger, 1981), namely: *O. makazayazaya* (Takahashi, 1922); *O. jenkinsi* Qiu et al., 2024; *O. malhotrae* Zeng, Li, Liu, Wu, Hou, Zhao, Nguyen, Guo & Shi, 2023; *O. monticola* (Gunther, 1864); *O. okinavensis* (Boulenger, 1892); *O. tonkinensis* (Bourret, 1934); and *O. zayuensis* (Jiang, 1977) (Malhotra et al. 2011; Zeng et al. 2023; Qiu et al. 2024; Uetz et al. 2024). The southernmost record of *O. zayuensis* is from Zayu, Motuo, Xizang province, China. During a herpetological field survey in northeastern India in 2012, 2022, and 2023, we came across one individual of *Bungarus* and two individuals of *Ovophis.* They were collected and based on morphological evaluation we identified them as *B. suzhenae* and *O. zayuensis*. Additionally, we generated new DNA sequences and compared them with published sequences of these species, including their types (*B. suzhanae* CIB 116088 from Yingjiang County, Yunnan Province, China, and *O. zayuensis* CIB 013375 from Chayu Co., Xizang, China), based on which we report here the first country records for India.

MATERIALS AND METHODS

We carried out field surveys during October 2012 in the Nagaland-Manipur border, between June and July 2022–2023 in Arunachal Pradesh, northeastern India (Figure 1). Collected specimens were fixed in formalin, washed, stored in 70% ethanol, and housed in the repository at the Wildlife Institute of India, Dehradun (WII-ADR1241, WII-ADR3316 and WII-ADR3491). Before fixation, live snakes were photographed, and liver tissues were collected and stored in absolute ethanol at -20°C.

Molecular phylogenetic analysis

Genomic DNA was extracted from liver tissue samples using DNeasy Blood and Tissue Kit (Qiagen™, Germany). For the *Bungarus* specimen (WII-ADR1241), we amplified and sequenced fragments of one mitochondrial gene, cytochrome *b* (cyt *b*) using the primers L14910 (5'-GACCTGTGATMTGAAAACCAYCGTTGT-3') and H16064 (5'-CTTTGGTTTACAAGAACAATGCTTTA) (Burbrink et al. 2000). Polymerase Chain Reaction (PCR) conditions followed was initial denaturation at 95°C for five minutes, followed by 35 cycles of denaturation at 95°C for 45 sec, annealing at 54°C for 45 sec, and extension at 72°C for 55 sec. The final extension was at 72°C for 10 min. For the *Ovophis* sample (WII-ADR3491) we amplified and sequenced fragments of 16s gene, using the primers 16Sar (5'-CGCCTGTTTATCAAAAACAT-3') + 16Sbr (5'-CCGGTCTGAACTCAGATCACGT-3') (Palumbi et al. 1991). Polymerase chain reaction (PCR) condition followed was initial denaturation at 95°C for five minutes, followed by 35 cycles of denaturation at 95°C for 35 sec, annealing at 55°C for 45 sec, and extension at 72°C for one minute. The final extension was at 72°C for 10 min. Amplified PCR products were run on a 2% agarose gel and viewed under a UV transilluminator. The purified PCR product was sequenced directly in an Applied Biosystems Genetic Analyzer 3500 XL in both directions using BigDye v3.1 kit.

We manually checked bidirectional sequences using the CHROMAS v2.6.6 software (http://technelysium.com.au/wp/chromas/) and aligned using ClustalW (Thompson et al. 199) with default prior settings implemented in MEGA v7.1 (Kumar et al. 2016). For the protein-coding gene (cyt *b*), we checked for unexpected stop codons by translating the sequence to amino acids in MEGA v7.1 (Kumar et al. 2016). We used *Naja atra* and *Protobothrops mucrosquamatus* as outgroup for phylogenetic analyses of *Bungarus* and *Ovophis*, respectively. The newly generated sequences were aligned with the sequences downloaded from GenBank

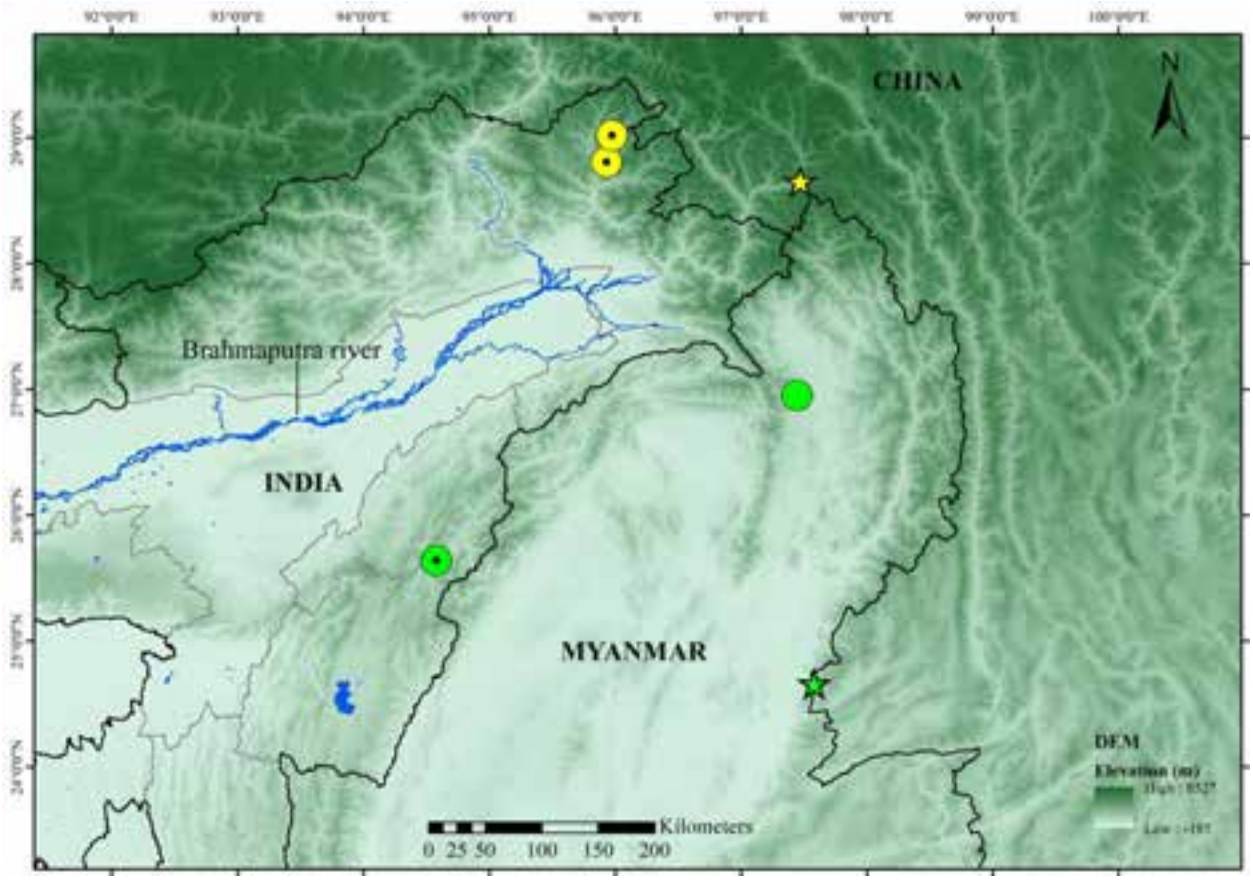

Figure 1. Map showing the locality of Indian records of *Bungarus suzhenae* (green) and *Ovophis zayuensis* (yellow). Type locality denoted by star, known locality shown as circles and new records denoted by circles with a black centre.

(Benson et al. 2009) (Appendix 1).

We performed maximum likelihood (ML) analyses using IQ-TREE (Nguyen et al. 2015), implemented in the web server version (http://iqtree.cibiv.univie.ac.at) (Trifinopoulos et al. 2016). For cyt *b*, the dataset was partitioned by codon positions using Modelfinder (Kalyaanamoorthy et al. 2017), to find the best-fit partitions and models of sequence evolution for each partition (Appendix 2). Support for internal branches was quantified using the bootstrap approximation (UFB 1000 pseudoreplicates) (Minh et al. 2013). Uncorrected P-distance was calculated in MEGA v7.1 (Kumar et al. 2016) with pairwise deletions of missing data and gaps.

Morphological character scoring and identification

Total length, snout-vent length, and tail length were measured with a thread and a metre tape in millimetre (mm). Morphometric measurements were taken with the help of a digital calliper (Mitutoyo TM) to the nearest 0.1 mm. Length and width of head scales were measured at the longest and the widest points of the respective scales. Morphological comparisons follow Das et al. (2021). All measurements were taken on the specimen's right side and scales were counted on both sides for bilateral scales. Morphometric and meristic characters were examined with the help of the Olympus SZX10 microscope. Dorsal scale rows (DSR) were counted at one head length behind the head, at midbody, and at one head length anterior to the anal scute. Ventral scales were counted following Dowling (1951). Bilateral scale counts separated by a comma are given in left, and right order. Abbreviations used are WII-ADR: Wildlife Institute of India Abhijit Das Reptile collection.

RESULTS

Molecular phylogeny

Based on mitochondrial gene cyt *b*, the specimen of *Bungarus* from Northeastern India clustered with the type sequences of *B. suzhenae* with strong bootstrap value (100) (Figure 2). Uncorrected P-distance between

Table 1. Uncorrected P-distances (%) of *Bungarus* species based on the cyt *b* sequences.

	1	2	3	4	5	6
1. *Bungarus suzhenae* (India)						
2. *B. bungaroides* (AY973270)	0.188					
3. *B. caeruleus* (AJ749305)	0.135	0.189				
4. *B. candidus* (AJ749329, AJ749339, AJ749341, MN165133)	0.098–0.101	0.167–0.17	0.139–0.142	0.003–0.008		
5. *B. ceylonicus* (KC347457)	0.144	0.201	0.101	0.151		
6. *B. fasciatus* (AJ749350, MW596457)	0.147–0.154	0.171–0.183	0.152–0.154	0.152–0.154	0.174–0.176	0.041
7. *B. lividus* (MW596472)	0.137	0.201	0.114	0.144	0.111	0.169
8. *B. multicinctus* (AJ749344, MN165136, MN165137, MN165139, MN165138, MN165135)	0.086–0.090	0.169–0.171	0.143–0.145	0.026–0.031	0.147–0.148	0.153–0.154
9. *B. niger* (AJ749304, MW596473)	0.091–0.095	0.177–0.181	0.135–0.14	0.101–0.106	0.144–0.146	0.152
10. *B. sindanus* (AJ749346)	0.145	0.186	0.129	0.136	0.134	0.166
11. *B. slowinskii* (AJ749306)	0.176	0.087	0.190	0.179	0.199	0.174
12. *B. suzhenae* (AJ749435, MN165142, MN165140, MN165141, MN165143)	0.015–0.019	0.185–0.187	0.133–0.136	0.096–0.1	0.138–0.142	0.151–0.156
13. *B. wanghaotingi* (MN165144, KY952766, MN165146, MN165145, MN165132, AJ749336, AJ749308, MN165134, AJ749309, MN165131, AJ749331, AJ749337)	0.092–0.1	0.163–0.177	0.136–0.144	0.018–0.024	0.142–0.151	0.148–0.161

Table 1. continue...

7	8	9	10	11	12
0.136–0.139	0–0.006				
0.14–0.143	0.102–0.104				
0.142	0.130	0.129			
0.197	0.170	0.171	0.183		
0.135–0.140	0.087–0.091	0.091–0.095	0.141–0.144	0.171–0.176	0.002–0.007
0.134–0.139	0.026–0.03	0.096–0.102	0.126–0.137	0.164–0.175	0.087–0.097

the newly collected Indian samples of *Bungarus* and the type series of *B. suzhenae* from the type locality varied 0.015–0.019 (Table 1). The inferred ML tree based on *cyt*–b showed *B. suzhenae* as a sister lineage to the cluster containing *B. caeruleus*, *B. ceylonicus*, *B. lividus,* and *B. sindarus* with low bootstrap value (48) (Figure 2). Based on 16s gene, the *Ovophis* sample from Arunachal Pradesh nested with the *Ovophis zayuensis* sequence from Xizang province, China (with strong bootstrap value, (97) (Figure 3) along with two other samples from Yunnan province, China and Chin state, Myanmar. These samples altogether form a sister relationship with the samples of *O. zayuensis* from Tongmai and Xizang provinces, China with low node support (Figure 3). Uncorrected P-distance between our newly collected samples of *Ovophis* and samples of *O. zayuensis* from China and Myanmar was minimal (Table 2).

Morphology

We confirmed the new krait specimen as *Bungarus suzhenae* based on the following set of diagnostic morphological characteristics (Chen et al. 2021): enlarged hexagonal vertebral scale rows present, dorsal scales in 15:15:15 rows, anterior chin shields are slightly larger than the posterior chin shields, dorsal body black with 34 white bands, ventral scales connected with the black bands of the dorsal body by small dark patches, the ventral surface uniform white, underside of tail white with tiny brown dots in the middle.

The two viper specimens we collected were confirmed as *Ovophis zayuensis* based on the following set of diagnostic morphological characteristics (Che et al. 2020): the third supralabial larger is than the fourth, the second supralabial is fused with the loreal, internasal scales are separated by two scales; the ventral scale count is 169–172, dorsal scale count is 23 or 25:23:19 rows, the subcaudal count of 34–48, mostly single and

Table 2. Uncorrected P-distances (%) of *Ovophis* species based on the 16s gene sequences.

	1	2	3	4	5	6
1. *Ovophis zayuensis* (India)						
2. *O. zayuensis* (HQ325109, HQ325111, HQ325118, HQ325089, MK193194, MK193195)	0.004–0.019	0.0–0.013				
3. *O. monticola* (HQ326117, HQ325121, HQ325078, MG995792)	0.05–0.062	0.039–0.057	0.004–0.017			
4. *O. makazayazaya* (HQ325107)	0.056	0.039–0.055	0.05–0.054			
5. *O. tonkinensis* (HQ325096, HQ325070)	0.031–0.032	0.026–0.032	0.049–0.056	0.03–0.034	0.004	
6. *O. okinavensis* (AB175670)	0.056	0.035–0.046	0.057–0.059	0.054	0.052–0.053	
7. *O. convictus* (HQ325082, HQ325083)	0.046–0.052	0.032–0.05	0.041–0.059	0.05–0.052	0.042–0.043	0.05–0.056

Table 3. Morphometric and meristic data of newly collected specimens of *Bungarus suzhenae*. All the measurements are given in millimetre. Bilateral characters are given in left, and right order separated by comma. "N" denotes sample size, "-" indicates data not provided.

Voucher ID	WIIADR1241	Chen et al. (2021)	
Sex	male	male (N = 3)	female
Snout- vent length (SVL)	664	620–1140	1310
Tail length (TL)	109	109–180	-
Head length (HL)	21.6	21–39	30.2
Head width (HW)	10.7	12.3–15.5	19.4
Head height (HH)	6.5	8.7–12.8	14.2
Eye diameter	2.3	9.3–10.5	14.6
Ventrals	219	220–229	222
Subcaudals	57	51–54	11+
Anal plate	single	single	single
Dorsal scale row	15:15:15	15:15:15	15:15:15
Supralabial	7,7	7,7	7,7
Infralabial	7,7	7,7	7,7
Preocular	1,1	1,1	1,1
Postocular	2,2	1–2	2
Temporal (anterior + posterior)	1+2	1+2	1+2
Nasal	divided	divided	divided
No. of white bands (body + tail)	34+13	26–38+9–12	34+3

some are paired, anal scale is single.

Description of *Bungarus suzhenae* (WII-ADR1241) (Image 1,2)

An adult male specimen. Body nearly triangular in cross-section, broader at midbody, more tapering posteriorly. Head slightly distinct from the neck and longer than broad (head width/head length = 0.5); head dorsally depressed at the parietal region, frontal area flat, gradually sloping towards snout from prefrontals; loreal region concave; supralabial sloping towards outer margin; snout rounded in dorsal and lateral view; eyes with rounded pupil; external nares oval, smaller than eye diameter; nasal large and divided; prenasal touches first supralabial, rostral and internasal; postnasal touches first and second supralabial, preocular, internasal and prefrontal; postnasal-preocular suture short and straight; preocular one, hexagonal on right side and pentagonal left side, bordered by second and third supralabials, postnasal, prefrontal and supraocular; internasals two, wider than long, in contact with rostral, nasals and prefrontals; prefrontals large, slightly wider than long; internasal suture shorter than prefrontal suture length and not aligned with latter; frontal shield-shaped, pointing posteriorly, 1.3 times longer than wide, bordered by prefrontals, supraoculars and parietals; supraoculars small, 1.5 times longer than wide, in contact with preoculars, upper postoculars, prefrontals, frontal and parietals; parietals large, longer than broad, bordered by frontal, supraoculars, upper postoculars, anterior temporal and upper posterior temporal on each side, and three smalls nuchal scales on posterior margins, posterolateral margins of parietals bordered by one enlarged elongate scales that anteriorly contact upper posterior temporals on each side; postoculars two on each side; temporals 1+2; supralabial seven on both side, third and fourth touches eye, lower postocular touches by fourth and fifth supralabials on each side; anterior temporal bordered by two postoculars, fifth and sixth supralabial, parietal, and two posterior temporals; lower posterior temporal in contact with sixth and seventh supralabial; rostral wider than long and triangular; mental smaller than rostral, bordered by first pair of infralabials; infralabial seven on both sides, fourth largest; first pair of chin shields slightly larger than the

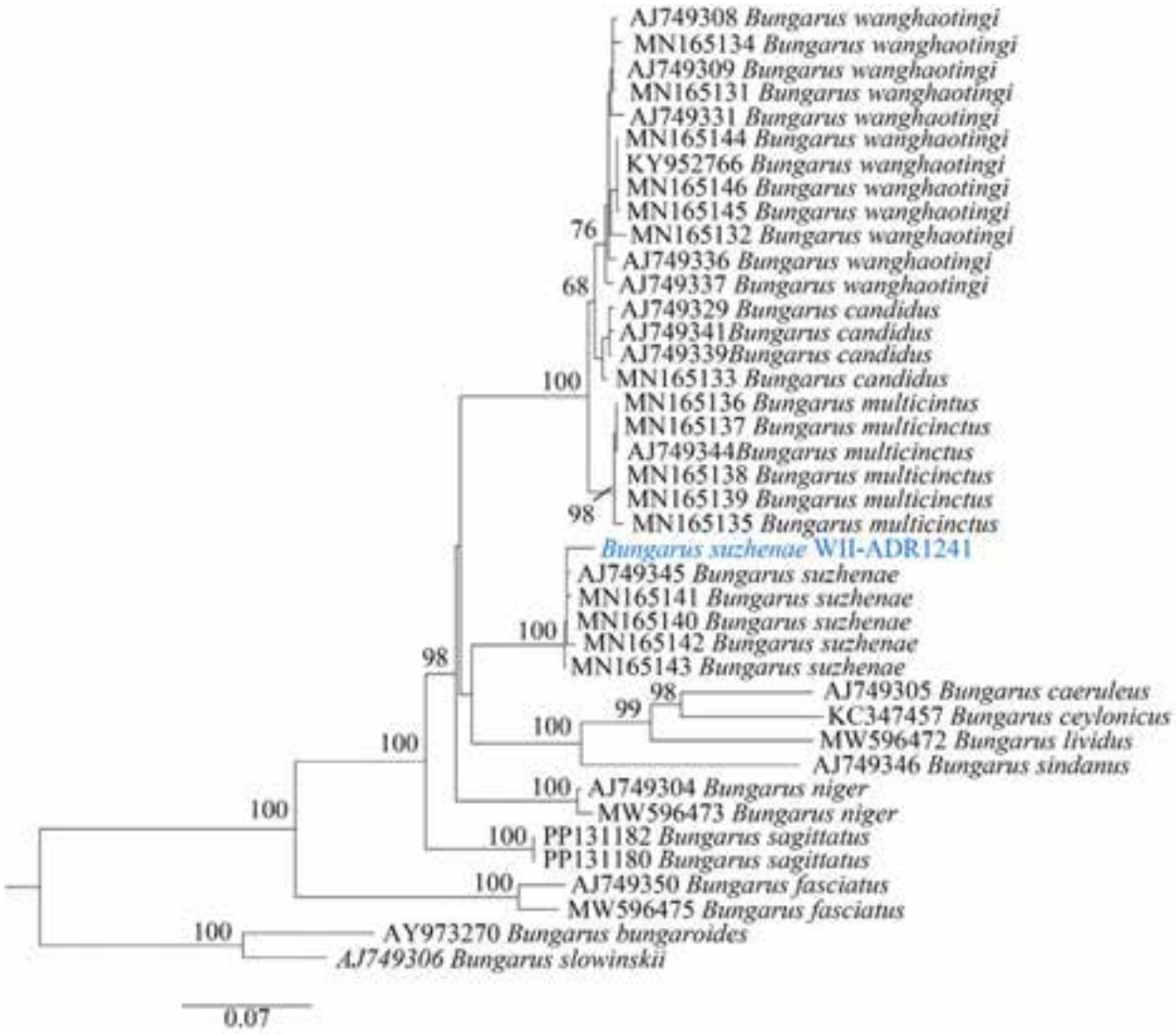

Figure 2. Maximum likelihood phylogeny of *Bungarus* based on cyt *b*. The newly generated sequences is shown in blue text. Bootstrap values <50 are not shown in the tree.

second pair chin shields; first chin shield is in contact with four infralabials on the right side and three infralabials on the left side; second chin shields contact with fourth infralabial on both sides, posteriorly bordered by three scales on the right side and fourth scales on the left side. Dorsal scales on body and tail smooth, no keel and apical pit; vertebral scale row enlarged and hexagonal; dorsal scale rows 15:15:15; ventrals 219; anal plate single; subcaudals 57, undivided; terminal scute conical; snout-vent length 664 mm and tail length 109 mm. Details of the morphometric and meristic characters of the specimen (WII-ADR1241) are given in (Table 3).

The hemipenes of the newly reported specimen of *B. suzhenae* from India agree with the description provided by Chen et al. (2021). Hemipenis can be divided into three distal calyculate region, middle spinose region, and basal region. The top of the hemipenis is slightly bilobed. The calyculate region is covered with well-developed small calyces. The spinose zone is covered with fang-shaped large keratinized spines and the basal region is covered with tiny spines; the basal region is nearly smooth towards the proximal end.

Dorsally head, body, and tail are uniformly dark brown. The rostral upper half is dark brown, the lower half (below the level of the lower edge of external nares) white; the nasals are also white below the level of the lower edge of external nares; supralabials are partly dark brown on the upper part and lower part (more than half of the scales) white; 34 narrow white cross bands on the dorsal body; bands widening on the flank before meeting

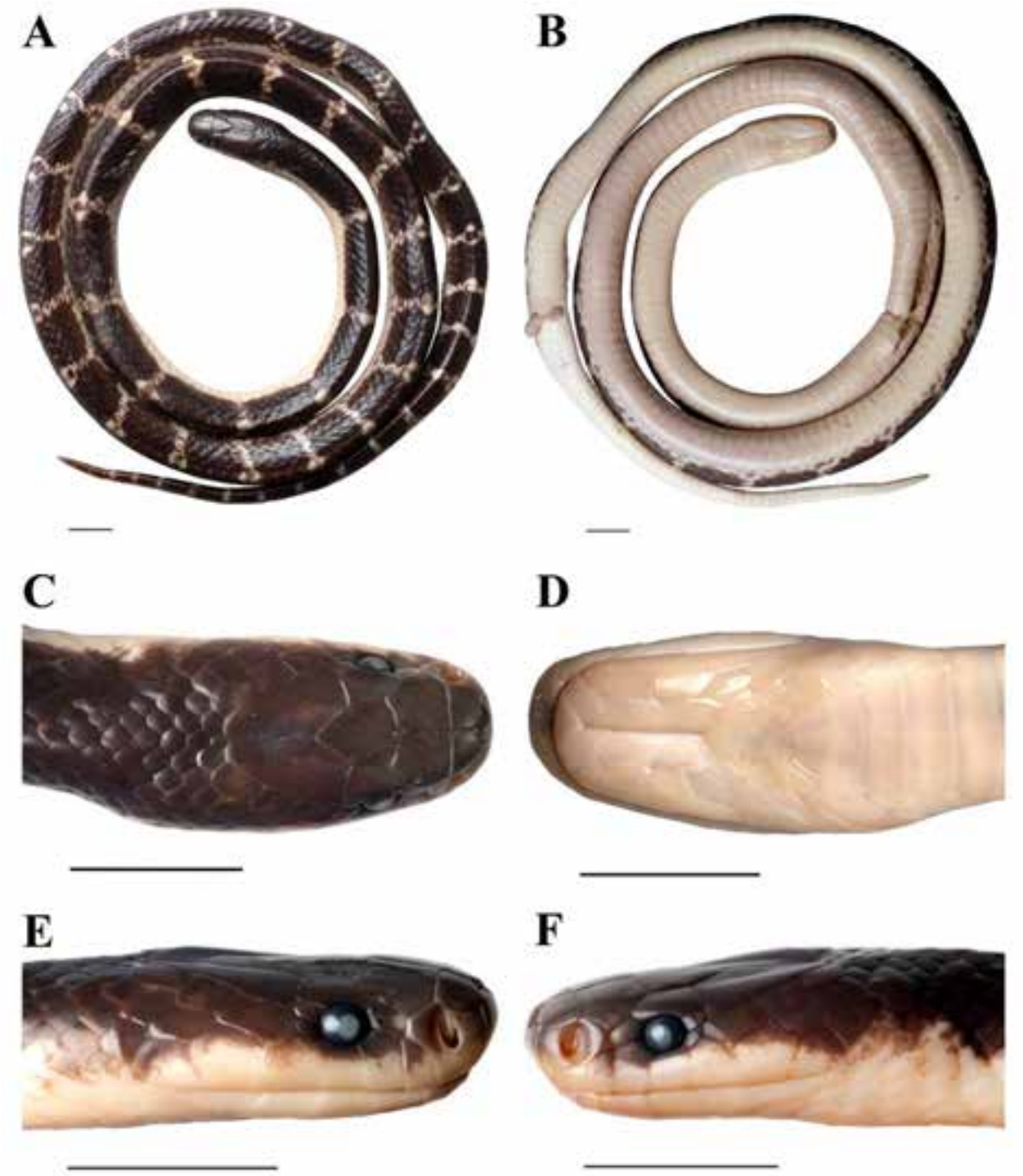

Image 1. Newly collected specimen of *Bungarus suzhenae* (WII-ADR1241) from India: Full body in A—dorsal view | B—ventral view | C—dorsal view of head | D—ventral view of head | E–F—lateral views of head, in preservation. Scale bars 10 mm. Photo: A. Das; edited by: B. Boruah

the ventrals; a dark spot present at the junctions where the white bands meet the ventrals; white bands 5–7, 13, 15, 18–26, 28, and 31–33 are broad at mid dorsum with a central dark spot forming a white semicircle; white band 27 is incomplete; black bands wide and not intruding to venter; 13 white cross bands on the tail; ventrally white including infralabials, mental, chin shields, gular scales, ventrals, and subcaudals; the edge of the ventrals with slightly dark brown patch; tail ventrally white with tiny brown dots in the middle. The specimen is dorsally dark

Image 2. *Bungarus suzhenae* (WII-ADR1241) in life from Nagaland-Manipur border, India. © A. Das.

brown with white transverse bands on the body and tail. Interstitial skin white. Ventrally white, subcaudals with tiny brown dots in the middle (Image 2). Difference between the newly reported specimen and original description of *B. suzhenae:* Notable difference between the type specimen (based on the original description) and our newly reported specimen (WII-ADR1241) is a lower number of ventrals in the new specimen (219 vs. 220–229), the higher number of subcaudals in the new specimen (57 vs. 51–54).

This newly reported specimen was encountered along Jessami–Meluri road (25.6393^{0}N, 94.5791^{0}E, elevation 599 m), at the Nagaland-Manipur border ca. 6 km from Meluri, Nagaland towards Jessami, Manipur. This individual was found while it was crossing the road at around 2100 h on 20 October 2012. The Tiji River flows ca. 20 m away from the collection locality. A roadkill *Bungarus niger* was also recorded 100 m away from the location of *B. suzhenae* indicating their sympatric occurrence. The surrounding landscape was mostly with secondary vegetation with extensive jhum cultivation areas. While photographing, the snake showed head-hiding behaviour and bit the snake bag in defence.

Description of *Ovophis zayuensis* (WII-ADR3316 and WII-ADR3491) (Image 3,4)

Both the specimens are adult females. Specimens are in good condition, latero-ventral incision between ventral scale 99–102 in WII-ADR3316 and between ventral scale 66–70 in WII-ADR3491. Head triangular, body stout and the dorsal scales are strongly keeled, ventrally plain pale yellow or orangish in color with no patterns. There are faint black blotches on the anterior dorsal region of the body and the blotches are dark on the posterior dorsal region. After preservation, the specimen's colour changed into smokey grey with black blotches on the dorsal side. Dorsally head is completely covered with small scales. The head length ranges 34.2–37.9 mm, the head width is 23.1–25 mm, the eye diameter is 2.5–2.6 mm, the eye-to-nostril distance is 5.5–7.3 mm, and the snout length is 10.1–11.3 mm. No supralabials touching the eye, one preocular and three postocular present. Nasal single and undivided in both specimens. There is no distinguishable temporal, parietal, and frontal scales present. The second supralabial is fused with the loreal pit. The total length of the specimens is 826–900 mm, SVL 699–746 mm, tail length 127–154 mm, ventral scales 166–167 mm, anal scale single and undivided, subcaudals 46–49 with 5–6 paired. WII-ADR3491 has nine supralabials on the left, third is the

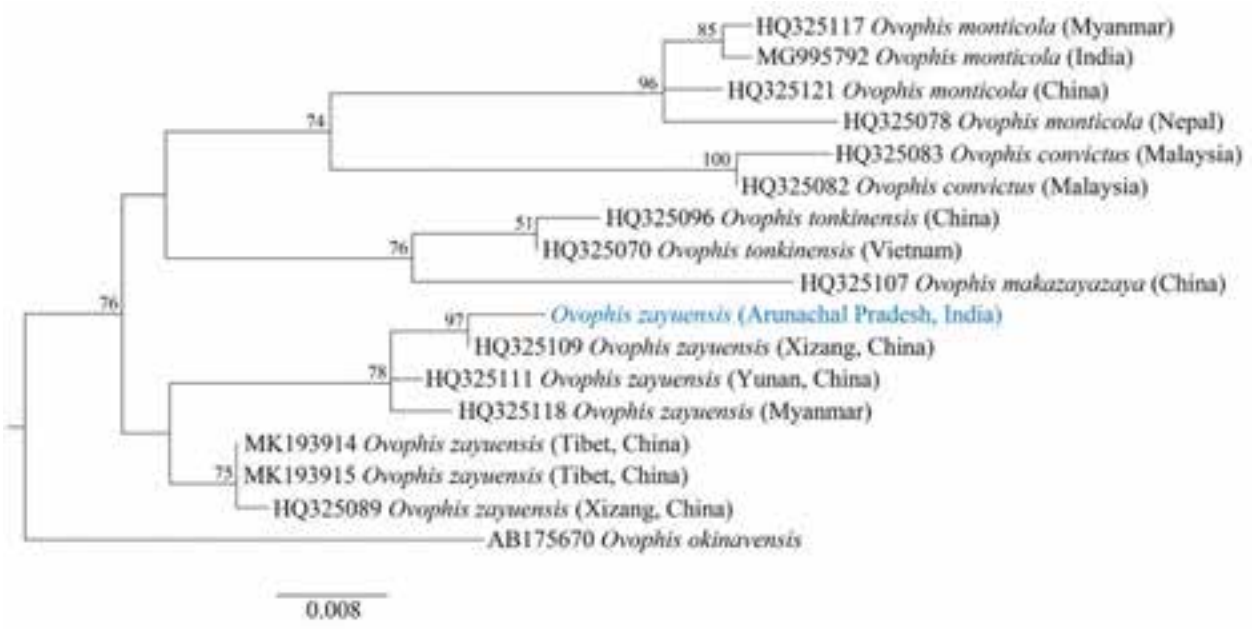

Figure 3. Maximum likelihood phylogeny of *Ovophis* based on 16s gene. The newly generated sequence is shown in blue text. Bootstrap values <50 are not shown in the tree.

Table 4. Morphometric and meristic data of newly collected specimens of *Ovophis zayuensis*. All the measurements are given in millimetre.

Voucher ID	WII-ADR3491	WII-ADR3316
Sex	female	female
Snout- vent length (SVL)	746	699
Tail length (TL)	154	127
Head length (HL)	37.9	34.2
Head width (HW)	25	23.1
Head height (HH)	14.3	14.2
Eye diameter	2.6	2.5
Ventrals	167	166
Subcaudals	49	46 (missing tip)
Anal plate	single	single
Dorsal scale row	25:23:19	23:23:19
Supralabial	9,8	9,9
Infralabial	10,11	9,9
Preocular	1,1	1,1
Postocular	3,3	3,3
Nasal	undivided	undivided

largest measuring 4.3 mm; eight supralabials on the right, third is the largest measuring 3.6 mm. Infralabials 10 on the left, the fourth is the largest measuring 3.2 mm; 11 infralabials on the right and the sixth is the largest measuring 2.8 mm, dorsal scale rows 25:23:19. WII-ADR3316 has nine supralabials on both sides, third is the largest measuring 3.7 mm. Infralabials nine on both sides, on the right sixth is the largest measuring 3.5 mm, and on the left, fifth is the largest measuring 3.3 mm, dorsal scales rows 23:23:19.

The individual WII-ADR3491 was recorded at Dri River bank (28.8056^{0}N, 95.9321^{0}E, elevation 1,288 m), near Etabe village (~2.5 km north-east from Anini), Dibang Valley district, Arunachal Pradesh. This individual was found while it was moving on the ground along the edge of a first-order stream on 16 August 2022 at 2000 h. The stream edge was covered with small to moderate-sized boulders covered with moss and leaf litter, fern, and other vegetation. The recorded locality was ~100 m from the Dri river near Etabe village. Along the stream, we observed a few anuran species such as *Xenophrys* sp. and *Amolops beibengensis* on the vegetation and also an unidentified rodent species. The second individual WII-ADR3316 was collected from the newly constructed Chigu Pani road, Anini, Dibang Valley (29.0182^{0}N, 95.9755^{0}E, elevation 1,800 m). The habitat in this region was disturbed due to the recent construction of roads, small streams were blocked by retaining walls. It was found perched in a bush 50 cm above the ground around 1900 h between the walls, blocking the stream. There was a mild yet constant drizzle throughout the night. Many *Amolops* froglets were found near the blocked stream and on the road. This individual was a bit aggressive while trying to bag, it puffed up, flattened

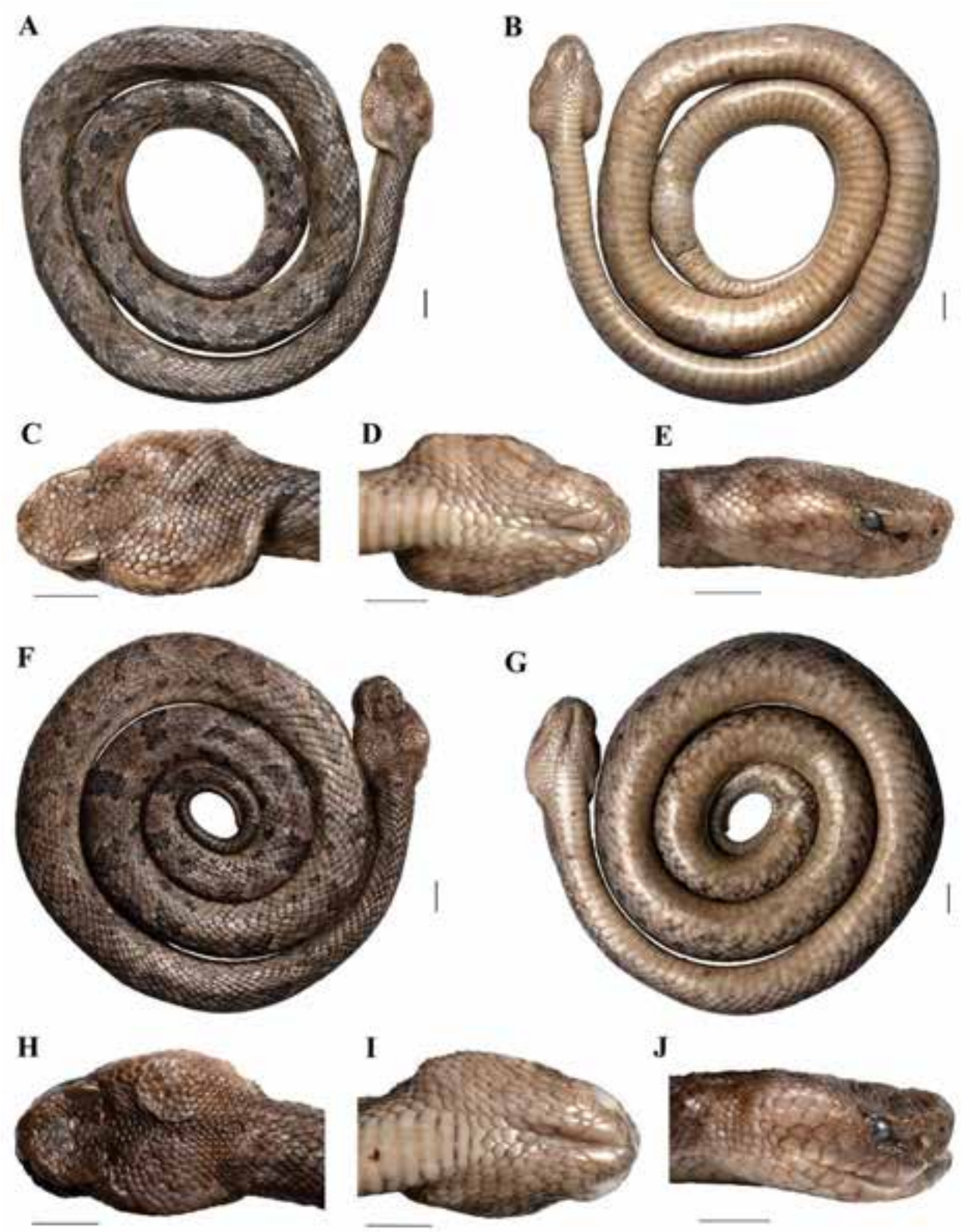

Image 3. Newly collected specimen of *Ovophis zayuensis* from India: A–E—WII-ADR3491 | F–J—WII-ADR3316. Full body in A & F—dorsal view | (B & G)—ventral view | C & H—dorsal view of head | D & I—ventral view of head | E & J—lateral views of head, in preservation. Scale bars 10 mm. © A. Das; edited by: B. Boruah

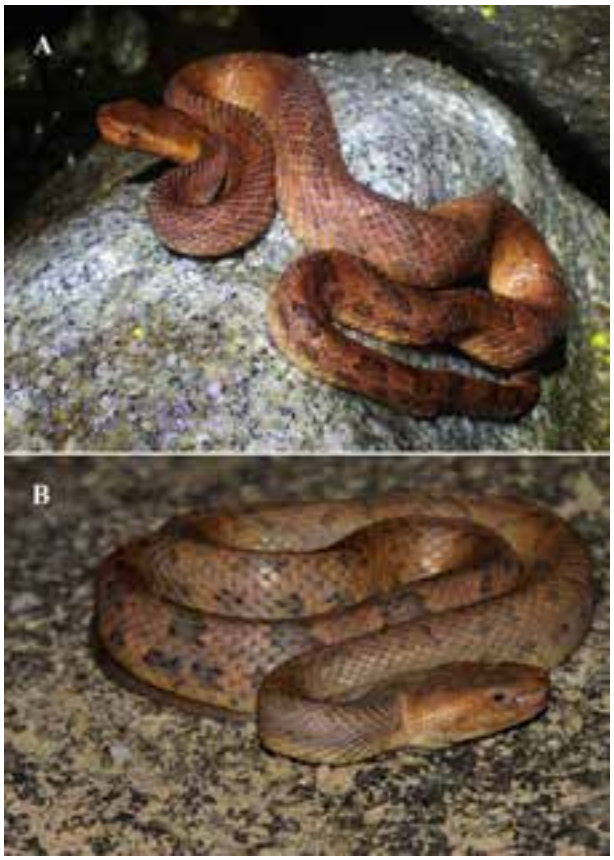

Image 4. *Ovophis zayuensis* in life from Arunachal Pradesh, northeastern India. A. WII-ADR3316, B. WII-ADR3491. © A. Das (A) | B. Boruah (B).

its body, and struck the snake hook. The next day around 2000 h on the same road, close to a small stream two other individuals of *O. zayuensis* male and female were spotted crossing the road from both sides. The blocked streams were seen to be harbouring tadpoles of multiple species of frogs including *Amolops* sp. and *Megophrys* sp. These two snakes were removed from the roadside and released by the stream.

DISCUSSION

There are over 400 known species of snakes in India (Uetz et al. 2024), where 1.2 million snakebite deaths were recorded during the years 2000–2019 (Suraweera et al. 2020). The Mountain Pit Viper *Ovophis monticola* Günther, 1864 has recently shown to cause medically significant envenoming (Ralph et al. 2023) while the *Bungarus* species have always been among the big four snakes of medical importance from India (Simpson & Norris 2007; Suraweera et al. 2020; Sunagar et al. 2021). *Bungarus suzhenae* and *Ovophis zayuensis* are two venomous snakes being reported for the first time from India, from the border of Nagaland-Manipur and Arunachal Pradesh, respectively.

Among the 18 known species of *Bungarus*, the maximum diversity is congregated in southeastern Asia. Until now eight species of *Bungarus* have been reported from India and are known for frequently causing fatal envenoming in the region (Suraweera et al. 2020; Sunagar et al. 2021). Despite several fatalities by other *Bungarus* species, the commercial antivenom is manufactured only against the most widespread congener *B. caeruleus* (Sunagar et al. 2021). This new finding reported here also indicates the lack of systematic studies on this group of snakes especially in northeastern India. Identification of *Bungarus* species is still a challenge which is evident by the recent discovery of *B. suzhenae* from China and Myanmar. *Bungarus* species with white cross bands—*B. andamanensis* Biswas & Sanyal, 1978; *B. bungaroides* Cantor, 1839; *B. caeruleus* Scheider, 1801; *B. multicinctus* Blyth, 1861; *B. sindanus* Boulenger, 1897; *B. slowinskii* Kuch, Kizirian, Nguyen, Lawson, Donnelly & Mebs, 2005; *B. suzhenae* Chen, Shi, Vogel, Ding & Shi, 2021; *B. walli* Wall, 1907; *B. canidus* Linnaeus, 1758; *B. magnimaculatus* Wall & Evans, 1901; and *B. persicus* Abtin, Nilson, Mobaraki, Hosseni & Dehgannejhad, 2014—are most complex and difficult to identify only based on external appearance (Leviton et al. 2003; Chen et al. 2021).

The genus *Ovophis* has eight known species globally (Malhotra et al. 2011), and now two species from India, namely: *O. monticola* and *O. zayuensis*. Though not commonly found in conflict with humans some species of *Ovophis* are capable of delivering a severely painful or life-threatening bite (Ralph et al. 2023). The venom composition of these less medically significant snakes and their clinical effects on humans still need to be studied (Tan et al. 2021). The current distribution range of *O. zayuensis* extends into the upper region of Dibang Valley, Arunachal Pradesh, Northeast India. However, it is important to carefully look into the distribution of *O. zayuensis* from the rest of Arunachal Pradesh. Being in the transition zone, the geographical range of these and other such species is likely to overlap in northeastern India. Therefore, proper identification of such venomous species and understanding of geographic distribution is crucial for general awareness, venom research as well as development of lifesaving antivenin.

Northeastern India is known to have Tibeto-Yunanese, Indo-Malayan, and its own unique faunal elements (Das 1996; Giri et al. 2019; Lalronunga et al. 2020; Vogel et al. 2020; Deepak et al. 2021; Das et al. 2021). The

Identification key to the *Bungarus* species of northeastern India

Crossbands on body and tail absent 1
1A. Mid-dorsal scale distinctly enlarged ..... *Bungarus niger*
1B. Mid-dorsal scale not enlarged ..... *Bungarus lividus*
Crossbands present 2
2A. Crossbands yellow and black ..... *Bungarus fasciatus*
2B. Crossbands white 3
3A. White crossbands not paired, 26–38 in number ..... *Bungarus suzhenae*
3B. White crossbands not paired, 46–60 in number ..... *Bungarus bungaroides*

Identification key to the *Ovophis* species from India

Ventral scales
A. 135–154 ..... *O. monticola*
B. 158–176 ..... *O. zayuensis*

new record of *B. suzhenae* from India indicates the possibility of the occurrence of other *Bungarus* species reported from Myanmar such as *B. magnimaculatus*, *B. wanghaotingi,* and *B. flaviceps*. Therefore, a systematic study is necessary across northeastern India to document the diversity of medically important snakes. With the present report of *B. suzhenae,* the number of *Bungarus* species in India increases to nine, and the distribution range of *B. suzhenae* is extended by ca. 321 km north-west from the nearest known locality, Yingjiang County, Yunnan Province, China. The geographical area of occurrence of *B. suzhenae* is currently ca. 38,000 km^2 within China, Myanmar, and northeastern India. In earlier documentation, other *Bungarus* species such as *B. bungaroides*, *B. fasciatus,* and *B. niger* were reported from Nagaland (Ao et al. 2004; Dasgupta & Raha 2006; Das 2018). Singh (1995) and Sinate et al. 2021 also reported *B. fasciatus* and *B. niger* from Manipur respectively. Since the present specimen of *B. suzhenae* was encountered at the Nagaland-Manipur border, there is a possibility of the occurrence of the species in other parts of Manipur. In a herpetofaunal biodiversity report of Nagaland, Grewal et al. (2011) provided a photograph of a road-killed unknown *Bungarus* sp. from Pungro-Shatuza road (nearest distance ca. 13 km from the present locality) which is similar to *B. suzhenae* (based on the lower number (<40) of unpaired white cross bands on body). Therefore, the distribution range of this medically important snake is likely to be wider than hitherto known in the region. Despite several reports of fatal snake bites by other species, commercial Indian antivenoms are only manufactured against *Daboia russelii, Naja naja, Echis carinatus,* and *Bungarus caeruleus.* Hence, it is important to recognise other medically important Indian snake species as it also has great significance in the field of snake antivenom design and manufacture (Simpson & Norris 2007).

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Appendix 1. Details of the GenBank sequences used in this study. The sequence of *Bungarus suzhenae* and *Ovophis zayuensis* generated in this study is given in bold.

Taxa	Voucher numbers	Locality	AccessionNo. (cyt– *b*)	Reference
B. bungaroides	KIZ 98R0186	Medog, Medog County, Tibet, China	AY973270	Kuch et al. 2005
B. caeruleus	UK H7	Pakistan	AJ749305	Kuch 2007
B. candidus	UK B39	Vicinity of Jambah, Losarang District, Indramayu Regency, West Java, Indonesia	AJ749329	Kuch 2007
B. candidus	UK BcBa	Bali Island, Indonesia	AJ749339	Kuch 2007
B. candidus	UK B21	Vicinity of Jambah, Losarang District, Indramayu Regency, West Java, Indonesia	AJ749341	Kuch 2007
B. candidus	SYNU R180411	Endau Rompin National Park, Taman Negara, Johor, Malaysia	MN165133	Chen et al. 2021
B. ceylonicus	RS-135	Sri Lanka	KC347457	Pyron et al. 2013
B. fasciatus	UK B24	Vicinity of Jolo, Central Java, Indonesia	AJ749350	Kuch 2007
B. fasciatus	MZMU978	Mizoram, India	MW596475	Biakzuala et al. 2021
B. lividus	YSR187	Baridua, Meghalaya, India	MW596472	Biakzuala et al. 2021
B. multicinctus	CIB104228	Nanning Zoo, Guangxi, China (locality uncertain)	MN165137	Chen et al. 2021
B. multicinctus	UK Bm1	Zhejiang, China	AJ749344	Kuch 2007
B. multicinctus	CIB DL18090209	Wuyi Moutain, Fujian, China	MN165138	Chen et al. 2021
B. multicinctus	CIB DL18090210	Wuyi Moutain, Fujian, China	MN165139	Chen et al. 2021
B. multicinctus	CIB93923	Guangxi, China	MN165136	Chen et al. 2021
B. multicinctus	SYNU R180305	Haikou, Hainan, China	MN165135	Chen et al. 2021
B. niger	Bnig	Nepal	AJ749304	Kuch 2007
B. niger	MZMU975	Mizoram, India	MW596473	Biakzuala et al. 2021
B. sindanus	Bsin1	Pakistan	AJ749346	Kuch 2007
B. slowinskii	IEBR 1172	Na Hau Commune, Van Yen District, Yen Bai,Vietnam	AJ749306	Kuch 2007
B. suzhenae	CAS 221526	Naung Mon Township, Rabaw Kachin State, Burma (Myanmar)	AJ749345	Kuch 2007
B. suzhenae	CIB116088	Yingjiang, Yunnan, China	MN165140	Chen et al. 2021
B. suzhenae	CIB116089	Yingjiang, Yunnan, China	MN165141	Chen et al. 2021
B. suzhenae	CIB116090	Yingjiang, Yunnan, China	MN165142	Chen et al. 2021
B. suzhenae	CIB116091	Yingjiang, Yunnan, China	MN165143	Chen et al. 2021
B. suzhenae	**WIIADR1241**	**Nagaland-Manipur border, India**	**PP808595**	**This study**
B. wanghaotingi	ROM 35250	Quang Thanh, Cao Bang, Vietnam	AJ749308	Kuch 2007
B. wanghaotingi	ROM 35256	Chi Linh, Hia Duong, Vietnam	AJ749309	Kuch 2007
B. wanghaotingi	UK BT6	Nakhon Si Thammarat, Thailand	AJ749331	Kuch 2007
B. wanghaotingi	UK BT8	Nakhon Si Thammarat, Thailand	AJ749336	Kuch 2007
B. wanghaotingi	FMNH 255259	Hin Nam No National Biodiversity Conservation Area, Boualapha District, Khammouan, Laos	AJ749337	Kuch 2007
B. wanghaotingi	FMNH 255260	Nam Et Phou Louey Mountain, Phou Louey National Biodiversity, Conservation Area, Vieng Tong, Huaphahn, Laos	AJ749338	Kuch 2007
B. wanghaotingi	CIB FCDZ20170806	Dongzhong, Fangchenggang, Guangxi, China	MN165131	Chen et al. 2021
B. wanghaotingi	CIB104227	Beiliu, Guangxi, China	MN165134	Chen et al. 2021
B. wanghaotingi	SYNU R170408	Bang Lang National Park, Yala, Thailand	MN165132	Chen et al. 2021
B. wanghaotingi	CIB ML20170801	Menglun, Yunnan, China	MN165145	Chen et al. 2021
B. wanghaotingi	CIB MLMY20170801	Mengla, Yunnan, China	MN165144	Chen et al. 2021
B. wanghaotingi	JK20181101	Jinghong, Yunnan, China	MN165146	Chen et al. 2021
B. wanghaotingi	GP 3375	Xishuangbanna, Yunnan Province, China	KY952766	Xie et al. 2018
Naja atra	-	China	DQ343648	Yan et al. 2008

O. zayuensis	**WII-ADR3491**	**Dibang Valley district, Arunachal Pradesh, India**	**PP794643**	**This study**
O. zayuensis	GP90	Xizang Autonomous Region, China	HQ325109	Malhotra et al. 2011
O. zayuensis	GP92	Yunnan Province, China	HQ325111	Malhotra et al. 2011
O. zayuensis	CAS 233203	Chin State, Myanmar	HQ325118	Malhotra et al. 2011
O. zayuensis	CHS099	Tibet, China	MK193914	Li, J. N et al. 2020
O. zayuensis	CHS101	Tibet, China	MK193915	Li, J. N et al. 2020
O. zayuensis	GP89	Xizang Autonomous Region, China	HQ325089	Malhotra et al. 2011
O. tonkinensis	MVZ 226627	Vinh Phu Province, N Viet Nam	HQ325096	Malhotra et al. 2011
O. tonkinensis	B581	China	HQ325070	Malhotra et al. 2011
O.monticola makazayazaya	GP24	Yunnan Province, China	HQ325107	Malhotra et al. 2011
O. monticola	CAS 224424	Kachin State, Myanmar	HQ325117	Malhotra et al. 2011
O. monticola	V16	North East India	MG995792	
O. monticola	CAS 234866	Chin State, Myanmar	HQ325121	Malhotra et al. 2011
O. monticola	ZMB 70216	Gandaki Zone, W Nepal	HQ325078	Malhotra et al. 2011
O. okinavensis	-	-	AB175670	Dong & Kumazawa 2005
O. convictus	B629	Pulau Langkawi, West Malaysia	HQ325083	Malhotra et al. 2011
O. convictus	B628	Pulau Langkawi, West Malaysia	HQ325082	Malhotra et al. 2011
Protobothrops mucrosquamatus	B106	Vin Phuc Province, N Viet Nam	AY294271	Herrmann et al. 2004

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ARTICLE

Bio-ecology of the bush cricket *Tarbinskiellus portentosus* (Lichtenstein, 1796) (Insecta: Orthoptera: Gryllidae): a relished edible insect in Nagaland, India

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Abstract: *Tarbinskiellus portentosus* (Lichtenstein, 1796) (bush cricket), also called "viituo" in the Angami dialect, belongs to the order Orthoptera and the family Gryllidae. It is one of the most common edible insects found in Nagaland and is a potential source of animal protein and other nutrients. Despite being highly preferred as food and relished, studying their ecology, biology, and market potential is nonexistent, at least in Nagaland, India. Therefore, the present study was conducted to fill the knowledge gap on the biology and market potential of *T. portentosus.* Insects were collected from the wild and reared as stock at 20–25 °C. The results show that *T. portentosus* undergoes seven nymphal instars to fully develop into an adult with an average growth rate of 9.94 ± 2.43 mg/day. *T. portentosus* is found in the grassland vegetation in burrows up to 800 mm depth. Adult males weigh about 2940 ± 93.0 mg, and females weigh 2980 ± 200 mg. The incubation period of eggs was 33.8 ± 0.96 days and showed a moderate percent of hatching efficiency (45.20 ± 0.28). In laboratory conditions, this cricket completed its life cycle in 341 ± 4.29 days. Collection of adults involves handpicking and pouring water, cleaning involves a gut removal process through head pulling, and preparation for consumption is done by cooking with local spices, fried or roasted. *T. portentosus* are sold in the local market at INR 300/- for 250–300 g. With scanty information on growth and reproduction, the present study serves as a baseline for future studies on the biology of *T. portentosus* that may uplift the local market through mass rearing.

Keywords: Entomophagy, food security, northeastern India, rearing, socio-economy, soil cricket.

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Author contributions: PK—experimentation, field visitation, data collection, manuscript drafting; LJ—experimentation, field visitation, data collection, editing, and statistical analysis; BA—supervision, review, and editing; LK—conceptualisation, supervision, review and editing

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INTRODUCTION

Expansions of food production are the primary source of greenhouse gas emissions, with livestock products being one of the most significant contributors that trouble the ideas of modern sustainable means of livelihood (FAO 2017). Insect productions have little environmental consequences compared to traditional livestock, and due to their physiology, insects have better feed conversion rates and growth efficiency (Oonincx et al. 2015). For instance, *Acheta domesticus* has a feed conversion ratio of 2.1, meaning 2.1 kg of feed is required to produce 1 kg of edible products. In comparison, for other conventional livestock such as cattle, pigs, and poultry, 25, 9.1, and 4.5 kg of feed is required to produce 1 kg of meat (Van Huis 2013). Edible insects provide 5–10% of the animal protein as well as fat and calories, and various vitamins (A, B1, B2, and D) and minerals (iron, calcium) (Gullan & Cranston 2005; McCluney & Date 2008). Therefore, developing a new sustainable source of edible insects has been recommended (Nikkhah et al. 2021). Despite serving as a potential source of nutrients, only a few species of insects are mass-reared. According to the European Food Safety Scientific Committee, only nine different species of insects are being reared and farmed in mass to be used as food (Halloran et al. 2017).

One of the downfalls of unsuccessful mass-rearing of edible insects could be lack of essential information on biology, growth, and reproduction. There are approximately 20,000 insect farms in Thailand that produce 7,500 metric tons per year, and cricket is one of the promising insect that is farmed, produced in mass, and used for domestic consumption as well as for selling in the market (van Huis et al. 2015). South Korea is another leading consumer of edible insects, and their consumption has resulted in increased demand. The edible insect market's value in south Korea increased from 143 million in 2011 to 259 million in 2015 (Shin et al. 2018). Similarly, entomophagy practices are widespread in India (particularly Nagaland, northeastern India) (Kiewhuo et al. 2022). Among the 106 edible insects consumed and relished, bush cricket *Tarbinskiellus portentosus* is one of the most preferred insects in the region (Mozhui et al. 2020). Therefore, studies on its biology and reproduction are essential to enable the efficient usage of this promising insect.

T. portentosus belongs to the order Orthoptera, family Gryllidae, and is commonly found in southern and southeastern Asia, including India, Thailand, and Indonesia. This species spends most of its time under burrows with a single individual per burrow (Tantrawatpan et al. 2011). It feeds on fresh plants and is considered crucial human food as this species has higher economic value in southeastern Asia, especially Thailand (Sverdrup-Jensen 2002). Yhoung-Aree (2010) reported protein and fat content of 12.8/100 g and 5.7/100 g, respectively in *T. portentosus.* Due to its high nutritional value, *T. portentosus* has been consumed in many countries (Buzzetti & Devrisese 2008; Yi et al. 2010). In Thailand, *T. portentosus* is available all year round at US$ 4.8 per kg (Siriamornpun & Thammapat 2008). *T. portentosus* is also an important protein source for fisheries and poultry production (Sverdrup-Jensen 2002; Razak et al. 2012) . A noteworthy study on the life history of *T. portentosus* in the laboratory was conducted at 24.68 ± 1.26 °C by Hanboonsong & Rattanapan et al. (2001). The authors highlighted information on its longevity, number of instars, incubation period, and food habits. A recent studies on genetic variation in mainland Southeast Asia, such as the Lao People's Democratic Republic, Cambodia, and Myanmar, show that three morphotypes of *T. portentosus* are available (Pradit et al. 2022). Although considered highly relished insects with potential economic value, detailed information on their biology under Nagaland's climatic condition is lacking.

In Nagaland, *T. portentosus*, commonly known as 'viituo', is primarily available during the rainy season, with its population peaks during August–October. They are preferred as food by many sections of society due to the nutritional and cultural values associated with them. Although *T. portentosus* is preferred as a food supplement it is not fully explored in Nagaland due to lack of knowledge of its biology. Given the availability of technique to mass-produce, *T. portentosus* has enormous potential to be made available for consumption at a minimal cost of environmental pollution. In its available season (June–August), *T. portentosus* adults are sold at INR 150/- per 300 g in the local market. However, before mass production, life history study is a vital footstep that can facilitate the efficiency of insect utilization. Therefore, the present study assesses the biology and life cycle of *T. portentosus* under laboratory conditions to fill the gap in the existing knowledge on this novel insect**.**

MATERIAL AND METHODS

Study area

The present survey for soil cricket was carried out in one-year-old abandoned Jhum cultivated lands

at Lumami and Zaphumi villages, Zunheboto district (26°13′42.82′′N and 94.28′24.70′′E) (Figure 1). Since, the two villages are in close proximity, both areas exhibit primarily grassland type vegetation.

Sample collections

Field visits were carried out to collect *T. portentosus* adults from the above-mentioned sites during the summer season (June–August in each year) consecutively for three years from 2019–2021. Crickets were collected by digging their burrows using a spade/ machete and kept in containers with holes to provide sufficient oxygen till they were brought to the laboratory for rearing. Morphologically, identification was done by Mr. Sawapan Pal, Assistant Zoologist, Orthoptera Section, Zoological Survey of India (ZSI), Kolkata.

Rearing

The natural light and dark cycle during insect rearing ranged from 10–13 h to 12–14 h. Adult crickets were kept in large plastic containers with dimensions of 60 cm (length), 40 cm (breadth), and 45 cm (height) filled with 40 cm of loose soil. The adults of *T. portentosus* were provided with natural food (leaves found in their burrows such as *Brassica oleracea var capitata* (cabbage), *Ageratina adenophora* (Mexican devil) and

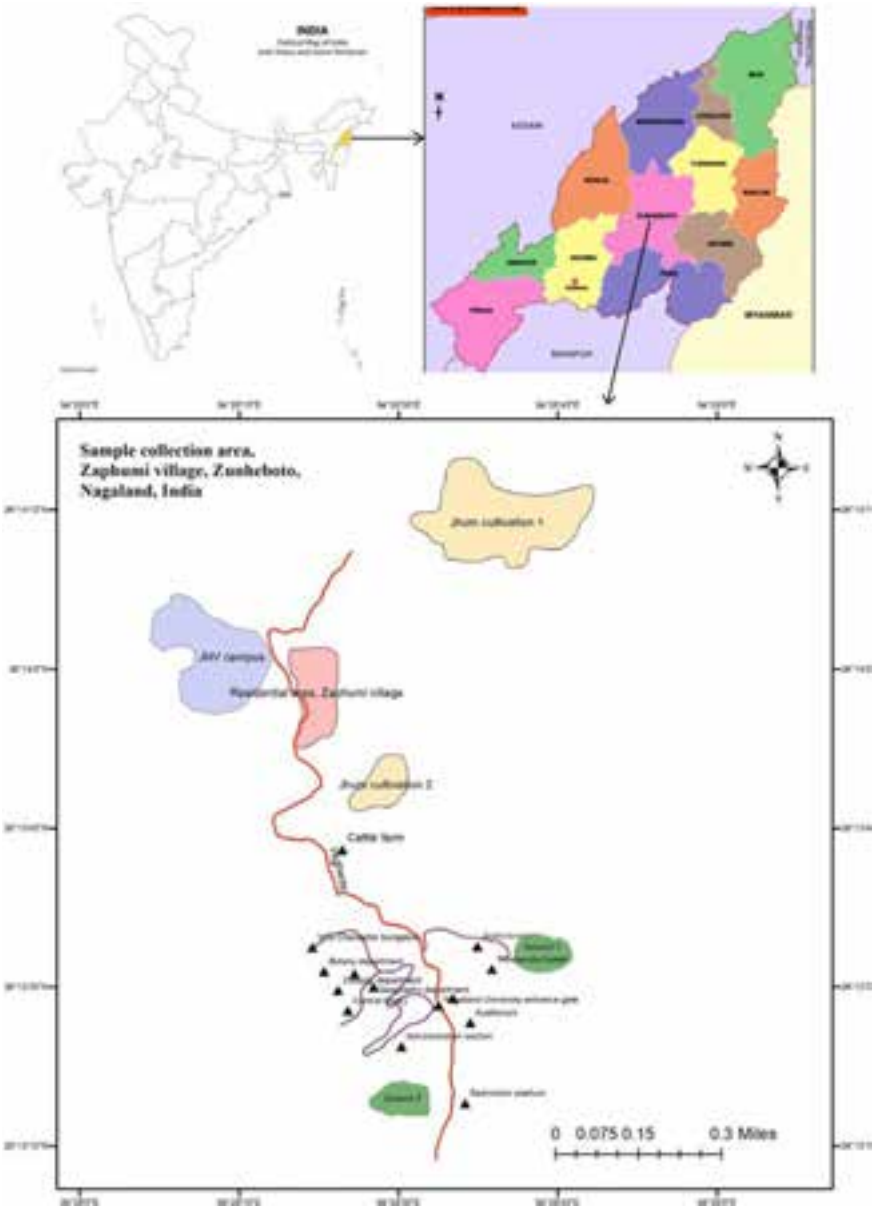

Figure 1. Map showing the sample collection areas at Zaphumi and Lumami village, Zunheboto, Nagaland.

water. The moisture content of the soil was maintained at 35–45 % (Gravimetric method) and the temperature of the rearing room ranged between 20–25 °C. During the year 2019–2021, life cycle studies were repeated thrice (once in each year), and the results were based on a sample size of 75 males and 75 females in each cycle.

For growth rate studies, fresh weight of different nymphal stages (alive) of *T. portentosus* was taken using a portable weighing machine (iScale i-400c) at intervals of seven days (irrespective of nymphal period) until the adult stage, and the growth rate was calculated using the formula.

$$\text{Growth rate} = \frac{\text{Maximum weight–minimum weight}}{\text{Number of days to gain maximum weight}}$$

The final growth rate was reported as mg per day, where, Maximum weight = Final weight of the nymph on the day of measurement | Minimum weight = Weight of the previous measurement (beginning of the 7 day) | Number of days to gain maximum weight = Number of days counted from the day of minimum to maximum weight of the nymph (here we count 7 days and weight was taken in triplicate).

To estimate eggs laid per female, penultimate nymphs were segregated in a separate container at a 2:1 ratio of male to female. This experiment was performed in five containers keeping three individuals (2:1 male:female) in each container; consequently, egg counting per female was carried out using five females. Egg collection was done daily; prior to egg collection, adults were shifted to another container with the help of insect-catching nets. Once all the adults were carefully shifted, eggs were collected manually using a spatula by searching through the soil (Image 1A). A single egg was kept in each of the five containers (100 mm length, 40 mm breadth, 30 mm height) and observed using a Labomed CZM6 microscope. Further, five eggs were taken for morphological observations, such as changes in their color, length (alloet-vernier caliper), weight (iScale i-400c), and incubation period were observed till they hatched. Ten containers were utilized for life cycle studies, each containing soil with an adequate moisture level. Subsequently, a single nymph (first instar) was introduced into each container and observed daily to understand the changes in body coloration, weight, size, and length.

The size of the container for rearing was as per the size of the instar. Water was sprayed regularly to moisten the soil (Image 1B). The first four instars were kept in rounded containers of 110 mm diameter and 120 mm height filled with soil up to 50 mm and covered with net (Image 1C). The last three instars were kept in circular plastic containers of 180 mm in diameter, 200 mm in height, filled with soil up to 100 mm, and covered with nets. Adults were kept in plastic containers 280 mm in length, 200 mm in breadth, and 150 mm in height (Image 1D) filled with loose soil up to 120 mm and provided with sufficient leaves (*Brassica oleracea* var. *capitata*, *A. adenophora*). The excess food in the rearing containers was removed and cleaned by handpicking on a regular basis. Once the nymphs matured into adults, the interactions between males and females were observed in five containers by keeping five males and five females in each container and the experiment was done in five containers simultaneously.

All data were presented as mean ± SD for three years. Analysis of variance (One-way ANOVA) at 95% interval (p <0.05) was done to find the mean significance difference in *T. portentosus* instars. Each test was followed by a multiple comparisons test (Tukey test) to find the mean difference between the variables. Statistical analysis was performed using SPSS-22 software.

Observations of burrows in the wild

The depth of the burrows was estimated by digging from the entrance to the bottom and measuring using a scale. At the same time, the distance between burrows was measured from the entrance of one burrow to the other.

RESULT

Life stages *T. portentosus*

Eggs: Five eggs were observed for morphological study. Freshly laid eggs are oblong in shape, glabrous, and yellowish-white, 3 ± 0.05 mm in length, and 36 ± 0.57 mg in weight. The weight of eggs was recorded on day 2 (36 ± 1.04 mg), day 7 (56 ± 0.21 mg), and day 11 (66 ± 1.23 mg), and it constantly increased till the final weight on day 31 (74.8 ± 1.67 mg). While no difference in egg weight between day 1 (on laying) and day two was observed, a significant increase in weight (p <0.05) was noticed, and eggs became heavier prior to the hatching. There were not many changes in the length of the eggs from the initial to the final stage. The eggs are slightly more pointed towards one end and round towards the other end (Image 2A). The chorion being translucent, the embryo is visible to some extent.

On the 7th day after oviposition, the middle part of the egg becomes bent, forming a convex plane on one side and a concave plane on the other (Image 2B). On

Image 1. A—Collection of the egg using high-intensity light | B—Water sprayed to keep the soil moist for eggs | C—The round container | D—Rectangular box for rearing adult's crickets. © Authors.

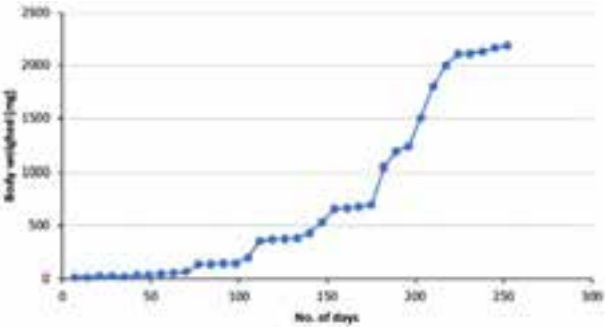

Figure 2. Increase body weight (mg) of *T. portentosus* during different stages of development.

the 13th day, the egg becomes slender and more bent towards the ends (Image 2C). On day 20, the eggs begin to break open, and the embryonic eyes become visible (Image 2D). The eyes, outlines of the wings, and body appendages became distinct on day 28 (Image 2E). The forelegs, hind legs, wings, and cerci became visible as the egg starts to break open widely (Image 2F) and subsequently hatching took place. By the 28th, 29th, and 30th days, the eyes became more prominent, and body appendages were faintly visible until the cracks began to occur till hatching. The final weight and length of egg before hatching was 89.0 ± 0.13 mg and 4.89 ± 0.16 mm. The incubation period of eggs was 33.8 ± 0.96 days. The hatching efficiency was 45.20 ± 5.28 %.

Nymphs

In *T. portentosus,* seven instars were observed. The newly hatched nymph was white and possessed a soft body until transitioning into light brown. The main morphological changes between the instars were the development of the wing pad, coloration, body size, body mass, ovipositor development, and an increase in antennal length. A newly hatched instar weighed 34 ± 1.13 mg and had a body length of 4.0 ± 0.00 mm with an 8 mm antenna and 3 mm cerci (Table 1). The coloration of the body was grey-blackish on the abdomen, and its head region was light brown during the first three instars. The first five instars had a round head and abdomen with not-so-visible segments on the body (Image 3A–E). No differences were observed during the first five instars concerning their body color and shapes except for increased body sizes, weight, antennal length, etc. The wing pad developed in the sixth instar (Image 3F) in both male and female nymphs. In females, the ovipositor appeared in the seventh instar (Image 3G) while the body color was darker, and the nymphs became broader and less rounded than the first five instars. With further development, the head, legs, and abdomen became more turgid, and the color became dark brown. After the final molt, the adults weighed 2100 ± 379.86 mg with length 31.7 ± 1.0 mm, antennae 40 mm, and cerci 16 mm.

Body weight, total length, antennae, and cerci were significantly different (p <0.05) from instar to instar (Table 1). As shown in Figure 2, the first, second, third, fourth, fifth, sixth, and seventh instars molted on day 42, 77, 119, 147, 182, 210, and 252, respectively. During the rearing period the growth rate ranged 4.2–7 mg/day. Wide variations in growth rate were observed, where the maximum growth rate was observed at 70–80 days (during II instar). With further maturity, the average growth rate declines gradually. The development from the first instar to the final molt required 298 ± 8.24 days. After the final molt, cricket lived for another 43 ± 6.5 days. Therefore, the total number of days required to complete the entire life cycle was found to be 341 ± 4.29 days.

Adults

Adult cricket has a cylindrical body, long slender antennae (34–40 mm), a round head, and two long cerci (15–16 mm) and a long ovipositor (11 mm) for females. The hind leg has an enlarged femur followed by three tarsal segments. The forewings (30 ± 1.4 mm) are smooth in females and rough in males (Image 3H). The hind wings (41.5 ± 2.1 mm) are longer than the fore wings and are lighter in color (Image 4A). The female body measured about 36 ± 1.7 mm in length, and weight about 2980 ± 200 mg, while the male measured about 37.3 ± 0.05 long (Image 4B), weight about 2940 ± 93.0 mg. The morphological study of adults was done based

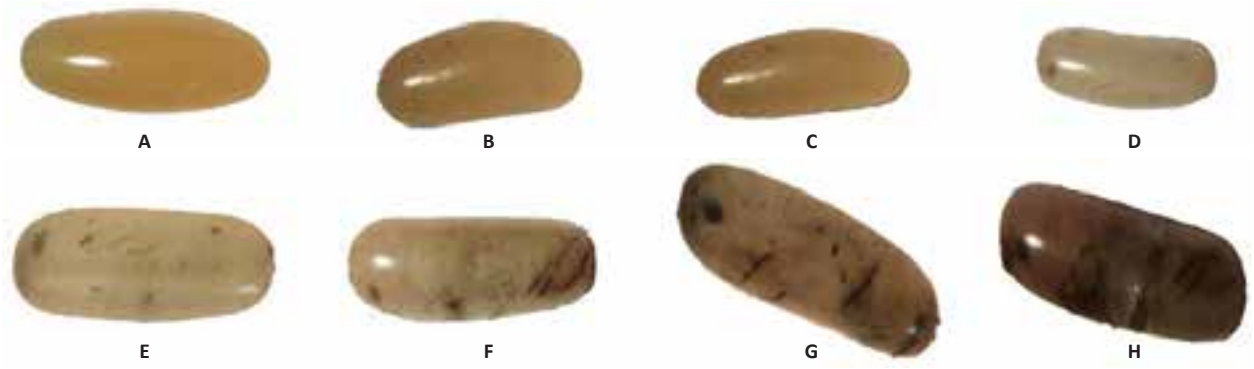

Image 2. A—Day 1 oblong compact yellowish in color | B—Day 7 yellowish-white in color and bent at the center | C —Day 13 more slender and thinner | D—Day 20 eyes become visible, egg white | E—Day 28 egg white and more compact, body appendages visible | F–H—Day 29 to 31 brown dirty look on the inside with stretch marks, cracks appear. © Authors.

Table 1. The instars of *T. portentosus* with details of body weight, body length, antennal length, and cerci length.

Instar	Fresh body weight (mg)	Body length (mm)	Antennal length (mm)	Cerci length (mm)
1st	34 ± 19.13[a]	4.0 ± 0.00[a]	8.0 ± 0.21[a]	3.0 ± 0.76[a]
2nd	137 ± 90.37[b]	13.3 ± 1.7[b]	10 ± 0.44[b]	4.0 ± 0.01[b]
3rd	360 ± 124.34[c]	16.6 ± 2.0[c]	15 ± 0.19[c]	6.0 ± 0.34[c]
4th	561 ± 68.00[d]	21.6 ± 1.5[d]	20 ± 0.32[d]	8.0 ± 0.12[d]
5th	1044 ± 434.72[e]	24.0 ± 1.0[e]	31 ± 1.53[e]	10.0 ± 2.00[e]
6th	1802 ± 296.02[f]	31.0 ± 4.3[f]	37 ± 1.41[f]	12.0 ± 0.45[f]
7th	2100 ± 379.86[g]	31.7 ± 1.0[g]	40.0 ± 1.89[g]	16.0 ± 2.90[g]

Mean with different superscripts indicates the statistically significant difference at $p<0.05$.

on three males and three females.

Ecology of *T. portentosus*

In the wild, we found cricket burrows in grassland-type vegetation with sparse trees. Burrows were located by searching for a heap of loose soil mounted around the entrance (Image 5A). A heap of moist and finely-grained soil at the entrance indicates the presence of cricket inside the burrow. Depending on the instar and texture of the soil, the burrows can be as deep as 50–800 mm. In loose soil areas, adult burrows go as deep as 800 mm, while in rocky soil, if less moisture and roots of trees are present, burrows can be as shallow as 50–200 mm. The burrows do not have any branching at any angle, but towards the bottom, they become less vertical, and that is where crickets store their food brought from outside. The burrows are constructed in such a way that the bottom is not exposed directly to sunlight. At the end of the burrow, crickets were found embedded in soil with its back towards the entrance (Image 5B). Fresh plant leaves such as *Brassica oleracea* (cabbage) and *A. adenophora* (Mexican devil) were found inside the burrow (Image 5C). During the spring season (March–April of each year), in its nymphal stage, cricket burrows were found to be located very close to one another, just 20–50 mm apart. However, in the summer season (August–September, 2019–21), adult burrows were never found close to each other. Single adult per burrow was observed except during mating season, i.e., August–mid-October, when we observed a male and a female together in one burrow. Adults begin to appear on the ground and are attracted towards the light source at night during the month of May, peaking from July–September, with a few still present in October. During mating season, male crickets were observed stridulating near the burrow entrance, (Image 6A), during the evening and night hours, to attract females.

Adults and nymphs mostly stay inside the burrows and are not seen much as they do not venture out during daylight, except for food collection and mating purposes. All stages are nocturnal, and individuals construct their burrows using the mandibles to clear the soil, which

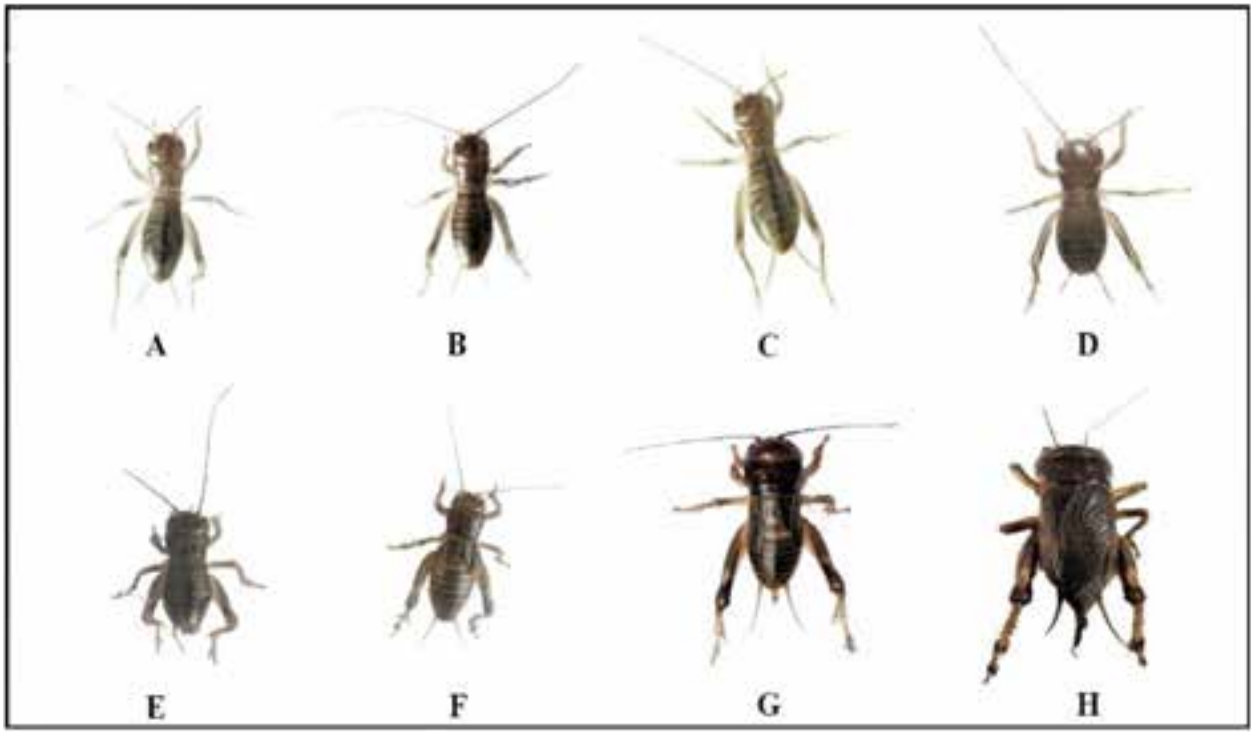

Image 3. A–G—The seven instars | H—an adult *T. portentosus*. © Authors.

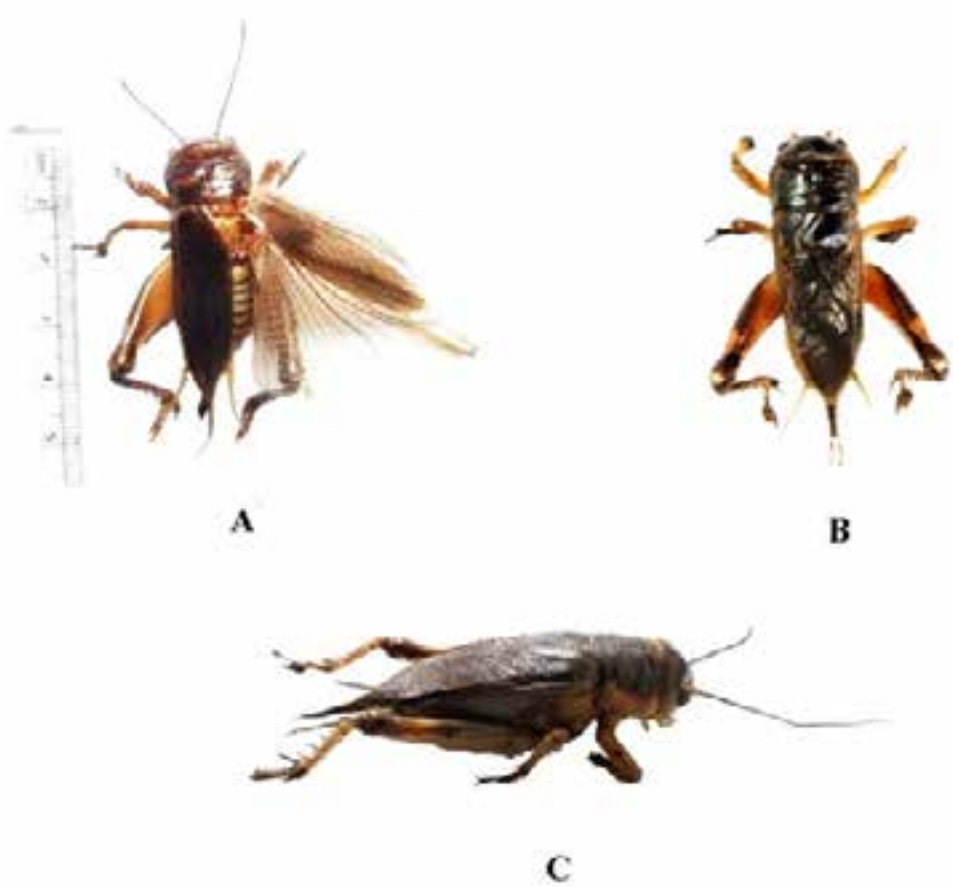

Image 4. A—Adult female | B—Adult male *T. portentosus* | C—Lateral view of *T. portentosus*. © Authors.

Image 5. A—Heap of loose soil mounted around the burrow's entrance | B—*T. portentosus* embedded at the end of the burrow | C—Food stored in burrows. © Authors.

Image 6. A—A male *T. portentosus* | B—Adult *T. portentosus* digging its burrow. © Authors.

is pushed outside the burrows using their hind legs backward (Image 6B). During mid-August, most are in their nymphal stage, while a few are in their adult stage.

Behavioral observation in the laboratory showed that adults of the same gender showed more aggression towards each other when put together for the first time. However, within 5–10 minutes, they start constructing their burrows, which keeps them away from each other. Aggressive behavior such as kicking, chirping, and biting one another was observed mainly in males during mating calls and in ovipositing females. Nymphs showed no sign of aggression towards each other. Eggs are deposited by the female into the soil through ovipositor at the bottom of the burrow at 750.8 ± 60 mm depth.

DISCUSSION

Due to bigger body size than most crickets, it is one of the Nagaland's most preferred edible insects (Mozhui et al. 2020). This is considered as one of the giant and prominent edible cricket found in Asia, with a body length and weight of 37.30 ± 5.0 mm and 2980 ± 200 mg. In Lao PDR, Hanboonsong & Durst (2014) reported that adult body length of *T. portentosus* is 50 mm, the slight variations in body size could be due to differences in climatic conditions, food availability, and nutritional content of their food.

Hanboonsong & Rattanapan (2001) reported that a single female laid about 123.00 ± 46.44 eggs, and the incubation period of eggs was 56.10 ± 15.03 days, with 40.70 ± 4.74 % of hatching, while the whole growth period including seven instars of nymph and adult was 173.70 ± 19.86 days. In the present study, the incubation

period of eggs was 33.8 ± 0.96 days and showed a moderate percentage of hatching efficiency (45.20 ± 0.28%). Lesser incubation period and more hatching efficiency than that found in our population could be attributed to difference in climatic conditions. Based on five observed females, the present study records that females individually lay 98 ± 11.4 eggs throughout its reproductive life cycle. *T. portentosus* is found in abandoned jhum cultivated areas and is available for consumption from May till September. The crickets live in burrows, where they store food and lay eggs. With the growth and development of the nymph, its burrow goes as deep as 50–800 mm, and only a single generation of *T. portentosus* is produced per year. The use of mandibles and forelegs during the construction of burrows recorded in this study agrees with the study on *Anurogryllus muticus* (Lee & Loher 1996), which uses its forelegs to push out the soil substrates when digging burrows. *T. portentosus* lives inside its burrows and comes out primarily for food collection and mating. Usually, collected food is taken back to the bottom of the tunnel for feeding. During mating season, adult males come out of burrows in search of a mate and call for partner by stridulating at the edge of their burrows. After attracting a female, mating takes place, and the mated female remains within the burrow to lay eggs at the bottom. The present study observed that mated females lay eggs at the bottom of the tunnel, and similar behavior is also found in *A. muticus* (Lee & Loher 1996).

The burrow serves as a congenial environment for *T. portentosus*, allowing mating and providing protection against predators, rain, sun, and wind and acts as a convenient environment for reproduction. In addition, a sealed burrow offers protection from predators, further enhanced by increased aggression of the females during oviposition and brood care (West & Alexander 1963; Alexander & Otte 1967). Females of *Brachytrupes achatinus* Stoll (Brachytrupinae), the 'big-brown cricket' of India, deposit their eggs in shallow burrows at the end of one of their galleries, and the young nymphs leave the parental burrow a few days after hatching (Ghosh 1912). In the present study also, it has been observed that in natural condition, *T. portentosus* nymphs leave the original burrow to construct independent burrows of their own.

After the final molt, *T. portentosus* lives for another 43 ± 6.5 days; therefore, the total number of days required to complete the entire life cycle was 341 ± 4.29 days. Hanboonsong & Rattanapan (2001) also reported that *T. portentosus* completes its life cycle in 333.30 ± 20.06 days and has 6–7 instars at 24.68 ± 1.26 °C. In the present study, seven (7) nymphal instars were observed. The first molting took the most extended period, which could be attributed to the colder climate and lesser humidity (October, November, December, and January, 2019–22). The subsequent instars required lesser days for molting, which could be due to warmer season.

Egg morphology shows that on the seventh day after oviposition, it bent towards the middle, and by the 12th day, eyes were visible, and the body appendages were visible on day 28. In *Acheta domesticus*, also called house cricket, after four days of oviposition, as the eggs undergo developmental changes it become slightly curved for a few days. By the 12th day, eyes become visible; by the 16th day, just before hatching, inner body appendages are visible (Douan et al. 2021). Present study also shows similar morphological changes in the egg, but the number of days differed. The variation between species explains most of this difference, although experimental conditions could also affect the developmental time and growth of the egg (McCluney & Date 2008; Doherty et al. 2018).

CONCLUSIONS

T. portentosus is a promising edible insect that shows positive prospects for future food development. Compared to most crickets, it has a larger body mass, making it more preferred as food, especially in Asian countries. For better access to any food product, continuous market supply is an important key that should depend on a mass production unit. With proper knowledge of its biology and domestication, *T. portentosus* can be a potential insect as food in Nagaland, India. However, further extensive study of its biology, along with technology for mass rearing, can boost the economy and provide a livelihood for the weaker sections of society.

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ARTICLE

Addition to the liverwort flora (Marchantiophyta) of Arunachal Pradesh, India

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Abstract: The present study identified 20 liverwort species from Tirap district, Arunachal Pradesh, India, marking the first ever documentation of bryophytes from the region. The specimens were collected from various locations within the study area and subsequently brought to the laboratory. Micromorphological and anatomical characteristics of the specimens were analysed and identified by consulting relevant literatures. Three species, viz. *Plagiochila himalayana* Schiffn., *P. khasiana* Mitt., and *Solenostoma lanigerum* (Mitt.) Váňa & D.G.Long, are newly reported for the first time from the state of Arunachal Pradesh. The species were found to be an integral part of ecosystem growing in association with various plant species, providing soil stability, and shelter for other organisms. The study is important for understanding bryophyte diversity and ecosystem health of the region. In addition, it will also help in planning conservation strategy and sustainable management of bryophytes, their habitat or host species and the overall biodiversity in the region.

Keywords: Bryophytes, conservation, diversity, eastern Himalaya, ecosystem, epiphytic, *Plagiochila himalayana*, *Plagiochila khasiana*, *Solenostoma lanigerum,* Tirap district.

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Authors contribution: NC collected the specimens, prepared herbarium species, and examined detailed morphological and anatomical characters. PM, AD, MP, and SNA studied detailed morphological and anatomical characters. PLU and DS established and confirmed the identity of the species. HE conceptualized the study and guided throughout the entire research process.

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INTRODUCTION

Marchantiophyta is globally represented by about 7,486 species (Söderstorm et al. 2016) of which nearly 854 species have been recorded in India (Singh et al. 2016a; Majumdar & Dey 2021). A few studies reported the presence of liverworts in Arunachal Pradesh. Deo & Singh (2013, 2014, 2016, 2020), Singh & Singh (2016) documented bryophytes from West Siang district, Majumdar et al. (2013), Majumdar & Singh (2015, 2016, 2017) and Singh et al. (2016b) reported bryophytes from Anjaw district. Rawat & Verma (2014) and Rawat et al. (2017) collected bryophytes from Tawang District and Dey et al. (2009) from many areas of Arunachal Pradesh. In total, at present 84 species of liverworts from the state are recorded. However, the Tirap district of the state was bryologically unattended.

Tirap district is a part of the Eastern Himalayas, one of the biodiversity hotspots of the world. It is located in the southernmost part of the state and lies between the latitude 27.018 °N, 95.519 °E (District website of Tirap 2022, accessed on 22 September 2022). The elevation of the district ranges 200–4,000 m in the northwest to the Patkai hills. Tirap is bounded by Changlang district in the east, Assam state in the north, Longding district and Nagaland in the west, and Myanmar in the south (Wangpan et al. 2019). The district has an annual rainfall of 2,754 mm per year and temperature ranges 14–25 ^{0}C (World Data Atlas 2023). The vegetation of Tirap is primarily comprised of tropical and subtropical evergreen forests, with interspersed grasslands and temperate forests in the upper elevations. The temperature in Tirap is moderate to warm with frequent rainfall. The district offers a virgin area for the diverse and luxuriant growth of many plants including bryophytes. The inhabitants of Tirap, revere and offer prayers to nature for their reliance on plants for food, shelter, livelihood, and well–being. Wangpan et al. (2019) and Tangjang et al. (2011) documented flowering plants for various purposes such as food, medicine, and house construction. The district remained unattended for the lower plant groups like bryophytes and pteridophytes which provide the intricate relation with the higher plants. Therefore, the present study was undertaken to survey and document the bryoflora of the region (Figure 1).

MATERIALS AND METHODS

Liverwort samples were collected from the Tirap district, Arunachal Pradesh, India, during May 2021 and 2022. Field data, including habit, habitat, temperature, humidity, and soil types, were recorded for each species. The specimens were initially stored in zip-lock plastic bags, air-dried, and later transferred to paper bags in the laboratory. To aid in identification, the specimens were rehydrated in water until they regained their original shape. Micromorphological and anatomical characteristics were studied using a stereo zoom microscope (Zeiss Stemi 508) and a compound microscope (Zeiss Lab A.1). Identification was based on relevant literature. Voucher specimens were deposited in the Herbarium of Arunachal University (HAU) and the Delhi University Herbarium (DUH), following the classification system by Crandall-Stotler et al. (2009).

RESULTS

Throughout the study, 20 liverwort species from 15 genera and 11 families were documented in the Tirap district of Arunachal Pradesh, representing the initial record of bryophytes in this area (Table 1).

Among the recorded species, three species, viz, *Plagiochila himalayana* Schiffn., *P. khasiana* Mitt., and *Solenostoma lanigerum* (Mitt.) Váňa & D.G.Long., are noteworthy as they are recorded for the first time from Arunachal Pradesh.

A majority of these species were observed in damp, shady locations, thriving on both soil and rocks (e.g. *Solenostoma lanigerum, Notoscyphus darjeelingensis* Udar & Ad. Kumar var. *darjeelingensis, Plagiochila uniformis, P. khasiana*). Few species were epiphytic (*Frullania arecae, Spruceanthus semirepandus*), while some could be found on multiple substrates, including soil, rocks, and the roots and debris of other plants (*Riccardia inconspicua* (Steph.) Reeb & Bardat, *Heteroscyphus argutus* (Reinw., Blume & Nees) Schiffn.). The frequently recorded species in the study area are *Dumortiera hirsuta* (Sw.) Nees and *Targionia hypophylla* L., followed by *Ptychanthus striatus* (Lehm. & Lindenb.) Nees, *Riccardia inconspicua* (Steph.) Reeb & Bardatand and *Solenostoma lanigerum* (Mitt.) Váňa & D.G. Long. The species, which were found only in small patches are *Lejeunea tuberculosa* Steph. and *Notoscyphus darjeelingensis* var. *darjeelingensis***.** Image 1–Image 5. The reported species are enumerated here.

ANEURACEAE

Riccardia inconspicua (Steph.) Reeb & Bardat, Cryptog. Bryol. 35(1): 61. 2014.

Habitat: Terrestrial and epilithic, growing on soil and

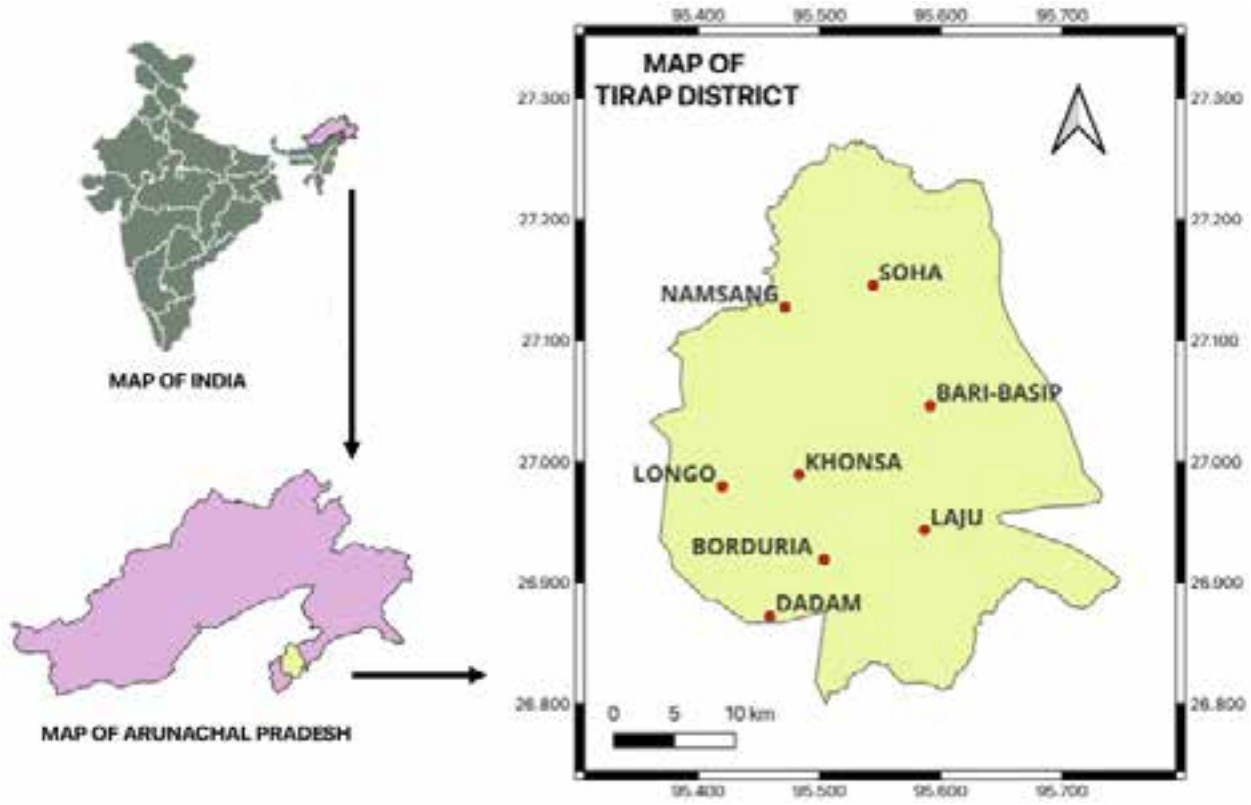

Figure 1. Map of Tirap district, Arunachal Pradesh, India.

rock in association with moss species in moist and shady areas. The species was in the vegetative stage.

Specimen examined: India, Arunachal Pradesh, Tirap District, Khonsa Circle. Lapnan–Hydel Road. 26.996 °N; 95.489 °E; elevation 580 m. HAU/AN- 1866; DUH15116.

Distribution: India [Andhra Pradesh, Arunachal Pradesh, Assam, Himachal Pradesh, Kerala, Manipur, Meghalaya, Nagaland, Sikkim, Tamil Nadu, Uttarakhand, West Bengal], Indonesia, Malaysia, Nepal, Singapore (Sahu & Asthana 2022; Sahu et al. 2023).

Riccardia multifida (L.) Gray, Nat. Arr. Brit. Pl. 1: 684. 1821.

Habitat: Epixylic, growing on rotten wood. The species was found in the reproductive stage with gynoecium and androecium branches.

Specimen examined: India, Arunachal Pradesh, Tirap District, Namsang Circle. 27.099 °N; 95.472 °E; elevation 265 m. HAU/AN- 1868; DUH15521.

Distribution: India [Andhra Pradesh, Arunachal Pradesh, Assam, Kerala, Maharashtra, Meghalaya, Sikkim - East and West districts, Tamil Nadu, Tripura, Uttarakhand, West Bengal], China, Hawaii, Russia, Sri Lanka, Taiwan, Turkey, Africa, Europe, Micronesia, North America (Singh & Singh 2023).

DUMORTIERACEAE

***Dumortiera hirsuta* (Sw.)** Nees, Nova Acta Phys.-Med. Acad. Caes. Leop. -Carol. Nat. Cur. 12(1): 410. 1825.

Habitat: Terrestrial, growing on soil in moist and shady areas. The species was in the reproductive stage.

Specimen examined: India, Arunachal Pradesh, Tirap District, Khonsa Circle. Lapnan Village. 26.988 °N; 95.487 °E; elevation 809 m. HAU/AN- 1939; DUH15128.

Distribution: India [Arunachal Pradesh, Assam, Chhattisgarh, Goa, Himachal Pradesh, Jammu & Kashmir, Karnataka, Kerala, Madhya Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Odisha, Tamil Nadu, Uttarakhand, West Bengal], Africa**,** Europe, Hawaii, Japan, Nepal, New Zealand, North America (Singh & Singh 2023).

FRULLANIACEAE

Frullania arecae (Spreng.) Gottsche Mexik. Leverm. 236. 1863 var. ***arecae***

Habitat: Epiphytic, growing on bark of *Saurauia roxburghii* Wall. together with *Ptychostomum capillare* (Hedw.) D.T.Holyoak & N.Pedersen, *Porella caespitans* var. *cordifolia* (Steph.) S.Hatt. ex T.Katag. & T.Yamag, *Spruceanthus semirepandus* (Nees) Verd. The species was found in the vegetative stage.

Specimen examined: India, Arunachal Pradesh, Tirap District, Dadam Circle. Moktowa Village. 26.871 °N; 95.457 °E; elevation 1,805 m. HAU/AN- 1940; DUH15513.

Distribution: India [Arunachal Pradesh, Meghalaya, Sikkim - East, West, North and South districts, Tamil Nadu, West Bengal], Bhutan, China, Fiji, Indonesia, Malaysia, Myanmar, Nepal, New Guinea, Pacific Is., Philippines, Sri Lanka, Taiwan, Thailand, Africa, Australia, North America, South America (Majumdar 2017; Singh & Singh 2023).

GEOCALYCACEAE

Notoscyphus darjeelingensis Udar & Ad.Kumar, J. Hattori Bot. Lab. 49: 250.1981. var. ***darjeelingensis***

Habitat: Terrestrial, growing on damp soil. The species was found in vegetative stage.

Specimen examined: India, Arunachal Pradesh, Tirap District, Dadam Circle. Dadam–Moktowa road. 26.926 °N; 95.470 °E; elevation 1,097 m. HAU/AN- 1946; DUH15120.

Distribution: India [Arunachal Pradesh, Manipur, Sikkim, Tamil Nadu, West Bengal] (Singh & Singh 2023).

HERBERTACEAE

Herbertus armitianus (Steph.) H.A.Mill., J. Hattori Bot. Lab. 28: 324. 1965.

Habitat: Terrestrial, growing on soil. The species was found in vegetative stage.

Specimen examined: India, Arunachal Pradesh, Tirap District, Dadam Circle. Moktowa Village. 26.870 °N; 95.456 °E; elevation 1,826 m. HAU/AN- 1941; DUH15520.

Distribution: India [Arunachal Pradesh, Nagaland, Sikkim - East, West, and North districts], Indonesia, Malaysia, Papua New Guinea, Philippines, Thailand, Vietnam (Singh & Singh 2023).

LEJEUNEACEAE

Spruceanthus semirepandus (Nees) Verd., Ann. Bryol., Suppl. 4: 153. 1934.

Habitat: Epiphytic, growing on tree bark of *Saurauia roxburghii* Wall. in association with *Ptychostomum capillare* (Hedw.) D.T.Holyoak & N.Pedersen, *Porella caespitans* var. *cordifolia* (Steph.) S.Hatt. ex T.Katag. & T.Yamag, *Frullania arecae* (Spreng.) Gottsche var. *arecae*. The species was found in vegetative stage.

Specimen examined: India, Arunachal Pradesh, Tirap District, Dadam Circle. Moktowa Village. 26.871 °N; 95.457 °E; elevation 1,805 m. HAU/AN- 1945; DUH15515.

Distribution: India [Arunachal Pradesh, Kerala, Manipur, Meghalaya, Odisha, Sikkim, Tamil Nadu, Uttarakhand, West Bengal], Bhutan, Cambodia, China, Indonesia, Japan, Laos, Malaysia, Myanmar, Nepal, Philippines, Sri Lanka, Taiwan, Thailand (Singh & Singh 2023).

Lejeunea tuberculosa Steph., Sp. Hepat. 5: 790. 1915.

Habitat: Epilithic, growing on rock. The species was found in vegetative stage.

Specimen examined: India, Arunachal Pradesh, Tirap District, Dadam Circle. Dadam–Moktowa road. 26.922 °N; 95.456 °E; elevation 1,205 m. HAU/AN- 1944; DUH15119.

Distribution: India [Andaman & Nicobar, Arunachal Pradesh, Assam, Kerala, Maharashtra, Manipur, Meghalaya, Sikkim, Tamil Nadu, Uttarakhand, West Bengal], Africa, Bhutan, China, Indonesia, Nepal, Philippines, Sri Lanka, Thailand, Vietnam (Singh & Singh 2023).

Ptychanthus striatus (Lehm. & Lindenb.) Nees, Naturgesch. Eur. Leberm. 3: 212. 1838.

Habitat: Epiphytic, growing on branches of *Pouzolzia rugulosa* (Wedd.) Acharya & Kravtsova in association with *Pelekium investe* (Mitt.) Touw, *Pseudotrachypus convolvens* (Mitt.) W.R.Buck, *Meteoriopsis reclinata* (Müll.Hal.) M.Fleisch.

Specimen examined: India, Arunachal Pradesh, Tirap District, Laju Circle. Kolam village. 26.937 °N; 95.576 °E; elevation 1,588 m. HAU/AN- 1859; DUH15123.

Distribution: India [Andaman & Nicobar, Arunachal Pradesh, Assam, Goa, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Nagaland, Sikkim, Tamil Nadu, Uttarakhand, West Bengal], Africa, Australia. Bhutan, China, Fiji, Indonesia, Japan, Laos, Malaysia, Nepal, New Zealand, Papua New Guinea, Philippines, Samoa, Sri Lanka, Taiwan, Thailand, Vietnam (Singh & Singh 2023).

LEPIDOZIACEAE

Bazzania sumbavensis (Gottsche ex Steph.) Steph., Hedwigia 32: 204. 1893.

Habitat: Epilithic, growing on rock. The species was found in vegetative stage.

Specimen examined: India, Arunachal Pradesh, Tirap District, Namsang Circle. Namsang Village. 27.100 °N; 95.472 °E; elevation 257 m. HAU/AN- 1938; DUH15516.

Distribution: India [Arunachal Pradesh, Assam, Manipur, Meghalaya, Sikkim, West Bengal, Kerala], Bhutan, Java, Indonesia, Nepal, Papua New Guinea, Samoa, Thailand (Singh & Singh 2023).

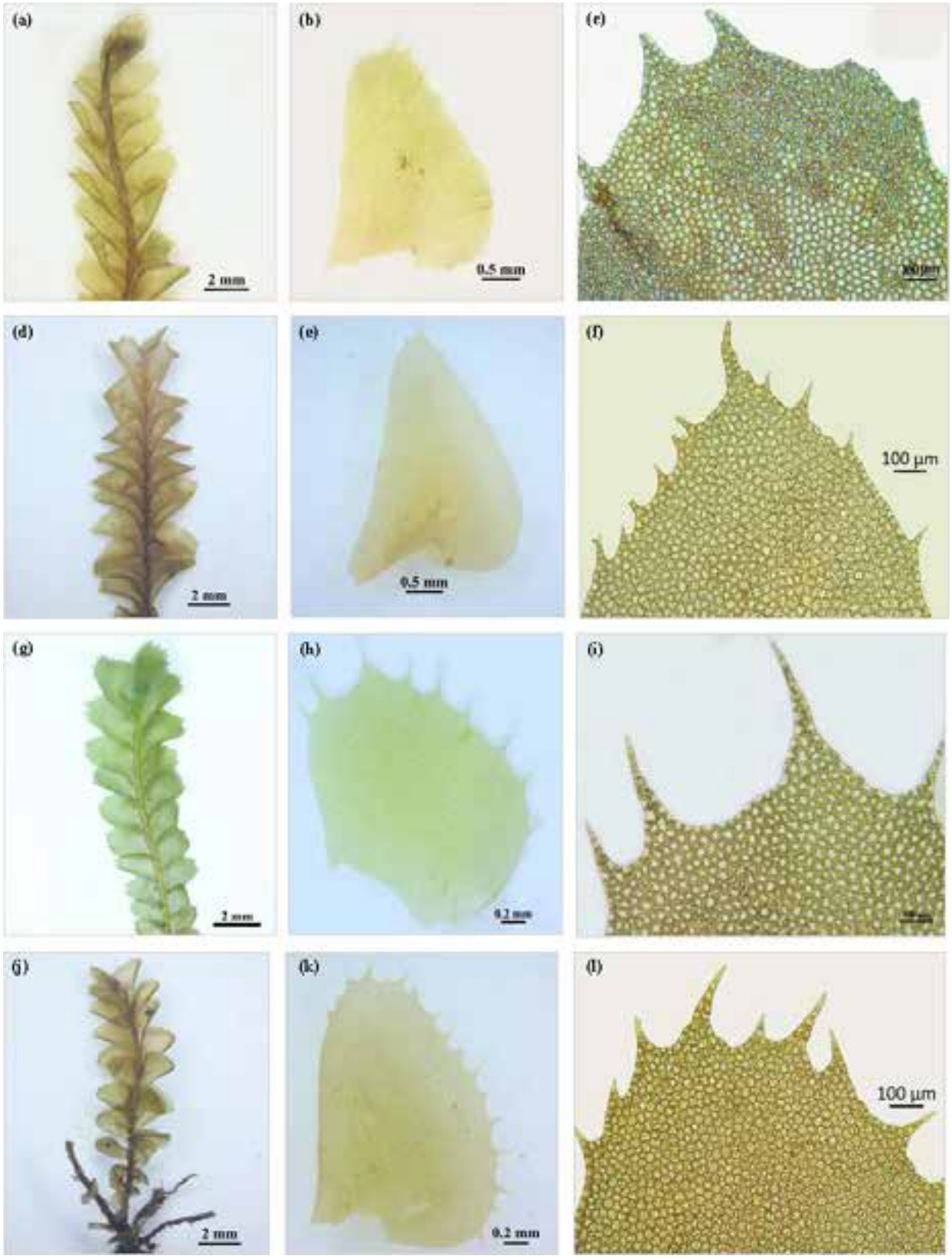

Image 1. Liverwort species collected from Tirap District: a–c—*Plagiochila himalayana* Schiffn.: a—whole plant | b—whole mount of leaf | c—leaf cells | d–f—*Plagiochila khasiana* Mitt..: d—whole plant | e—whole mount of leaf | f—leaf cells | g–i—*Plagiochila sciophila* Nees ex Lindenb.: g—whole plant | h—whole mount of leaf | i—leaf cells | j–l—*Plagiochila uniformis* Mitt.: j—whole plant | k—whole mount of leaf | l—leaf cells. © Nonya Chimyang.

LOPHOCOLEACEAE

Heteroscyphus argutus (Reinw., Blume & Nees) Schiffn., Oesterr. Bot. Z. 60: 172. 1910.

Habitat: Epilithic and Terrestrial. Growing on rock, soil and roots of ferns, and debris of other plants, in association with hornwort sp. and moss spp. at moist and shady area. The species was found in vegetative stage.

Specimen examined: India, Arunachal Pradesh, Tirap District, Khonsa Circle. Khonsa–Hydel Road. 26.996 °N; 95.489 °E; elevation 580 m. HAU/AN- 1947; DUH15113.

Distribution: India [Andaman & Nicobar, Andhra Pradesh, Arunachal Pradesh, Assam, Himachal Pradesh, Jammu & Kashmir, Karnataka, Kerala, Madhya Pradesh, Manipur, Meghalaya, Odisha, Sikkim, Tamil Nadu, Uttarakhand, West Bengal], Australia, Bhutan, Cambodia, China, Fiji, Hawaii, Indonesia, Japan, Korea, Malaysia, Melanesia, Nepal, New Caledonia, New Zealand, Philippines, Singapore, South America, Sri Lanka, Thailand, Tonga, Vietnam (Singh & Singh 2023).

MARCHANTIACEAE

Marchantia linearis Lehm. & Lindenb., Nov. Stirp. Pug. 4: 8. 1832.

Habitat: Growing on soil and rock.

Specimen examined: India, Arunachal Pradesh, Tirap District, Khonsa Circle. Lapnan village. 26.989 °N; 95.483 °E; elevation 901 m. HAU/AN- 1949; DUH15519.

Distribution: India [Andaman & Nicobar, Andhra Pradesh, Arunachal Pradesh, Assam, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Odisha, Punjab, Rajasthan, Sikkim, Uttar Pradesh, West Bengal], Indonesia, Malaysia, Nepal, Pakistan, Papua New Guinea, West Indies (Singh & Singh 2023).

Marchantia polymorpha L., Sp. Pl. 2: 1137. 1753.

Habitat: Growing on black, hard, rock-like soil together with *Pohlia crudoides* (Sull. & Lesq.) Broth. The species was found in the reproductive stage with male and female thalli bearing matured antheridia and archegonia.

Specimen examined: India, Arunachal Pradesh, Tirap District, Laju Circle. On the way to Pongkong village. 26.893 °N; 95.540 °E; elevation 1,337 m. HAU/AN- 1950; DUH15125.

Distribution: India [Arunachal Pradesh, Assam, Himachal Pradesh, Jammu & Kashmir, Kerala, Ladakh, Madhya Pradesh, Maharashtra, Meghalaya, Nagaland, Odisha, Punjab, Rajasthan, Sikkim - East and North districts, Tamil Nadu, Uttar Pradesh, Uttarakhand, West Bengal], widely distributed throughout the globe (Singh & Singh 2023).

PLAGIOCHILACEAE

Plagiochila himalayana Schiffn., Oesterr. Bot. Z. 49: 131. 1899.

Habitat: Epiphytic, growing on the tree. The species was found in the vegetative stage.

Specimen examined: India, Arunachal Pradesh, Tirap District, Dadam Circle. Dadam Village. 26.904 °N; 95.458 °E; elevation 1,080 m. HAU/AN- 1954; DUH15517.

Distribution: India [Arunachal Pradesh (Present Study), Kerala, Sikkim, West Bengal], Bhutan, China (Singh & Singh 2023).

Plagiochila khasiana Mitt., J. Proc. Linn. Soc., Bot. 5: 95. 1861 [1860].

Habitat: Epilithic, growing on rock. The species was found in the vegetative stage.

Specimen examined: India, Arunachal Pradesh, Tirap District, Dadam Circle. Moktowa Village. 26.870 °N; 95.453 °E; elevation 1,765 m. HAU/AN- 1955; DUH15122.

Distribution: India [Arunachal Pradesh (present study), eastern Himalaya, Kerala, Meghalaya, Tamil Nadu, Uttarakhand, West Bengal, western Himalaya], Bhutan, China, Nepal, Sri Lanka, Taiwan, Thailand, Vietnam (Singh & Singh 2023).

Plagiochila sciophila Nees ex Lindenb., Sp. Hepat. (Lindenberg) (fasc. 2–4): 100. 1840.

Habitat: Epilithic, growing on rock. The species was in the vegetative stage.

Specimen examined: India, Arunachal Pradesh, Tirap District, Khonsa Circle. Lapnan village. 26.988 °N; 95.487 °E; elevation 809 m. HAU/AN- 1956; DUH15114.

Distribution: India [Andaman & Nicobar, Arunachal Pradesh, Himachal Pradesh, Jammu & Kashmir, Kerala, Manipur, Meghalaya, Sikkim, Tamil Nadu, Uttarakhand, West Bengal], Australia, Bhutan, China, Indonesia, Japan, Korea, Malaysia, Nepal, Pakistan, Papua New Guinea, Philippines, Samoa, Singapore, Sri Lanka, Taiwan, Thailand, Vietnam (Singh & Singh 2023).

Plagiochila uniformis Mitt., J. Proc. Linn. Soc., Bot. 5: 98. 1861 [1860].

Habitat: Epilithic, growing on rock. The species was found in the vegetative stage.

Specimen examined: India, Arunachal Pradesh, Tirap District, Dadam Circle. Moktowa Village. 26.870 °N; 95.452 °E; elevation 1,730 m. HAU/AN- 1957; DUH15518.

Distribution: India [Arunachal Pradesh, Himachal Pradesh, Jammu & Kashmir, Manipur, Meghalaya,

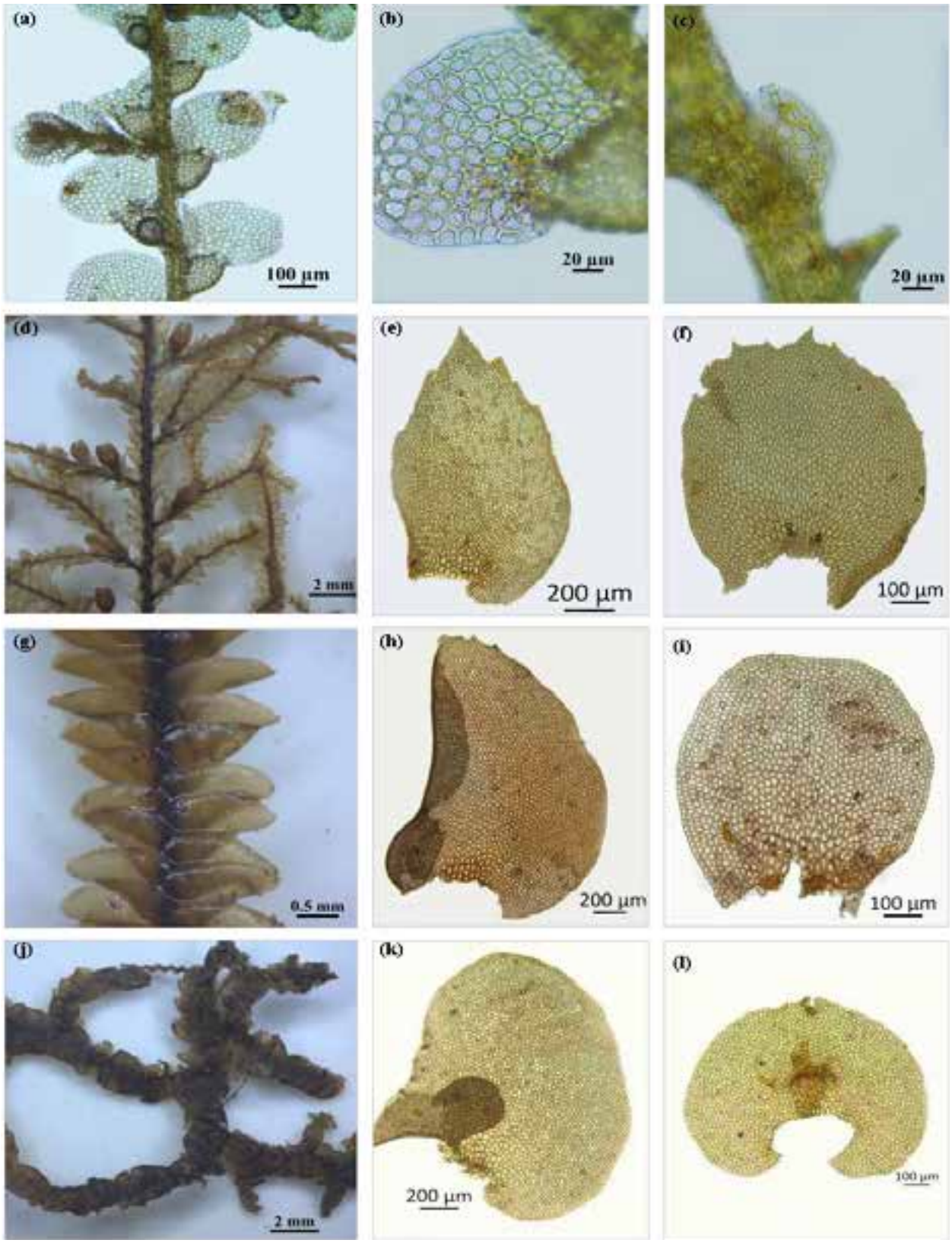

Image 2. Liverwort species collected from Tirap district. *Lejeunea tuberculosa* Steph.: a—Whole plant | b—whole mount of leaf | c—whole mount of underleaf; *Ptychanthus striatus* (Lehm. & Lindenb.) Nees | d—Whole plant | e—whole mount of leaf | f—whole mount of underleaf; *Pruceanthus semirepandus* (Nees) Verd. | g—Whole plant | h—whole mount of leaf | i—whole mount of leaf underleaf; *Frullania arecae* (Spreng.) *Gottsche* var. *arecae* | j—Whole plant | k—whole mount of leaf | l—whole mount of underleaf. © Nonya Chimyang.

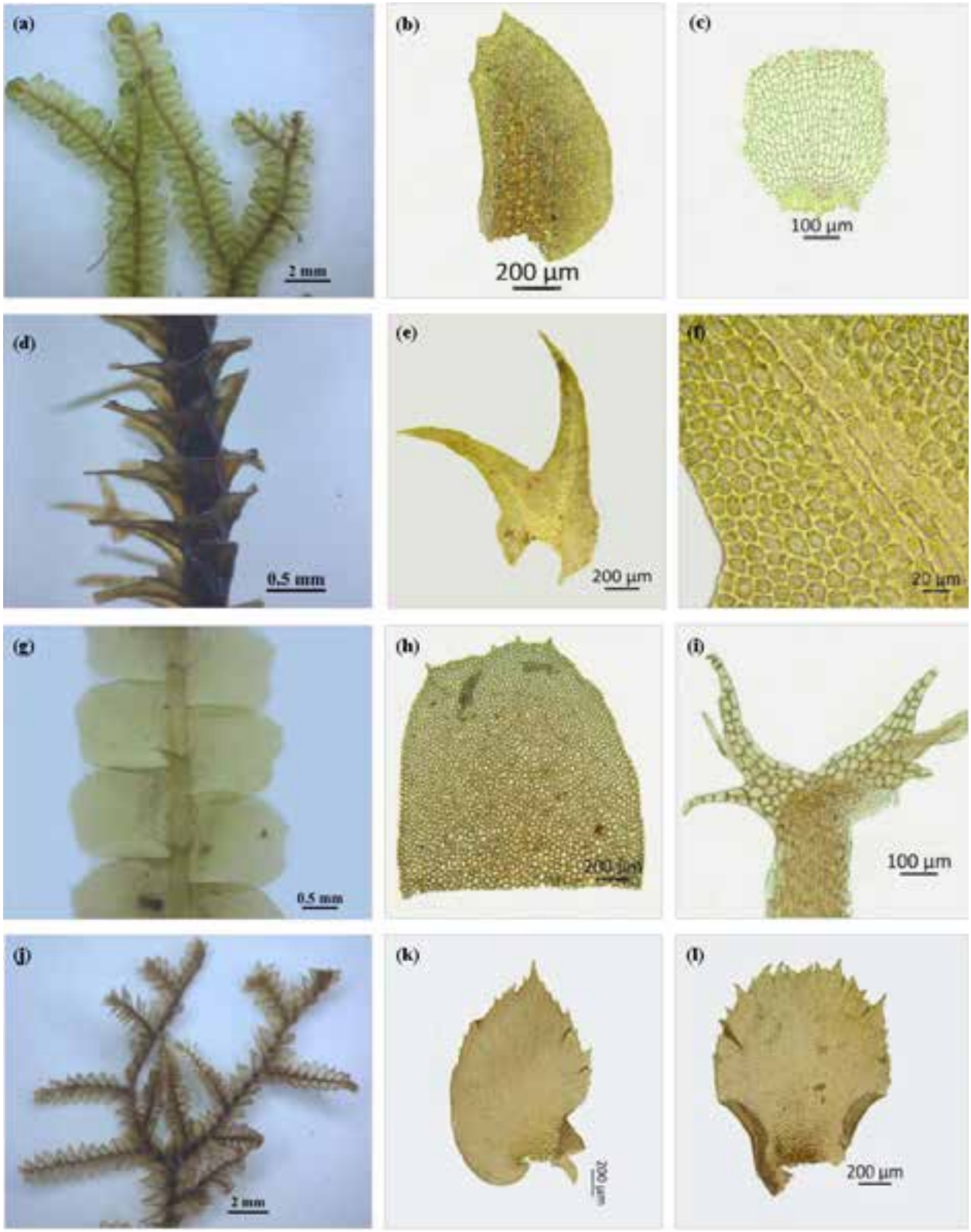

Image 3. Liverwort species collected from Tirap district. *Bazzania sumbavensis* (Gottsche ex Steph.) Steph.: a—Whole plant | b—whole mount of leaf | c—whole mount of underleaf; *Herbertus arminatus* (Steph.) H.A. Mill. | d—Whole plant | e—whole mount of leaf | f—leaf cells; *Heteroscyphus argutus* (Reinw., Blume & Nees) Schiffn | g—Whole plant | h—whole mount of leaf | i—whole mount of underleaf; *Porella caespitans* var. *cordifolia* (Steph.) S. Hatt. ex T. Katag. & T. Yamag. | j—Whole plant | k—whole mount of leaf | l—whole mount of underleaf. © Nonya Chimyang.

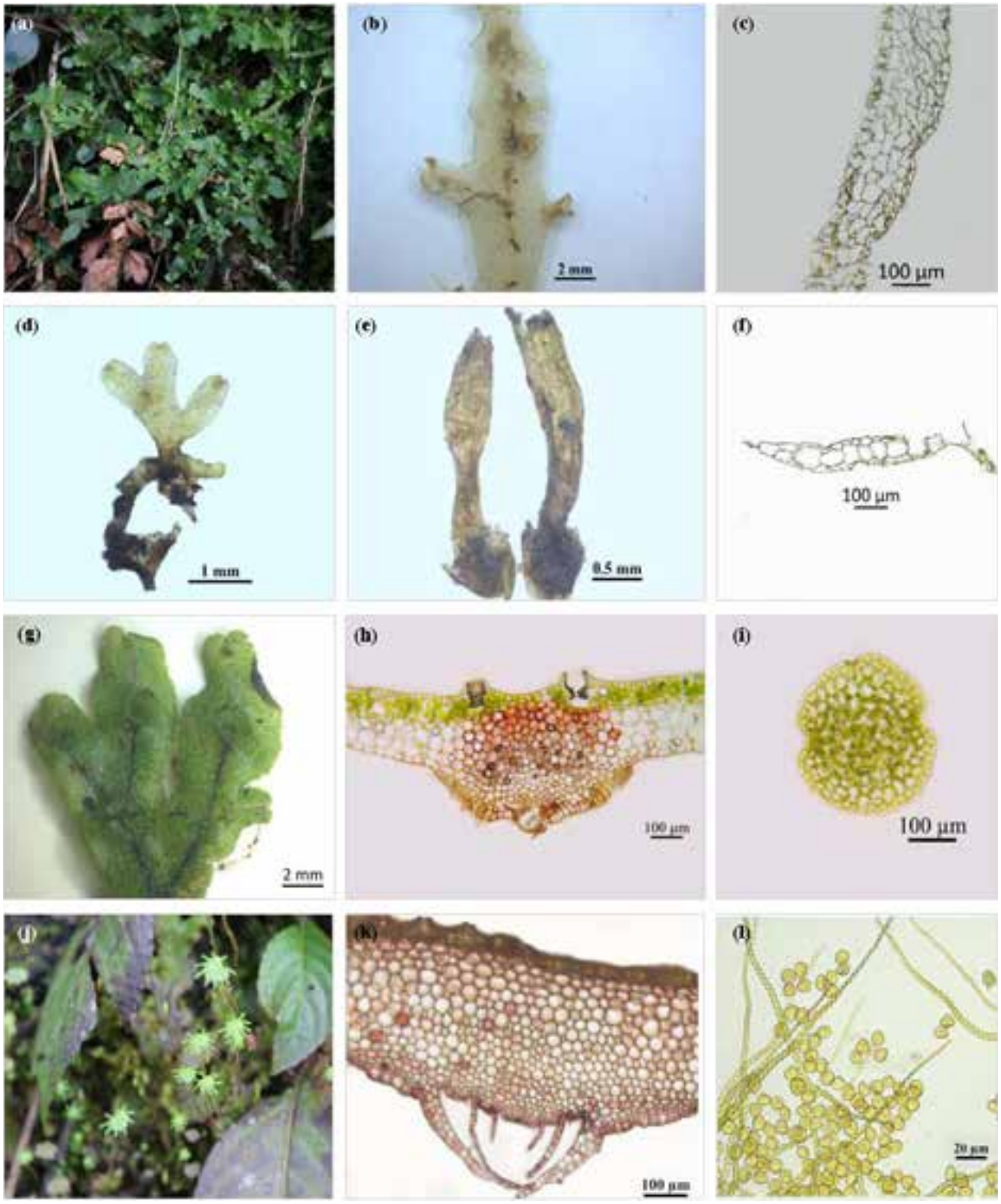

Image 4. Liverwort species collected from Tirap district. *Riccardia inconspicua* (Steph.) Reeb & Bardat: a—Habit | b—whole mount of leaf | c—T.S of thallus; *Riccardia multifida* (L.) Gray | d—Whole plant | e—Archegonia | f—T.S of thallus; *Marchantia linearis* Lehm. & Lindenb. | g—Thallus | h—T.S of thallus | i—Gemma; *Marchantia polymorpha* L. | j—Habit | k—T.S of thallus | l—Spores and Elaters. © Nonya Chimyang.

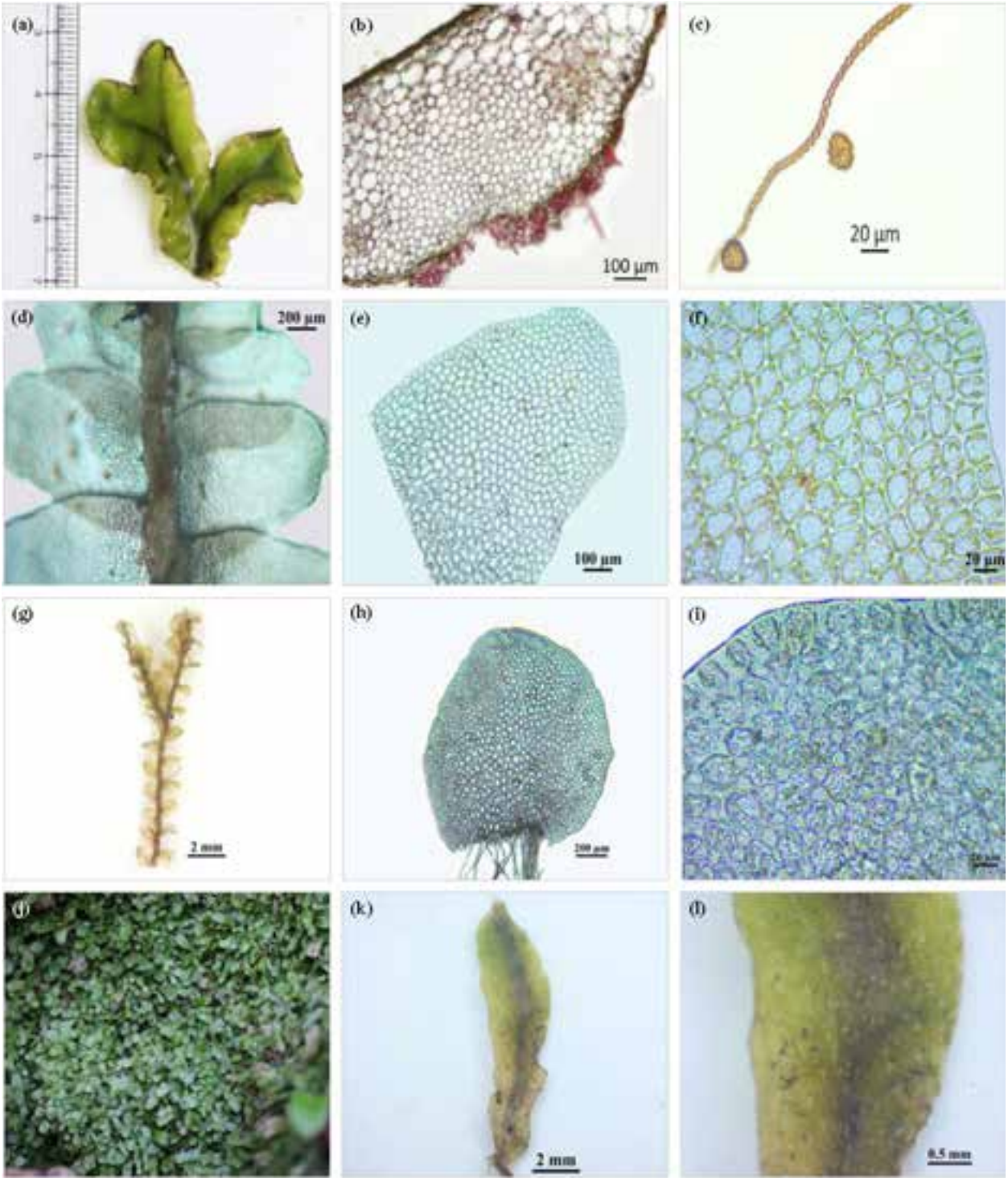

Image 5. Liverwort species collected from Tirap district. *Dumortiera hirsuta* (Sw.) Nees (a) Thallus, (b) T.S of thallus, (c) spores and elater; *Notoscyphus darjeelingensis* Udar & Ad. Kumar var. *darjeelingensis* (d) Whole plant, (e) whole mount of leaf, (f) leaf cells; *Solenostoma lanigerum* (Mitt.) Váňa & D.G. Long (g) Whole plant, (h) whole mount of leaf, (i) leaf cells; *Targionia hypophylla* L. (j) Habit; (k) Thallus; (l) A portion of thallus showing air pores. © Nonya Chimyang.

Table 1. Liverwort species of Tirap District, Arunachal Pradesh, India.

	Species	Family
1	*Riccardia inconspicua* (Steph.) Reeb & Bardat	Aneuraceae
2	*Riccardia multifida* (L.) Gray	Aneuraceae
3	*Dumortiera hirsuta* (Sw.) Nees	Dumortieraceae
4	*Frullania arecae* (Spreng.) Gottsche var. *arecae*	Frullaniaceae
5	*Notoscyphus darjeelingensis* Udar & Ad.Kumar var. *darjeelingensis*	Geocalycaceae
6	*Herbertus armitanus* (Steph.) H.A.Mill.	Herbertaceae
7	*Lejeunea tuberculosa* Steph.	Lejeuneaceae
8	*Ptychanthus striatus* (Lehm. & Lindenb.) Nees	Lejeuneaceae
9	*Spruceanthus semirepandus* (Nees) Verd.	Lejeuneaceae
10	*Bazzania sumbavensis* (Gottsche ex Steph.) Steph.	Lepidoziaceae
11	*Heteroscyphus argutus* (Reinw., Blume & Nees) Schiffn.	Lophocoleaceae
12	*Marchantia linearis* Lehm. & Lindenb.	Marchantiaceae
13	*Marchantia polymorpha* L.	Marchantiaceae
14	*Plagiochila himalayana* Schiffn. *	Plagiochilaceae
15	*Plagiochila khasiana* Mitt. *	Plagiochilaceae
16	*Plagiochila sciophila* Nees ex Lindenb.	Plagiochilaceae
17	*Plagiochila uniformis* Mitt.	Plagiochilaceae
18	*Porella caespitans* var. *cordifolia* (Steph.) S.Hatt. ex T.Katag. & Yamag.	Porellaceae
19	*Solenostoma lanigerum* (Mitt.) Váňa & D.G.Long *	Solenostomaceae
20	*Targionia hypophylla* L.	Targioniaceae

Note: The superscript '*' in the names of some bryophytes represents the new records for the state.

Sikkim, Uttarakhand, West Bengal], Bhutan, Myanmar, Nepal, Pakistan, Thailand (Majumdar 2017; Singh & Singh 2023).

PORELLACEAE

Porella caespitans (Steph.) S.Hatt. ex T.Katag. & T.Yamag., Bryol. Res. 10(5): 133. 2011. var. ***cordifolia***

Habitat: Epiphytic, growing on the bark of *Saurauia roxburghii* Wall. together with *Frullania arecae* (Spreng.) Gottsche var. *arecae, Rosulabryum capillare* (Hedw.) J.R. Spence, *Spruceanthus semirepandus* (Nees) Verd. The species was in the vegetative stage.

Specimen examined: India, Arunachal Pradesh, Tirap District, Dadam Circle. Moktowa Village. 26.871 °N; 95.457 °E; elevation 1,805 m. HAU/AN- 1953; DUH15514.

Distribution: India [Arunachal Pradesh, Himachal Pradesh, Jammu & Kashmir, Kerala, Sikkim, Uttarakhand], Bhutan, China, Nepal, Russia, Taiwan (Singh & Singh 2023).

SOLENOSTOMACEAE

Solenostoma lanigerum (Mitt.) Váňa & D.G.Long, Nova Hedwigia 89: 503. 2009.

Habitat: Terrestrial, growing on soil. The species was in the vegetative stage.

Specimen examined: India, Arunachal Pradesh, Tirap District, Dadam Circle. Dadam Village. 26.904 °N; 95.458 °E; elevation 1,070 m. HAU/AN- 1960; DUH15132.

Distribution: India [Arunachal Pradesh (present study), Meghalaya, Sikkim, Uttarakhand, West Bengal], China, Nepal, Pakistan (Singh & Singh 2023).

TARGIONIACEAE

Targionia hypophylla L.**,** Sp. Pl. 2: 1136. 1753.

Habitat: Terrestrial and epilithic, growing abundantly on soil and rock. The species was in the vegetative stage.

Specimen examined: India, Arunachal Pradesh, Tirap District, Laju Circle. Kolam Village. 26.938 °N; 95.577 °E; elevation 1,527 m. HAU/AN- 1961; DUH15124.

Distribution: India [Andhra Pradesh, Arunachal Pradesh, Gujarat, Himachal Pradesh, Jammu & Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Meghalaya, Odisha, Rajasthan, Sikkim, Tamil Nadu, Uttarakhand, West Bengal], widely distributed throughout the globe (Singh & Singh 2023).

DISCUSSION

The study area represents a diverse species of liverworts, owing to its mild temperature, high humidity, and frequent rainfall. *Dumortiera hirsuta* and *Targionia hypophylla* were the most frequently recorded species in the area, while *Lejeunea tuberculosa* and *Notoscyphus darjeelingensis* var. *darjeelingensis* were found only in small patches. The species were found inhabiting different habitats, for example, in damp shady locations, thriving on various substrates such as soil, rocks plant debris, etc. The prevalence of species in various habitats highlights the adaptability and resilience of liverworts in diverse environmental conditions. The observation of epiphytic species and those found on multiple substrates further emphasizes the ecological versatility of liverworts in colonizing different microhabitats. The frequently recorded species indicate their ecological importance and potential role in the local ecosystem. In addition, the species found in small patches signal the necessity to take conservation actions in order to safeguard them from the risk of extinction.

Many of the presently collected bryophyte samples were found growing exclusively on certain

tree species. These host trees must be considered in conservation efforts as they serve as essential habitats for various species. Bryophytes enhance water-holding capacity, nutrient status, and soil particle aggregation. Consequently, other plant species associated with bryophytes may also benefit from them. Additionally, Tirap's hilly terrain makes it highly susceptible to landslides. The widespread practice of Jhum cultivation in the area leads to deforestation, destroying natural habitats, and increasing soil erosion. Bryophytes, with their ability to naturally cover and restore disturbed habitats, can potentially play a crucial role in mitigating these environmental challenges in the region.

Therefore, this study contributes to the scientific understanding of liverwort diversity as well as the ecological importance of these understudied bryophytes in maintaining the balance and resilience of the region's ecosystem. Continued research and conservation efforts are crucial to further unravel the intricate relationships between liverworts and their environment, ensuring the preservation of this unique botanical heritage in the eastern Himalaya.

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OPEN ACCESS

COMMUNICATION

A preliminary assessment of the bat fauna (Mammalia: Chiroptera) of Murlen National Park, Mizoram, India: distribution, morphology, and echolocation

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Abstract: As part of a faunal documentation work in Murlen National Park in Mizoram, two field surveys were conducted in the park area and its immediate periphery which resulted in capture of 39 individuals of bats. Based on these captures and a previous published record, 14 bat species belonging to nine genera and three families were recorded from the study area. Despite lesser sampling coverage and shorter duration of the surveys, uncommon and little-known species like *Arielulus circumdatus, Kerivoula* cf. *hardwickii, Myotis annectans, Myotis montivagus*, and *Mirostrellus joffrei* were recorded, thereby highlighting the rich assemblage of chiropteran fauna and also the need for effective protection of the area. Based on the collected samples, five species—*Rhinolophus affinis, R. perniger*, *Myotis annectans*, *Pipistrellus javanicus*, and *Mirostrellus joffrei*—are first recorded from Mizoram state. The echolocation call structures of four of the recorded species from the study area are also presented. We have also provided an updated checklist of the bat fauna of Mizoram state comprising 35 species of five families.

Keywords: Bat diversity, checklist, inventory, new records, northeastern India, protected area.

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Author contributions: US conducted the field surveys, identified the specimens and wrote the first draft. RC analyzed the echolocation calls, provided inputs to the text and helped finalizing the manuscript.

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INTRODUCTION

Murlen National Park is one of the ten protected areas in Mizoram and is the second National Park in the state. Encompassing diverse vegetation from tropical, semi evergreen to sub-montane forest, the Park has a relatively pristine ecology. Considering its contiguity with Kachin Hills in Myanmar and relatively intact nature of forest, the area has the potential to harbor a rich assemblage of fauna including a high diversity of mammals (Saikia & Bal in press). However, information on faunal diversity of the Park is scanty except for a select group of vertebrates (Kaul et al. 2001; Mandal et al. 2007; Saikia et al. 2021; Bal et al. 2022a,b; Bal & Giordono 2022; Lalramsanga et al. 2022). Bats are one of the least known mammalian groups from Mizoram with only 29 authentically recorded species (Dobson 1874; Bates & Harriosn 1997; Mandal et al. 2007) and information on the bat diversity from protected areas of the state are nearly nonexistent. The only report on the bat fauna of any protected area of Mizoram pertains to Lengteng Wildlife Sanctuary, wherein nine species of bats were reported (Vanlalnghaka 2013). However, considering the inclusion of extralimital species like *Rousettus aegyptiacus* and *Rhinolophus hipposideros* and lack of taxonomic rigor of that study, the identity of several recorded species remains to be verified. In order to fill the biodiversity information gap and consequently to help the Park authorities with better management plan of the resources, a series of faunal surveys were initiated by the North Eastern Regional Centre (NERC) of Zoological Survey of India, Shillong. As part of this survey, the first author conducted sampling in the Park and its immediate surroundings during October 2018 and March 2022. Based on the collected specimens from the aforementioned surveys and record of a single species in Mandal et al. (2007), a preliminary assessment of bat diversity in Murlen National Park and its environ has been presented. Additionally, we provide the echolocation call structures of free flying individuals of four of the recorded species from the study area. An updated checklist of the bat fauna of Mizoram comprising 35 species of five families is also provided.

MATERIALS AND METHODS

Study area

Murlen National Park is located in Champhai district of Mizoram state in India adjacent to the Chin Hills of Myanmar. The Park encompasses an area of 100 km^2 spreading between 23.53–23.70 N and 92.21–92.45 E (Environment, Forest and Climate Change Department, Govt of Mizoram 2017) (Image 1). It was declared as National Park vide notification No.B.12012/5/99-FST dated 24 January 2003. The Park area spreads over a significant elevation range from 400–1,900 m. Vegetation is tropical, semi-evergreen and sub montane forests dominated by *Quercus* sp.*, Schima wallichai, Betula* sp., *Michelia champaca, Pinus kesiya, Prunus* sp., *Myrica* sp.*, Rhododendron* sp.*, Saccharum* sp., and varieties of orchids (Kumar et al. 2018).

Field sampling and species identification

Field samplings in the National Park area and its immediate surroundings were conducted in October–November 2018 and March 2022. Bats were trapped at several localities in the immediate periphery of the Park, i.e., Murlen village and adjacent agricultural areas (23.64561 ^{0}N, 93.296179 ^{0}E, 1,580 m; 23.66166 ^{0}N, 93.28333 ^{0}E, 1,345 m) and along the Vapar–Murlen road (23.66403 ^{0}N, 93.29623 ^{0}E, 1,430 m) and a Forest Camp (Tuikual Duty Post) in the Park area (23.64464 ^{0}N, 93.29786 ^{0}E, 1,640 m) (Image 1). Mist nets (6 x 2.5 m and mesh size 16 x 16 mm, Ecotone Poland) and one two bank harp trap (Austbat, Australia) were deployed. Mist nets were set near water holes, across streams especially during the dry period of March 2022 and kept open for about three hours after sunset (Image 2). The harp trap was set across possible flight paths inside forest and forest openings and placed overnight. A total of nine nights of bat trapping were conducted. Thirty-nine individuals of bats were captured. Almost all the bats were captured in mist nets except for one individual of *Kerivoula* cf. *hardwickii* and two *Rhinolophus affinis*. Fifteen of those individuals were retained as vouchers and rest were released at the capture sites. No visibly pregnant or lactating females were retained as vouchers. Captured animals were handled following standard methods in mammalogy (Sikes & Animal Care and Use Committee of the American Society of Mammalogists 2016) and vouchers were deposited into the North Eastern Regional Centre of Zoological Survey of India, Shillong for further investigations.

The acronyms for measurements are: Ear length (E); Tragus length (TR); Hindfoot length, including claw (HF c.u.); Forearm length (FA); Tibia length (TB); 3rd metacarpal length (3MT); 4th metacarpal length (4MT); 5th metacarpal length (5MT); Greatest length of skull including incisors (GTLi); Condylocanine length (CCL); Maxillary toothrow length (CM^3); Width across third molars (M^{3}M^3); Width across canines (C^{1}C^1); Zygomatic breadth (ZB); Postorbital constriction (POC); Breadth

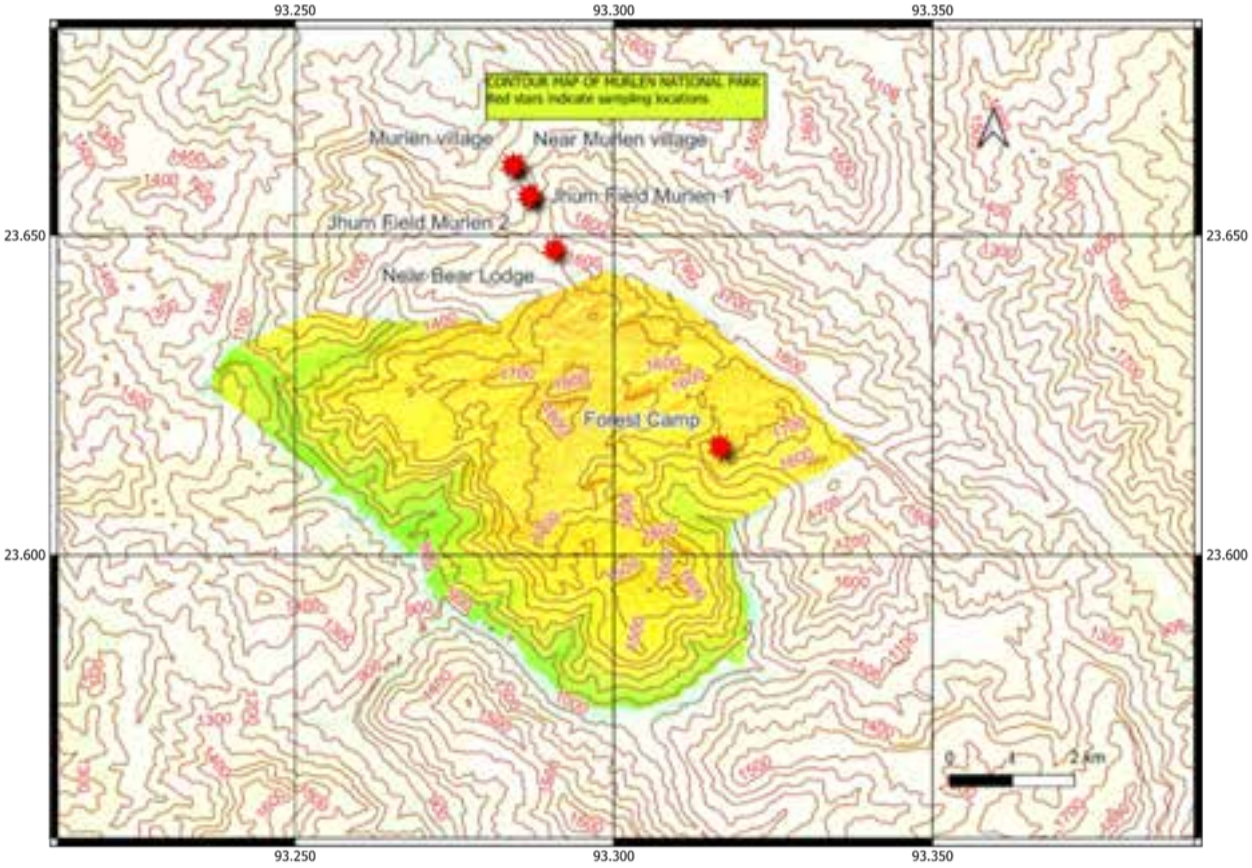

Image 1. Map of Murlen National Park and surrounding areas showing sampled areas (red stars).

of braincase (BB); Mastoid breadth (MAB); Length of mandible including incisors (MLi); Mandibular toothrow length (CM_3); Coronoid height (COH). These measurements generally follow definitions by Bates & Harrison (1997).

Echolocation call analysis

The ultrasonic calls at the sampling site were recorded with an Anabat Walkabout detector (Titley Scientific, Brendale, Australia). As the primary purpose of the survey was to document and provide unambiguous identification of species through specimens, we recorded calls by placing the bat detector in front of the nets. Calls recorded before captures were attributed to that particular individual. Although this method is prone to ambiguity in call identification and attribution, the benefit is that the calls recorded were more representative of search phase calls. Calls that are recorded upon release (the standard protocol) are rarely representative of search phase calls rendering them less useful for acoustic identification of bats recorded in free flight.

The recordings were carried at a sampling rate of 500 KHz and analyzed using Raven Pro 1.5.0 (Cornell Lab of Ornithology, Ithaca, USA). From up to 15 pulses that appeared to represent search phase calls (with short terminal narrowband FM tails), we measured start frequency (high frequency, SF), end frequency (low frequency, EF), peak frequency (PF), bandwidth (BW) and duration (D) from a spectrogram of FFT size 1024 with 95% overlap and a Hanning window. For rhinolophid bats, the measurements were extracted from the second harmonic, whereas for all other species, the first harmonic pulses were measured.

The checklist

The updated checklist of the bat fauna of Mizoram state is based on all published records till October 2023. The locality records mentioned are essentially based on Bates & Harrison (1997) and Mandal et al. (2007) updated with any succeeding publications. The chiropteran collection at NERC, Shillong is also examined and included wherever applicable. Only those published records authenticated by vouchers are taken into consideration.

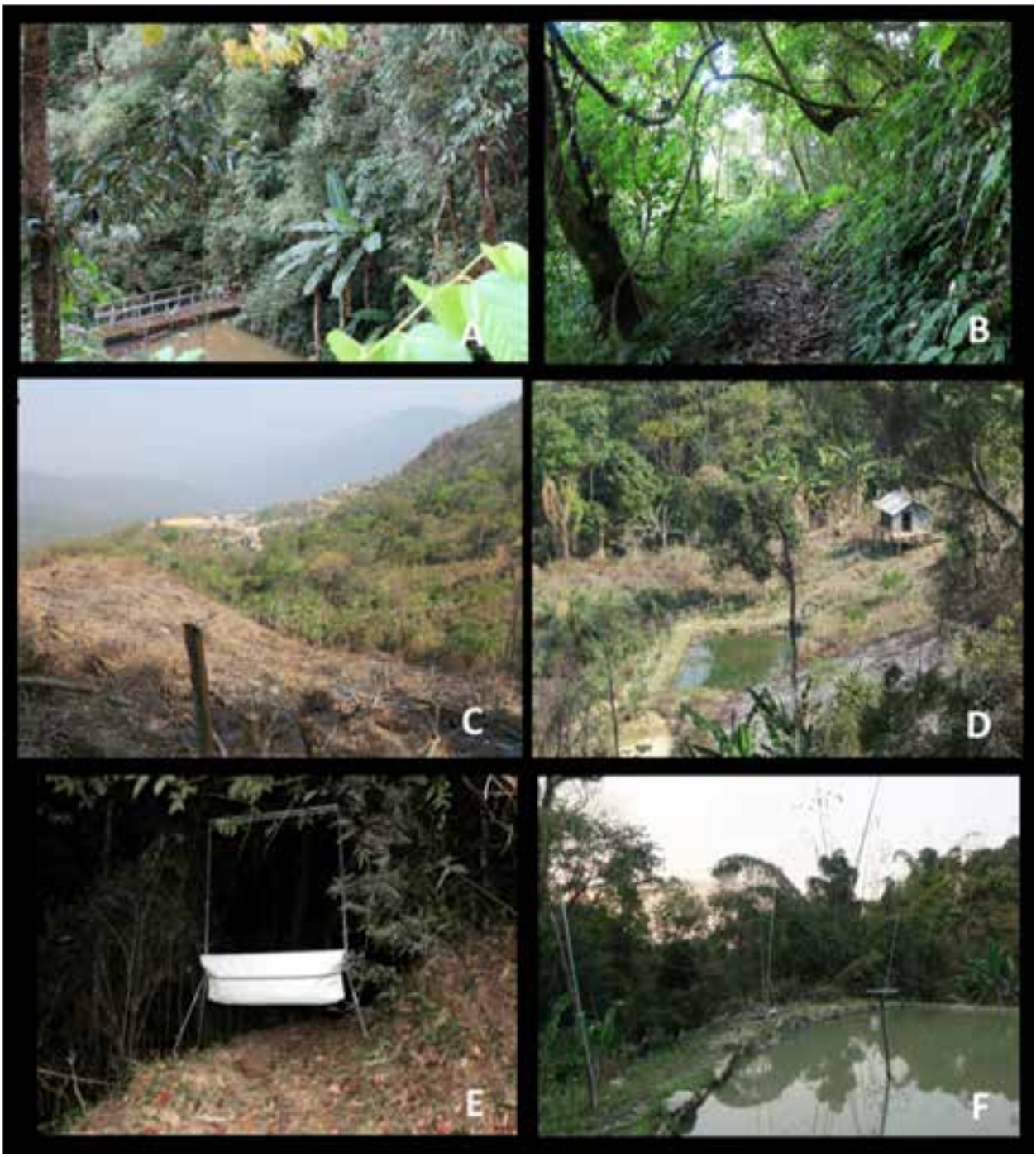

Image 2. Landscape in some of the sampling localities. © Uttam Saikia.

RESULTS

Thirteen bat species belonging to three families were recorded from inside the Park and its immediate surroundings. Photos of the species are in Images 3 & 4, and their morphological and anatomical measurements are provided in Tables 1 & 2, respectively. The echolocation call parameters of four species, viz., *Rhinolophus affinis, Mirostrellus joffrei, Myotis annectans and Myotis montivagus* have been provided in Table 3.

We have also provided a consolidated checklist of bats of Mizoram in Appendix 1.

Systematic accounts

Order: Chiroptera

Family: Pteropodidae

1. *Eonycteris spelaea* (Dobson, 1871)

(Dawn Bat)

Material examined: 1♂, V/M/ERS/532 (Figure 3A), 3♀(released), 09.xi.2018, along Vapar-Murlen Road (1,662 m), Champhai district, Mizoram.

Remarks: The individuals were caught in a mist net set across a forest opening in the early evening hours possibly en route to foraging places.

Family: Rhinolophidae

2. *Rhinolophus affinis* Horsfield, 1823

(Intermediate Horseshoe Bat)

Material examined: 2♂, V/M/ERS/702 (Figure 3B),703, 18.iii.2022, near Bear Lodge (1587 m), Murlen National Park.

Echolocation call: The average echolocation call peak frequency was recorded at 88.79 kHz (Table 3; Image 5) which is similar to that recorded in western Himalaya (88 kHz, Chakravarty et al. 2020) and southeastern China (Jiang et al. 2008).

Remarks: First report of this species from Mizoram state. Apparently widespread in the area as call signatures matching the above described structure were recorded in several other places in the periphery of the Park.

3. *Rhinolophus rouxii* Temminck, 1835

(Rufous Horseshoe Bat)

Material examined: 3♀, V/M/ERS/533, 534, 542, 08–09.xi.2018, along Vapar-Murlen Road (1,463 m), Champhai district, Mizoram.

Remarks Several *Rhinolophus rouxii* individuals were also caught at the same location where *Eonycteris spelaea* were caught.

4. *Rhinolophus perniger* Hodgson, 1843

(Northern Wooly Horseshoe Bat)

Material examined: 1♀, V/M/ERS/706 (Figure 3C), 18.iii.2022, near Bear Lodge (1,587 m), adjacent to Murlen National Park, Champhai district, Mizoram.

Remarks: The specimen was caught in a mist net set around an abandoned forest house. The current record constitutes the first mention of this species from Mizoram.

Family: Vespertilionidae

5. *Arielulus circumdatus* (Temminck, 1840)

(Bronze sprite)

Material examined: 2♀, V/M/ERS/685 (Figure 3D), 699, 19.iii.2022 & 21.iii.2022, Jhum field near Murlen village (1,490 m), Champhai district, Mizoram.

Remarks: Individuals were caught in mist nets while coming to drink around an artificial water source.

6. *Barbastella darjelingensis* (Hodgson, 1855)

(Eastern Barbastlle)

Material examined: 1♀, V/M/ERS/698 (Figure 3E), 18.iii.2022, near Bear Lodge (1,587 m), Murlen National Park.

Remarks: Caught in a mist net set across an open

Table 1. Morphological data of the measured bat specimens from Murlen NP and it's environ.

Species	HF	TB	FA	E	TR	3MT	4MT	5MT	No. of examples measured
Eonycteris spelaea	15.2–20.1 (17.3)	29.8–34.5 (32.6)	65.1–74.7 (70.8)	16.7–18.4 (17.5)	-	-	-	-	4
Rhinolophus affinis	11.2, 12	23.4, 24.2	53.0, 53.5	15.4, 16.8	-	39.8, 40.4	41.5, 42.4	42.9, 43.7	2
R. perniger	17.9	69.4	37.6	36.5	-	48.2	56.3	57	1
R. rouxii	11.0, 11.7	23.3, 23.8	52.9, 53.4	17.9, 18.4	-	39.8, 41	41.8, 42.6	43.0, 43.9	2
Arielulus circumdatus	8.6, 9.1	16.5, 17.5	39.4, 39.9	10.6, 11.0	4.6, 5.2	37.6, 38.9	36.3, 37.8	35.1, 35.6	2
Barbastella darjelingensis	8.1	19.3	40.0	13.5	6.1	41.1	38.8	37.2	1
Kerivoula sp.	8.0	16.2	34.8	12.5	6.4	37.0	36.5	34.9	1
Mirostrellus joffrei	7.6, 8.7	14.7, 16.7	36.7, 38.4	11.5	3.6, 4.3	37.0, 39.4	36.8, 38.0	32.2, 34.6	2
Myotis annectans	8.3	19.3	44.25	13.1	6.0	42.3	40.9	39.7	1
M. montivagus	8.7, 9.0	15.9, 17.4	39.4, 40.2	12.1, 12.9	6.3, 6.9	37.8	36.6	35.8	2
M. muricloa	8.9	17.5	35.0	11.3	5.4	32.8	32.0	31.4	1
Pipistrellus javanicus	6.9	13.5	32.4	10.2	4.8	32.2	32.4	31.7	1
Tylonycteris malayana	6.4	13.0	30.5	10.5	3.5	28.9	28.3	27.2	1

space surrounded by trees.

7. *Kerivoula* cf. *hardwickii* (Horsfeild, 1824)

Material examined: 1♀, V/M/ERS/698 (Figure 3F), 18.iii.2022, near Bear Lodge (1,587 m), Murlen National Park

Remarks: The specimen was caught in a harp trap set across a narrow forest trail dominated by bamboo. Our specimen apparently belongs to the *K. hardwickii* complex and actual identity of the specimen is still under investigation.

8. *Mirostrellus joffrei* (Thomas, 1915)
(Joffre's Pipistrelle)

Material examined: 2♀, V/M/ERS/684, 687 (Figure 4G), 19.iii.2022 & 23.iii.2022, Jhum field at Murlen village (1,345 m), Champhai district, Mizoram

Remarks: An IUCN Data Deficient species, this is the first record of this bat from Mizoram. Recently reported from Manipur (Saikia & Meetei 2022) indicating a broader distribution and relatively common occurrence than previously thought

Echolocation: Relatively narrowband (27–45 kHz) FM-QCF calls were recorded with an average peak frequency of 29.78 kHz (Table 3; Image 5). The calls were similar to those reported from western Himalaya (Chakravarty et al. 2020) and northern Vietnam (Görföl et al. 2020).

9. *Myotis annectans* Dobson, 1871
(Hairy-faced Bat)

Material examined: 1♀, V/M/ERS/686 (Figure 4H), 19.03.2022, Jhum field at Murlen village (1345 m), Champhai district, Mizoram

Echolocation calls: The calls were relatively broadband (32–68 kHz), relatively long (7.2 ms), largely FM but with a short QCF ending, typical of some Himalayan and Southeast Asian *myotids* (for example, *Myotis siligorensis*, Surlykke et al. 1993). End frequency (EF) which is less variable than peak frequency in *Myotis* spp. was recorded at an average of 32.27 kHz (Table 3; Image 5), which is lower than that recorded in western Himalayas (36.22 kHz, Chakravarty et al. 2020) and Cambodia (38 kHz, Sophany et al. 2013). However, the western Himalayan specimens are likely to be revised to *M. sicarius* (Görföl et al. in prep). Nonethless, the differences in call frequencies are likely due to the different recording scenarios. The calls recorded in western Himalaya and Cambodia come from hand-released bats while our calls were recorded in free flight.

Remarks: This is the first report of this species from Mizoram and recently been reported from neighboring Manipur (Saikia & Meetei 2022).

10. *Myotis montivagus* (Dobson, 1874)
(Burmese-whiskered Myotis)

Material examined: 1♂, 1♀, V/M/ERS/697 (Fig 4I), 704, 20.iii.2022, near Murlen village, Vapar-Murlen road (1,480 m), Champhai district, Mizoram

Remarks: A globally Data Deficient species, this bat was reported only from Mizoram state in India thus far. A possible specimen of this species has been recorded recently from Siju cave in Meghalaya (Kharkongor et al. 2024)

Echolocation: Short duration (2.6 ms), broadband calls (43–95 kHz) calls were recorded with a mean peak frequency of 51 kHz (Table 3; Image 5). The calls presented here are the first recordings of this species from India and are similar in structure and frequencies to closely related

Table 2. Craniodental measurements of some of the species recorded from the study area.

Species	GTLi	CCL	ZW	BW	POC	CM^3	C^1-C^1	M^3-M^3	MAB	MLi	CM_3	COH	No. of exs.
Arielulus circumdatus	15.45	14.78	11.05	8.12	4.43	5.84	4.83	7.14	8.80	11.94	6.12	3.85	1
Barbastella darjelingensis	15.0	13.55	7.53	7.26	3.87	4.70	3.42	5.28	8.32	9.61	5.12	2.68	1
Kerivoula cf. *hardwickii*	14.25	12.77	8.72	7.24	3.32	5.50	3.57	5.40	7.52	10.25	5.90	3.17	1
Mirostrellus joffrei	14.90	14.12	10.82	7.73	4.58	5.08	5.16	7.43	8.68	10.74	5.68	4.00	1
Myotis annectans	16.88	16.68	11.63	7.80	4.33	6.93	4.63	7.55	8.67	12.27	7.21	4.55	1
M. montivagus	15.51	14.28	10.82	7.36	4.10	6.25	4.22	7.17	7.60	11.90	6.55	4.00	1
M. muricloa	13.37	12.82	-	6.68	3.60	4.90	2.86	5.82	7.12	9.67	5.40	2.85	1
Pipistrellus javanicus	12.46	11.37	7.80	5.92	3.28	4.48	4.26	5.67	6.64	8.46	4.87	2.75	1
Tylonycteris malayana	13.66	11.84	9.34	7.16	4.76	4.17	4.25	5.60	7.66	9.25	4.27	2.66	1

Image 3. Bat species recorded from Murlen NP and its periphery: A—*Eonycteris spelaea* | B—*Rhinolophus affinis* | C—*Rhinolophus perniger* | D—*Arielulus circumdatus* | E—*Barbastella darjelingensis* | F—*Kerivoula* cf. *hardwickii*. © Uttam Saikia.

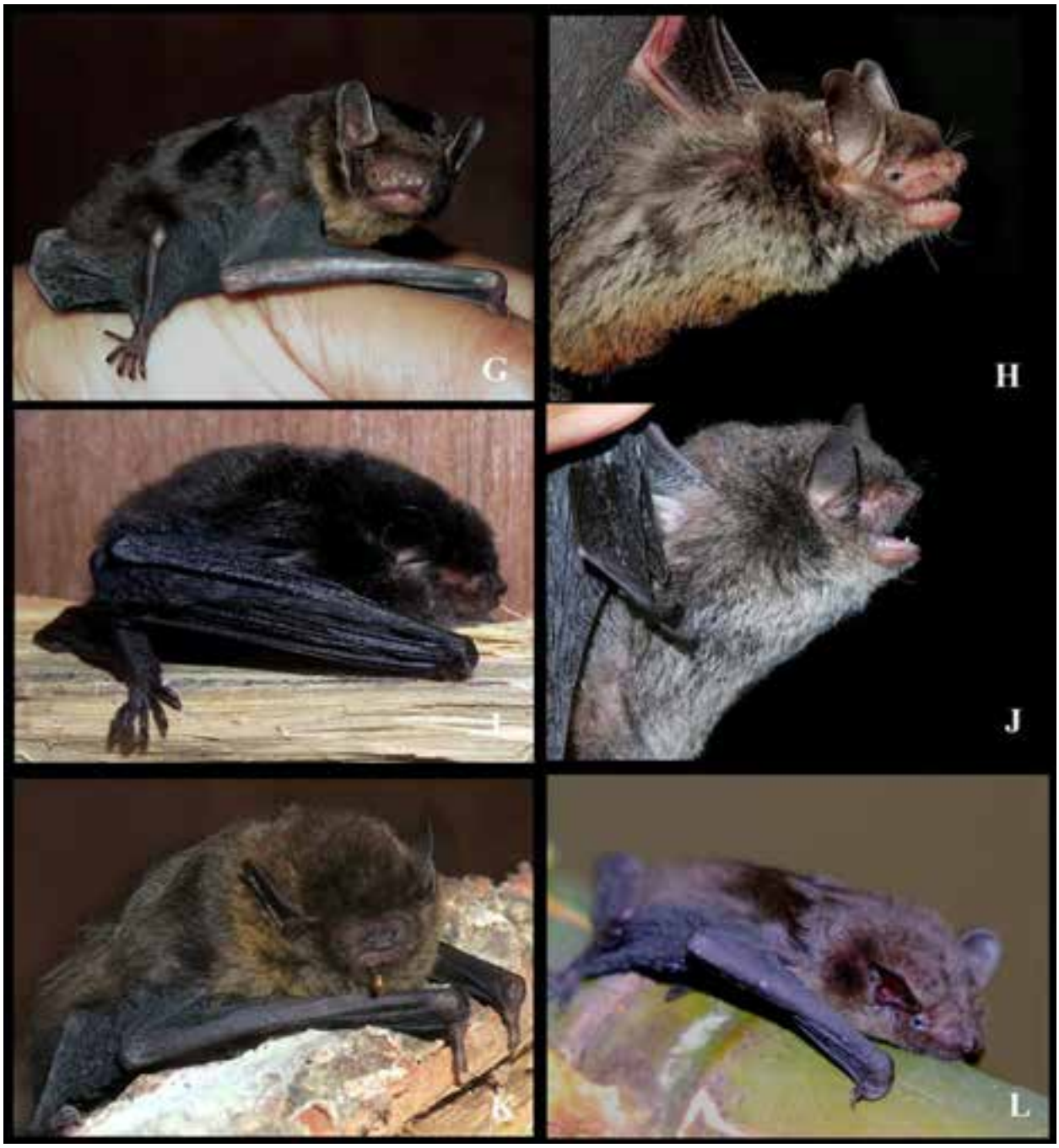

Image 4. G—*Mirostrellus joffrei* | H—*Myotis annectans* | I—*Myotis montivagus* | J—*Myotis muricola* | K—*Pipistrellus javanicus* | L—*Tylonycteris malayana*.

Table 3. Echolocation calls measurements of the species whose calls were definitively recorded. All measurements are given as mean ± standard deviation.

Species	No. of pulses	Start frequency (SF, kHz)	End frequency (EF, kHz)	Peak frequency (PF, kHz)	Bandwidth (kHz)	Duration (ms)
Rhinolophus affinis	15	90.15 ± 0.42	70.28 ± 3.06	88.79 ± 0.2	-	46.08 ± 5.2
Mirostrellus joffrei	15	45.07 ± 5.36	27.61 ± 0.27	29.78 ± 0.48	17.45 ± 5.35	9.08 ± 0.93
Myotis annectans	15	68.69 ± 7.79	32.27 ± 1.10	35.74 ± 2.02	36.41 ± 6.97	7.24 ± 1.96
Myotis montivagus	9	95.01 ± 4.52	43.23 ± 1.01	50.1 ± 3.12	51.78 ± 5.08	2.6 ± 0.26

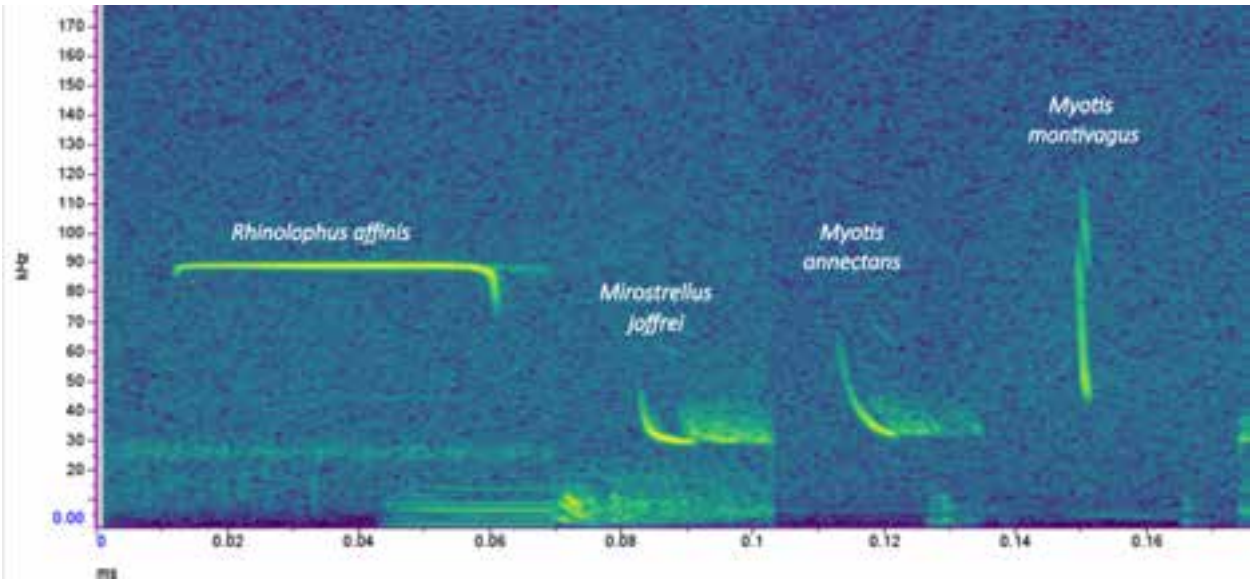

Image 5. Spectrogram depicting the echolocation calls of the four species of bats whose calls were recorded in our survey.

M. peytoni from the Western Ghats (Wordley et al. 2014; Raman et al. 2020)

11. *Myotis muricola* (Gray, 1846)
(Nepalese Whiskered Myotis)

Material examined: 1ó, V/M/ERS/709 (Fig 4J), 23.iii.2022, Jhum field at Murlen village (1,345 m), Champhai district, Mizoram.

12. *Pipistrellus javanicus* Gray, 1838
(Java Pipistrelle)

Material examined: 1ó, V/M/ERS/705 (Fig 4K), 22.iii.2022, near Murlen village, Vapar-Murlen road (1,480 m), Champhai district, Mizoram

Remarks: The individual was caught in a mist net near an artificial water source. A few other non-reproductive females were also caught at the same spot and were released. This is the first record of this species from Mizoram.

13. *Tylonycteris malayana* Chasen, 1840
(Malayan Bamboo Bat)

Material examined: 1ǫ, V/M/ERS/701 (Fig 4L) 23.iii.2022, Jhum field at Murlen village (1,345 m), Champhai district, Mizoram

Remarks: Also caught in mist nest around a water hole.

DISCUSSION

Water is a critical resource for wildlife. During the drier period of January–April, most of the water sources in Murlen National Park and its surroundings dry out except for scattered water puddles in the streambeds. The villagers also construct some ponds in the Jhum fields for irrigation and fishery purposes. These water sources attract a number of bat species offering excellent opportunity of studying bats. In spite of our limited area coverage and short study period, we could record 12 species of bats in three families out of which five namely *Rhinolophus affinis, R. perniger*, *Myotis annectans*, *Pipistrellus javanicus* and *Mirostrellus joffrei* are new additions to the state of Mizoram. *Sphaerias blanfordi* was already reported from the Park (Mandal et al. 2007) indicating a very diverse bat community in the study area. Among the presently recorded species, *Mirostrellus joffrei* was considered as a rare species and only represented by a few museum specimens until recent times. The IUCN Red List still considers it as a 'Data Deficient' species (Görföl et al. 2016). However, after its discovery from Meghalaya, Sikkim, and from Nepal (Saikia et al. 2017), it was subsequently reported from Uttarakhand (Chakravarty et al. 2020) and Manipur (Saikia & Meetei 2022). The current record from Murlen further underscores the fact that this bat is more widely distributed in the Himalayan region and in the southeastern Asia. Another little-known species recorded in the study area is *Myotis montivagus* which is also currently recognized as 'Data Deficient' by the IUCN

Red List (Görföl 2020). Primarily known from scattered records from southern China, Myanmar, Vietnam, and Laos, this species is thus far definitively known only from a few localities of Mizoram in India. We characterize the echolocation call structure of free flying individual of this species from the area. It may be noted that another two species with taxonomic ambiguity, e.g., *Hipposideros* cf. *larvatus* and *Kerivoula* cf. *hardwickii* have also been recorded from Mizoram during the aforementioned surveys. However, the taxonomic status of *H. larvatus* s.l. in northeastern India is uncertain (Thabah et al. 2006) and a thorough integrative taxonomic reassessment is required. Similarly, the identity of *Kerivoula* specimen from Murlen NP also needs careful investigations as apparently it belongs to the cryptic *K. hardwickii* complex. As a derivative of the study, we also recorded the bat echolocation calls at our sampling sites although it was not meant for an echolocation call library. Even though a large number of calls were recorded in each sampling sites, due to difficulty in attributing a particular call to a free flying species, we provided the call structure details of only four species which we could attribute with a fair degree of certainty. Standardizing the recording protocols to obtain the "most natural" search phase calls remains another avenue of future research.

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Appendix 1. Checklist of the bat fauna of Mizoram state.

	Species	Locality records	Reference
1	*Cynopterus sphinx* (Vahl)	Aibawk (c.800 m), North Khawbubg (c.1500 m) and Dampa (c.250 m) in Aizawl district; Ngengpui (200 m) in Lawngtlai district and Sairep (1500 m) in Lunglei district	Mandal et al. 2007
2	*Cynopterus brachyotis* (Muller)	Ngengpui (200 m) in Lawngtlai district	Mandal et al. 2007
3	*Eonycteris spelaea* (Dobson)	Dampa (c.250 m) in Aizawl district; Lungsen (c. 650 m) in Lunglei district; 4 km from Tui-Pui, Champhai Aizawl Road in Champhai district	Mandal et al. 2007; V/M/ERS/529-531
4	*Macroglossus sobrinus* Anderson	Ngengpui (c.200 m) in Lawngtlai district	Mandal et al. 2007
5	*Megaerops niphanae* Yenbutra & Felten	North Khawbubg (c.1500 m) in Aizawl district and Sairep (1500 m) in Lunglei district	Mandal et al. 2007
6	*Pteropus medius* Temminck	North Khawbubg (c.1500 m) and Dampa (c.250 m) in Aizawl district	Mandal et al. 2007
7	*Rousettus leschenaulti* (Desmarest)	Aibawk (c.800 m), North Khawbubg (c.1500 m) and Dampa (c.250 m) in Aizawl district; 4 km from Tui-Pui (830 m), Champhai Aizawl Road in Champhai district	Mandal et al. 2007; V/M/ERS/527-528
8	*Sphaerias blanfordi* (Thomas)	Tuikual Duty Post (c.850 m), Murlen NP in Champhai district and Sairep (1500 m) in Lunglei district	Mandal et al. 2007
9	*Rhinolophus affinis* Horsfield	Near Bear Lodge, Murlen-Vapar Road, Champhai district	Present study
10	*Rhinolophus lepidus* Blyth	Dampa (c.250 m) in Aizawl district; Lungsen (c. 650 m) in Lunglei district	Mandal et al. 2007
11	*Rhinolophus perniger* Hodgson	Near Bear Lodge (1587 m), adjacent to Murlen NP in Champhai district	Present study
12	*Rhinolophus pearsonii* Horsfield	Sairep (c.1500 m), Lunglei district	Mandal et al. 2007
13	*Rhinolophus rouxii* Temminck	Dampa (c.250 m) in Aizawl district; Lungsen (c. 650 m) in Lunglei district; 4 km from Tui-Pui, Champhai Aizawl Road, and along Vapar-Murlen Road in Chanphai district	Present study; Mandal et al. 2007; V/M/ERS/537, 538
14	*Rhinolophus yunanensis* Dobson	Areas adjacent to Tipaimukh in Aizawl district	Dobson, 1874;
15	*Hipposideros cineraceus* Blyth	Dampa (c.250 m) in Aizawl district; Sairep (1500 m) in Lunglei district	Mandal et al. 2007
16	*Hipposideros lankadiva* Kelaart	Dampa (c.250 m) in Aizawl district	Mandal et al. 2007
17	*Hipposideros* cf. *larvatus* Horsfeild	Tuival Bridge (480 m) in Champhai district	V/M/ERS/521-524
18	*Megaderma spasma* Linnaeus	Paikla? (most probably Paikhai c.760 m in Aizawl district)	Bates & Harrison, 1997
19	*Arielulus circumdatus* (Temminck)	Sairep (1500 m) in Lunglei district and Murlen village (1490 m) in Champhai ditrict	Mandal et al. 2007; present study
20	*Barbastella darjelingensis* Hodgson	Sairep (1500 m) in Lunglei district and Near Bear Lodge (1587 m), adjacent to Murlen NP in Champhai ditrict	Mandal et al. 2007; present study
21	*Eptesicus pachyotis* (Dobson)	Sairep (1500 m) in Lunglei district	Mandal et al. 2007
22	*Harpiocephalus harpia* (Temminck)	Sairep (1500 m) in Lunglei district and Sangau (c. 1380 m) in Lawngtlai district	Bates and Harrison, 1997; Mandal et al. 2007 as *H. mordax*
23	*Harpiola grisea* (Peters)	Sairep (1500 m) in Lunglei district	Mandal et al. 2007
24	*Kerivoula* cf. *hardwickii* (Horsfield)	Sangau (c. 1270 m) in Lawngtlai district and Near Bear Lodge (1587 m), adjacent to Murlen NP in Champhai district	Bates & Harrison, 1997; Present study
25	*Mirostrellus joffrei* (Thomas)	Near Murlen village (1490 m), Champhai district	Present study
26	*Murina cyclotis* (Dobson)	Sairep (1500 m) in Lunglei district	Mandal et al. 2007
27	*Murina tubinaris* (Scully)	Sairep (1500 m) in Lunglei district and Sangau (c. 1380) in Lawngtlai district	Bates & Harrison, 1997; Mandal et al. 2007
28	*Myotis formosus* (Hodgson)	Sairep (1500 m) in Lunglei district	Mandal et al. 2007
29	*Myotis annectans* (Dobson)	Near Murlen village (1490 m) in Champhai district	Present study
30	*Myotis montivagus* (Dobson)	Sairep (1500 m) in Lunglei district and Near Murlen village (1490 m) in Champhai district	Mandal et al. 2007; Present study
31	*Pipistrellus javanicus* (Gray)	Near Murlen village (1490 m) in Champhai district	Present study
32	*Scotozous dormeri* (Dobson)	Lungsen (c. 650 m) in Lunglei district	Mandal et al. 2007
33	*Myotis muricola* (Gray)	Sairep (c.15000 m) and Lungsen (c. 650 m) in Lunglei district and Murlen village (1490 m) in Champhai district	Mandal et al. 2007; Present study
34	*Tylonycteris fulvida* (Blyth)	Sangau (c.1380 m) in Lawngtlai district	Bates & Harrison, 1997 (as *T. pachypus*)
35	*Tylonycteris malayana* Chasen	Sangau (c.1380 m) in Lawngtlai district; Murlen village (1490 m) in Champhai district	Bates & Harrison, 1997 (as *T. robustula*); present study

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COMMUNICATION

First record of albinism in Lesser Woolly Horseshoe Bat *Rhinolophus beddomei* (Chiroptera: Rhinolophidae) with an updated list of chromatic aberrations in bats in India

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Abstract: There have been worldwide reports of chromatic aberrations in bats, most striking among which is albinism. Albinism is an inherited, hypo-pigmentary state characterised by a complete lack of melanin. Albinistic individuals have pale skin, white fur, and pinkish-red eyes. Here we report the first record of albinism in Lesser Woolly Horseshoe Bat *Rhinolophus beddomei.* During a bat survey in Goa, India; a single individual of albino Lesser Woolly Horseshoe Bat was recorded along with a normally coloured conspecific individual from a small shelter with tiled roof. We confirm the species identity of this bat based on its morphology, and acoustic characteristics of its echolocation call. We further update the list of colour aberrations in bats reported from India.

Keywords: Acoustic signature, albino, chiroptera, documentation, echolocation, Goa, horticulture, pigmentation, shelter.

Konkani: आज मेरेन संवसार भर जाल्ल्या संशोधनातल्यान अशे दिसून आयलां, कीं वागोळ्यांच्या कातीच्या कोराच्या दोशां भितर 'अल्बिनिसम' हो प्रकार असादारण जावन आसा. 'अल्बिनिसम' म्हळ्यार एक अनुवांशिक दोश, जाका लागून वागोळ्याच्या काती भितर 'मेलॅनिन' हया रंगद्रव्याचो आस्पाव जायना. अश्या वागोळ्यांची कात धवी-फटफटीत, लंव धवी, आनीक दोळे लेव गुलाबी रंगाचे आसतात. हया सोद निंबधात आमी 'लेसर वूली हॉर्स शू' म्हळ्यार व्हिनोलॉफस बेडोमाई हया वागोळ्याच्या प्रजाती भितर अल्बिनिसमाचो संवसारांतलो पयलो अहवाल सादर करतां. गोयांत सापडपी वागोळ्यांच्या प्रजातींच्या विविधतायेच्या अभ्यासा खातीर केल्या एका सर्वेक्षणात, आमका एका पोरन्या घराच्या नळयाच्या पाख्या पोंदा, माडाच्या वाश्यांचेर 'लेसर वूली हॉर्स शू' हया प्रजातीचे एक जोडपें दिसले, तातूंतले एक वागोळे नेमा प्रमाण कातीच्या कोराचे आशिल्लें, जाल्यार दुसरे वागोळे 'अल्बिनो' आशिल्लें. हया वागोळ्यांची प्रजाती वळखूपा खातीर आमी तांच्या आकृती विज्ञानाचो आणि प्रतिध्वनी लहरींचो अभ्यास केलो. आज मेरेन भारत देसांतल्या वागोळ्यां भितर मेळळील्या कातीच्या कोराच्या दोशांच्या वळेरीन आमी नवी भर घाल्या.

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INTRODUCTION

Abnormal pigmentation of skin and its derivatives are results of chromatic disorders (Rook et al. 1998). They are caused either by a deficiency or an excess of melanin (Hofreiter & Schöneberg 2010; Abreu et al. 2013). These are reported in many vertebrate groups and classified under broad terms such as hypopigmentation and hyperpigmentation (Uieda 2000). Based on the mutations and phenotypic effects, pigmentation disorders can be classified as albinism, leucism, piebaldism, hypomelanism and melanism (Lucati & Lopez-Baucells 2016). Hypopigmentation cases are, however, most easily detected. Pigmentation disorders and unusual coloration occur because of mutations in genes expressing for skin and fur coloration in animals (Fertl & Rosel 2002; Alexis & Marin-Vasquez 2018).

Albinism is an inherited, hypo-pigmentary disorder characterised by a complete lack of melanin. It is caused by absence of the enzyme tyrosinase that causes individuals to have pale skin, white fur or feathers, and pinkish - red eyes (van Grouw 2006, 2013; Hofreiter & Schöneberg 2010). Albinism is controlled by an autosomal recessive gene (van Grouw 2006; Falcão 2014). Due to their nocturnal and cryptic habits, bats with atypical colouration are difficult to observe, and reports on aberrant bat skin and hair colouration are very infrequent. Though many reports of albino bats have come from different parts of the world, records of albinism in Indian bat species are scarce (Khajuria 1972, 1984; Karim 1983; Bhati 1988; Senacha & Purohit 2005; Aul & Marimuthu 2006; Devkar et al. 2011; Dhanya et al. 2015; Singh & Yadav 2016; Mahabal et al. 2019). Also, some workers have suggested that albinism is rare in bats (Uieda 2000; Devkar et al. 2011; Tello et al. 2014). According to recent reviews, of the approximately 1,300 species of bats in the world, chromatic aberrations have been reported from 115 species belonging to 11 families (Lucati & Lopez-Baucells 2016) and albinism has been described in 60 species (Zortea & Silva 2017).

Here we report a case of albinism in the Lesser Woolly Horseshoe Bat *Rhinolophus beddomei*. This paper presents the first record of chromatic aberration seen in this species. We provide an updated list of chromatic aberrations in bats reported from India for referral purpose.

MATERIALS AND METHODS

During a reconnaissance survey of bats in South Goa on 29 October 2023 at 1630 h (IST), we observed a pair of Lesser Woolly Horseshoe Bat *Rhinolophus beddomie* Andersen, 1905 roosting in a small shelter with tiled roof (15.24643056˚ N & 74.21220833˚ E) in a horticultural landscape (Figure 1 & Image 1). The shelter had two rooms with one used as a pump house, and the other as an unused lavatory. The temperature and humidity of the roost site were measured using a digital thermo-humidity meter (Aceteq). Echolocation calls were recorded using Echo Meter Touch 2 (Wildlife Acoustics, USA). The recorded calls were analysed using Raven Pro 1.6.5 software. Frequency of maximum energy (FMAXE, in kHz) and duration (d, in ms) were considered as bioacoustics parameters (Wordley et al. 2014).

RESULTS

The temperature and humidity in the room where the bats roosted were 33.2˚ C and 75%, respectively. The pair of bats was clinging on to the Coconut Palm *Cocos nucifera* wood frame beneath the roof tiles at the height of 2.5 m above ground. Each individual occupied a separate wood frame, separated by a distance of 0.5 m (Image 1). The pelage and patagium of the normally coloured individual were typically dark greyish-brown and woolly, rough-textured, and notably grizzled on the upper side (Image 2). The albino individual had white skin, fur on its entire body and pale pinkish ears and eyes. In this individual, the blood vessels were seen through the skin of the patagium (Image 3). Both the individuals of the pair had similar body sizes, and were identified as the Lesser Woolly Horseshoe Bat, based on the distinctive morphological features (Bates & Harrison 1997; Srinivasulu et al. 2010) (Images 2 & 3). The owner of this shelter revealed that this albino individual has been roosting in this place since last five years.

Lesser Woolly Horseshoe Bat echolocation call has Frequency-modulated (FM) and Constant-frequency (CF) components. Since bat ultrasonic sounds are species specific, we also recorded the bioacoustics aspect. The characteristics of recorded calls were typical FM/CF/FM, emitted by Rhinolophid bats; with a short upward FM sweep followed by a long CF component, followed by a short downward FM sweep as previously corroborated (Raghuram et al. 2014; Srinivasulu et al. 2023) (Image 4). The calls (n = 20 pulses) had a mean FMAXE of 41.00 kHz, and a mean duration of 84.11 ± 7.6 ms. The observed

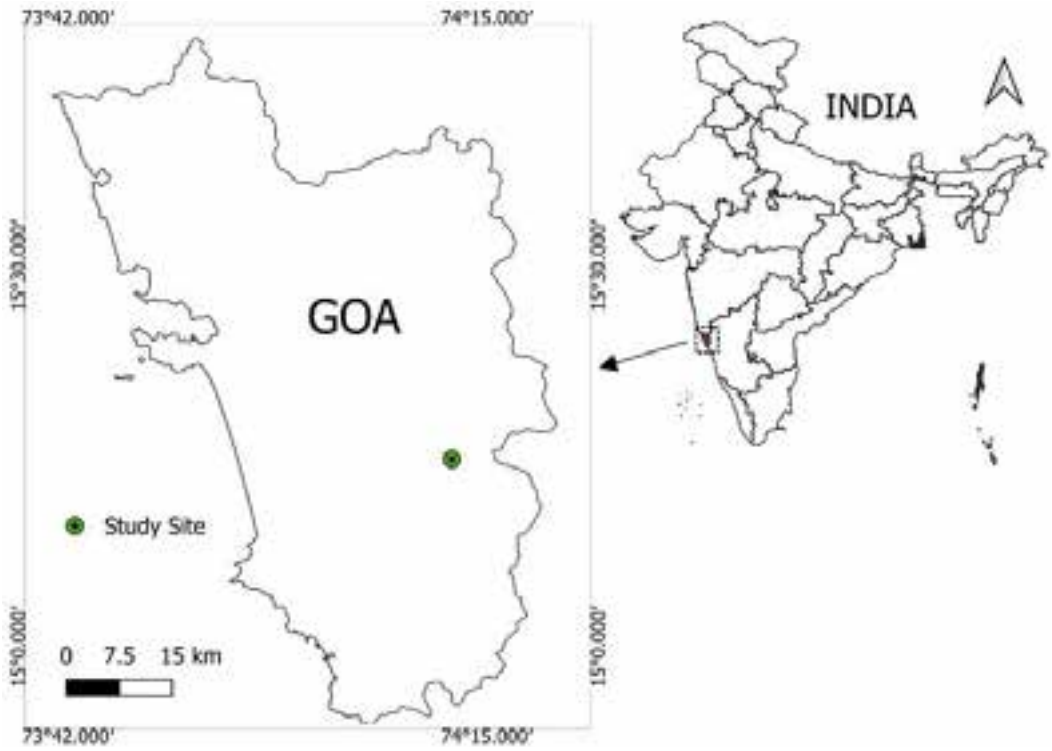

Figure 1. Map showing location of albino and normal coloured Lesser Woolly Horseshoe bat reported in the study.

Table 1. Summary of records of chromatic aberration in bats reported from India.

Species	Chromatic aberration	n	Sex	Habitat	Location State/ Union territory	Biogeographic zone	Reference
Megachiroptera							
Pteropodidae							
Rousettus leschenaultii	Albinism	1	♀	Mine	Maharashtra	Deccan Peninsula	Karim (1983)
Microchiroptera							
Rhinolophidae							
Rhinolophus beddomei	Albinism	1	-	Shelter with tiled roof	Goa	Western Ghats	Present Study
Hipposideridae							
Hipposideros diadema nicobarensis	Albinism	2*	♂	Cave	Nicobar Islands	Island	Aul & Marimuthu (2006)
Hipposideros lankadiva	Albinism	1	-	Temple	Madhya Pradesh	Deccan Peninsula	Khajuria (1984)
Hipposideros sp.	Albinism	1	-	Cave	Madhya Pradesh	Deccan Peninsula	Khajuria (1972)
Rhinopomatidae							
Rhinopoma hardwickii	Albinism	1	♀	Cave	Madhya Pradesh	Deccan Peninsula	Khajuria (1972)
Rhinopoma hardwickii	Piebaldism	3	-	Building	-	-	Senacha & Purohit (2005)
Rhinopoma hardwickii	Albinism	1	-	Cave	Rajasthan	Desert	Singh & Yadav (2016)
Rhinopoma microphyllum	Albinism	1	♂	Building	Rajasthan	Desert	Bhati (1988)
Rhinopoma microphyllum	Albinism	1	-	Mine	Gujarat	Semi-arid	Devkar et al. (2011)
Emballonuridae							
Taphozous sp.	Albinism	1	-	Fort	Delhi	Semi-arid	Dhanya et al. (2015)

* One dead individual, no information on sex

Image 1. Roost site of the normal coloured and albino bat, *Rhinolophus beddomei*. © Pratiksha Sail.

attributes tally with acoustic signature of *Rhinolophus beddomei.*

In India, chromatic aberrations in bats have been reported among eight species, one of Megachiroptera and seven species of Microchiroptera. Thus far a total of 14 individuals have been reported with cases of chromatic aberrations, 11 of albinism and three of piebaldism.

DISCUSSION

Pigmentation anomaly is a rare phenomenon in nature; however, studies have reported such cases in bats from different parts of the world. In their robust global review, Zortea & Silva (2017) have listed 60 species of bats with cases of albinism. Lucati & Lopez-Baucells (2016) have listed 269 individual records of piebaldism, 152 of albinism, 94 of melanism, 20 of hypomelanism, 11 of leucism, and three of partial melanism; in 60 bats the chromatic disorder being 'undetermined'. After both these reviews, there have been more reports of albino bats from across the world (Cichocki et al. 2017; Moreno et al. 2020; Aguilar-lopez et al. 2021; Leal & Ramalho 2021; Leal et al. 2021; Ventorin et al. 2021).

From India, including the present study, cases of chromatic aberrations have been reported in only eight species of bats (Table 1). Of the 14 individuals with chromatic aberrations listed, 11 are of albinism and three of piebaldism. Senacha & Purohit (2005) had incorrectly reported three individuals of *Rhinopoma hardwickii* as cases of partial albinism, however subsequently it has been revised as piebaldism (Lucati & Lopez-Baucells 2016; Mahabal et al. 2019). The reported cases from India are from families: Pteropodidae, Rhinolophidae, Hipposideridae, Rhinopomatidae, and Emballonuridae. In India most cases of albinism have been reported in Hipposideridae, followed by Rhinopomatidae.

The present study is the first record ever for albinism in *Rhinolophus beddomei* across the globe, and the first record of chromatic aberrations reported from bats in Goa, India; increasing the cases of albinism in rhinolophids to five. Chromatic aberrations are designated based on the phenotypic effect. The individual in this study presented pale pinkish coloured eyes. In albino individuals, the phenotype shows all-white hairs, pale skin and pinkish-red eyes (Lucati & Lopez-Baucells 2016; Moreno et al. 2020). Previously for the Genus *Rhinolophus*, albinism has been reported from Little Japanese Horseshoe Bat *Rhinolophus cornutus* (Sawada 1990), Mediterranean horseshoe bat *Rhinolophus euryale* (Dorst 1957), Greater horseshoe bat *Rhinolophus ferrumequinum* (Allen 1939; Fontanel 2001; Frontera 2002; Prevost et al. 2011), and Lesser Horseshoe Bat *Rhinolophus hipposideros* (Horaček 1995; Redant 2002).

Efforts at compiling systematic records of pigmentary anomalies in bats is low, and the ecological implications of these anomalies remain unclear (Romano et al. 1999). Most of the bat species in which albino individuals were recorded, including the present study; occupy sheltered roosts like caves, mines, and buildings (Uieda 2000). The absence of pigmentation could present a disadvantage for concealment, communication, and physiological regulation (Caro 2005). Some workers theorise that hypopigmentation is detrimental to bats; due to poor

Image 2. Normal coloured individual of *Rhinolophus beddomei*. © Pratiksha Sail.

Image 3. Albino individual of *Rhinolophus beddomei*. © Pratiksha Sail.

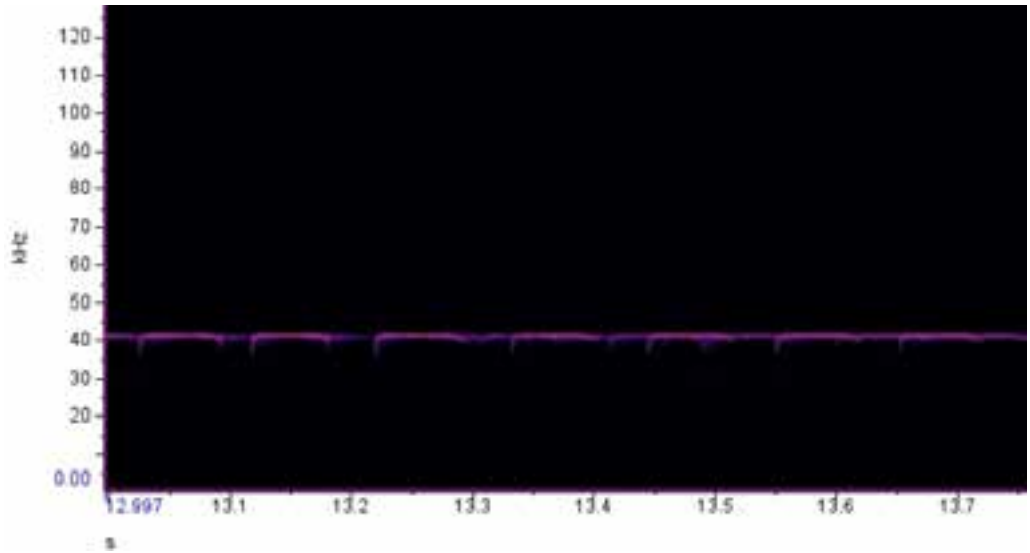

Image 4. Spectrogram recorded from echolocation calls of *Rhinolophus beddomei*.

vision, greater predation risk, lower mating success and lower survival rates (Caire & Theis 1988; Caro 2005; Oliveira & Aguiar 2008). Also, Oliveira & Aguiar (2008) suggest that sheltered roosts offer a clear advantage for the survival of albino bats, providing them protection against sunlight, water loss, and predation. However, there is no validation of such putative effects in bats with hypopigmentation or any chromatic aberrations. López-Baucells et al. (2013) argue that pigmentary disorders hardly influence survival of species that are affected.

Insectivorous bats use echolocation for orientation and foraging; and as such hypopigmentation may have no effect on their survival (Lucati & Lopez-Baucells 2016). Though, a lack of pigment in the eyes may negatively affect vision in fruit eating bats, as they rely heavily on vision and olfaction to navigate and forage (Guillery 1996; Rydell & Eklöf 2003; Heiduschka & Schraermeyer 2008; Moreno et al. 2020). Albinism is a rare inherited abnormality and its frequency of occurrence could likely be increased with inbreeding (Stevens et al. 1997). For this reason, it could be more common in colonial species of bats where individuals have strong fidelity to their roosts.

That the albino bat reported in this study has been seen in the same place by the farm owner for the past five years, clearly hints at site fidelity, and this merits discussion. Brack & Johnson (1990) observed same albino individual of *Myotis sodalis* in a cave in Indiana (USA) in 1985, 1987 and 1989, Sánchez-Hernández et al. (2010) recaptured the same two albino individuals of *Desmodus rotundus* bats in 2008–2009 in a tunnel in Guerrero (Mexico), all these reports highlighting no effect of colour aberration and establishing that albino bats can survive for several years. Likewise, there are several reports of pregnant or lactating albino bats, refuting the idea of lower mating success in bats with colour aberrations (Brigham & James 1993; Talerico et al. 2008; Sánchez-Hernández et al. 2010; Rocha et al. 2013).

Efforts towards systematic records of pigmentary anomalies in bats is low, and their ecological implications remain unclear (Romano et al. 1999). Recent times have seen an increased number of publications reporting pigmentation anomalies in bats (Cichocki et al. 2017; Moreno et al. 2020; Aguilar-lopez et al. 2021; Leal & Ramalho 2021; Leal et al. 2021; Ventorin et al. 2021). Such reports are important to understand the evolutionary cost and benefits arising from chromatic disorders. Continuous documentation of chromatic aberrant bats will help understand geographic trends of albinism and allied pigment anomalies in bats, and further appreciate ecological effects of these anomalies on bat survival rates in natural populations (Lucati & Lopez-Baucells 2016).

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COMMUNICATION

First record of *Garra kempi* Hora, 1921 (Cypriniformes: Cyprinidae) from Lohandra River of Nepal

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Abstract: Nepal holds a high ichthyofaunal diversity, nevertheless, the molecular study of Nepalese fish is still in its early stages. The first record of a cyprinid fish species the *Garra kempi* Hora, 1921 for Nepal was reported from eastern Nepal's Lohandra River. Both morphology and molecular data affirmed the existence of *G. kempi* in Nepal's aquatic system. This species was previously reported from China (Tibet) and northern India. The maximum likelihood phylogenetic analysis and pairwise genetic distance based on Kimura 2 parameters using cytochrome oxidase subunit 1 (COI) segment sequences (665 bp) also confirmed the identity of the species as *G. kempi*. The COI sequences of specimens from Nepal formed a monophyletic clade with the sequence of *G. kempi* from northeastern India and the two contained a pairwise genetic distance of 1.8% only. The new record of *G. kempi* from Nepal warrants a detailed ichthyofaunal survey for documenting the fish diversity in Nepal.

Keywords: Bottom-dwelling fish, DNA barcode, fish diversity, freshwater, ichthyofauna, integrative taxonomy, lowland Nepal, new record, stream.

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Author contributions: The study design and conception were done by Jash H. Limbu and Dipak Rajbanshi. Material preparation, data collection, and analysis were performed by Jash H. Limbu, Dipak Rajabsnhi, and Laxman Khanal. The first draft was written by Jash H. Limbu, with the contribution of Dipak Rajbanshi, Ramchandra Adhikari and Laxman Khanal. All authors read and approved the final manuscript.

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INTRODUCTION

Nepal's fish taxonomy is in its early stages of investigation. According to Kottelat & Whitten (1996), Nepal is one of the Asian countries where some fish data are accessible, but their quality and geographical gaps necessitate substantial field investigation. The cyprinid genus *Garra* is a distinct group of bottom-dwelling fish found in fast-moving waters. They cling to the rocks using a small sucking disc on their lower lip (Zhou et al. 2015). In swift-moving water, the modified lower lip known as the suctorial disc is used to cling to rocks and pebbles (Rath et al. 2019). Currently, the genus *Garra* contains approximately 180 recognized species that range from Borneo, China, and southern Asia via the Middle East, Arabian Peninsula, and eastern to western Africa (Fricke et al. 2023).

During the ichthyofaunal survey, conducted from 02 September 2022 to 21 March 2023 in Lohandra River, four individuals of *Garra* species were collected which were not identifiable to the species level at the field. After close observation of morphometric and meristic characters and analyzing the mitochondrial cytochrome c oxidase subunit I (COI) gene sequences, those four specimens were confirmed to belong to *Garra kempi*. The occurrence of *G. kempi* from the Lohandra River in eastern Nepal is a new record for Nepal.

MATERIALS AND METHODS

Study area

The Lohandra River is one of the tributaries of the Koshi River system, flowing from the Letang Municipality in Morang District of southeastern Nepal, located between the Mahabharat hills and the Churia hills. The Lohandra River (Figure 1) is one of the most important water sources for irrigation and agriculture in Morang District. The study area is bordered by Warangi to the north, Biratnagar to the west, India to the south, and Rangeli to the east. The Lohandra River basin has a subtropical climate with an average yearly temperature of 30.9°C (Khanal 2015; Limbu et al. 2023). The riverbed predominantly consists of sand, gravel, cobble, and pebble whereas bamboo and bushes are the dominant vegetation.

Sampling, preservation, and measurements

Fish were collected from Lohandra River by using cast net, and local fishing gears (Dhadiya, Ghorlang, and Mosquito net) from 02 September 2022 to 21 March 2023. Collected specimens were preserved in 10% formalin for morphological examination by making their head upright to protect their caudal fin. For molecular study, the caudal fins of two individuals were preserved in 95% ethanol in the field and then transferred to 75% ethanol. All specimens were assigned a collection number to facilitate sample tracking. Voucher specimens were deposited at the Museum of the Central Department of Zoology, Tribhuvan University, Kirtipur Kathmandu, Nepal. Morphological measurements and meristic records were done according to Ng & Edds (2005). A digital Vernier caliper was used for point-to-point measurement, and data was recorded from the specimen's left side to the nearest tenth of a millimeter. Furthermore, water temperature, depth, velocity, and pH were also measured for the sampling locality.

DNA extraction, PCR, and sequencing

Total genomic DNA was extracted from the caudal fin using the Tiangen genomic DNA purification kit (Tiangen Biotech, Beijing, China). A partial fragment (~665 bp) of cytochrome c oxidase subunit I (COI) was amplified with the forward primer 5'-CGCTGATTCTTCTCTACCAAYCAYAAAGA-3' and the reverse primer 5'-ACTTCTGGGTGGCCGAAGAAYCARAA-3'. The PCR was performed in a 20 µl reaction volume containing 10 µl Taq Master Mix (Vazyme), 6 µl deionized nuclease-free water, 2 µl DNA, and 1 µl of each primer. The PCR protocol included 35 cycles with the following steps: initialization at 95°C for 2 mins, denaturation at 95°C for 30 s, annealing at 55°C for 45 s, elongation at 72°C for 45 s, and final elongation at 72°C for 5 mins. The amplified products were checked on a 1% agarose gel before sequencing. Successful amplicons were sequenced in both directions using the same primers and a BigDye Terminator Cycle Kit v.3.1 (Invitrogen) on an ABI 3730XL sequencer (Applied Biosystems).

Data analysis

The resulting sequences from the primer pairs were assembled using Geneious Prime 9.0.2 (https://www.geneious.com) software and aligned using MEGA 11 (Tamura et al. 2021). The noisy sequences of both ends were trimmed before subsequent sequence analysis. The aligned sequences were submitted to the GenBank database (GenBank accession numbers: OR889731, OR898805). The sequences of *G. kempi* from Nepal were used to search homologous sequences of congeners from the GenBank database using the MegaBlast tool. The homologous sequences from other *Garra* species were

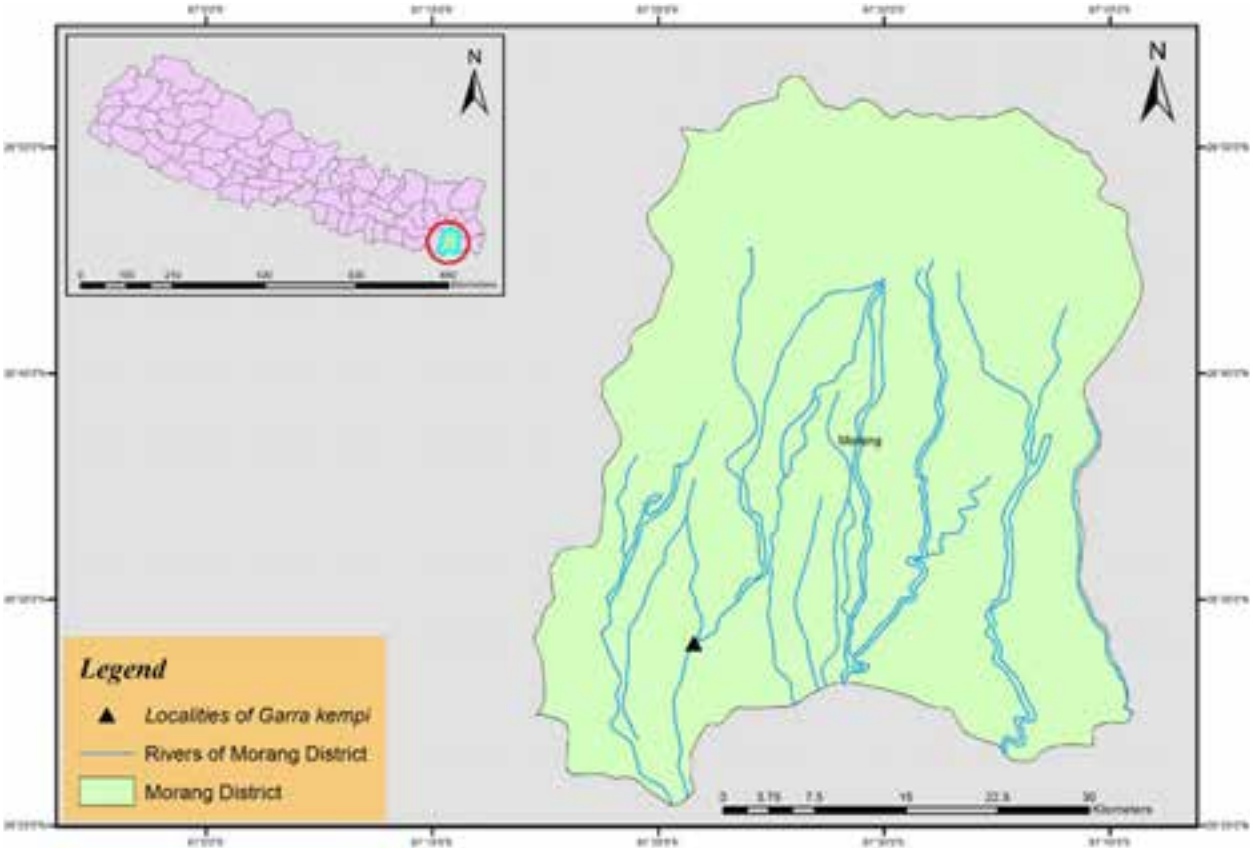

Figure 1. Map showing the locality of *Garra kempi* sampling in eastern lowland of Nepal.

downloaded and aligned using the ClustalW algorithm in MEGA 11 (Tamura et al. 2021). The COI sequence of *Anguilla bengalensis* was used as an outgroup for the phylogenetic tree construction. The final alignment of 665 bp was used for the phylogenetic analysis.

The maximum likelihood (ML) phylogenetic tree was constructed using the RAxML-HPC Blackbox 8.2.12 tool (Stamatakis 2014) in CIPRES Science Gateway V 3.3 (Miller et al. 2010) online platform (https://www.phylo.org/) with GTR+G evolutionary model and 1,000 bootstrap replicates. The resulting tree was visualized in FigTree v. 1.4.4 (Rambaut 2018).

Pairwise evolutionary distances among the *Garra* species in 665 bp long COI gene sequences were calculated using MEGA 11 (Tamura et al. 2021) using the Kimura-2 parameter (K2P) (Kimura 1980).

RESULTS

Materials examined: LR1001, LR1002; 68–71.5 mm, Lohandra River, Nepal, 6 km from Biratnagar Sub-metropolitan City, 26.54611°N & 86.9383°E, 70 m; Limbu & Rajbanshi, 02 September 2023.

Diagnosis: The photographs and morphometric data are given in image 1 and table 1. The snout of *G. kempi* is rounded, the proboscis is absent, lateral surface of the snout in front of the nostrils is slightly raised from the general surface. Scales are absent on the chest and sparsely present along the midline of the belly. The pelvic fin is not reaching the anal origin, and 40–42 lateral line scales are present. Eight rows of scales are present between the bases of the dorsal and ventral fins. It has 7–8 branched dorsal fin rays. The pectoral fin has 12 branched fin rays whereas the pelvic fin has eight branched rays. The anal fin contains five branched fin rays. The caudal fin contains 10+9 principle fin rays. There are 40–42 lateral line scales whereas 11–12 predorsal and 15–16 circumpenducular scales.

Coloration: Dorsal and lateral surface body of this species is black, while the ventral part is dull white.

Dorsal and caudal fins are grayish. The dorsal part of paired fins is grayish whereas ventrally dull.

Distribution: Recorded from the Lohandra River in the eastern lowland.

Remarks: All specimens were collected from the

Table 1. Morphometric data of *Garra kempi*. N = number of specimens.

Characters	*Garra kempi* (n = 2)
Standard length (mm)	68–71.5
Percent of standard length (% SL)	
Head length	26.4–27.6
Body depth at dorsal-fin origin	20–23.3
Predorsal length	46.5–48.1
Preanus length	65.9–67.8
Prepectoral length	19.9–20.5
Prepelvic length	49.7–50.9
Dorsal fin base length	15.9–18.1
Dorsal fin length	21.7–23.8
Pectoral fin length	18.5–20.1
Pelvic fin length	17.9–19.2
Anal fin base length	5.8–6.7
Anal fin length	17.5–18.7
Caudal peduncle length	15.7–17.1
Percent of head length (% HL)	
Head depth	67.3–68.6
Snout length	52.4–53.8
Eye diameter	20.8–21.5
Interorbital space	42.1–43.7

fast-flowing water of the Lohandra River with rocky substratum. Water temperature of 24 °C, water velocity of 0.9 m/sec, water depth of 0.5 m, and pH 8.5 was recorded during the ichthyological survey. Altitude ranges 80–90 m. This species is also reported from Tibet (China) and India (Arunachal Pradesh, Manipur, Meghalaya, Mizoram, and Nagaland).

Economic importance: This fish is a prominent local food fish.

Phylogenetic analysis: The phylogenetic relationship of the *G. kempi* from Nepal was assessed with other 19 known species under the genus using cytochrome c oxidase subunit I (COI) sequences. The ML tree with a strong bootstrap support revealed that the recently discovered Nepalese *Garra* species forms a monophyletic clade with *Garra kempi* (Accession Number OL440722.1) from India (Figure 2). The Nepalese *G. kempi* had a genetic distance of just 1.8% with the *G. kempi* from India, 4.1% with *G. fluviatilis*, 7.4% with *G. spilota*, 9.0% with *G. yajiangensis*, 9.3% with *G. gotyla* and 9.6% with *G. qiaojiens* (Table 2). The GC content of the COI sequences of *G. kempi* in Lohandra River is 26.9% and 15.7%, respectively, which is nearly identical

Image 1 . *Garra kempi*: A—lateral view | B—dorsal view | C—ventral view. © Jash H. Limbu.

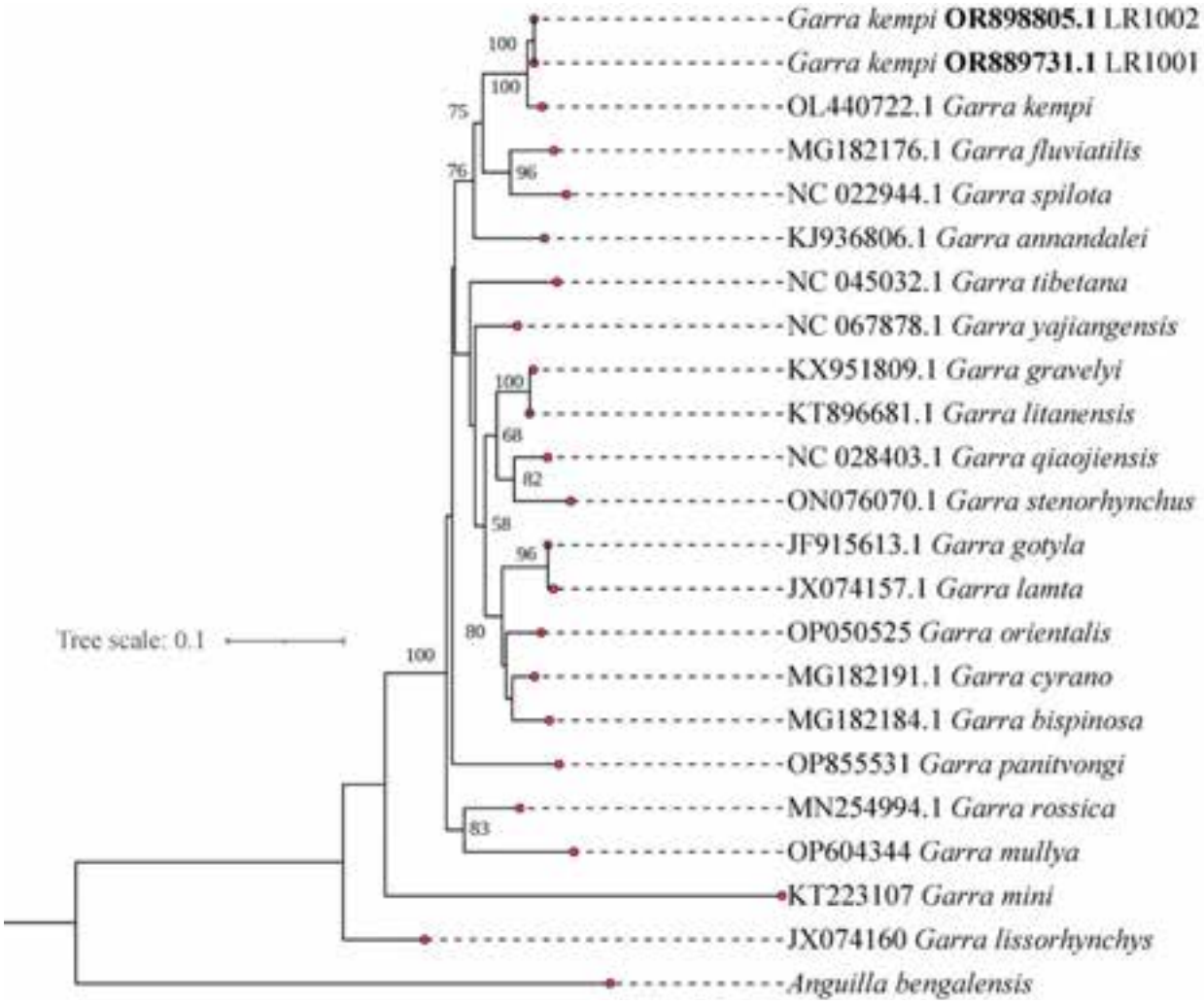

Figure 2. Maximum-likelihood (ML) tree of newly recorded *Garra kempi* from Lohandra River in the eastern lowland of Nepal (GenBank accession numbers: OR889731.1, OR898805.1; sample tracking numbers: LR1001, LR1002) and other species of the *Garra*, based on sequences (665 bp) covering the partial barcoding region of cytochrome c oxidase subunit I (COI) gene.

to previously deposited sequencing data from China and India (26.5% & 15.7%).

DISCUSSION

This study reports the first reliable record of *Garra kempi* in Nepal. Previously, *G. kempi* was only known from swift-moving mountain streams in northern India and Tibet (China) (Menon 1999; Nebeshwar et al. 2009). Since this species has not been documented at an elevation below 100 m, this finding is quite intriguing. Specimens were collected from fast-flowing water (0.9 m/sec) with a rocky substrate, a water temperature of 24°C, a depth of 0.5 m, and a pH of 8.5. The cyprinid genus *Garra*, typically found in swiftly moving waters, is known for bottom-dwelling fish that adhere to rocks using a tiny sucking disc on their lower lip (Zhou et al. 2015). Mitochondrial cytochrome c oxidase subunit I sequences of *G. kempi*, along with those of 19 other species in the genus, were analyzed to validate the new sequences and annotations. Molecular phylogenetic analysis revealed a clearly defined monophyletic clade that included *G. kempi* from Nepal and northeastern India. The rivers in eastern Nepal and northeastern India share similar climatic conditions and eventually merge to form large rivers that drain into the Indian Ocean, likely facilitating the dispersal of *G. kempi* into Nepalese rivers. Besides the Lohandra River, this species might inhabit other fast-flowing water bodies of Himalayan origin. Therefore, a detailed ichthyofaunal survey is essential in Nepal to properly document its fish diversity.

Table 2. Pairwise genetic distances among the species of the genus *Garra* based on COI sequences (665 bp) and Kimura 2 parameter computed in MEGA 11 (genetic distance below diagonal, standard error above diagonal).

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
***G. kempi* Nepal**		0.006	0.009	0.011	0.013	0.014	0.013	0.013	0.013	0.014	0.014	0.014	0.014	0.014	0.013	0.014	0.015	0.016	0.017	0.019
G. kempi	0.018		0.010		0.013	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.014	0.016	0.016	0.015	0.016	0.016	0.018	0.020
G. fluviatilis	0.041	0.052		0.009	0.010	0.010	0.010	0.010	0.010	0.010	0.011	0.010	0.011	0.012	0.012	0.011	0.011	0.012	0.012	0.016
G. spilota	0.074	0.080	0.044		0.014	0.014	0.015	0.014	0.014	0.014	0.013	0.014	0.014	0.015	0.014	0.017	0.013	0.015	0.015	0.019
G. yajiangensis	0.090	0.089	0.048	0.109		0.011	0.011	0.011	0.011	0.011	0.013	0.012	0.013	0.012	0.012	0.012	0.013	0.015	0.016	0.019
G. qiaojiens	0.096	0.104	0.059	0.116	0.071		0.011	0.010	0.011	0.011	0.014	0.011	0.012	0.011	0.013	0.011	0.015	0.017	0.017	0.020
G. gravelyi	0.090	0.104	0.052	0.114	0.065	0.062		0.002	0.011	0.011	0.015	0.011	0.014	0.011	0.011	0.012	0.015	0.014	0.016	0.020
G. litanensis	0.090	0.104	0.048	0.110	0.065	0.059	0.003		0.010	0.011	0.014	0.010	0.014	0.011	0.011	0.012	0.014	0.014	0.015	0.020
G. gotyla	0.093	0.103	0.052	0.103	0.073	0.074	0.070	0.068		0.003	0.014	0.010	0.014	0.011	0.011	0.014	0.013	0.015	0.017	0.019
G. lamta	0.095	0.105	0.054	0.104	0.075	0.077	0.072	0.070	0.005		0.014	0.010	0.014	0.011	0.011	0.014	0.014	0.016	0.017	0.019
G. rossica	0.096	0.098	0.059	0.096	0.086	0.106	0.107	0.103	0.105	0.102		0.013	0.015	0.013	0.013	0.016	0.015	0.014	0.016	0.020
G. cyrano	0.099	0.112	0.057	0.113	0.076	0.074	0.076	0.072	0.055	0.060	0.097		0.013	0.009	0.009	0.013	0.013	0.015	0.015	0.019
G. tibetana	0.099	0.098	0.065	0.111	0.093	0.085	0.096	0.096	0.102	0.102	0.114	0.092		0.014	0.014	0.014	0.016	0.015	0.016	0.019
G. orientalis	0.102	0.112	0.070	0.120	0.074	0.071	0.069	0.069	0.064	0.069	0.100	0.043	0.094		0.009	0.014	0.014	0.016	0.017	0.021
G. bispinosa	0.103	0.120	0.066	0.107	0.083	0.083	0.072	0.074	0.064	0.065	0.093	0.045	0.097	0.050		0.014	0.014	0.015	0.016	0.019
G. stenorhynchus	0.105	0.112	0.063	0.138	0.079	0.064	0.072	0.072	0.098	0.102	0.114	0.092	0.106	0.093	0.097		0.016	0.016	0.016	0.020
G. panitvongi	0.110	0.115	0.074	0.110	0.099	0.112	0.113	0.113	0.101	0.106	0.114	0.095	0.122	0.104	0.103	0.126		0.017	0.018	0.020
G. mullya	0.123	0.121	0.075	0.124	0.111	0.127	0.106	0.102	0.126	0.132	0.101	0.125	0.119	0.126	0.125	0.125	0.137		0.017	0.022
G. lissorhynchus	0.148	0.159	0.085	0.139	0.138	0.135	0.126	0.123	0.142	0.143	0.128	0.135	0.143	0.147	0.146	0.141	0.155	0.146		0.020
G. mini	0.179	0.179	0.127	0.178	0.181	0.192	0.199	0.196	0.193	0.193	0.178	0.183	0.173	0.204	0.187	0.193	0.192	0.206	0.188	

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COMMUNICATION

Earthworm (Oligochaeta) diversity of Kumaun Himalaya with a new record of *Drawida japonica* (Michaelsen, 1892) (Monaligastridae) from Nainital, Uttarakhand, India

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Abstract: The present study was conducted to investigate earthworm diversity in the Kumaun region of Uttarakhand, India. Earthworm sampling was made from 1,409–2,224 m from the foothills of the Kumaun Himalaya to higher altitudes monthly from April 2019 to April 2021, covering the major monsoon season in India. Earthworms were collected from twelve different sites using the hand sorting method and preserved in 10% formalin. We recorded 14 earthworm species representing four families: Megascolecidae (*Amynthas corticis*, *Amynthas morrisi*, *Amynthas alexandri*, *Metaphire anomala*, *Metaphire houlleti*, *Metaphire birmanica*, & *Perionyx excavatus*); Lumbricidae (*Aporrectodea caliginosa trapezoides*, *Aporrectodea rosea rosea*, *Eisenia fetida*, *Octolasion tyrtaeum*, & *Dendrodrilus rubidus*); Moniligastridae (*Drawida japonica*); and Octochaetidae (*Eutyphoeus nainianus*). *Drawida japonica* from the family Moniligastridae is being reported for the first time from the Kumaun Himalaya. Moniligastrids are an important, yet often ignored, earthworm group commonly found in cultivated soils of higher altitudes.

Keywords: Annelida, Clitellata, cultivated soil, deposition, first record, high altitude, Kumaun Region, Lumbricidae, macrofauna, zoological collection number.

Hindi: सार: वर्तमान अध्ययन उत्तराखंड, भारत के कुमाऊं क्षेत्र में केंचुओ की विविधता की जांच के लिए किया गया था। भारतीय मानसून के प्रमुख मौसम को कवर करते हुए, 1,409–2,224 मीटर की कुमाऊं हिमालय की तलहटी से उच्च ऊंचाई तक, अप्रैल 2019 से अप्रैल 2021 तक मासिक रूप से केंचुओ की सैंपलिंग की गयी थी। केंचुओं को बारह विभिन्न स्थलों से हाथ से छांटने की विधि का उपयोग करके एकत्र किया गया और 10% फॉर्मेलिन में संरक्षित किया गया। हमने चार परिवारों का प्रतिनिधित्व करने वाली 14 केंचुओं की प्रजातियाँ खोजी: Megascolecidae (Amynthas corticis, Amynthas morrisi, Amynthas alexandri, Metaphire anomala, Metaphire houlleti, Metaphire birmanica, & Perionyx excavatus); Lumbricidae (Aporrectodea caliginosa trapezoides, Aporrectodea rosea rosea, Eisenia fetida, Octolasion tyrtaeum, & Dendrodrilus rubidus); Moniligastridae (Drawida japonica); और Octochaetidae (Eutyphoeus nainianus)। Moniligastridae परिवार से Drawida japonica को पहली बार कुमाऊं हिमालय से रिपोर्ट किया गया। Moniligastridae एक महत्वपूर्ण, लेकिन अक्सर अनदेखा किया गया केंचुआ समूह है जो आमतौर पर उच्च ऊंचाई वाले खेती वाली मिट्टी में पाया जाता है।

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INTRODUCTION

Earthworms act on soil structure and function via feeding, digging and excretion, thereby affecting farmland soil nutrients and microbial diversity, and many taxonomists have been drawn towards them McTavish et al. (2021). Indeed, Charles Darwin described earthworms as the most important animal group in the history of the world; Darwin (1881). The first record of earthworm fauna of the western Himalaya was given by Bourne (1889), who described *Typhoeus masoni* (syn. *Eutyphoeus orientalis*) from Dehradun (Uttarakhand, India). There are 3,000–7,000 known species of earthworms worldwide (Phillips et al. 2021) but at the same time Misiragloglu et al. (2023) stated that a total of ca. 5,738 species/subspecies (5,406 species and 332 unique subspecies; i.e., not counting the nomino-typical subspecies) belonging to 23 families (including one non-crassiclitellate family: Moniligastridae) are currently recognized worldwide, of which three families (Tritogeniidae and Kazimierzidae from southern Africa and Arecoidae, a new family from Brazil described herein), 35 genera and close to 1,200 new taxa (including subspecies) were described in the 21st century. Nonetheless, the large number of undescribed species will likely increase this value to well over 8,000 species, broadly divided into three ecological groups based on feeding and burrowing habits: litter-dwelling epigeic species, shallow-burrowing endogeic species, and deep-burrowing anecic species (Lee 1985; Shipitalo & Korucu 2002). In his 1972 seminal book 'Lombriciens de France', Marcel Bouché initially described seven earthworm ecological categories (anecic, endogeic, epigeic, epi-anecic, endo-anecic, epi-endogeic, and intermediate) (Bouché 1972).

Five years later, he simplified the explanation of these categories by describing a ternary plot in which the three major categories (anecic, endogeic and epigeic) represent the three poles (Bouché 1977). *Drawida japonica* Michaelsen, 1892 (Oligochaeta, Moniligastridae) is considered an epigeic species because its preferred habitat is mostly humid litter layers or topsoil ground in particular areas like forests, drainage ditches and ponds or reservoirs. Nevertheless, Gates (1972) thought that this species came originally from the Indian Himalayas and questioned the identification of some earlier records from outside Japan or Korea. In India, 89% of the fauna are native and the rest exotic (Julka & Paliwal 2005; Verma et al. 2010).

Kumaun Himalaya, a west-central section of the Himalaya in northern India, ranges from 28° 44' & 31° 28' N and 77° 35' & 81° 01' East. Information on the earthworm community of the Kumaun region is minimal. Earthworms are required to survive a good supply of food, plenty of moisture, enough dissolved oxygen, shelter from sunlight, a balanced pH level, an environment free from toxic substances, and a suitable temperature (Reynolds et al. 2021). The present study is based on the diversity of earthworms located at different altitudes of the Kumaun Himalaya (1,409–2,224 m). The study reported one lumbricid species, *Drawida japonica* Michaelsen 1892 for the first time from Kumaun Himalaya (Image 1).

MATERIALS & METHODS

Earthworms were collected from Dhari tehsil (29.3397^{0}N, 79.5877^{0}E), Nainital District of Kumaun Himalaya region, by the hand sorting method from two cultivated land and orchards with two soil depths of 0–10 and 10–20 cm. The earthworms were sampled from twelve different sites for two years (April 2019–April 2021), covering the major monsoon period in India. The sampled worms were washed, anesthetized in 70% ethanol, preserved in 10% formalin and brought to the laboratory for further investigations.

RESULTS

The collected earthworms were identified to species level by the Zoological Survey of India (ZSI), Kolkata and a total of 14 earthworm species belonging to four different families: Megascolecidae, Lumbricidae, Moniligastridae, and Octochaetidae were recorded, with a new record of *Drawida japonica* from the cultivated land and orchards

Image 1. *Drawida Japonica* collected from Tehsil Dhari, Kumaun division Uttarakhand. © Shikha Bora.

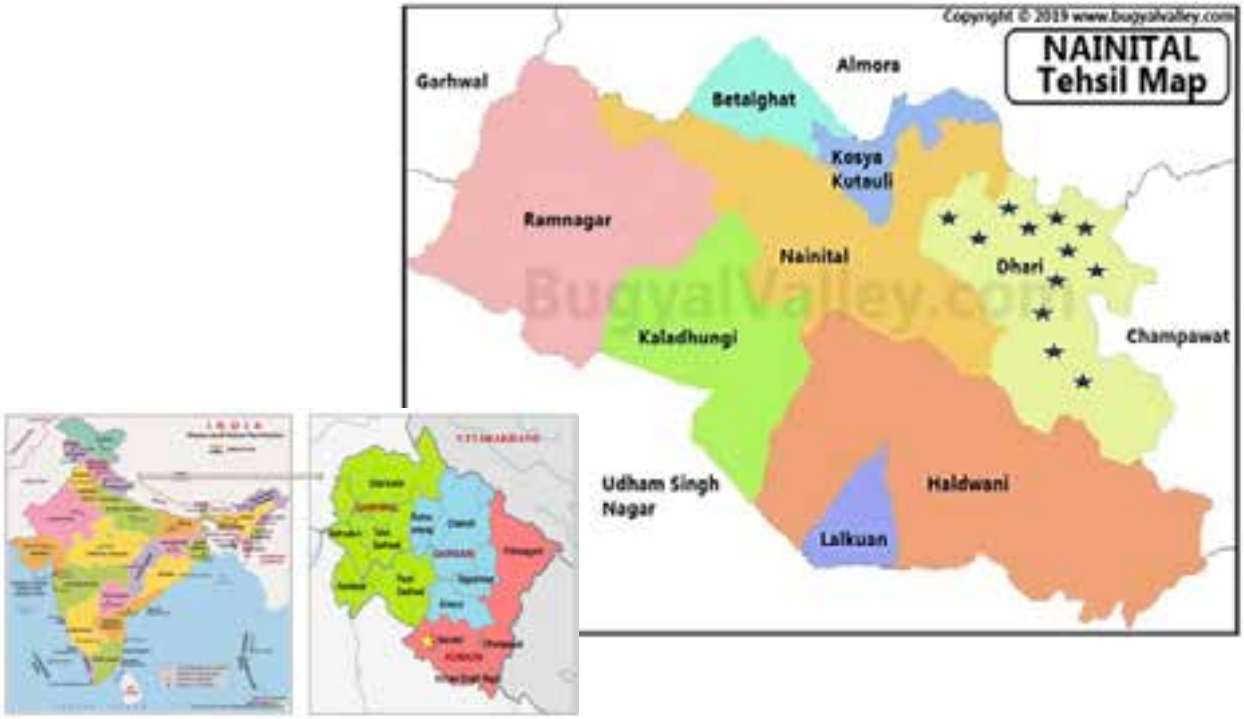

Figure 1. Study sites (⚜), District Nainital, Uttarakhand (⚜) Dhanachuli, Sasbani, Managair, Padampuri, Okhalkanda, Nadgal, Pahadpani, Sarnaa, Matiyal, Churigarh, Chaukhuta, Babiyar.

of Kumaun Himalayas. All the earthworm species have been deposited to ZSI Kolkata and provided with National Zoological Collection number.

Megascolecidae

***Amynthas corticis* (Kinberg, 1867) [syn. *Amynthas diffringens* (Baird, 1969)]**

Origin: Endemic.

Collection no.(s): M4, P1, P4, P6, P7, N1, N5, N7, N8 PP1, PP3, PP7, SN2, MT3, MT4, C1

Date(s) of collection: 24.vi.2020, 12.vii.2019,31. vii.2020, 09.ix.2019, 30.ix.2020, 15.x.2019, 29.x.2020, 27.xi.2019, 30.xii.2020, 31.i.2020

Collection site: Cultivated land, orchards

Garhwal: Chamoli District – Bhimtoli, Joshimath, Mandal, Pandukeshwar, Mana, Govindghat; Pauri District – Lansdowne, Kanda, Pauri, Malan Sanctuary, Chamdhar, Gumkhal; Rudra Prayag District – Phata, Augastmani, Narainkoti, Trijuginarain; Tehri District – Kirtinagar, Kaddukhal, Pokhal; Uttarkashi District – Uttarkaskhi, Maneri, Rautri Sera, Jashyra, Badyar Gad, Mori Dunda.

Kumaun: Almora District – Kausani, Chaukni, Sheraghat, Lakhidiyar, Soni; Bageshwar District – Begeshwar, Garur, Jogeshwar, Baijnath; Champawat District – Lohaghat, Bed Bagad; Dehra Dun District – Amlawa river bed, Kalsi, Rajpur, Ramgash; Nainital District – Bhimtal, Nainital, Sattal, Ramgarh, Mohan, Malani; Pithoragarh District – Didihat, Thal, Jharia Gad,Pithorgarh,Berinag, Dhamrikhet, Arca.

***Amynthas morrisi* (Beddard, 1892)**

Origin: Endemic.

Collection no.(s): O1,O2, O3, O8, O11

Date(s) of collection: 27.viii.2019, 31.viii.2020

Collection site: Cultivated land, orchards

Garhwal: Dehradun District – Raipur, Dehradun.

Kumaun: Nainital District – Kungaon, Bhowali, Patwadangar, Shantipuri.

***Amynthas alexandri* (Beddard, 1900)**

Origin: Endemic.

Collection no.(s): O6, O7, O11, O12,

Date(s) of collection: 27.viii.2019, 31.viii.2020

Collection site: Cultivated land, orchards

Garhwal: Dehradun District – Gujrara, Sahastradhara, Nehrugram; Pauri District – Khankra.

Kumaun: Nainital District – Ranibagh.

***Metaphire anomala* (Michaelsen, 1907)**

Origin: Endemic.

Collection no.(s): O2, O4, O5, O6, O9, O10, N4

Date(s) of collection: 27.viii.2019, 31.viii.2020, 30.ix.2020

Collection site: Cultivated land, orchards

Garhwal: Chamoli District – Nandprayag, Thirpali; Dehardun District – Sahastradhara, Dehradun, Lachhiwala, Ghattikhola, Gujrara, Mussoorie Forest range; Pauri District – Dhikala-Kanda Road; Tehri District – Deoprayag.

Kumaun: Nainital District – Naukuchia Tal.

***Metaphire houlleti* (Perrier, 1872)**

Origin: Endemic.

Collection no.(s): O1, O4, O7, O11

Date(s) of collection: 27.vii.2019, 31.viii.2020, 30.ix.2020

Collection site: Cultivated land, orchards

Garhwal: Chamoli District – Thirpali; Dehradun District – Dehradun; Dehradun, Sahiya, Nehrugram, Ghattikhola, Lalpul, Timli Forest, Shastradhara, Rishikesh, Phanduwala, Gujrara; Rudraprayag District – Rudraprayag; Tehri District – Kirtinagar, Aglar River, Gulabrai, Chamba.

Kumaun: Almora District – Soni, Chitai; Champawat District – Champawat; Nainital District – Gagasat Sultan, Ranibagh, Bhowali, Dhangarhi, Naukuchia Tal, Sat Tal, Kaladhungi, Bhim Tal; Pithoragarh District – Thal, Jharia Gad, Oriti, Ravti Nalla, Kolika.

***Metaphire birmanica* (Rosa, 1888)**

Origin: Endemic.

Collection no.(s): O1

Date(s) of collection: 27.viii.2019

Collection site: Cultivated land, orchards

Garhwal: Chamoli District – Pipalkoti, Kuher, Nandprayag; Dehradun District – Mussoorie, Nehrugram, Ghattikhola, Kandholi Forest; Pauri District – Dhikala-Kanda Road, Dhikala Sarapduli Road; Rudraprayag District– Rudraprayag.

Kumaun: Bageshwar District – Garur, Kapkote; Nainital District – Nainital, Deochauri, Naukuchia Tal.

***Perionyx excavates* (Perrier, 1872)**

Origin: Exotic.

Collection no.(s): B1

Date(s) of collection: 03.iii.2020

Collection site: Cultivated land, orchards

Garhwal: Dehra Dun district – Phanduwala, Dehra Dun, Satyanarain, Kansro Forest, Motichur Rao; Chamoli District – Joshimath; Pauri dist.- Khankara, Chamdhar, Kanda Nala; Uttarkashi dist.- Barnigad Kuwa.

Kumaun: Uttaranchal: Almora, Sheraghat; Phorti, Sandev; Naini Tal District - Bhowali, Naini Tal, Mohan.

Lumbricidae

***Aporrectodea trapezoids* (Dugès, 1828)**

Origin: Exotic.

Collection no.(s): M4, C2, C3

Date(s) of collection: 24.vi.2020,19.i.2021

Collection site: Cultivated land, orchards

Garhwal: Chamoli District – Joshimath, Mana, Joshimath-TapovanRoad, GarurGanga, Helong; Dehradun District –Chakarata, Mussoorie, Sahiya; Tehri District – Patli Devika; Uttarkashi District – Bhairo, Ghati, Lanka.

Kumaun: Almora District – Ranikhet, Soni, Punwa Nalla; Champawat District – Champawat; Nainital District – Nainital, Ramgarh; Pithoragarh District – Deval Thal.

***Aporrectodea rosea rosea* (Savigny, 1826)**

Origin: Exotic.

Collection no.(s): M4, C2, C3

Date(s) of collection: 24.vi.2020, 19.i.2021

Collection site: Cultivated land, orchards

Garhwal: Uttaranchal: Chamoli District – Valley of Flowers, Joshimath; Dehra Dun District - Mussoorie; Pauri District - Lansdowne; Tehri District – Kaddukhal.

Kumaun: Nainital District – Nainital, Ramgarh.

Eisenia fetida

Origin: Exotic.

Collection no.(s): D3, D5, P5, PP4, SN4, SN5, MT2, C2, CT1

Date(s) of collection: 11.iv.2020, 12.vii.2019, 15.x.2019, 30.xi.2020, 30.xii.2019, 19.i.2021, 20.ii.2020

Collection site: Cultivated land, orchards

Garhwal: Chamoli District – Govindghat, Joshimath, Padukeshwar; Dehradun District – Mussoorie; Tehri District – Kaddukhal.

Kumaun: Nainital District – Ghorakhal, Kathgodam, Khurpata.

***Octolasion tyrtaeum* (Savigny, 1826)**

Origin: Exotic.

Collection no.(s): D2, D3, D4, S1, S2, M1, M2, M3, N2, N4, N6, N7, PP2, PP5, PP6, SN1, SN4, SN6, MT1, MT4, CT2, CT4,

Date(s) of collection: 09.iv.2019, 11.iv.2020, 25.v.2020, 18.vi.2019, 24.vi.2020, 09.ix.2019, 30.ix.2020, 15.x.2019, 29.x.2020,27.xi.2019, 30.xi.2020, 30.xii.2019, 30.xii.2020, 20.ii.2020, 28.ii.2021

Collection site: Cultivated land, orchards

Table 1. The detailed distribution of the habitats and the collection information of collected earthworms are given below.

Family	Species	Ecological/ Feeding Category	Ecotype of study sites											
			D	S	M	P	O	N	PP	SN	MT	C	CT	B
Lumbricidae	*Aporrectodea caliginosa trapezoids* (Dugés, 1828)	Endogeic	-	-	+	-	-	-	-	-	-	+	-	-
	Aporrectodea rosea rosea (Savigny, 1826)	Endogeic	-	-	-	-	-	-	-	-	+	-	-	-
	Eisenia fetida (Savigny, 1826)	Epigeic	+	-	+	-	-	-	+	+	+	+	+	-
	Octolasion tyrtaeum (Savigny, 1826)	Endogeic	+	+	+	-	-	+	+	+	+	-	+	-
	Dendrodrilus rubidus (Savigny, 1826)	Epigeic	-	-	-	-	-	+	-	-	-	-	-	-
Megascolecidae	*Amynthas alexandri* Beddard, 1900	Endogeic	-	-	-	-	+	-	-	-	-	-	-	-
	Amynthas corticis (Kinberg,1867)	Epi-endogeic	-	-	+	+	-	+	+	+	+	+	-	-
	Amynthas morrisi (Beddard, 1892)	Epi-endogeic	-	-	-	-	+	-	-	-	-	-	-	-
	Metaphire anomala (Michaelsen, 1907)	Anecic	-	-	-	-	+	+	-	-	-	-	-	-
	Metaphire birmanica (Rosa, 1888)	Endogeic	-	-	-	-	+	-	-	-	-	-	-	-
	Metaphire houlleti (Perrier, 1872)	Epi-endogeic	-	-	-	-	+	-	-	-	-	-	-	-
	Perionyx excavates Perrier, 1872	Epigeic	-	-	+	-	+	-	-	-	-	-	-	+
Mongiligastridae	*Drawida japonica* Michaelsen, 1892	Endogeic	-	-	-	+	-	-	-	+	-	-	+	-
Octochaetidae	*Eutyphoeus nainianus* (Michaelsen, 1907)	Epigeic	+	-	-	-	-	-	-	-	-	-	-	-

D—Dhanachuli | S—Sasbani | M—Managair | P—Padampuri | O—Okhalkanda | N—Nadgal | PP—Pahadpani | SN—Sarnaa | MT—Matiyal | C—Churigarh | CT—Chaukhuta | B—Babiyar.

Garhwal: Chamoli District – Joshimath, Padukeshwar; Dehradun District – Mussoorie, Bahmanpur, Shahastrdhara, Chakrata; Tehri District – Dhanaulti, Kaddukhal, Patli, Devika.

Kumaun: Almora District – Jhoola Devi; Nainital District – Bhim Tal, Ramgarh, Nainital.

***Dendrodrilus rubidus* (Savigny, 1826)**

Origin: Exotic.

Collection no.(s): N3

Date(s) of collection: 09.ix.2019

Collection site: Cultivated land, orchards

Garhwal: Dehra Dun District – Chakrata, Musoorie; Rudraprayag District - Phata, Trijuginaraian; Tehri District - Dhanaulti; Uttarkashi District – Harsil, Bhairon Ghati Lanka, Uttarkashi

Kumaun: Almora District – Almora, Khati; Chamoli District – Kedarnath, Tungnath, Vasu Dhara, Chopta, Hemkund, Valley of Flowers, Mana, Joshimath, Bedni; Naini Tal District – Gairal, Ramgarh, Nainital.

Moniligastridae

***Drawida japonica* (Michaelsen, 1892)**

Origin: Exotic.

Collection no.(s): P2, P3, P6, P7, SN5, CT3, CT5

Date(s) of collection: 12.vii.2019, 31.vii.2020, 30.xi.21, 20.ii.20, 28.ii.21

Collection site: Cultivated land, orchards

Garhwal: Uttaranchal: Dehra Dun District – Chakrata, Mussoorie.

Kumaun: First record from Dhari, Nainital.

Octochaetidae

***Eutyphoeus nainianus* (Michaelsen, 1907)**

Origin: Endemic

Collection no.(s): D1, D4

Table. 2. Earthworm diversity along the altitudes of Kumaun Himalaya.

Date of collection	Location	Altitude (m)	Latitude	Longitude	Collection Number	Registration Number
09.iv.2019	Dhanachuli	2126	29. 23747	79.39480	D1, D2	ZSIHQ-AN6533/1
25.v.2019	Sasbani	1936	29.2556	79.4006	-	
18.vi.2019	Managhair	2224	29.23797	79.46836	M1	ZSIHQ-AN6532/1
12.vii.2019	Padampuri	1599	29.23415	79.37029	P1–P5	ZSIHQ-AN6501/1, ZSIHQ-AN6505/1, ZSIHQ-AN6527/1, ZSIHQ-AN6565/1, ZSIHQ-AN6566/1, ZSIHQ-AN6579/1,
27.viii.2019	Okalkanda	1663	29.19428	79.44009	O1–O8	ZSIHQ-AN6583/1, ZSIHQ-AN6584/1, ZSIHQ-AN6585/1, ZSIHQ-AN6588/1, ZSIHQ-AN6589/1, ZSIHQ-AN6580/1, ZSIHQ-AN6569/1, ZSIHQ-AN6570/1, ZSIHQ-AN6556/1, ZSIHQ-AN6557/1, ZSIHQ-AN6514/1, ZSIHQ-AN6572/1, ZSIHQ-AN6573/1
09.ix.2019	Nadgal	1673	29.24741	79.43276	N1–N3	ZSIHQ-AN6528/1, ZSIHQ-AN6509/1, ZSIHQ-AN6520/1
15.x.2019	Pahadpani	2106	29.25656	79.42622	PP1–PP4	ZSIHQ-AN6508/1, ZSIHQ-AN6510/1, ZSIHQ-AN6524/1, ZSIHQ-AN6531/1
27.xi.2019	Sarna	1675	29.22930	79.37907	SN1–SN3	ZSIHQ-AN6542/1, ZSIHQ-AN6530/1, ZSIHQ-AN6536/1,
30.xii.2019	Matiyal	1649	29.22706	79.36772	MT1, MT2	ZSIHQ-AN6504/1, ZSIHQ-AN6534/1
31.i.2020	Churigarh	1545	29.20663	79.39921	-	
20.ii.2020	Chaukhuta	1737	29.24628	79.38005	CT1–CT3	ZSIHQ-AN6503/1, ZSIHQ-AN6525/1, ZSIHQ-AN6517/1
03.iii.2020	Babiyar	1499	29.17613	79.41457	B1	ZSIHQ-AN6516/1
11.iv.2020	Dhanachuli	2126	29.23747	79.39480	D3–D5	ZSIHQ-AN6571/1, ZSIHQ-AN6507/1, ZSIHQ-AN6587/1, ZSIHQ-AN6586/1
25.v.2020	Sasbani	1936	29.2556	79.4006	S1, S2	ZSIHQ-AN6560/1, ZSIHQ-AN6529/1
24.vi.2020	Managhair	2224	29.23797	79.46836	M2, M3, M4	ZSIHQ-AN6502/1, ZSIHQ-AN6561/1, ZSIHQ-AN6562/1, ZSIHQ-AN6515/1
31.vii.2020	Padampuri	1599	29.23415	79.37029	P6, P7	ZSIHQ-AN6558/1, ZSIHQ-AN6559/1, ZSIHQ-AN6581/1, ZSIHQ-AN6582/1
31.viii.2020	Okhalkanda	1663	29.19428	79.44009	O9–O12	ZSIHQ-AN6538/1, ZSIHQ-AN6526/1, ZSIHQ-AN6522/1, ZSIHQ-AN6539/1, ZSIHQ-AN6540/1, ZSIHQ-AN6541/1, ZSIHQ-AN6572/1, ZSIHQ-AN6573/1
30.ix.2020	Nadgal	1673	29.24741	79.13276	N4–N8	ZSIHQ-AN6567/1, ZSIHQ-AN6568/1, ZSIHQ-AN6548/1, ZSIHQ-AN6549/1, ZSIHQ-AN6550/1, ZSIHQ-AN6523/1, ZSIHQ-AN6535/1, ZSIHQ-AN6518/1,
29.x.2020	Pahadpani	2106	29.25656	79.42622	PP5–PP8	ZSIHQ-AN6546/1, ZSIHQ-AN6547/1, ZSIHQ-AN6553/1, ZSIHQ-AN6554/1, ZSIHQ-AN6519/1, ZSIHQ-AN6512/1
30.xi.2020	Sarna	1675	29.22930	79.37907	SN4–SN6	ZSIHQ-AN6506/1, ZSIHQ-AN6552/1, ZSIHQ-AN6551/1, ZSIHQ-AN6563/1, ZSIHQ-AN6564/1
30.xii.2020	Matiyal	1649	29.22706	79.36772	MT3, MT4	ZSIHQ-AN6576/1, ZSIHQ-AN6577/1, ZSIHQ-AN6578/1, ZSIHQ-AN6574/1, ZSIHQ-AN6575/1
19.i.2021	Churigarh	1545	29.20663	79.39921	C1–C3	ZSIHQ-AN6544/1, ZSIHQ-AN6545/1, ZSIHQ-AN6537/1, ZSIHQ-AN6521/1,
28.ii.2021	Chaukhuta	1737	29.24628	79.38005	CT4, CT5	ZSIHQ-AN6545/1, ZSIHQ-AN6513/1,
11.iii.2021	Babiyar	1499	29.17613	79.41457	-	

Date(s) of collection: 09.iv.2019
Collection site: Cultivated land, orchards
Garhwal: Chamoli District – Talwari.
Kumaun: Naini Tal District – Naini Tal; Pithoragarh District – Pabta.

DISCUSSION

Fourteen species recorded from the study area, seven were identified belonging to the family Megascolecidae, five from Lumbricidae, one from Moniligastridae, and one from Octochaetidae, respectively. Megascolecidae was dominant in all habitats of the Kumaun Himalaya, and the most widely distributed species was *Octolasion tyrtaeum* and *Eisenia fetida*. *Drawida japonica* belongs to family Moniligastridae has been reported for the first time from the Kumaun region, and for a second time from Uttarakhand. All the other species were reported previously by various authors including: Mubeen & Hatti (2018); Rajwar et al. (Rajwar et al. 2018, 2022); Bora et al. (2021a,b); Saikia et al. (2021); Ahmad et al. (2022); Khan (2022). *Drawida japonica* was reported from high-altitude cultivated land and orchards, i.e., 1400 m; therefore, it is assumed that it could be present in other parts of the Himalayan mountains with similar geo-climatic conditions and it is possible that this species might also be available in other parts of the Himalaya besides the studied region due to similarity in biomes.

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COMMUNICATION

Woody flora of Karumpuliyuthu Hill, Tenkasi, Tamil Nadu, India: a checklist

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Abstract: Qualitative field surveys were conducted to record the woody plant (tree, shrub, and liana) wealth in Karumpuliyuthu Hill, Tenkasi district, Tamil Nadu. All the recorded species were confirmed with regional floras. The qualitative field survey allowed us to record 42 species in 32 genera and 19 families. The family Fabaceae had a large number of species (13 species) in the study area. The present study adds valuable information about the occurrence of 42 woody plant species in a tropical thorn forest ecosystem. The woody plant community is dominated by native plants, and only three are introduced. Nearly half of the recorded species produce fleshy fruits, thus providing food to small mammals and birds.

Keywords: Dry forest, fruit, peninsular India, southern thorn forest, woody plant wealth.

Tamil: தமிழ்நாட்டிலுள்ள தென்காசி மாவட்டத்தில் அமைந்துள்ள கரும்புளியூத்து மலையில் வாழ்ந்து வரும் கட்டைத்தன்மை வாய்ந்த தாவரங்களான மரம், குறுமரம் மற்றும் பெருங்கொடிகளின் வளங்களை பட்டியலிடுவதற்காக பண்பறி களஆய்வுகள் மேற்கொள்ளப்பட்டன. சேகரிக்கப்பட்ட அனைத்து தாவரங்களும் அங்கீகரிக்கப்பட்ட தாவர வளம் குறித்த கையேடுகள் மூலம் கண்டறியப்பட்டன. பண்பறி களஆய்வுகள் மூலம் 19 குடும்பம் மற்றும் 32 பேரினங்களைச் சேர்ந்த 42 சிற்றினங்கள் பட்டியலிடப்பட்டுள்ளன. பேபேசி எனும் பயறுவகை தாவரங்களை கொண்ட குடும்பம் 13 சிற்றினங்களுடன் அதிக அளவில் காணப்படுகின்றன. இந்த ஆய்வானது 42 கட்டைத்தமை வாய்ந்த சிற்றினங்களின் இருப்பிடத் தகவலை நமக்கு அளிக்கின்றது. மேலும், இந்தக் காடானது இயல்வகை தாவரங்களின் இருப்பிடமாக விளங்குகின்றது, அயல்வகைச் சிற்றிங்கள் மூன்று மட்டுமே காணப்படுகின்றன. பட்டியலிடப்பட்ட மொத்த தாவரங்களில் இரண்டில் ஒரு பங்கு சதைப்பற்றுள்ள கனிகளை உற்பத்தி செய்வதன் மூலம் சிறிய வகை பறவைகள் மற்றும் பாலூட்டிகளுக்கு உணவினை வழங்குகின்றன.

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Author contribution: AS and MU designed and conceptualized the study. AS, MU, and LK conducted field surveys, collection, identification and documentation of woody plants from study area. MU and LK prepared the first draft of the manuscript and AS corrected it.

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INTRODUCTION

Information on plant diversity such as flora, checklist, and quantitative or qualitative ecological studies are useful for understanding the changes that take place in forest plant communities (Armonies et al. 2018). Besides, these data are vital to frame conservation measures (Francisco-Ortega et al. 2010) and forest restoration (Shetu et al. 2018). Invariably all types of forests and trees deliver an array of ecosystem services (Taye et al. 2021). There are about 61,000 tree species flourishing on this earth (Qian et al. 2019). Trees provide a range of non-timber forest products including honey, fuel wood and fiber (FAO 2014). In addition, they play important roles in combating global climate change through carbon storage and sequestration (Roebroek et al. 2023). In general, woody plants store relatively more amount of biomass than herbaceous communities in forest ecosystems (Borah et al. 2015). Tropical thorn forests support moderate woody plant diversity (Rahangdale et al. 2014; Evitex-Izayas & Udayakumar 2021; Muneeswaran & Udayakumar 2022). Data on plant diversity of tropical thorn forests in Tamil Nadu remain scarce. This study aims to explore the woody plant wealth (shrubs, trees, and woody liana) of a tropical thorn forest ecosystem existing within Karumpuliyuthu Hill located in Tenkasi district, Tamil Nadu.

MATERIALS AND METHODS

Study area

Karumpuliyuthu Hill located in Tenkasi district, Tamil Nadu (Figure 1). The district was bifurcated from Tirunelveli district in 2019. The northern, eastern, western, and southern boundaries of the district are Virudhunagar, Thoothukudi, Tirunelveli, and Kerala, respectively. The mean annual precipitation of the district is 769.2 mm, while the mean maximum and minimum temperatures are 29 and 27°C, respectively (https://mausam.imd.gov.in/chennai/). The total geographical area of the district is 2,882.43 km^2, whereas the forest cover is 439.99 km^2 (https://tenkasi.nic.in/).

Field survey

A sum of 32 field surveys have been conducted to record woody plant wealth (shrubs, trees, and liana) in the tropical thorn forest ecosystem existing within Karumpuliyuthu Hill, located in Tenkasi district, one of the southernmost districts of India. All the recorded species were identified with available regional floras and checklists (Gamble & Fischer 1921–1935; Muneeswaran & Udayakumar 2022). The nomenclature of families and the author citation of species followed Plants of the World Online (https://powo.science.kew.org/). The current status of all the recorded species was verified with the help of the IUCN Red List of Threatened Species (https://www.iucnredlist.org/). Further, the flowering and fruiting phenophases of woody plants were recorded monthly for one year. A plant with flower (bud & open) and fruit (immature & mature) considered as 'reproducing'. The length of reproductive phenophase was calculated and recorded in months.

RESULTS AND DISCUSSION

The qualitative field survey allowed us to record 42 species in 32 genera and 19 families. The family Fabaceae had the large number of species (13 species) followed by Apocynaceae and Rubiaceae (three species each). Capparaceae, Euphorbiaceae, Menispermaceae, Rhamnaceae, Malvaceae, Verbenaceae, and Vitaceae had two species each, while, nine families represented by just a single species each in the study area (Figure 2 & Table 1). Important species of study area featured in Image 1.

The woody plant wealth of Karumpuliyuthu Hill (42 species) is comparable with a tropical thorn forest existing within Asola-Bhatti wildlife sanctuary, India (42 woody plants including 17 trees, 15 shrubs, and 10 climbers; Sharma & Chaudhry 2018); lower than in Carnatic umbrella thorn (53 and 54 in Hosur and Dharmapuri, respectively), secondary dry deciduous (48), southern dry mixed deciduous (95), southern tropical dry moist mixed deciduous (67), southern thorn (52), southern thorn scrub (53 and 49 in Hosur and Dharmapuri, respectively) and tropical dry evergreen forests in Tami Nadu (Tiwari & Ravikumar 2018a,b); and, tropical thorn forest of Gujarat (58 tree species, 44 mature, 41 seedlings, and 32 saplings; Rajendrakumar & Kalavathy 2010). However, the woody plant wealth of present study area is higher than in southern moist mixed deciduous (29), dry deciduous (22), *Hardwickia* (18 and 9 in Hosur and Dharmapuri, respectively), dry deciduous scrub (30), *Euphorbia* scrub (24), southern tropical dry deciduous (34) and southern dry scrub (16 and 34 in Hosur and Dharmapuri, respectively) forests flourishing in Tamil Nadu (Tiwari & Ravikumar 2018a,b); tropical thorn forest of Gujarat (8 climbers, 14 shrubs, and 17 trees; Patel et al. 2014); *Prosopis juliflora* invaded (27 tree species) and uninvaded southern thorn forest

Figure 1. Map of study area in which field surveys conducted to record woody flora.

(35 tree species; Athamanakath et al. 2023).

The anthropogenic activities (cutting of trees, fuel wood collection etc.) transformed close-canopied dry deciduous forest in to tropical thorn forest (Champion & Seth 1968). Murphy & Lugo (1986) found relationships among species richness and moisture gradients across tropical forests and shown least number of tree species in driest areas. Singh & Singh (1988) recognized tropical thorn forest as extremely poor in terms of species richness and inhabited by mostly deciduous species. Tropical thorn forests occurring in a drier habitat and experience 5–6 dry months in a year, hence act as a habitat for moderate number of woody plants. It has been investigated that range of factors including altitude, mean annual minimum and maximum temperatures, distribution and frequency of precipitation and soil moisture content influence tree density, species richness and diversity (e.g., Thakur et al. 2022). For instance, Dattaraja et al. (2018) investigated the relationship between diversity of woody plants and environmental factors in Indian tropical forests and found thorn forests support least number of woody species. Detailed studies of impact of environmental factors on thorn forest ecosystem are limited.

The members of Fabaceae dominating the woody plant community in tropical thorn forest ecosystem. It is well known that a considerable number of species belongs to the family Fabaceae (e.g., *Acacia* & *Vachellia*) are able to fix nitrogen with the help of soil bacteria (Brockwell et al. 2005). Nitrogen fixation by members of Fabaceae could enhance the fertility of soil in tropical thorn forest. Recently, Evitex-Izayas & Udayakumar (2021) in a thorn forest ecosystem, Uthumalai, Tirunelveli; Nagaraj & Udayakumar (2021) in a southern thorn forest existing within Vallanadu Blackbuck Sanctuary (VBS), Thoothukudi; Muneeswaran & Udayakumar (2022) in a Carnatic umbrella thorn forest, Therikadu, Thoothukudi observed the dominance of Fabaceae members. Notably, the members of Fabaceae constituted 52.36% of tree community in VBS (Nagaraj & Udayakumar 2021). Besides, Indian thorn forests act as home for threatened species (Joshi et al. 2012; Baskaran & Desai 2013); range of insects (Adarsh et al. 2013; Majumder et al. 2015), and birds (Narwade & Fartade 2011; Babu & Bhupathy 2013).

Mode of regeneration

All the recorded plants produce seeds and regenerate from them during wet season. Eight species viz., *Coccinea grandis*, *Cissus quadrangularis*, *C. vitiginea*, *Commiphora berryi*, *Euphorbia antiquorum*, *Morinda coreia*, *Sarcostemma acidum*, and *Tinospora cordifolia* regenerate through seeds and vegetative parts (stems and root sucker). In general, seed predation by insects and rodents affects seed germination and seedling establishment in tropical forests (e.g., Guariguata et al. 2000). Information on various functional traits of seeds and seedlings are limited, therefore, continuous field studies and monitoring are necessary for better understanding of regeneration of tropical thorn forests.

Life form and conservation status

Among three life forms (trees, shrubs, and lianas), the trees dominated the study area with 18 species, shrubs represented by 15, whereas the liana represented by nine species (Figure 3 & Table 1). Half of all the recorded species were categorized under Least Concern (LC), 20 species were identified as Not

Table 1. Botanical name, family and life form of woody plants found in Karumpuliyuthu hill, Tenkasi district, Tamil Nadu. (introduced species marked with '*' mark, wild edible plants with '@').

	Botanical name	Family	Life form	IUCN Red List status	Fruit type	Mode of regeneration	Flowering and fruiting season
1	*Albizia amara* (Roxb.) Boivin	Mimosaceae	Tree	Least Concern	Pod	Seed	April–July
2	*Azadirachta indica* A.Juss.	Meliaceae	Tree	Least Concern	Drupe	Seed	April–August
3	*@Borassus flabellifer* L.	Arecaceae	Tree	Least Concern	Drupe	Seed	March–August
4	*Canthium coromandelicum* (Burm.f.) Alston	Rubiaceae	Tree	Not Evaluated	Berry	Seed	January–June
5	*Capparis sepiaria* L.	Capparidaceae	Shrub	Least Concern	Berry	Seed	April–August
6	*Capparis grandiflora* Wall. ex Hook.f. & Thomson	Capparidaceae	Liana	Not Evaluated	Berry	Seed	April–July
7	*@Carissa spinarum* L.	Apocynaceae	Shrub	Least Concern	Berry	Seed	March–July
8	*Catunaregam spinosa* (Thunb.) Tirveng.	Rubiaceae	Shrub	Least Concern	Drupe	Seed	April–September
9	*Coccinia grandis* (L.) Voigt	Cucurbitaceae	Liana	Not Evaluated	Pepo	Seed and vegetative	Throughout the year
10	*@Cissus quadrangularis* L.	Vitaceae	Liana	Not Evaluated	Berry	Seed and vegetative	February–August
11	*Cissus vitiginea* L.	Vitaceae	Liana	Not Evaluated	Berry	Seed and vegetative	March–July
12	*Cocculus hirsutus* (L.) W.Theob.	Menispermaceae	Liana	Not Evaluated	Berry	Seed	February–June
13	*Commiphora berryi* (Arn.) Engl.	Burseraceae	Shrub	Not Evaluated	Drupe	Seed and vegetative	April–September
14	*Dalbergia spinosa* Roxb.	Papilionaceae	Shrub	Least Concern	Pod	Seed	March–August
15	*Dichrostachys cinerea* (L.) Wight & Arn.	Mimosaceae	Tree	Least Concern	Pod	Seed	February–June
16	*Dodonaea viscosa* Jacq.	Sapindaceae	Shrub	Least Concern	Capsule	Seed	Throughout the year
17	*Ehretia aspera* Willd.	Boraginaceae	Tree	Data Deficient	Berry	Seed	April–September
18	*Euphorbia antiquorum* L.	Euphorbiaceae	Shrub	Least Concern	Capsule	Seed and vegetative	Throughout the year
19	*Flueggea leucopyrus* Willd.	Euphorbiaceae	Shrub	Least Concern	Berry	Seed	October–January
20	*Gmelina asiatica* L.	Verbenaceae	Shrub	Least Concern	Drupe	Seed	February–September
21	*Grewia hirsuta* Vahl	Tiliaceae	Liana	Least Concern	Drupe	Seed	February–June
22	*Grewia serrulata* DC.	Tiliaceae	Shrub	Not Evaluated	Drupe	Seed	March–June
23	*Holoptelea integrifolia* (Roxb.) Planch.	Ulmaceae	Tree	Not Evaluated	Samara	Seed	February–August
24	*Lannea coromandelica* (Houtt.) Merr.	Anacardiaceae	Tree	Least Concern	Drupe	Seed	April–July
25	*@Morinda coreia* Buch.-Ham.	Rubiaceae	Tree	Not Evaluated	Berry	Seed and root sucker	Throughout the year
26	*Premna tomentosa* Willd.	Verbenaceae	Shrub	Least Concern	Drupe	Seed	March–August
27	*Prosopis cineraria* (L.) Druce	Mimosaceae	Shrub	Not Evaluated	Lomentum	Seed	April–September
28	**Prosopis juliflora* (Sw.) DC.	Mimosaceae	Tree	Not Evaluated	Lomentum	Seed	Throughout the year
29	*Rivea hypocrateriformis* (Desr.) Choisy	Convolvulaceae	Liana	Least Concern	Capsule	Seed	October–April
30	*Sarcostemma acidum* (Roxb.) Voigt	Apocynaceae	Liana	Not Evaluated	Follicle	Seed and vegetative	February–July
31	*Senegalia chundra* (Roxb. ex Rottler) Maslin	Mimosaceae	Tree	Not Evaluated	Pod	Seed	March–July
32	**Senegalia mellifera* (Benth.) Seigler & Ebinger	Mimosaceae	Tree	Least Concern	Pod	Seed	March–July
33	*Senna auriculata* (L.) Roxb.	Caesalpiniaceae	Shrub	Not Evaluated	Pod	Seed	Throughout the year
34	*Tinospora cordifolia* (Willd.) Hook.f. & Thomson	Menispermaceae	Liana	Not Evaluated	Berry	Seed and vegetative	February–June
35	*Vachellia horrida* (L.) Kyal. & Boatwr.	Mimosaceae	Tree	Not Evaluated	Pod	Seed	July–November
36	*Vachellia leucophloea* (Roxb.) Maslin, Seigler & Ebinger	Mimosaceae	Tree	Least Concern	Pod	Seed	March–July
37	*Vachellia nilotica* (L.) P.J.H.Hurter & Mabb.	Mimosaceae	Tree	Least Concern	Lomentum	Seed	July–December

	Botanical name	Family	Life form	IUCN Red List status	Fruit type	Mode of regeneration	Flowering and fruiting season
38	*Vachellia planifrons* (Wight & Arn.) Ragup., Seigler, Ebinger & Maslin	Mimosaceae	Tree	Not Evaluated	Pod	Seed	February–July
39	**Vachellia tortilis* (Forssk.) Galasso & Banfi	Mimosaceae	Tree	Least Concern	Pod	Seed	March–July
40	*Wrightia tinctoria* B.Heyne ex Roth.	Apocynaceae	Tree	Not Evaluated	Follicle	Seed	December–June
41	*@Ziziphus nummularia* (Burm.f.) Wight & Arn.	Rhamnaceae	Shrub	Not Evaluated	Drupe	Seed	October–May
42	*Ziziphus xylopyrus* (Retz.) Willd.	Rhamnaceae	Shrub	Not Evaluated	Drupe	Seed	October–June

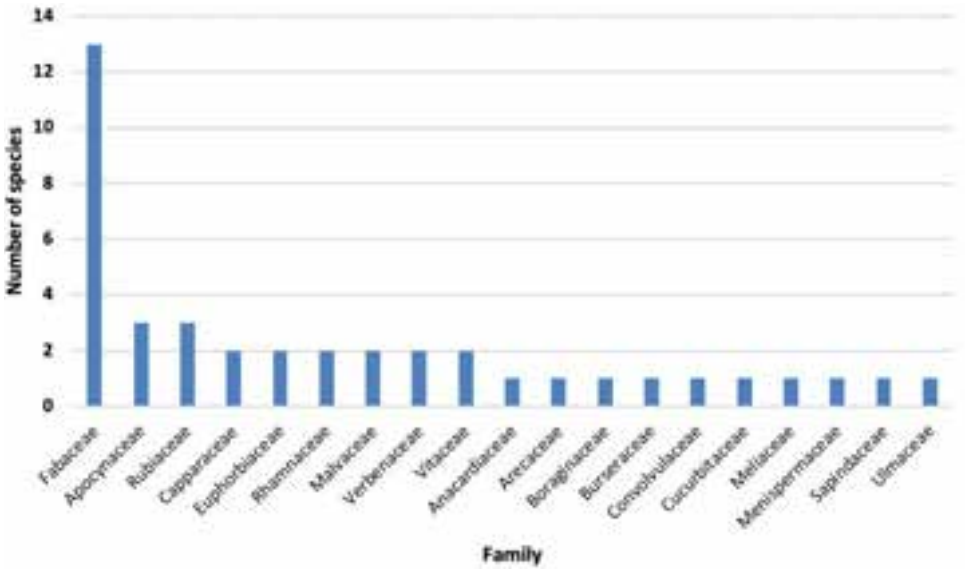

Figure 2. Number of species represented by families in study area.

Evaluated (NE) and only one was listed as Data Deficient (DD) (Table 1). All the listed species are native to India, except *Prosopis juliflora*, *Senegalia mellifera,* and *Vachellia tortilis*. Twenty-three species produced fleshy fruits (berry or drupe), remaining formed dry fruits (pod, lomentum, dehiscent and indehiscent capsules), thus the existing woody plant community in the study area partially fulfilled the food requirement of various birds (e.g., Bulbul, Myna) and small mammals (e.g., Squirrel, Civet, Forest rat). In addition, 21 species had mechanical protective structures either spine or thorn. It is well known that the presence of sharp protective structures (spine, thorn, prickle) is one of the common features for species growing in drier environments.

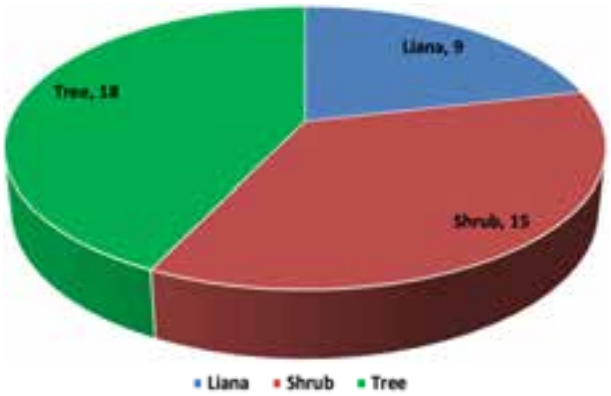

Figure 3. Life form composition of woody plants recorded from study area.

Reproductive phenophase of woody plants

The length of reproductive phenophase varied across species. Of 41 species, five species had four months of reproductive phenophase, 12 had five months, 11 had six months and six reproduced throughout the year (Table 1). The mean duration of reproductive phenophase of studied species was 5.214 ± 2.469 months. The reproductive phenophase peaked in April (39 species) followed by May (38), June (37), and July

Image 1. 1—*Ehretia aspera* | 2—*Capparis sepiaria* | 3—*Vachelia planifrons* | 4—*Albizia amara* | 5—*Commiphora berryi* | 6—*Carissa spinarum* | 7—*Dalbergia spinosa* | 8—*Sarcostemma acidum* | 9—*Albizia amara* Tree stand | 10—*Albizia amara* with multiple stems. © M. Udayakumar.

(31). Whereas, 12 species each reproduced in January, October, November, and December. Most of the species tends to reproduce after north-east monsoon (October–December). Researchers found close relationships among reproduction of trees, relative humidity and moisture content of tropical forests (Bhat 1992; Sundarapandian et al. 2005; Selwyn et al. 2006; Nanda et al. 2014).

Wild edible plants

The thorn forest acts as a home for five wild edible plants. The palmyra palm *Borassus flabelliber* provides edible tender and mature fruits, seed haustoria, and

seedling. It has been well documented and known that many parts of the palmyra palm are economically important (Rahman et al. 2021). *Carissa spinarum*, *Morinda coreia,* and *Ziziphus nummularia* yield edible fruits. A large number of researchers made a detailed study on these fruits and recorded vitamin, mineral, anti-oxidant, and nutrient contents (*C. spinarum*: Liu et al. 2021; *M. coreia*: Chandra & Meel 2020; *Z. nummularia*: Uddin et al. 2022). Young and tender stems of *Cissus quadrangularis* is edible and medicinal. A considerable number of medicinally important bioactive chemical compounds have been isolated from *C. quadrangularis* (Bafna et al. 2021).

CONCLUSION

The present study adds valuable information about the occurrence of 42 woody plant species in the tropical thorn forest ecosystem located at Karumpuliyuthu Hill, Tenkasi district, Tamil Nadu. The forest ecosystem supports a moderate woody plant diversity and five wild-edible plants. Most of the recorded woody plants belong to India, except three species. Tropical thorn forests are least explored in terms of ecology and taxonomy, thus extensive quantitative field studies are to be carried out to record the plant wealth and realize the range of ecosystem services. Further, the thorn forests are endowed with substantial number of trees with nitrogen fixing ability, research on these lines are helpful to understand the evolution and survival of drought tolerant forest systems.

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SHORT COMMUNICATION

First record of Croaking Gourami *Trichopsis vittata* (Cuvier, 1831) from West Bengal, India

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Abstract: The Croaking Gourami *Trichopsis vittata* (Cuvier, 1831) is a native fish to southeastern Asia and Sundaland, with introduction reports from the USA, Philippines, and many other countries including India. In India, this species was first reported from Chembarampakkam Lake situated in Chennai during the year 2015. This study reports the presence of this fish for the first time in the Magra Beel, a wetland in the district of Nadia, West Bengal, in 2021, 2022, 2023. The laboratory evaluated the fish samples taken from the marsh to determine their fin ray counts and morphometric data. The results identified the species as *T. vittata* and supported previous research.

Keywords: Aquarium trade, distribution, invasion, Magra Beel, meristic count, morphometry, osphronemid fish, species identification.

Trichopsis vittata (Cuvier, 1831), known as Croaking Gourami in the ornamental fish trade, is a small air-breathing osphronemid fish, reported as native from Java, Borneo, Sumatra, Peninsular Malaysia, Thailand, and the Mekong basin in Cambodia, Laos, and Vietnam (Kottelat 1985; Baird et al. 1999). The species is an obligate air-breathing fish that prefers to live in shallow sluggish or standing-water habitats with abundant vegetation (Rainboth 1996). It can survive in brackish water up to 20 ppt salinity, and in temperatures down to 7.2^{0}C (Schofield & Schulte 2016). It feeds on small planktonic crustaceans and insect larvae (Rainboth 1996). This species comprises more-extended filamentous anal-fin rays extending almost to the tip of the caudal-fin and also possesses three dark lateral stripes on the body. A typical dark spot is present above the pectoral fin of the fish as a unique identifying character. Unlike other osphronemid fishes, *T. vittata* is popularized for the production of audible sounds or "croaks" (Ladich & Yan 1998).

Trichopsis vittata has shown invasiveness and introduced itself to a larger extent. Since its description by Cuvier in 1831 it has extended its range. The feral population has been documented in the USA (Florida) and the Philippines (Shafland 1996; Schofield & Pecora 2013; Schofield & Schulte 2016). The southeastern Asian countries including Indonesia, Thailand, Java, Borneo, Sumatra (Rainboth 1996; Kottelat 1985; Liengpornpan et al. 2007; Beamish et al. 2010), Vietnum (Freyhof et al. 2000; Herder & Freyhof 2006), Mekong tributaries of Indochina (Robins 1992; Baird et al. 1999; Kottelat 2013), Laos (Martin et al. 2011), Singapore (Alfred 1996; Low & Lim 2012), Cambodia (Rainboth 1996), Malaysia (Beamish et al. 2003) are reported to be the native places of *T. vittata*.

The non-native population of *T. vittata* has been documented from Myanmar and Bangladesh (Noren et al. 2017; Akash et al. 2018; Hossain et al. 2019). Literature depicts that in India *T. vittata* was first reported from the Chembarampakkam Lake situated in southern (Knight & Balasubramanian 2015); but its existence has not yet

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been reported from West Bengal.

Study Area and Methods

The fish samples were first collected on 1 August 2021 from the Magra Beel. The collection was done by using a hand held drag net as per the conventional method. Then in quest of other populations of fish, multiple field visits were done between August 2021 and July 2023 in different fishing points of the Magra Beel within a distance of 1.5 km (Point-1: Opposite to Bijra Primary School; Point-2: Concrete bridge at 3 number Magra Beel; Point-3: Kheya Ghat opposite to Birahi Union Tapashili Fishermen's Cooperative Society Limited office). The sampling sites of the Magra Beel are presented in Image 1.

After collection, the fish specimens were immediately preserved in 10% formalin for taxonomic study (Joshi et al. 2015). Different morphometric characteristics including total length, standard length, pectoral fin base length, pelvic fin base length, and anal fin base length were measured as per the conventional method and different meristic counts for dorsal fin rays, anal fin rays, pectoral fin rays, pelvic fin rays were observed accordingly (Murdy & Shibkawa 2001). The preserved fish samples were submitted to the Fresh Water Fish Section of the Zoological Survey of India, Kolkata for identification and documentation. Some fish samples were subsequently transferred into 30%, 50%, and 70% ethanol for long-term preservation (Sterba 1962; Talwar & Jhingran 1991) for further study.

Results

Morphometric and meristic characters

The collected samples have laterally elongated bodies with a standard length of 4.10 cm (Table 1). The dorsal fin originates far behind the base of the pectoral fin corroborating the previous findings of Hossain et al. (2019) and Shefat et al. (2020). A thin black line is found below the eye (Noren et al. 2017). Stripes and black spots are visible on the fin of both sides of the body. The morphometric measurements including total length, standard length, pectoral fin base length, pelvic fin base length, and anal fin base length of the fish have been

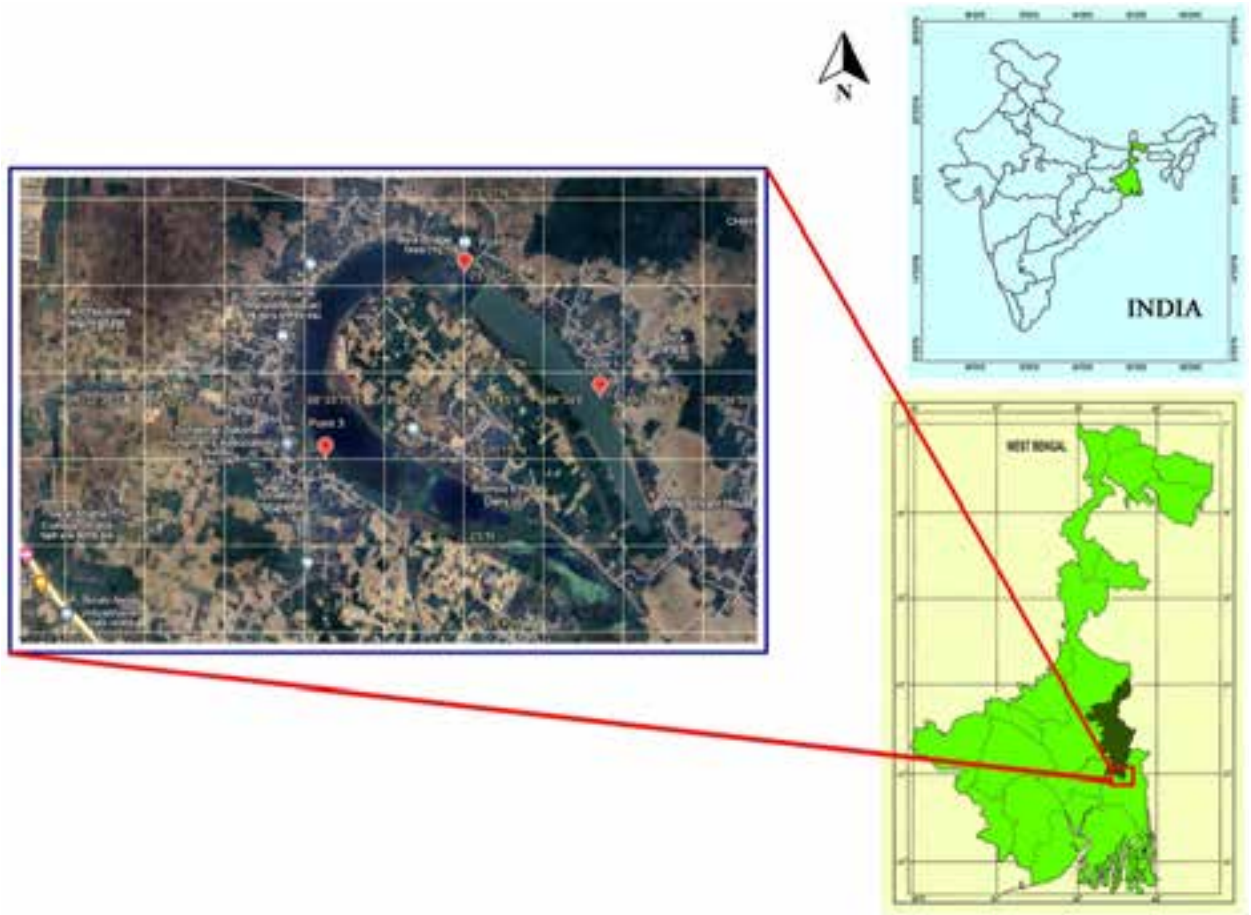

Image 1. The sampling points during study in Magra Beel.

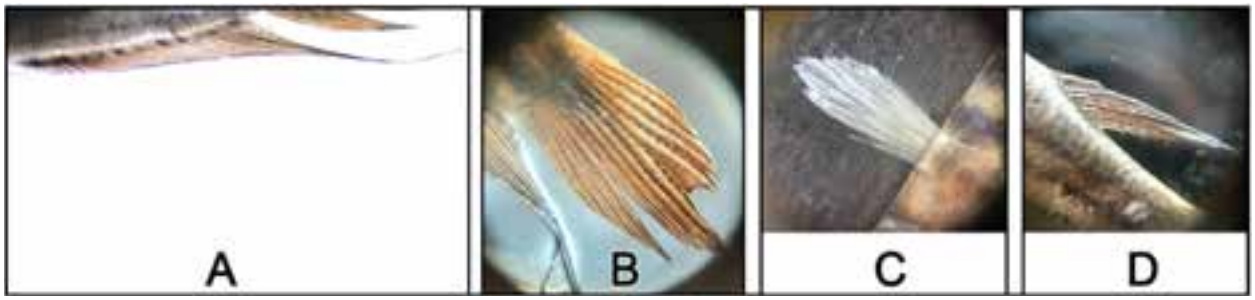

Image 2. *Trichopsis vittata* collected from Magra Beel: A—Anal fin | B—Caudal fin | C—Pectoral fin | D—Dorsal fin. © Bakul Biswas.

Image 3. *Trichopsis vittata* collected from Magra Beel. © Bakul Biswas, Sujal Dutta.

Table 1. The morphometric measurement and meristic count of fin rays in *Trichopsis vittata*.

Morphometric characters	Length (cm)	Meristic characters	Number (range)
Total length	5.70	Dorsal fin ray	7–8
Standard length	4.10	Pectoral fin ray	10–11
Pectoral fin base length	1.20	Ventral fin ray	7–9
Pelvic fin base length	2.30	Anal fin ray	31–33
Anal fish base length	1.60	Caudal fin ray	12–16
-	-	Lateral line scales	29

presented in Table 1. The anal fin is comprised of multi-branched fin rays with 6–8 spines and a few elongated filaments-like rays which are extended almost to the tip of the caudal fin. The dorsal fin of *T. vittata* has 2–4 spines, while the pelvic fin contains one spine followed by a filament and four rays. On the posterior half of the body, there are three longitudinal dark bands, which help to distinguish *T. vittata* from the related species *T. schalleri* and *T. pumila* (Noren et al. 2017). The fin ray counts are detailed in Table 1 and are consistent with the findings reported by Hossain et al. (2019).

Identification and cataloguing

After collecting the samples of fish from three different spots, the specimens were submitted to the Zoological Survey of India (ZSI) for identification and cataloguing. The ZSI has identified the species and registered the submitted specimens as *Trichopsis vittata* (Cuvier, 1831) [Regd. No. ZSI FF 9935 dt. 24. 08. 2023].

Discussion

In this present study, *T. vittata* was found in a lower abundance than the other native fish species; but the overall count is sufficient to prove its strong adaptability to this new environment. *T. vittata* is an efficient invader that can survive in a small volume of water and can tolerate high pollution and low dissolved oxygen level conditions (Wongsiri, 1982). Knight & Balasubramanium (2015) reported that in India *T. vittata* may compete for niche space with native species such as *Trichogaster lalius* (Hamilton, 1822) and Spiketail Paradise Fish *Pseudosphromenus cupnus* (Cuvier, 1831). The negative effects of *T. vittata* may also include aggressive displacement of native species or it may also act as a vector for parasites or pathogens such as trematode, *Euclinostomum heterostomum* (Purivirojkul & Sumontha 2013). Thus, the spreading of *T. vittata* across the country over the years will affect the native fish biodiversity. Of late, the particular impact of this species on other indigenous fish species is currently unknown, therefore, further in-depth study regarding its biology, ecology, and inter-specific interactions among the non-native range in

India are required at the earnest level.

The way of introduction of the fish species in the Magra Beel is not known. However, the most probable mechanism of introduction may be the release from the aquarium trade (Noren et al. 2017). As per the first recommendations of ZSI, Kolkata, "is an exotic species and distributed worldwide via aquarium trade. The specimen shows some variations from the description of *Trichopsis vittata* and may be a hybrid also. It needs further study based on freshly collected specimens for confirmation". Later on ZSI Kolkata identified and registered the specimen as *Trichopsis vittata* (Cuvier, 1831), family Osphronemidae [Regd No. ZSI FF 9935 dt. 24. 08. 2023]. Deliberate aquaculture efforts could serve as a vector for invasion (Akash & Hossain 2018). Given that *T. vittata* has been previously reported in various rivers across Bangladesh (Noren et al. 2017), some of which are in close proximity to the state of West Bengal, it is plausible that this species could migrate to West Bengal via these river routes.

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SHORT COMMUNICATION

Lasioptera sharma, a new species of gall midge (Diptera: Cecidomyiidae) feeding on *Leea indica* (Vitaceae) in India

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Abstract: A new species of gall midge associated with the leaves of *Leea indica* (Burm.fil.) Merr. (Vitaceae) is described and illustrated. Two species of *Lasioptera* have been reported from the plant genus *Leea* so far and the present species is the third one, known to cause galls on the leaves of *Leea indica*. The type specimens are deposited in the National Zoological Collection, Zoological Survey of India, Western Regional Centre, Pune, India.

Keywords: Bandicoot Berry, Gall midge, Lasioptera, leaf galls, Mollem, Western Ghats.

The genus *Lasioptera* includes more than 120 species until now, belonging to Lasiopterini, and Lasiopteridi (Gagné & Jaschhof 2021). Up to now, two species of gall midges have been reported from *Leea* species: *Lasioptera manilensis* Felt 1918 (Host plant: *Leea manillensis*) from the Philippines and *Asphondylia leeae* Felt, 1921 (Host plant: *Leea indica*) from Indonesia (Felt 1918, 1921; Kolesik & Gagné 2020). From India, leaf galls on *Leea indica* were first reported by Mani (1959) from southern parts of Western Ghats of India but the causative organism was not known. The species was likely not described because adults could not be collected from these galls. Subsequently, Sharma (2003) reared a few adult female gall midges from the leaf galls of *L. indica* and identified them as *Lasioptera* sp. The species was not described due to the lack of available male specimens.

The present attempt to rear adult gall midges from the leaf galls of *L. indica* collected from Mollem, Goa yielded several adult male and female specimens of *Lasioptera* sp. The specimens were processed and mounted in Canada balsam as per the method described by Kolesik et al. (2015). Holotypes and paratypes were carefully prepared and subsequently deposited in the collection of the Zoological Survey of India, WRC, Pune. In this paper, we formally describe it as a new species *Lasioptera sharma* and its affinities are discussed.

Lasioptera Meigen 1818.

Type species, *Lasioptera picta* Meigen (subs. des. Karsch 1877: 14; validated ICZN 1970: 75) = rubi Schrank. Refer to Gagné & Jaschhof (2021) for the detailed synonymic list of Lasioptera.

The members of the genus *Lasioptera* can be distinguished by several apomorphic features: antennae typically possessing more than 12 antennal flagellomeres; the male 7th tergite greatly reduced in size compared to 6th tergite and the gonostylus with a

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Competing interests: The authors declare no competing interests.

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strong apical claw. In females, the 8th tergite is usually longitudinally divided into two discrete sclerites; fused cerci are cylindrical, with a glabrous dorsal, saddle-shaped area, usually with prominent hooked setae, and the remainder microtrichose with scattered setae (Yukawa et al. 2019 & Gagné 2018).

Lasioptera sharma Vasanthakumar sp. nov. (Figure 1–6; Image 1–7)

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Material examined

Holotype: Ent 10/269 (on slide), 10.vii.2021, male, Mollem (15.3777°N; 74.23059°E), Goa, India, collected as gall by P.S. Bhatnagar & party, ZSI WRC, Pune.

Paratypes: 3 males (Ent 10/270), 5 females (Ent 10/271), 4 pupa (Ent 10/272), 4 pupal exuviae (Ent 10/273), 4 larva (Ent 10/274) same data as holotype.

Description: Head: Eyes connate, 4–5 facets long at the vertex, facets circular, closely adjacent. Frontoclypeal setae 30–36 in number. Palpus 3-segmented, segments successively longer, first palpal segment 21 µm, second 33–35 µm, third 36–39 µm (Figure 1). Antenna: scape, pedicel globose, densely covered with scales; flagellomeres 12–15 in male (n = 4), 17–19 in female (n = 5); first two flagellomeres partially fused, node of third flagellomere about 33–35µm, 1.2 times as long as wide (Figure 2), remaining flagellomeres except for apical rectangular, wider than long.

Thorax: Wing: length in males, 1.5 mm (n = 4); in females, 1.7 mm (n = 5) 2.2–2.4 as long as wide (Figure 3). Legs covered by dark brown scales. Tarsal claws toothed; teeth curved near the base. Empodia as long as claws (Figure 3).

Male abdomen: Tergites 1–6 rectangular with two trichoid sensilla anteriorly and row of setae posteriorly; Sclerotization of tergite 7–8 reduced to narrow band, with two anterior trichoid sensilla and no posterior setae; Sternites 2–7 quadrate with anterior pair of closely adjacent trichoid sensilla, row of strong setae posteriorly and few strong setae mesally; sclerotization of sternite 8 greatly reduced anteriorly, without anterior trichoid sensilla, with numerous strong setae mesally and posteriorly. Terminalia: gonocoxite with numerous strong setae evenly distributed ventrally, posterior two-thirds dorsally; gonostylus broadened basally, tapering apically, with scattered setae, microtrichose only basally, well- developed tooth apically; mediobasal lobe sheathing aedeagus, slightly shorter than aedeagus; cerci separated by a deep notch; hypoproct entire, shorter than aedeagus; aedeagus rounded apically, longer than cerci (Figure 5).

Female Abdomen: Tergites 1–7 as of male, tergite 8 divided into two longitudinal sclerites, each widened posteriorly with one anterior trichoid sensilla at mid -length and a few setae posteriorly. Sternites 2–7 as of male, sternite 8 not apparent. ovipositor with a laterodistal group of 42–46 curved setae; cercus with 06 large, hooked setae on dorsal saddle-shaped area and straight setae posteriorly (Image 7).

Larva (Image 2): white, with dark brown spatula; Length 1.4–1.6 mm. Antenna is about twice as long as wide. Cephalic apodemes are about twice as long as a head capsule. Spatula with a long shaft and two pointed anterior teeth separated by v-shaped notch (Figure 4). On each side of the spatula one sternal papilla and four lateral papillae, all asetose. Terminal segment with six papillae (Figure 6).

Pupa (Image 6): Orange when young, brown when mature. Length 1.6–1.9 mm. Antennal bases developed into two distinct triangular serrated horns (Image 5). cephalic setae 50–55 µm long; prothoracic spiracle elongate, curved, 87–90 µm long. Abdomen uniformly covered with tiny spicules.

Gall: Leaf gall (Image 1), sub-cylindrical or sub-globose, nearly equally developed on both sides of the leaf blade, though often the hypophyllous part is somewhat larger and narrower than the epiphyllous, yellowish- green or brown, glabrous, solid, hard, indehiscent; larval chambers 4 per gall (Image 1a); more than 10 galls per leaf; exit hole, epi or hypophyllous (Image 4); size 10–14 mm long and 5 mm thick (Mani 2000).

Etymology: The species is named in the honour of Dr. Radheshyam Muralidhar Sharma, an eminent Indian Cecidologist. The specific epithet is used here as a noun in apposition.

Host plant: *Leea indica* (Burm.fil.) Merr. (Vitaceae) commonly known as Bandicoot Berry, is an evergreen perennial shrub distributed in India, Sri Lanka, throughout South Asia, to northern Australia, Solomon Islands, New Hebrides, and Fiji. This plant has numerous medicinal properties and used for treating various diseases (Chatterjee & Prakashi 2003).

Distribution: India: Maharashtra, Pune district, Tamhini (18.4738^{0}N; 73.418^{0}E); Goa: South Goa district, Mollem National Park (15.3777^{0}N; 74.23059^{0}E).

Remarks: *Lasioptera sharma* sp. nov. differs from all other Indian species in having the following characteristics. Palpus 3-segmented, third female flagellomeres 1.2 times as long as wide, empodia longer than bend in claws, female cercus with 06 large

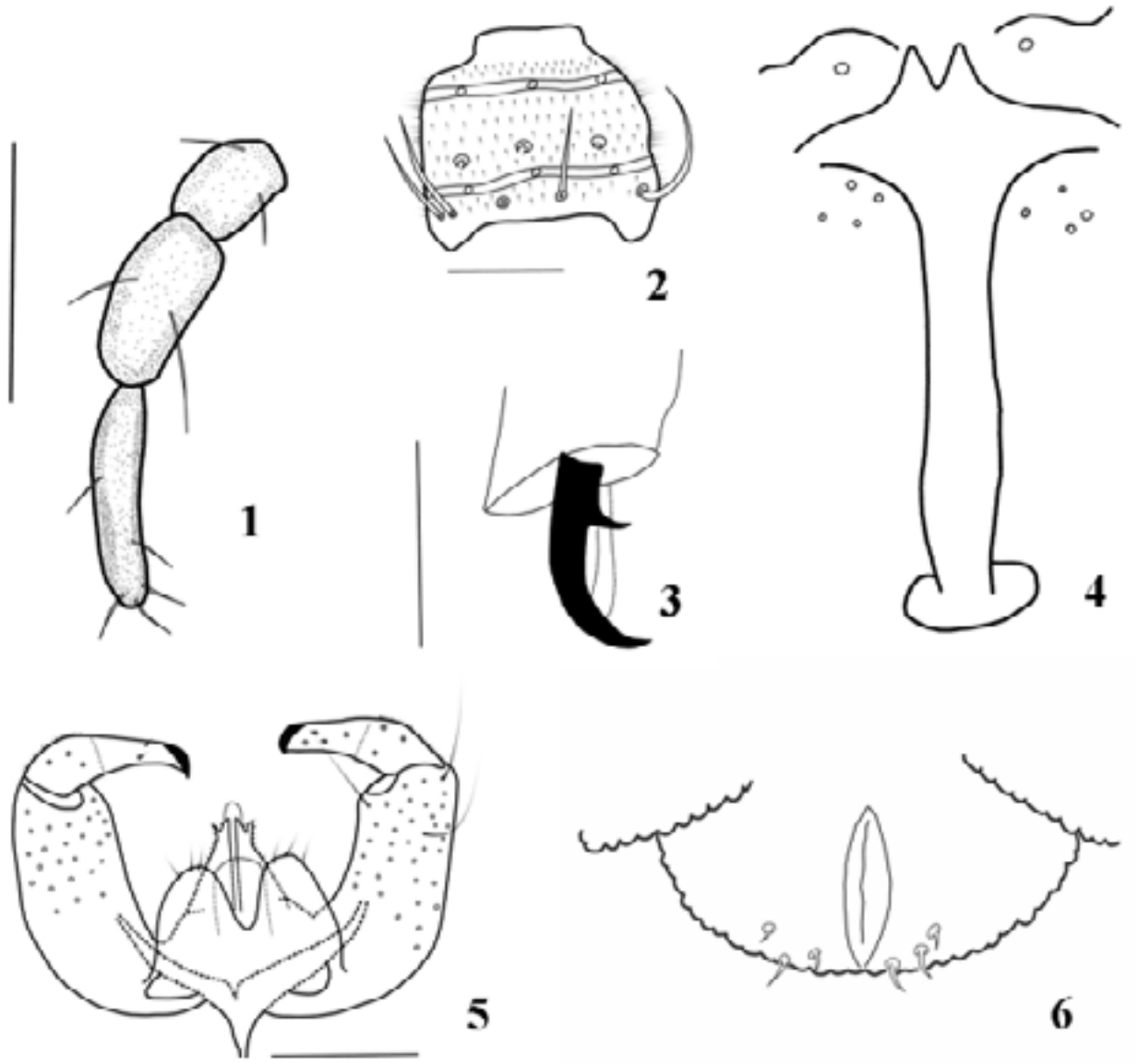

Figure 1–6. *Lasioptera sharma*, sp. nov.: 1—Palpus | 2—3rd female flagellomere | 3—tarsal claw with empodium | 4—prothoracic spatula with adjacent papillae | 5—male terminalia (dorsal) | 6—Larva, terminal segment with adjacent papillae. Scale bars = 50 µm (1,3,5); 25 µm (2).

hooked setae on dorsal saddle-shaped area, gonostylus broadened basally, tapering apically, the proportion of aedeagus, cerci, and hypoproct.

The present species is closely related to *L. manilensis* Felt 1918. However *L. manilensis* can be distinguished from *Lasioptera sharma* sp. nov., by the structure of the ovipositor, the number of hooked spines the absence of apically broadened setae on the cerci, and the proportion of third female flagellomere. Also, the galls produced by *L. manilensis* contain only one chamber whereas the galls produced by *L. sharma* contain 4 chambers. We could not compare this species with the adult male and immature stages of *L. manilensis* as the latter has been described only based on the adult female.

Lasioptera sharma sp. nov. is the first report of a *Lasioptera* species from the family Rutaceae from India. Kolesik & Gagné (2020) have mentioned in the monograph that the species of *Lasioptera manilensis* Felt, 1918 causing leaf galls on *Leea manillensis* Walp. (Rutaceae) from Philipines. A similar type of gall is also reported from *Leea indica* but no adults have been described from it (Kolesik & Gagné 2020).

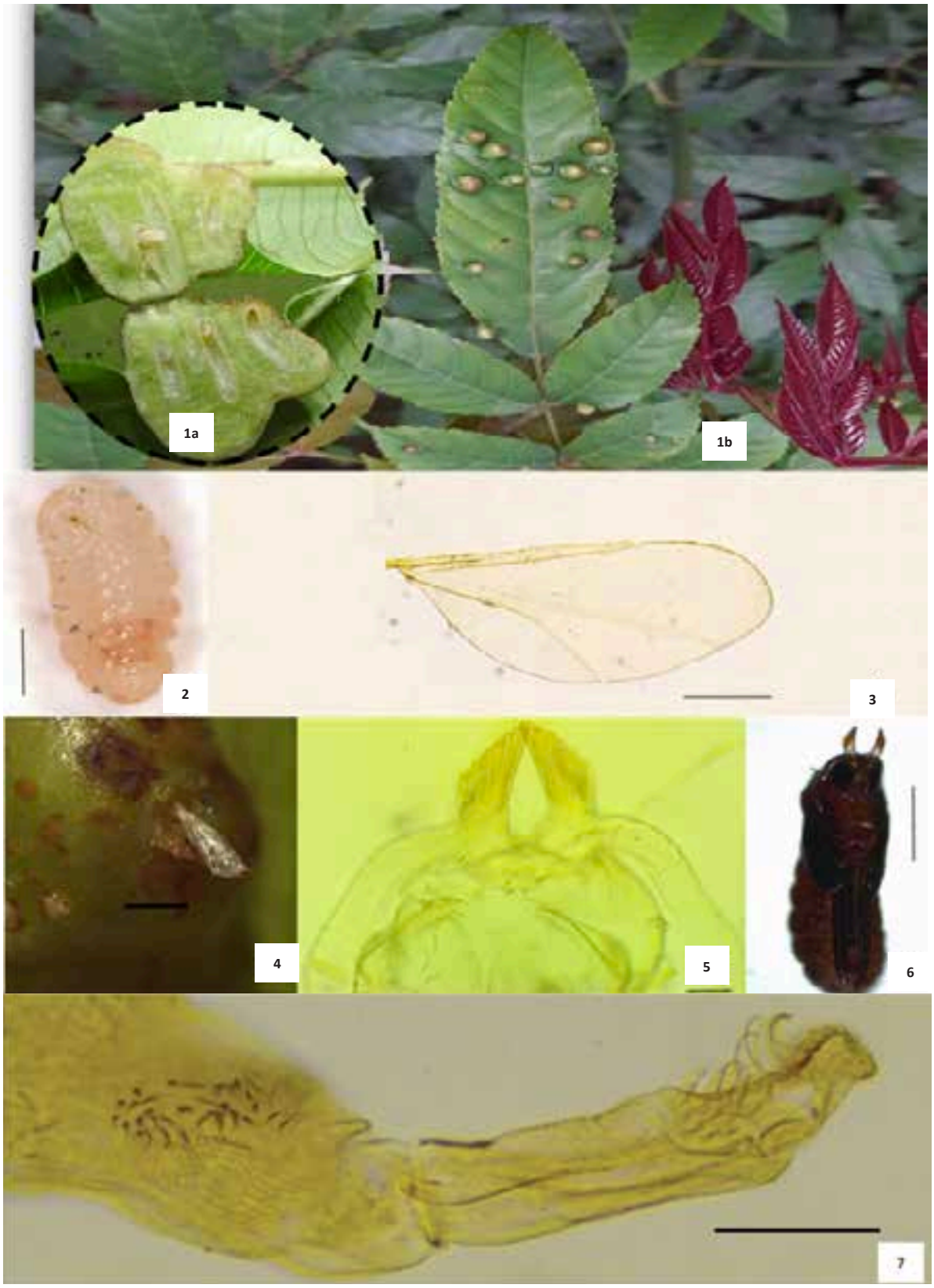

Image 1–7. 1—leaf gall | 1a—dissected gall showing larval chambers | 2—larva | 3—wing | 4—exit hole with pupal exuviae | 5—pupa showing antennal horn and prothoracic spiracle | 6—pupa | 7—end of ovipositor. Scale bars = 500 µm (2,3,4,6); 100 µm (5,7). © Duraikannu Vasanthakumar.

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SHORT COMMUNICATION

Epipogium Borkh. (Orchidaceae): a new generic record for Andhra Pradesh, India

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Abstract: *Epipogium roseum* (D.Don) Lindl., an ephemeral, achlorophyllous, mycoheterotrophic, terrestrial orchid is reported as a new state record after its first collection from the Paderu hills of Andhra Pradesh, India. Detailed descriptions, information on the type, ecology, photographs, and details of voucher specimens are provided.

Keywords: Achlorophyllous, Alluri Sitharama Raju District, Eastern Ghats, Epidendroideae, Ephemeral, Mycoheterotrophic, Paderu hills, Photosynthesis, terrestrial orchid.

Orchidaceae is the second largest family of flowering plants, with around 29,481 species found worldwide (Kumar 2024) and India has 1,256 species belonging to 155 genera (Singh et al. 2019). Orchids feature a highly specialized flower structure, and unique pollination process, a peculiar interaction with mycorrhiza, and tiny seeds that lack reserve food stores (Arditti & Ghani 2000). This fungus-dependent life of leafless orchids is known as the mycoheterotrophic mode of growth because they cannot photosynthesise due to a lack of chlorophyll pigments (Jalal & Jayanthi 2013).

The genus *Epipogium* Borkh. is an ephemeral, achlorophyllous, mycoheterotrophic, terrestrial orchid that belongs to the family Orchidaceae (Chase et al. 2015); usually grows in organic matter-rich habitats of evergreen and semi-evergreen forests and is distributed in tropical Africa, tropical & temperate Asia, Australia, and Europe (POWO 2024). So far, this genus is represented by six species: *Epipogium aphyllum* Sw., *E. japonicum* Makino, *E. kentingense* T.P.Lin & Shu H.Wu, *E. meridianum* T.P.Lin, *E. roseum* (D.Don) Lindl., and *E. taiwanense* T.C.Hsu (Wu et al. 2020; POWO 2024; IPNI 2024). India has only three species, i.e., *E. aphyllum* Sw., *E. japonicum* Makino, and *E. roseum* (D.Don) Lindl. (Kumar et al. 2019). Odisha and Tamil Nadu have *E. roseum* from the Eastern Ghats region (Truptirekha et al. 2017), hence the occurrence in Andhra Pradesh was not unexpected, however there is not report of this genus from this state (Venkaiah et al. 2020).

Materials and Methods

In July 2021, during field explorations in the Eastern Ghats of Andhra Pradesh, the first author discovered

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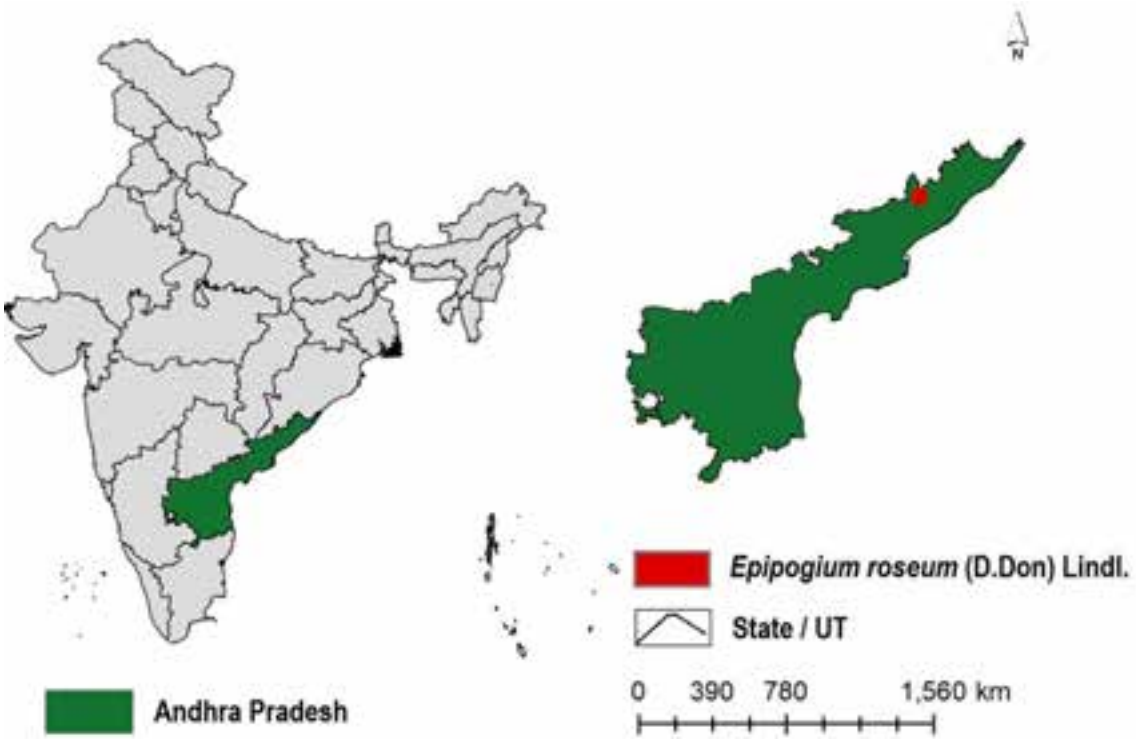

Figure 1. Location map of the *Epipogium roseum* in Andhra Pradesh.

an interesting ground orchid in bloom in the Paderu hill ranges (Figure 1). After careful examination of literature, protologue, and herbarium specimens (Lindley 1857; Prasad et al. 2019; Singh et al. 2019; POWO 2024), it was identified as *Epipogium roseum*. Notably, this genus had not been previously recorded in Andhra Pradesh, prompting the documentation of this finding as a new generic record and addition to the state's flora. A voucher specimen was prepared according to standard methods (Jain & Rao 1977) and stored in the Herbarium (AUV) at Andhra University. Photographs were captured with a Canon 500D camera, and a location map was created using ArcMap software.

Results

***Epipogium roseum* (D.Don) Lindl.** J. Proc. Linn. Soc., Bot. 1: 177 (1857). *Limodorum roseum* D.Don, Prodr. Fl. Nepal. 30. 1825; Murugan et al., Indian J. Forestry 18(2): 174. 1995. *Epigonium nutans* (Blume) Rchb.f., Bonplandia 5: 36. 1857; Hook.f., Fl. Brit. India 6: 124. 1890; C.E.C.Fisch. FL. Madras 1460. 1928. *Epipogium tuberosum* Duthie, Ann. Roy. Bot. Gard. (Calcutta) 9(2): 151.1906. *Epipogium africanus* Schltr., Bot. Jahrb. Syst. 45: 399. 1911. *Epipogium sessanum* S.N.Hegde & A.N.Rao, L. Econ. Taxon. Bot. 3: 598. 1982. *Epipogium indicum* H.J.Chowdhery, G.D.Pal & G.S.Giri, Nordic. Bot. 13: 419. 1993. (Image 2 & 3). Type: Nepal: Wallich s.n. (BM-Holotype).

Specimen examined: India, Andhra Pradesh, Alluri Sitharama Raju District, Allangiputtu Village, 18.1868°N; 82.6149°E, elevation 1,087 m, 15 July 2021, P. Janaki Rao 23400 (AUV).

Description: A terrestrial, ephemeral, achlorophyllous, mycoheterotrophic, slender, orchid, growing up to 40–50 cm in height. Rhizome tuberous, ellipsoid, wrinkled, ca. 3–4 × 2–3 cm, pale brown. Aerial stalk, slender, fleshy, hollow, ca. 10–20 × 0.6–0.7 cm, glabrous, tereteor inflated, sterile bracts ovate to lanceolate, membranous. Inflorescence racemose, ca.15–30 in number, ca. 15–20 × 0.5–0.6 cm. Fertile bracts membranous, ovate-lanceolate, ca. 1–1.3 × 0.5–0.6 cm, nerves 2 or 3 purple dotted, inconspicuous. Flowers drooping, resupinate, creamy-white with a purple tinge, not opening widely, ca. 1.3–1.5 × 0.8–0.9 cm. Pedicel ca. 0.8 × 0.1 cm, slightly recurved at the apex. Dorsal sepal linear-lanceolate or oblanceolate, ca. 0.7–0.8 × 0.2–0.3 cm, 3-nerved, apex sub-acute. Lateral sepals lanceolate, ca. 0.8–0.9 × 0.1–0.2 cm, margins slightly upcurved, apex acuminate. Petals 2, slightly shorter and wider than sepals, ca. 0.6–0.8 × 0.2–0.4 cm, obtuse or apex acute. Lip ovate-lanceolate, concave, ca. 1–1.2 × 0.6–0.7 cm, spurred at the base, margins crenulated, midvein

Image 1. a—*Epipogium roseuma* natural habitat | b—Tip of the inflorescence | c—Rhizome | d—Flower lateral view | e—Flower front view | f—Opened perianth | g—Opened lip | h—Later view of the lip with spur | i—Matured capsules | j—Close up of opened capsule showing seeds. © P. Janaki Rao & J. Prakasa Rao.

prominent, slightly lobed, two densely papillose ridges, and purple dotted. Spur ca. 0.4 × 0.2 cm, projecting backward, scrotiform or cylindrical, parallel to the ovary, fleshy, transparent. Column truncate, 0.2–0.3 cm long, anther sub-globose, pollinia 2, ovoid. Ovary broadly ovoid, 0.8–1 × 0.3–0.6 cm, creamy white, ovules many. Fruit capsule, ca. 0.9–1 × 0.5–0.6 cm, ovoid-ellipsoid, many seeded.

Flowering and fruiting: June-October, the present collection of this species along with flowering and fruiting was observed in July.

Habitat and Ecology: Rarely found in moist deciduous forest adjacent to the coffee, silver oak, and pepper plantations in Allangiputtu Village in Alluri Sitharama Raju District of Andhra Pradesh, with an association of trees like *Mangifera indica* L., *Syzygium heyneanum* (Duthie) Gamble, *Pterocarpus marsupium* Roxb., *Terminalia bellirica* (Gaertn.) Roxb., *Neolitsea foliosa* (Nees) Gamble, *Diospyros sylvatica* Roxb., *Zanthoxylum aromaticum* Miq., shrubs: *Ageratina adenophora* (Spreng.) R.M.King & H.Rob., *Colebrookea oppositifolia* G. Lodd., *Clausena heptaphylla* (Roxb.) Wight & Arn., *Lantana camara* L., *Eupatorium odoratum* L., climbers: *Clematis gouriana* Roxb. ex DC., *Clematis smilacifolia* Wall., *Clematis zeylanica* (L.) Poir., *Phanera vahlii* (Wight &Arn.) Benth., *Dioscorea pentaphylla* L., herbs; *Orthosiphon rubicundus* (D.Don) Benth., *Globba bulbifera* Roxb., and *Curculigo orchioides* Gaertn.

Distribution: Angola, Borneo, Cameroon, Fiji, Ghana, Guinea, Gulf of Guinea Is., Hainan, India, Japan, Jawa, Kenya, Laos, Lesser Sunda Is., Liberia, Malawi, Malaya, Maluku, Myanmar, Nansei-shoto, Nepal, New Caledonia, New Guinea, New South Wales, Nigeria, Pakistan, Philippines, Queensland, Solomon Is., Sri Lanka, Sudan, Sulawesi, Sumatera, Taiwan, Tanzania, Thailand, Tibet, Uganda, Vanuatu, Vietnam, Zaïre (POWO 2024). In India, it was reported from Arunachal Pradesh, Himachal Pradesh, Jammu & Kashmir, Karnataka, Kerala,

Image 2. Herbarium of *Epipogium roseum* (D.Don) Lindl. © P. Janaki Rao & J. Prakasa Rao.

Maharashtra, Meghalaya, Mizoram, Odisha, Sikkim, Tamil Nadu, Uttarakhand, West Bengal (Kar et al. 2017; Prasad et al. 2019; Singh et al. 2019).

Discussion

The distribution of *E. roseum* is quite diverse, ranging from tropical to chilly temperate climates of India, and rarely found in the Eastern Ghats region of Tamil Nadu, Odisha, and Andhra Pradesh (present report) between 900–3,000 m (Kuruppusamy et al. 2009; Jalal & Jayanthi 2013; Kar et al. 2017).

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SHORT COMMUNICATION

Physcomitrium eurystomum Sendtn. (Funariaceae): a rare species recorded for Assam, India

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Abstract: In this study, distributional record of the moss *Physcomitrium eurystomum* Sendtn. for the state of Assam is established for the first time. Taxonomic description and illustration of the same, based on specimens collected from Kamrup and Morigaon districts of the state are provided.

Keywords: Collection, cotton, distribution, exploration, flora, habitat, Indo-Burma hotspot, Kamrup, moss, specimen.

The moss genus *Physcomitrium* (Brid.) Brid. (Funariales: Funariaceae) has 80 species spread across wet and cool areas of the world (Bansal & Srivastava 2017) and 13 species belonging to this genus were reported from India (Dandotiya et al. 2011). Eastern India and the Gangetic Plains have been reported to be home to seven different species of this genus (Gangulee 1974). Six species within the genus were found in Eastern Himalaya and Punjab (Gangulee 1974; Lal 2005), followed by the Gangetic Plains and western Himalaya with five species each (Gangulee 1974; Alam 2013; Schwarz 2016), four species from the Western Ghats (Daniels 2010; Schwarz 2016; Bansal & Srivastava 2017). Five species of the genus—*Physcomitrium acuminatum*, *P. brevinervis, P. japonicum, P. pulchellum*, and *P. repandum*—were reported from the state of Assam (Dandotiya et al. 2011).

Physcomitrium eurystomum Sendtn. was reported from eastern Himalaya by Lal (2005), but the precise location of its occurrences was not specified. Manju et al. (2023) reported this rare species from the Western Ghats of Kerala stated "It is also known to occur in Lower Bengal and Assam in northeastern India and Parasnath Wildlife Sanctuary in Jharkhand in central India (Saha & Singh 2020)". However, Saha & Singh (2020) never reported the species from Assam. In India, the species is known from Hoogli & Burdwan in West Bengal, Kumaon in Uttarakhand (Gangulee 1974), Jharkhand (Saha & Singh 2020), Kerala (Manju et al. 2023), Banswara (Rana 2020), and Manipur (Dandotiya et al. 2011; Govindapyari et al. 2012; Asthana et al. 2021). Though Schwarz (2016) listed this species from Assam, but without any specific locality and literature or specimen reference. The present collection of *Physcomitrium eurystomum* from the Cotton University campus and the vicinity of Chandubi lake of Kamrup and Ahatguri of Morigaon district of Assam, therefore, for the first time authentically establishes its record from the state.

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Image 1. Physcomitrium eurystomum Sendtn: A—Habit | B–C—Single plant with Sporophyte | D–E—Leaves | F—Sporophyte | G—Capsule with operculum | H—Apical leaf portion | I—Basal leaf cells | J—Operculum | K—Calyptra | L—Median leaf cells | M—Dehisced Capsule enlarged view | N–O—Spores. © Twinkle Chetia.

In the present communication, detailed illustrated description of the species is provided with notes on its habitat and distribution within and outside.

Materials and Methods

Extensive bryofloristic exploration in the Kamrup district since 2020 till 2023 was conducted. The sporophyte-bearing plants of *Physcomitrium eurystomum* were collected from the study area, where these species grew abundantly from November to February. The specimens were collected and field observations were recorded based on the methodology provided by Glime (2017) and digital photographs of the habit and habitat were taken using a digital camera (Nikon, D-5600). The parts of the plant were dissected using a Stereo Zoom dissecting microscope, and further study was carried out using compound light microscope, and their size were measured using an Ocular micrometer (ERMA) by calibrating with a known scale provided by a Stage micrometer (ERMA) to ensure the accuracy of the measurement. Taxonomic literature (Rana 2020; Saha & Singh 2020; Manju et al. 2023) were consulted to determine the identity of the species. Voucher specimens were prepared following Glime & Wagner (2017). One set of the specimens are kept in the Herbarium of the Department of Botany, University of Delhi (DUH) and the duplicates in the Herbarium of the Department of Botany, Cotton University.

Results

Taxonomic enumeration

Physcomitrium eurystomum Sendtn., Denkschr. Bayer Bot. Ges. Regensburg 3: 142. 1841; Bansal & Alka Srivast., Caryologia 70(2): 121. 2017; Saha & D. Singh, Indian J. Forest. 43(4): 343. 2020.

Small moss, grows in groups or open tufts, 3–7 mm long, bright green when young, yellowish-green at maturity, and turns light to dark brown in herbarium. Stems simple, short, erect, slender, base with many rhizoids. Rhizoids brownish, few at older part of stem, many at leaf base and ventral surface. Leaves frequently clustered at stem ends, oblong-obovate, rosulate, erecto-patent to erect-spreading when moist, shrunk when dry, larger at upper stems, 3.0–3.5 × 1.0–1.4 mm, smaller at lower stems, 1.0–1.7 × 0.3–0.7 mm, acute or shortly apiculate at apex; margins serrulate in the upper part, entire in the basal part; apical-leaves 40–60 × 18–27 µm, median-leaves 35–70 × 20–25 µm, leaf cells hexagonal to oblong-hexagonal to elliptic-hexagonal; basal cells large, 90–135 × 20–40 µm, rectangular; marginal cells sublinear, narrow elongated, 140–150 × 10–12 µm; costa strong, slender, yellowish, extending to the apex or short excurrent. Setae light yellowish to yellowish-brown, 1600–1750 × 120–125 µm, somewhat flexuose, slender. Capsules subspherical, short pyriform, green when young, reddish brown when mature, 1.1–1.3 × 0.9–1 mm, mouth wide, neck short; operculum rostellate, conical convex, c. 0.8 mm in diameter; annuli narrow; peristome absent; calyptra c. 2 mm, inflated-mitrate, long–rostrate, conical, easily dropping off before the capsules reached their full maturity. Spores irregularly spherical, spinulosely papillose, blackish-brown, 26–32 µm in diameter.

Habitat: The species was observed in shady, moist, muddy soil in association with grasses, and herbs.

Distribution: India [West Bengal (Hoogli, Burdwan), Uttarakhand (Kumaon) (Gangulee 1974); Jharkhand (Parasnath WS) (Saha & Singh 2020); Kerala (Iduki district) (Manju et al. 2023); Rajasthan (Banswara) (Rana 2020); Assam—present study; Manipur (Dandotiya et al. 2011; Govindapyari et al. 2012; Asthana et al. 2021), Belarus (Maslovsky 2005), Bulgaria (Sabovljević et al. 2001), Hungary (Papp et al. 2010), Great Britain (Hodgetts 2011), Montenegro (Stešević et al. 2020), Romania (Sabovljević et al. 2001), Slovenia (Sabovljević et al. 2001), and Turkey (Sabovljević et al. 2001).

Specimens examined: INDIA. Assam: Kamrup, Chandubi, 25.507^{0}N, 91.2292^{0}E, 11 September 2021, T. Chetia 113 (DUH!, Herbarium of Department of Botany, Cotton University); Kamrup Metro, Cotton University, 26.186°N, 91.7500°E, 26 December 2022, T. Chetia 259 (DUH!, Herbarium of Department of Botany, Cotton University); Morigaon, Ahatguri Natua Gaon, 26.2657°N, 92.3160°E, 30 December 2022, T. Chetia & H. Roy 260 (Herbarium of Department of Botany, Cotton University!).

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NOTE

First photographic evidence of Mainland Serow *Capricornis sumatraensis thar* (Bechstein, 1799) in Raimona National Park, Assam, India

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The Mainland Serow *Capricornis sumatraensis thar* is present across various habitats extending from the Himalayas on the Indian subcontinent to southern China, mainland southeastern Asia, and Sumatra (Groves & Grubb 2011; Choudhury 2013; Mori et al. 2019). Despite their widespread distribution, studies showed that Mainland Serow is highly restricted to rugged terrains between the mid- to high-elevation ranges between 200 to >2,000 m (Carr et al. 2023) and avoids human settlements (Phan et al. 2019). Listed as 'Vulnerable' by the IUCN Red List (Phan et al. 2020), the species' populations are fragmented, isolated, and rapidly declining due to poaching, habitat destruction, and habitat loss. The lack of reliable data on this species' abundance and distribution makes it difficult to implement effective conservation actions to ensure long-term survival (Phan et al. 2020; Carr et al. 2023). In the Indian subcontinent, Mainland Serow is widely distributed across community forests and protected areas of India, Nepal, Bhutan, and Myanmar, from 100 m (Choudhury 2013) up to an elevation of 3,500 m (Phan et al. 2020). In Bhutan, the species is documented both

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Image 1. Mainland Serow *Capricornis sumatraensis thar* was photo-captured in the Ripu-Chirang Forest Complex (presently Raimona National Park), Bodoland Territorial Region (BTR), Assam, India (29 December 2020) at an elevation of 96 m. © Department of Environment and Forests, BTC, and Aaranyak.

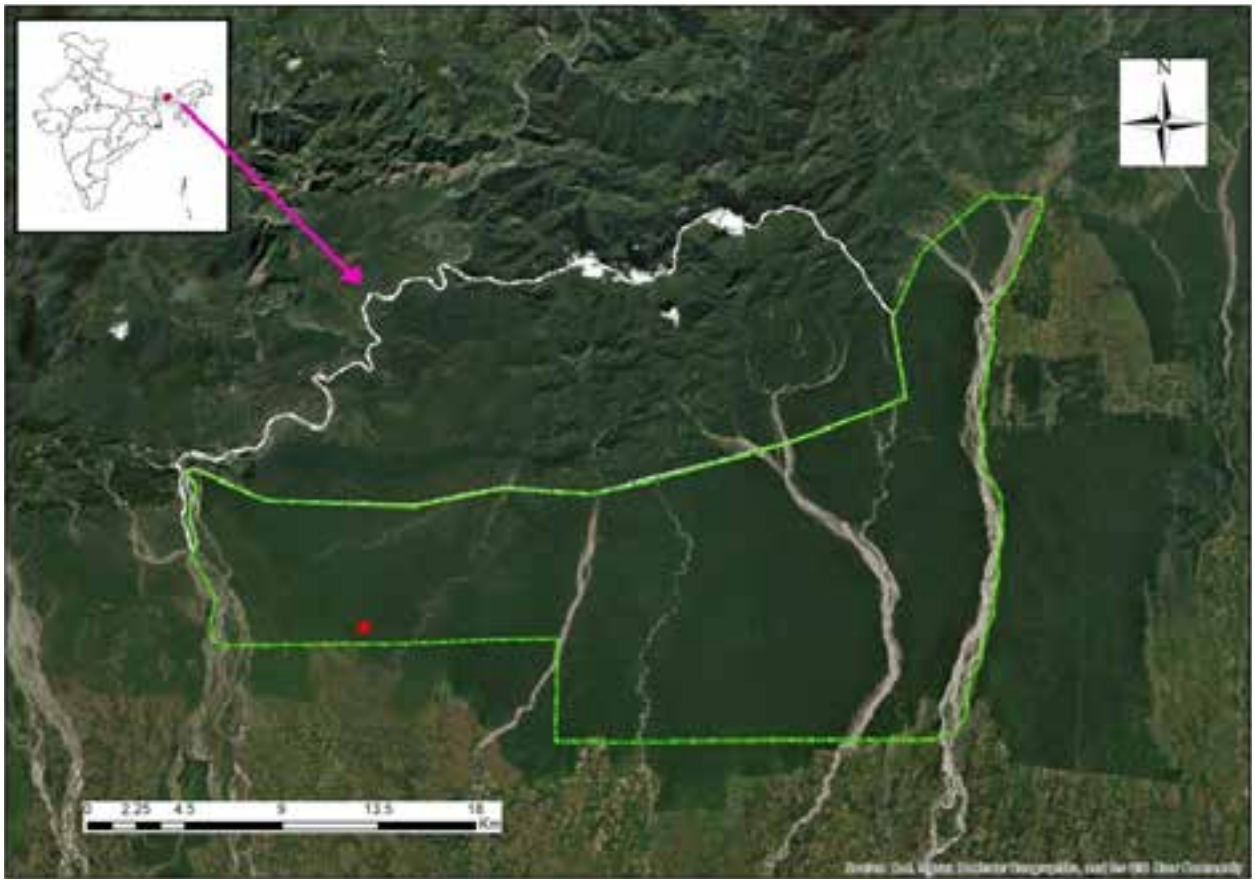

Image 2. The map shows the photo-captured location of Mainland Serow *Capricornis sumatraensis thar* in Raimona National Park located in the Bodoland Territorial Region (BTR) of Assam, India (29 December 2020).

in non-protected areas (e.g., Lamai Goempa Research Preserve of central Bhutan (Dhendup et al. 2019) and in protected areas (e.g., Royal Manas National Park, Phibsoo Wildlife Sanctuary and Jomotsangkha Wildlife Sanctuary (Ahmed et al. 2016, 2019; DoFPS 2023), that share contiguous forest with India, in the Transboundary Manas Conservation Area (TraMCA). In India, the species is continuously distributed across the Himalaya

from Jammu & Kashmir to Arunachal Pradesh's Mishmi Hills (Roy et al. 2020; Ahmad & Gopi 2024).

This study presents a photographic record of the species from a newly declared protected area in western Assam. The Assam government declared the area a national park on 08 June 2021. The area was severely impacted by ethnopolitical violence for nearly three decades, beginning in the late 1980s, until peace was restored with the declaration of the Bodoland Territorial Council (BTR) in 2020. The present camera trapping survey was carried out between 06 December 2020 and 05 January 2021 in Ripu Reserve Forest (presently Raimona National Park (RNP), contiguous with Phibsoo Wildlife Sanctuary of Bhutan, and is located in the western end of the India-Bhutan Manas Transboundary Conservation Area (TraMCA).

With the camera trapping effort of 2,542 trap-days using white flash passive Panthera (New York, USA) V6 digital camera traps, Mainland Serow was recorded in two independent events on 29 December 2020 at 0912 h and 1346 h, respectively, at an elevation of 96 m (Image 1), near Ganda Bajrum Anti-poaching camp (26.672N & 89.944E) located in the Western Range (Raimona) of RNP (Image 2). Ganda Bajrum Anti-poaching camp is just 1 km apart from the nearest settlements. This is the first photographic evidence of Mainland Serow in the RNP.

Mainland Serow is widely distributed in the neighbouring Phibsoo Wildlife Sanctuary (Tenzin et al. 2022) and Royal Manas National Park (Ahmed et al. 2016) of Bhutan, which may support population recovery in RNP. Contrary to previous records, the current photographic evidence of Mainland Serow is likely the lowest elevation record from the Indian sub-continent and is close to human settlements, suggesting that more studies on habitat associations are necessary. Previously, the species was recorded between the elevation of 100–300 m in Assam (Choudhury 2003). However, there are no studies on the species' habitat requirements in this region, which is crucial for considering species-specific conservation actions. Occasional poaching for bushmeat and habitat alteration due to logging during the ethnopolitical violence are the primary conservation concerns of the RNP. With the government now protecting the park, future conservation efforts should consider securing and recovering the species' population and restoration of the degraded habitats.

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NOTE

Design and field installation of automated electronic Asian Elephant signage for human safety

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The Human-elephant interactions have intensified exponentially over the years across tropical and subtropical countries of Asia and Africa. As human habitation is gradually overtaking the traditional elephant territories, the conflicts become more regular and extreme. The conflict not only causes financial turmoil in those remote areas, but it also causes fatal injuries and even deaths of both humans and elephants (Shaffer et al. 2019). When associated with India, the number of human deaths due to elephant attacks is significantly high and is a serious concern (Nath et al. 2009). One of the major reasons for such high numbers of human deaths is 'surprising human-elephant encounters' at remote elephant crossing points during night hours. Even though elephant corridor locations are mostly precise, it's difficult to identify them in the dark even for the locals. Whereas for outsiders, either in a vehicle or on foot, it's like moving through a deadly conflict zone without any hint of danger. Some of the crossing points are marked mostly with retroreflector signboards by the forest department and NGOs. Since they don't possess inherent luminescence, these objects remain invisible from a distance at night and require a specific angle of vehicle headlights to be illuminated (Karanth & Ranganathan 2018). Along with financial loss due to crop raids, such human death creates a terrifying and tense environment in those remote pocket areas which sometimes counter-fire by the killing of elephants through poison and electrocution (Panda et al. 2020). One of the possible solutions to neutralize the situation is to demark the elephant crossing points with electronic elephant signage (EES). The EES is an elephant-shaped light that glows during the night to warn vehicles and people about the specific location of the elephant crossing points and thus help them to take proactive measures to avoid any potential conflict. This innovative solution has the potential to significantly reduce human-elephant interactions, saving lives and preserving the delicate balance of our ecosystems.

The iterative co-designed Indigenous EES is pragmatic and aesthetic to be Indigenous-specific and relevant in this practical real-world application (Image 1) with a 12-in. x 12-in. x 2-in. (H x L x W) waterproof plastic enclosure with a LASER cut elephant shape as the front cover. This device is shown as a block diagram in Figure 1 and contains an integrated solar panel, battery, and electronic circuits. This has a darkness sensor that turns on the unit at night, where it flashes every second

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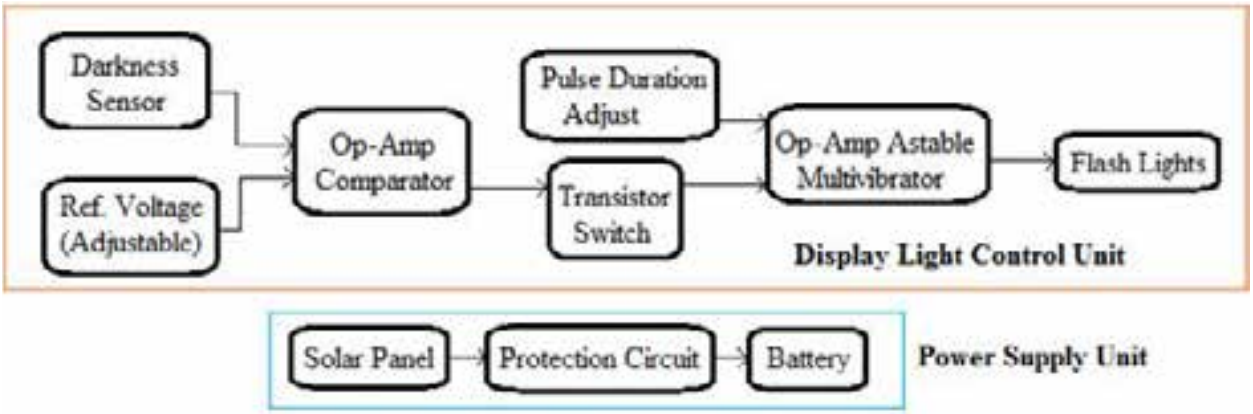

Figure 1. Circuit block diagram for electronic elephant signage.

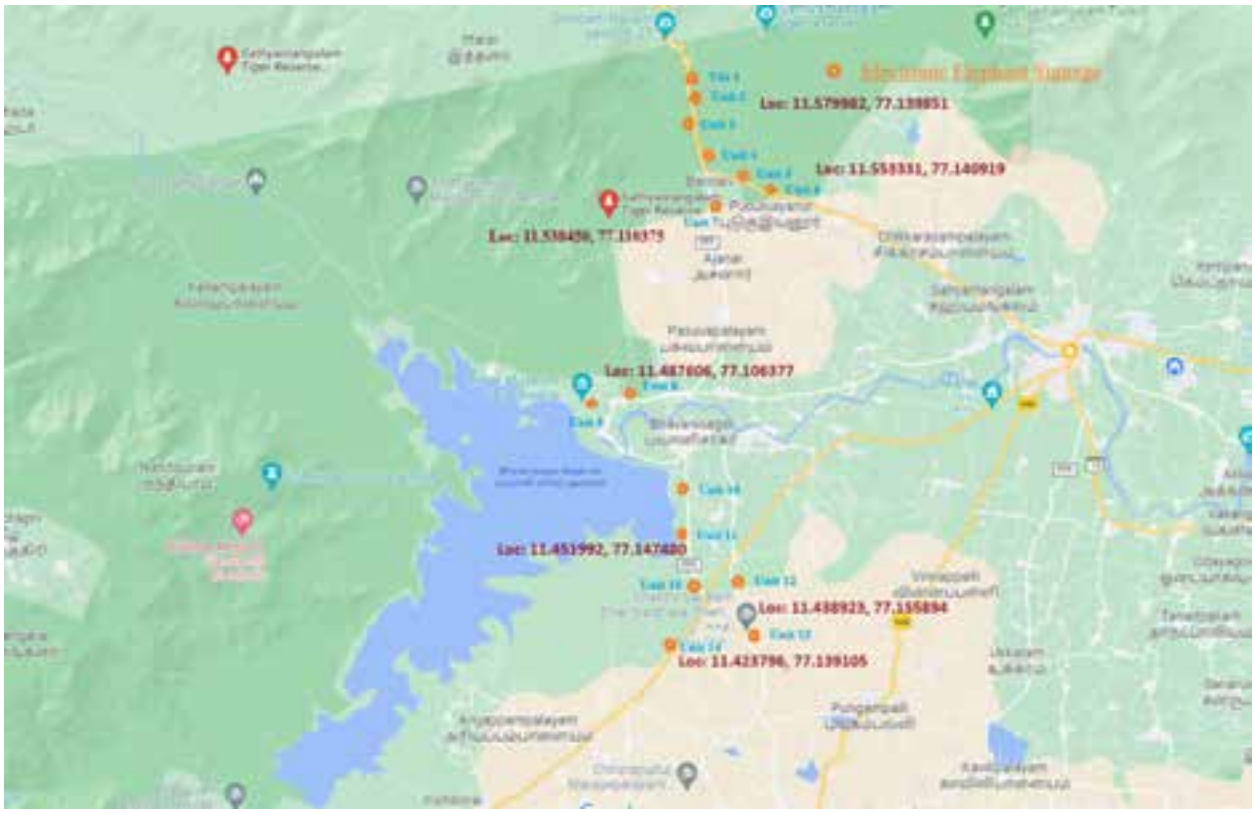

Figure 2. Locations of fifteen electronic elephant signage in the Sathyamangalam Tiger Reserve (STR) area.

until being turned off in the sunlight so that it can get people's attention from a far distance without running all day on battery. The 'reference voltage adjusting' potentiometer is to set the switching on-off time and the 'pulse duration adjustment' potentiometer is to adjust the on-off duration of the light. The signage has four sets of 0-watt red LED lights, each set containing four lights. A red glossy reflector sheet on the back boosts the light intensity.

A manual control switch is given for the user to make the signage 'on' or 'off'. The overall weight of the signage is 1.1 kg therefore it can be easily clamped over any pre-existing structures (pole, wall, and even on the tree wood) and thus extremely suitable for field installation. Even though it is relatively small, it's extremely bright and technically superior to any other existing comparative design. This innovative EES, designed and developed entirely in India, stands out for its affordability (Rs. 1,600

Image 1. Rooftop testing and trial run of EES for three days before taking to the field. © Sanjoy Deb.

Image 2. Glowing full elephant shape EES during the night at STR. © Sanjoy Deb.

Image 3. Glowing elephant head shape EES during the night at STR. © Sanjoy Deb.

Image 4. Installation of EES with support from the forest department at Velamundi, Bhavanisagar, and Sathy ranges of STR. A—Unit 2 Location 11.438163 N, 77.14556 E | B—Unit 7 Location 11.425191 N, 77.135714 E | C—Unit 8 Location 11.434828 N, 77.136601 E. © Sanjoy Deb.

INR/unit) and unique features. The built-in darkness sensor and control circuit automatically adjusts lighting based on ambient light, optimizing energy usage and reducing operating costs compared to passive non-self-glowing signage. Its user-configurable settings further enhance its adaptability and value.

The Sathyamangalam Tiger Reserve (STR), which is one of the prime human-elephant interphase hotspots on the Indian map, is selected for electronic elephant signage installation under the present project. The NH948 and the number of state highways form a mesh-like structure that spreads through forest buffers and core areas. There are hundreds of elephant crossing points over the forest road network. Moreover, there are hundreds of elephant activity zones in remote village areas that are scattered all over the STR. The spot identified for signage installation in the STR area after consecutive field surveys with the forest department at 15 elephant crossing points, as shown in Image 1. Images 2–4 show various stages of the EES installation project such as design testing and field installation. The devices were installed in September 2023 and have been running successfully ever since. The radiant elephant signage has received praise from residents, nature lovers, the Forest Department, and other stakeholders. Common questions address the night time visibility, the placement of the signs, and the response time to visual notifications. The feedback from readers is greatly appreciated and will be considered in future iterations of the electronic elephant signage.

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NOTE

First nesting record of Black-necked Stork *Ephippiorhynchus asiaticus* (Aves: Ciconiiformes) in Kumana National Park, Sri Lanka

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Black-necked Stork *Ephippiorhynchus asiaticus* is a rare breeding resident in Sri Lanka evaluated as a Critically Endangered bird species on the International Union for Conservation of Nature (IUCN) Sri Lanka Red List. It is confined to the low-country dry zone, especially to a narrow region in the southern and eastern coastal areas of Sri Lanka (Henry 1998). Kumana National Park (KNP) (6.500–6.700 N, 81.067–81.250 E), which is also a Ramsar wetland site, is an important protected area with a high diversity of avifauna (Rathnayake et al. 2012). Black-necked Stork, the tallest bird found on the island, is one of the distinct species in the park's rich assemblage of aquatic avifauna (Dewasurendra et al. 2013) and the population is less than fifty within Sri Lanka according to the IUCN Red List. Although juveniles of Black-necked storks have been observed, a nest of Black-necked stork has not been recorded within the country to this date.

The study was conducted from August 2022 to August 2023. Nesting locations were searched among the trees within the park (Choudhary et al. 2011; Chowdhury & Sourav 2012) covering all the habitat types including lagoons, inland waterbodies, villu, rocky outcrops, sand dunes, and forests. In an expansion of four consecutive days per month, observations were conducted using binoculars during three time periods per day morning (0600–0959 h), mid-day (1000–1359 h), and evening (1400–1800 h) (Aryal et al. 2009). Following the identification of a nest, the nest's material, shape, diameter, height above the ground, position in the canopy, and active or inactive status were recorded.

An active nest of Black-necked stork was confirmed in KNP in a forest patch adjacent to the 'Kudawila' inland waterbody (6.584 N & 81.735 E) (Image 1) in January 2023. A flying Black-necked Stork that was carrying a stick from the bank of the inland waterbody was tracked and the nesting tree was located based on the observations of this nest-building behaviour. The nest was positioned on top of a Tamarind Tree *Tamarindus indica* which is one of the tallest trees in the forest patch with a height of ~24 m and DBH of 1.8 m. The nest exhibited a large, oval shape, measuring approximately 199 cm in diameter and 68 cm in depth. It was made of a mass of sticks from the outside (Image 2). The nesting tree was located 624.71 m away from the jeep trail and

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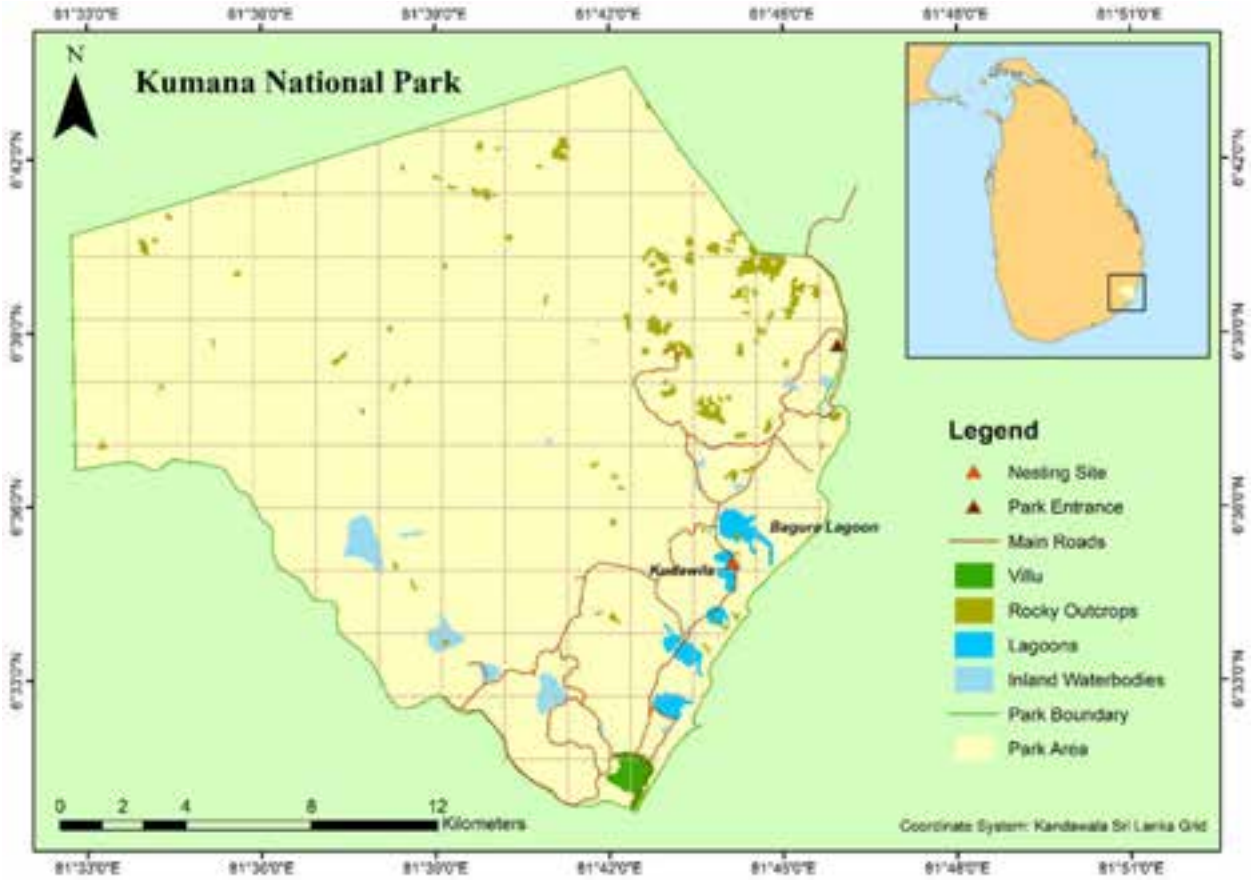

Image 1. Map of KNP with the nesting site of Black-necked Storks.

adjacent to a freshwater body. At the time of recording, the distance from the nest to the water level of the water body was measured at 388.27 m.

Since the first nest-building observation in January 2023, a male Black-necked Stork was consistently observed occupying the nest during January, February, and April, while the female bird was observed in March (Image 03) (Figure 1). During the study period, only two males and one female bird were observed within the park area. The presence of the female on the nest indicates that despite the critically low number of individuals in this population, they have successfully paired for breeding. The progression of the nest was observed by comparing photographs taken in previous months. The birds were observed standing inside the nest or on its periphery at various times.

This is the first published observation of the nesting behavior of Black-necked Stork in Sri Lanka. The park's sparse population of these birds, coupled with the discovery of the nest, underscores the critical need to preserve their habitat. When compared to the colonial nesting characteristics of Lesser Adjutant Storks, Openbills, and Painted Storks, Black-necked Storks build individual nests (Urfi et al. 2007; Katuwal et al. 2022). These observations are confirmed by the fact that only one Black-necked Stork nest has been recorded in the area. The Black-necked Stork chose a taller and larger tree for nesting, in comparison to the recorded height (17.07 m ± 5.66) and the DBH (98 cm ± 37.78) of the nesting trees of the lesser adjutant stork (Katuwal et al. 2022). These measures are compatible with the body size of the Black-necked Stork, enabling to effortlessly reach the nesting sites with broad wingspan. Their choice of a lofty tree for nesting highlights their preference for undisturbed natural environments, emphasizing the importance of safeguarding these nesting sites and the pristine forest areas, particularly the towering trees within them. Furthermore, the decline in the Black-necked Stork population can be attributed to factors like habitat loss, fragmentation, habitat conversion, and human disruptions. Since a very small population is present in Sri Lanka, it is important to manage and conserve their occupied habitats especially their foraging grounds, and nesting sites. In the absence

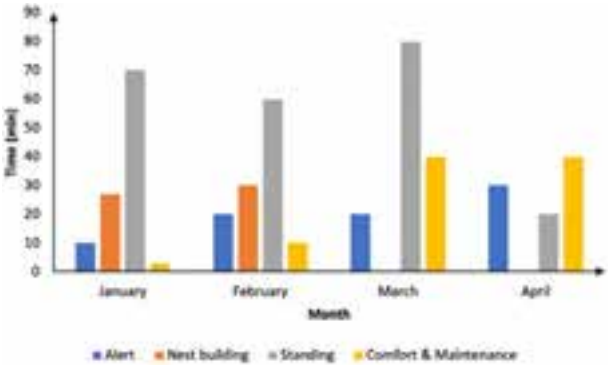

Figure 1. Activities of Black-necked Stork on the nest.

Image 2. Nest of Black-necked Stork.

Image 3. Nesting behavior of Black-necked Stork.

of no other nesting records for the species from Sri Lanka, this finding is important and provides valuable insights to expand the conservation measures for this 'Critically Endangered' bird and its associated habitats. The study will be continued and full details about habitat preference and nesting characteristics of the Black-necked Stork will be published in a forthcoming paper.

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Mugger Crocodile *Crocodylus palustris* (Lesson, 1831) predation on Brown Fish Owl *Ketupa zeylonensis* (J.F. Gmelin, 1788), with notes on existing literature regarding their predation on birds

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The Mugger Crocodile *Crocodylus palustris* (Lesson, 1831) is a medium-sized crocodile distributed across the Indian subcontinent and bordering regions. It is listed as a CITES Appendix I species and considered 'Vulnerable' by the IUCN Red List (Choudhury & de Silva 2013). Researchers have reported it to be a generalist predator, with its diet at various age classes including invertebrates, fish, amphibians, reptiles, birds, and mammals (Whitaker & Whitaker 1989; Bhatnagar & Mahur 2010).

On 23 March 2023 at 0814 h, the authors were rounding a bend on the Girwa River in Bardiya National Park, Nepal (28.4719 N, 81.2468 E), when an observation of a Brown Fish Owl *Ketupa zeylonensis* (J.F. Gmelin, 1788) wading in shallow water at the river's edge was made. At that moment, a Mugger Crocodile burst from the water and caught the owl in its jaws. Upon securing the bird, the crocodile appeared to respond to the authors' presence by swimming away and concealing itself beneath the cover of a submerged tree. The owl was confirmed as a Brown Fish Owl by Valia Pavlou of the Natural History Museum of Crete due to the pattern of the feathers (Valia Pavlou pers. comm. 25.i.2024). Photographic vouchers of the crocodile with the owl were deposited in the Zoological Reference Collection (ZRC) of the Lee Kong Chian Natural History Museum.

A literature review of observations of birds in the diet of Mugger Crocodiles reveals several instances. Battye (1945) witnessed a crocodile taking a struggling "whistling-teal" that he had just shot in a lake in Basur, Bastar State (modern-day Chhattisgarh, India). Whitaker (1978) reported Cattle Egret *Bubulcus coromandus* feathers in crocodile dung in Gir National Park, Gujarat, India. Whitaker & Whitaker (1989) cited "various authors" as reporting mugger predation on "egrets, herons, kites, waterhens, peacocks, dabchicks, and pigeons", later specifying the Brahminy Kite *Haliastur indus* in particular. A scat study by Kumar et al. (1995) in Manjira Wildlife Sanctuary, Andhra Pradesh, India, found feathers of Cattle Egret, Little Cormorant *Microcarbo niger*, and Eurasian Coot *Fulica atra* in crocodile dung. The authors of that study also observed direct predation on an Eurasian Coot and Purple Moorhen *Porphrio porphrio.* Jayson et al. (2006) reported that reintroduced Mugger Crocodiles in the Neyyar Wildlife Sanctuary of Kerala, India, predated domestic ducks. Venugopal (2006) observed Mugger Crocodiles feeding on a struggling Painted Stork *Mycteria leucocephala* and the

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Table 1. Documentation of Mugger Crocodile predation on birds.

Authors	Region	Bird species predated	Evidence
Battye 1945	Barsur, Chhattisgarh, India	"Whistling-teal" *Dendrocygna sp.*?	Direct observation
Whitaker 1978	Gir National Park, Gujarat, India	Eastern Cattle Egret *Bubulcus coromandus*	Scat samples
Whitaker & Whitaker 1989	Unspecified	Egrets and herons (Ardeidae) Waterhens (Rallidae) Indian Peafowl *Pavo cristatus* "dadchicks" Little Grebe *Podiceps ruficollis* Pigeons (Columbidae) Kites (Accipitridae)	"various authors"
Kumar et al. 1995	Manjira Wildlife Sanctuary, Andhra Pradesh, India	Little Cormorant *Microcarbo niger* Eurasian Coot *Fulica atra* Eastern Cattle Egret *Bubulcus coromandus*	Scat samples
Kumar et al. 1995	Manjira Wildlife Sanctuary, Andhra Pradesh, India	Purple Gallinule *Porphyrio martinica* Eurasian Coot *Fulica atra*	Direct observation
Jayson et al. 2006	Neyyar Wildlife Sanctuary, Kerala, India	Domestic Duck *Anas platyrhynchos domesticus*	Unspecified
Vengopal 2006	Ranganthittu Bird Sanctuary, Karnataka, India	Painted Stork *Mycteria leucocephala* Black-crowned Night Heron *Nycticorax nycticorax*	Direct observations
Bhatnagar & Mahur 2010	Baghdarrah Lake, Udaipur, Rajasthan, India	Eastern Cattle Egret *Bubulcus coromandus* unspecified birds	Direct observations
Vyas 2012	Vishwamitri River, Vadodara City, Gujarat, India	Little Cormorant *Microcarbo niger* Indian Pond Heron *Ardeola grayii* Eastern Cattle Egret *Bubulcus coromandus* Black-crowned Night Heron *Nycticorax nycticorax* Red-wattled Lapwing *Vanellus indicus* Black-winged Stilt *Himantopus himantopus* White-breasted Waterhen *Amauronis phoenicurus* Rock Pigeon *Columba livia*	Direct observations
Dinets et al. 2013		Intermediate Egret *Ardea intermedia*	Direct observation
Nala et al. 2017	Gir National Park, Gujarat, India	Unspecified birds	Scat samples
Vaghashiya et al. 2020	Girnar Wildlife Sanctuary, Gujarat, India	Eurasian Coot *Fulica atra*	Direct observation with photograph
Dave & Bhatt 2021	Anand district, Gujarat, India	Unspecified birds	Scat samples
Chavan & Borkar 2023	Savitri River, Maharashtra, India	"egrets and herons predominantly" (Ardeidae)	Direct observations with one photograph
This report	Bardiya National Park, Nepal	Brown Fish Owl *Ketupa zeylonensis*	Direct observation with photograph

fallen chick of a Black-crowned Night Heron *Nycticorax nycticorax* in Ranganthittu Bird Sanctuary, Karnataka, India.

Vyas (2012) recorded crocodile predation on Little Cormorants, Cattle Egrets, Black-crowned Night Herons, Indian Pond Herons *Ardeola grayii*, Red-wattled Lapwings *Vanellus indicus*, Black-winged Stilts *Himantopus himantopus*, White-breasted Waterhens *Amauronis phoenicurus,* and Rock Pigeons *Columba livia* in the Vishwamitri River in Gujarat, India. Nala et al. (2017) reported finding bird feathers in eight out of 100 scat samples in Gir National Park, Gujarat. Vaghashiya et al. (2020) observed an adult Mugger feeding on a Eurasian Coot *Fulica atra* in the Girnar Wildlife Sanctuary in Gujarat. Dave & Bhatt (2021), working in various locations in the Anand district of Gujarat, found bird feathers in 11% of scat samples during the hot season, 20% during the monsoon season, and 27% during the winter season. Chavan & Borkar (2023) report that 18% of Mugger Crocodile prey items in the Savitri River of Maharashtra, India were birds, predominantly egrets and herons. That study also detailed flight initiation times in response to the Mugger approach for 26 bird species across 11 families and suggested that crocodiles were using sticks as bait in order to lure birds closer to them. The results of this review are summarized in Table 1.

The observation thus represents the first published record of Mugger Crocodile predation on an owl (Raju Vyas pers. comm. 8.i.2024; and this review). This event is well-situated within the recorded literature of bird predation by Mugger Crocodiles, which primarily encompasses medium-to-large bird species associated with water—specifically wading birds, large shorebirds, rails, ducks, and aquatic-feeding raptors.

The literature survey also suggests that birds are a regular but not dominant feature of Mugger Crocodile diets in many parts of their range.

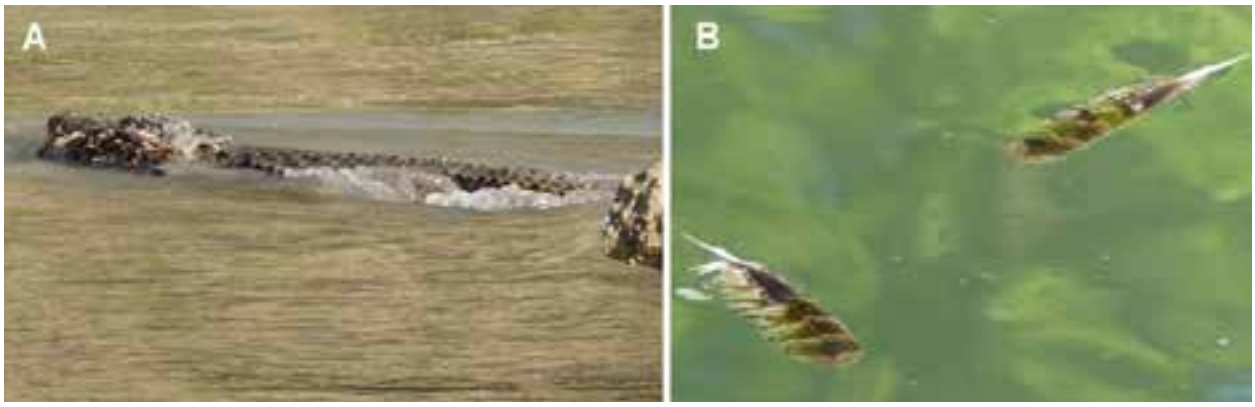

Image 1. Mugger Crocodile predation on owl: A—Mugger Crocodile *Crocodylus palustris* ZRC(IMG) 2.672 having captured Brown Fish Owl *Ketupa zeylonensis* | B—Brown Fish Owl feathers left at the scene of the take. © Jon Hakim.

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NOTE

New distribution records of two jumping spiders of the genus *Stenaelurillus* Simon, 1886 (Araneae: Salticidae) from Gujarat, India

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The jumping spider genus *Stenaelurillus* Simon, 1886, belonging to the tribe Aelurillini (Maddison 2015), is widely distributed and currently comprises 59 known species (World Spider Catalog 2024). Among these, 20 species have been documented in India (Caleb & Sankaran 2024). Of these, two species, *S. arambagensis* Biswas & Biswas, 1992 and *S. gabrieli* Prajapati, Murthappa, Sankaran & Sebastian, 2016, are recorded in Gujarat. Through recent investigations, we identified two additional species of the genus *Stenaelurillus* that have not been documented in Gujarat State till date. This paper presents new records and documentation of *S. marusiki* Logunov, 2001, and *S. vyaghri* Sanap, Joglekar & Caleb, 2022, marking their first appearance in Gujarat, India.

The specimens were hand-collected and studied under a Leica M205 A stereomicroscope and microphotographic images were taken by a Leica DFC2900 digital camera attached to the stereomicroscope and enabled with the software package Leica Application Suite (LAS), version 4.5.0. The epigyne was dissected and the soft tissues were cleared using 10% KOH. Left palps and epigyne were studied and photographed by placing them in a cavity block filled with ethanol. The species were identified based on Logunov (2001) and Marathe et al. (2022). The examined specimens have been deposited in the reference collection of the Web of Nature (WON) Research Foundation, Gujarat, India (curator: Dhruv A. Prajapati).

Family Salticidae Blackwall, 1841
Genus *Stenaelurillus* Simon, 1886
Type species: *Stenaelurillus nigricaudus* Simon, 1886

***Stenaelurillus marusiki* Logunov, 2001**

(Image 1, 4–5)

Stenaelurillus marusiki Logunov, 2001: 66, fig. 27–30

Stenaelurillus marusiki Marathe et al. 2022: 4, fig. 1–27

Material examined: WON103574A, 13.iii.2017, 1 male, India, Gujarat, Meva Village (23.3255 ^{0}N, 69.2738 ^{0}E), 162 m, leg. D. Prajapati; 21.v.2021, 1 male, India, Gujarat, Taranga (23.9694 ^{0}N, 72.7444 ^{0}E), 366 , leg. S. Parmar.

Diagnosis: The species can be easily distinguished by the following characters: embolus short, distal tegular projection cone shaped and as long as embolus (Image 5). RTA simple, slightly curved (Image 4).

Distribution: Iran and India (Logunov 2001; Marathe et al. 2022).

Distribution in India: Maharashtra (Marathe et al.

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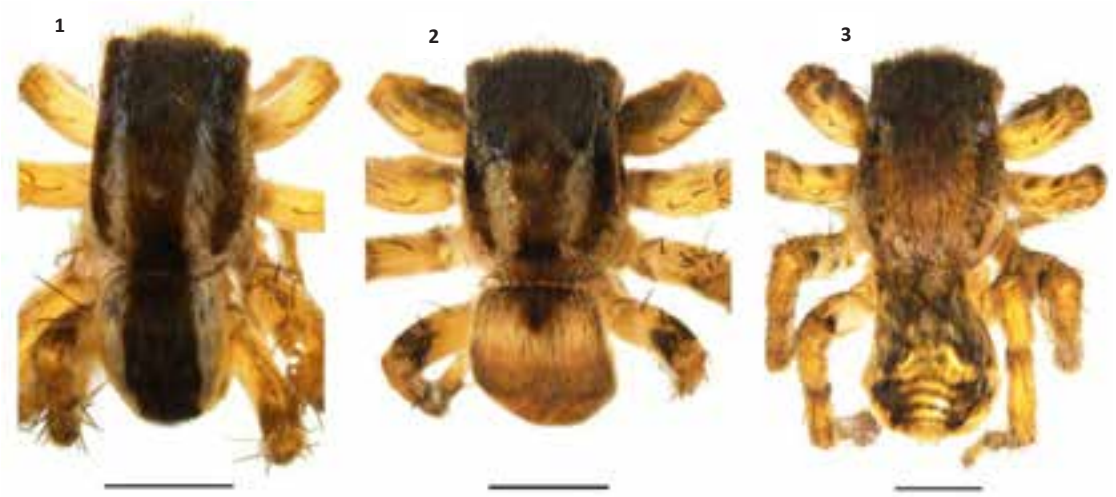

Image 1–3. 1—*Stenaelurillus marusiki* Logunov, 2001, male, dorsal view | 2—*Stenaelurillus vyaghri* Sanap, Joglekar & Caleb, 2022, male dorsal view | 3—*S. vyaghri*, female, dorsal view. Scale bars: 1 mm (1–3). © WON Research Foundation.

Image 4–9. 4 & 5 —*Stenaelurillus marusiki* Logunov, 2001: 4—Male left pedipalp, retrolateral view | 5— Male left pedipalp, ventral view. 6–9—*Stenaelurillus vyaghri* Sanap, Joglekar & Caleb, 2022: 6—Male left pedipalp, ventral view | 7— Male left pedipalp, retrolateral view | 8—Epigyne, ventral view | 9—Vulva, dorsal view. Scale bars: 0.1 mm (4–9). © WON Research Foundation.

2022) and Gujarat (new record).

***Stenaelurillus vyaghri* Sanap, Joglekar & Caleb, 2022**

(Image 2–3, 6–9)

Stenaelurillus vyaghri Sanap, Joglekar & Caleb, in Marathe et al., 2022: 14, fig. 94–114

Material examined: WON100351, 21.v.2021, 1 male & 1 female, India, Gujarat, Danta Village (24.1925°N, 72.783333°E), 327 m , from rocky patches, leg. S. Parmar.

Diagnosis: The species can be easily distinguished by following characters: male with short, thick and hook shaped embolus, RTA long with pointed tip (Image 6–7). Female with spherical spermathecae, epigynal pocket well-developed, narrowed and deep (Image 8–9) (Marathe et al. 2022).

Distribution: India (WSC 2024)

Distribution in India: Maharashtra (Marathe et al. 2022) and Gujarat (new record).

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