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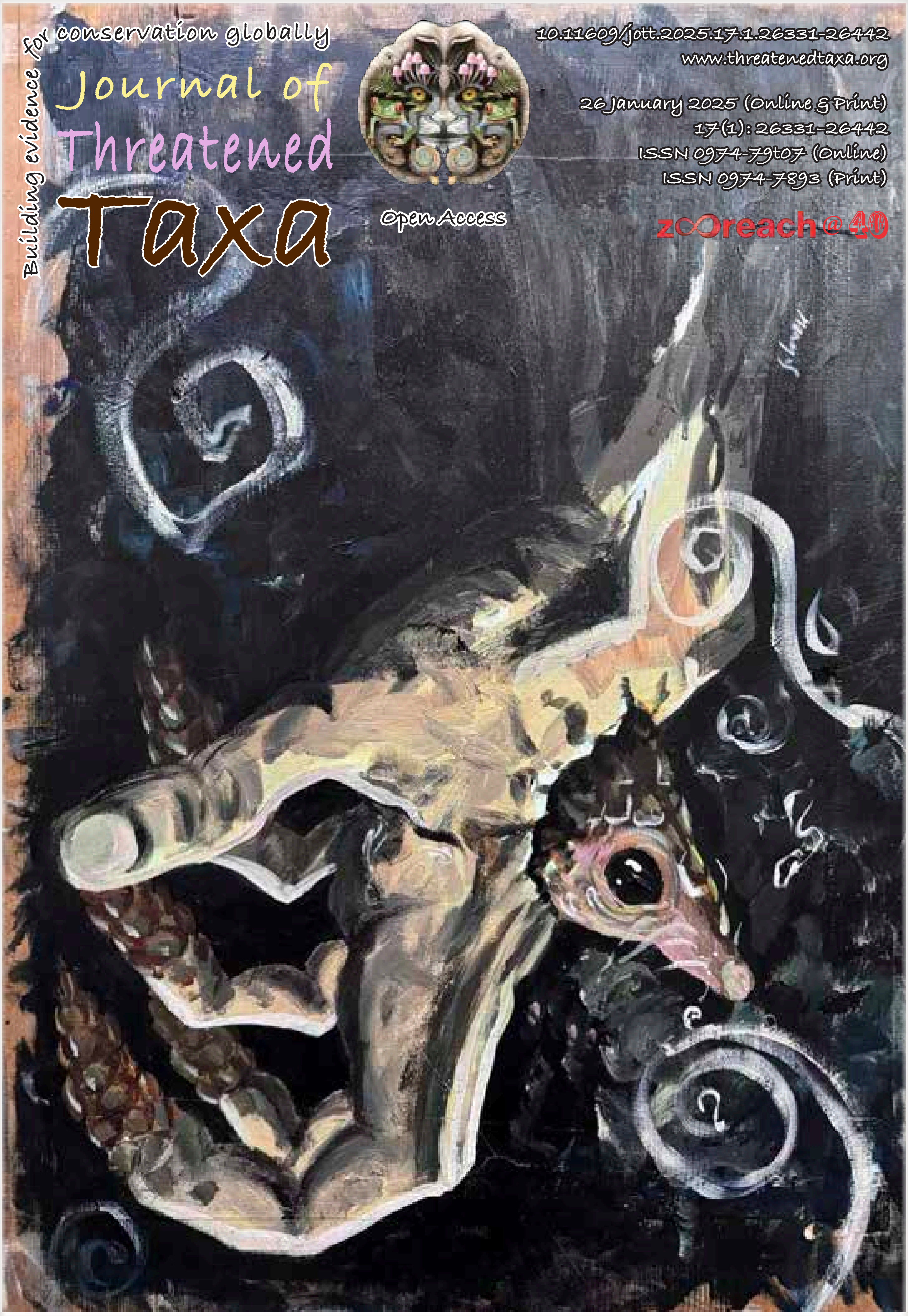

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continued on the back inside cover

Cover: Illuminating the cruelty of Pangolin trade in India for the purpose of black magic, for the sanctity of protection. Using an animal's shell, ripping its armor against the world to protect oneself. When does one become the evil they are trying to ward off? — Acrylic on wood. © Maya Santhanakrishnan.

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ARTICLE

Waterhole utilization pattern of mammals in Jigme Singye Wangchuck National Park, Bhutan

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Abstract: Most studies on waterholes come from arid and semi-arid countries where water availability for wildlife is limited. Bhutan is a country with rich running water sources. Less is known about the waterhole usage by wildlife in the country. The present study aimed to understand the importance and usage pattern of waterholes by mammals in the protected areas of Bhutan. Thirty waterholes in Jigme Singye Wangchuck National Park, Bhutan were monitored for dry and wet seasons. A generalized linear model was used to assess the impact of various waterhole parameters on mammal usage of the waterholes. Seven out of 12 parameters studied showed a significant impact on waterhole visitation by mammalian species. When water availability and salinity showed a positive impact on waterhole visits by mammals, distance from agricultural land, altitude, herb density, canopy cover, and livestock presence showed a negative impact. The study shows that even in the presence of major running water sources, waterholes are well utilized by mammals independent of seasons with ungulates being the most frequent visitors in the waterholes. This shows the importance of waterholes in protected areas of the country for better management of wildlife.

Keywords: Camera-trapping, negative binomial regression, species-environment relationship, waterholes.

Abbreviations: DO—dissolved oxygen | GBH—girth at breast height | JSWNP—Jigme Singye Wangchuck National Park | SMART—spatial monitoring and reporting tool | TDS—total dissolved solids.

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Author contributions: AKS—data collection, data analysis and paper writing; UD—principal supervisor, guidance in research methodology and manuscript preparation. KS—co-supervisor and provided guidance throughout the research work; MMG—Guidance in data analysis.

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INTRODUCTION

Bhutan is the only country that is entirely part of the eastern Himalayan hotspot known for its rich biodiversity and extensive forest cover (Banerjee & Bandopadhyay 2016; Nepal 2022). With a land area of <0.0075% of the world's surface, Bhutan is home to 1.99% of the world's mammal species, 7.07% of its bird species, and 4.29% of its butterfly species (Nepal 2022). The country places great emphasis on environmental protection and management through policies such as Gross National Happiness (Thinley & Hartz-Karp 2019). According to Lham et al. (2019), the effective management of the country's protected areas is limited due to gaps in monitoring and research data. Various scientific studies have been conducted in Bhutan on wildlife management, including human-wildlife interaction and climate change (Penjor et al. 2021; Yeshey et al. 2023). No major studies have been done on the water-related aspect of wildlife management in the country (Lham et al. 2019).

Wildlife water development is an effective and appropriate wildlife management tool, especially during the dry seasons (Rosenstock et al. 2004). The provision of sufficient water in the protected areas is considered a key managerial intervention (Hayward & Hayward 2012). The linkages between forests, water, and wildlife create a mosaic that benefits both wildlife and communities living in the forest (Warrington et al. 2017). The seasonal availability of water in the water sources can impact the individual species even in their habitat selection (Najafi et al. 2019). The non-uniform distribution of water resources can even affect the overconsumption of vegetation in an area and thereby the vegetative degradation in the forest (Dzinotizei et al. 2017). Waterholes are one of the major sources of water for wildlife, especially in arid and semi-arid ecosystems (Sirot et al. 2016). The importance of waterholes in supporting wildlife, especially during dry seasons, is well-documented in the context of other ecosystems too (Vaughan & Weis 1999).

More than a water source, the waterholes are utilized by wildlife as a foraging ground, hunting ground, and mineral sources (Adams et al. 2003; Davidson et al. 2013; Pin et al. 2020). Wildlife preference for waterholes may depend on various factors such as physical, chemical, geographical, and ecological factors. These factors must be properly studied and understood for the proper management of these waterholes. The present study tries to understand the importance of waterholes in Bhutan, a country with one of the highest per capita water resource availability of 94,500 m^3/capita/year (Tariq et al. 2021) and also to understand how water quality (salinity, dissolved oxygen, total dissolved solids), anthropogenic disturbances (distance from road, distance from agricultural land, distance from settlements, presence of livestock), vegetation (herb density, shrub density and canopy cover), geophysical factors (elevation and presence of other waterholes) and availability of water in the waterhole are related to the selection of waterholes by the mammal species in Jigme Singye Wangchuck National Park, Bhutan.

MATERIAL AND METHODS

Study Area

The study was conducted in Jigme Singye Wangchuck National Park, formerly known as Black Mountain National Park (JSWNP, 27.017 to 27.483 latitude and 90.067 to 90.683 longitude) in central Bhutan. With an area of 1,730 km^2, JSWNP is the third largest national park in Bhutan. It covers five political districts (Sarpang, Trongsa, Tsirang, Wangdue Phodrang and Zhemgang) with elevation differences ranging 250–4,925 m (Department of Forests and Park Services, Ministry of Agriculture and Forests, Bhutan 2021). The south-west monsoon contributes most of the annual rainfall in the region from June to September. JSWNP connects Jigme Dorji National Park (JDNP) with Wangchuck Centennial National Park (WCNP) in the north and Royal Manas National Park (RMNS) with Phibsoo Wildlife Sanctuary (PWS) in the south through biological corridors, making JSWNP biologically diverse (Tshewang & Letro 2018). The national park supports 876 species of plants, 55 species of mammals, 323 species of birds, 376 species of butterflies, 42 species of herpetofauna, and 16 species of fishes (Tshewang & Letro 2018; JSWNP 2021). The park also supports 10–15% of Bhutan's total tiger population in its cool and warm broadleaved forests (Wang & Macdonald 2006). Thirty natural waterholes, all of similar size, were monitored over a six-month period from March 2023 to August 2023 across four ranges (Taksha, Langthel, Tingtibi, and Nabji) of the national park (Figure 1). Most of these waterholes are fed by springs, while a few were sourced from rainwater.

Data Collection

The study attempted to conduct a homogeneous sampling effort of 30 days for 30 camera stations. Because the camera trap in station three was turned off within 20 days due to high animal activity and the distorted camera trap in station 17, these two camera

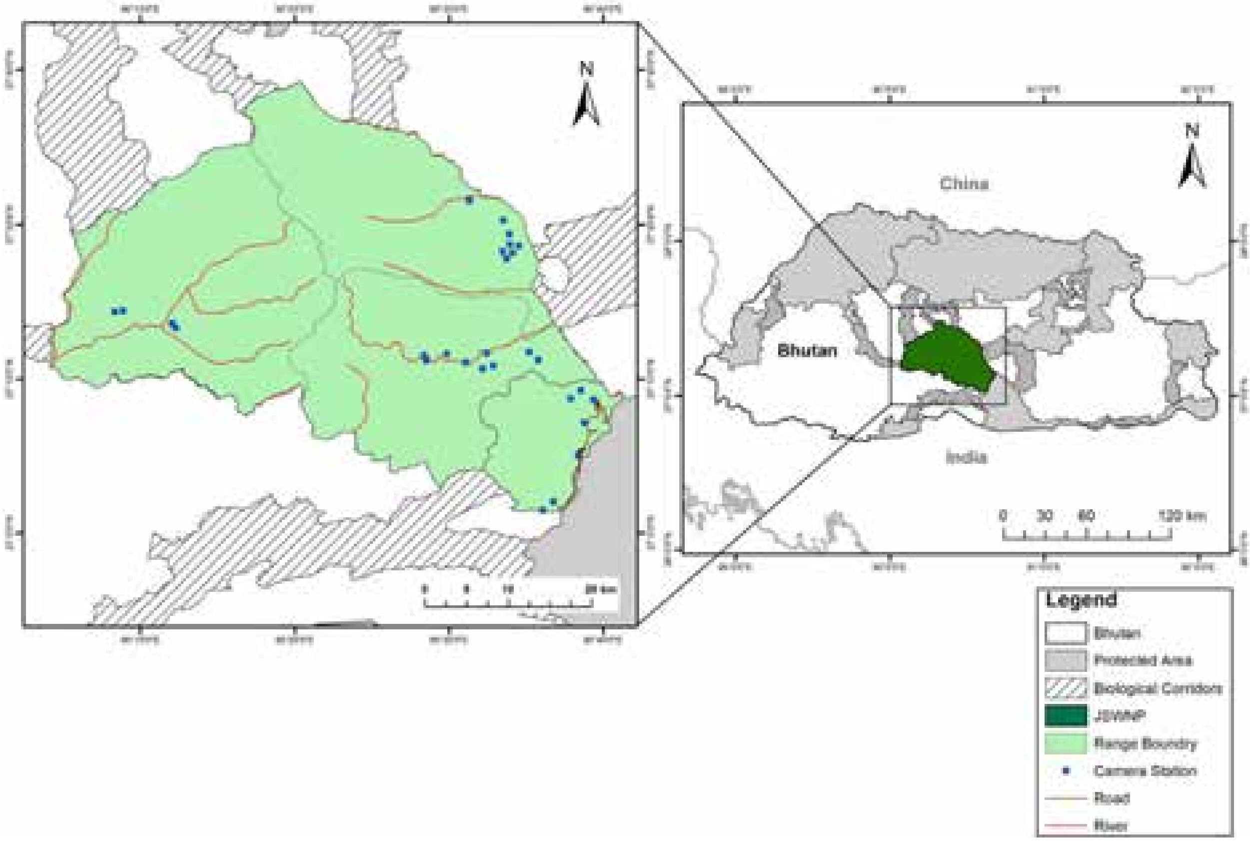

Figure 1. Map showing Jigme Singye Wangchuck National Park, Bhutan, different ranges, rivers, roads, and the camera station (waterhole that were monitored for the following research).

stations were avoided. Twenty-eight camera traps for 60 days in two seasons resulting in 1,680 trapping days. RECONYX Hyperfire II camera traps were used for the study. The cameras were oriented in such a way that water availability in the waterhole was evident in the captured images. To capture all mammal species visiting the waterhole and to avoid distractions from ground vegetation, the cameras were mounted at a height of 50 cm to 1 m above the ground level (Meek et al. 2014). Data was collected in two seasons, dry season (March–April 2023) and wet season (July–August 2023).

The time delay of each camera trap was 3 min and the delay between each image was 30 s . Of the images recorded by the camera traps, only those images from which the animal species can be identified properly were analyzed. The image of the same species within 30 minutes from the same waterhole was considered the same individual, therefore such images were not considered for analysis (Pin et al. 2020). It is not necessarily that the image captured shows animals drinking at the time of observation, even their proximity near to the waterhole was be considered as drinking behavior (Hayward & Hayward 2012).

Water quality parameters of each waterhole were recorded twice in each season. The parameters such as salinity, dissolved oxygen (DO) and total dissolved solids (TDS) of the water samples were tested and recorded. Hanna Edge HI2002-02 and Microprocessor COND-TDS-SAL-Meter LT-51 were used to test the following parameters. Parameters such as salinity and TDS were tested within 24 h of sampling and DO was tested in the field. The availability of water in the waterhole during the study period and the presence of livestock in the waterhole were also recorded using the camera trap images.

Additionally, vegetation assessment was carried out from three vegetation plots around each waterhole. The plots were taken in three directions (0° north, 120° south-east, and 240° south-west) 100 m from the waterhole, considering the waterhole as the center point. All tree species within a 12.62 m radius that had a GBH greater than 10 cm were recorded. Square plots of 5 x 5 m and 1 x 1 m were used to assess shrub and herb species, respectively, inside the same circular plot. The number of stumps was counted for both herb and shrub species. The canopy cover around the waterhole was recorded using Canopeo software (Patrignani & Ochsner 2015). Anthropogenic disturbance in the waterhole was recorded by measuring the shortest distance of the waterhole to human settlements, agricultural land, and roads. The coordinates of the waterholes and other parameters in the field were recorded using Garmin eTrex 32x. ArcGIS software was used to determine the shortest straight-line distance from anthropogenic disturbance to the waterhole using the recorded coordinates from the field (Environmental Systems Research Institute, Inc. 2016). The presence of other waterholes within 500 m of the studied waterhole was surveyed and recorded. The altitude and slope of the waterhole location were also recorded as geophysical parameters.

Data Analysis

The camera trap images were used as an index of animal visit to the waterhole. For images showing more than one individual, all the individuals were counted separately and recorded. The camera trap images were processed to correct date and time errors in some camera stations, and a species dataset was created using the Camera Trap File Manager software (Panthera). Species richness, evenness and abundance were calculated from the species dataset. For statistical analysis, paired t-test was adopted to assess seasonal differences in waterhole visitation by mammals (Wilkerson 2008).

The collinearity between environmental variables were examined with the variance inflation factor (VIF), using this function from the car package in R (Fox & Weisberg 2018). Variables with VIF >10 were considered to be highly correlated and therefore excluded from future analysis (Montgomery et al. 2012). There was no strong correlation between any environmental variables except salinity and TDS. Therefore, all environmental parameters except TDS were retained (Table 1).

The negative binomial regression model from the MASS package was used to understand the impact of different waterhole parameters on the waterhole visitation rate of mammal species (Ripley 2022). A separate negative binomial regression model was performed for wet and dry seasons using count data of mammalian species to examine their preferences concerning various waterhole parameters, including water quality (salinity and dissolved oxygen), anthropogenic disturbance (presence of livestock, agricultural land, and settlements), vegetation (herb density, shrub density, and canopy cover), geophysical factors (elevation and presence of other waterholes), and water availability.

To understand how different waterhole parameters affect each mammal species in the selection of a waterhole, a separate negative binomial regression model was performed for a select group of the most abundant mammals in the studied waterhole separately for wet and dry seasons. All environmental data were scaled using the scale function in r before performing a negative binomial regression model to avoid bias from variables with different scales. All the statistical analysis were performed using R v. 4.3.2 (R Development Core Team 2023).

RESULTS

Species Richness and Abundance in the waterholes

A total of 3,549 animal visits from 23 different mammal species were recorded over 1,680 trapping days (Table 2). Relatively high species richness was observed in the waterhole during the dry season (M = 4.29) compared to the wet season (M = 3.89). Camera station 13 in the Langthel range showed the highest species richness in both the wet and dry seasons. Ungulate species (*Rusa unicolor, Sus scrofa*, and *Muntiacus vaginalis*) showed higher abundance in the waterhole compared to the other mammal species in both the seasons (Figure 2). *Muntiacus vaginalis* was the only mammal species reported from all 28 waterholes.

Negative Binomial Regression Model

From the separate negative binomial regression

Table 1. Results of multicollinearity between variables showing the variance inflation factor of individual variable in wet and dry season.

Variable	Variance inflation factor (VIF)	
	Dry season	Wet season
Dissolved oxygen	2.44	1.83
Salinity	1.58	1.50
Water availability	4.25	3.01
Distance to river	2.45	2.60
Waterholes within 500 m	1.55	2.21
Altitude	2.56	2.65
Slope	2.02	2.51
Distance to road	4.37	5.08
Distance to agriculture land	2.60	2.10
Distance to settlement	1.66	2.39
Herb density	2.11	2.67
Shrub density	2.03	2.66
Canopy cover	2.50	2.80
Livestock	1.56	2.59

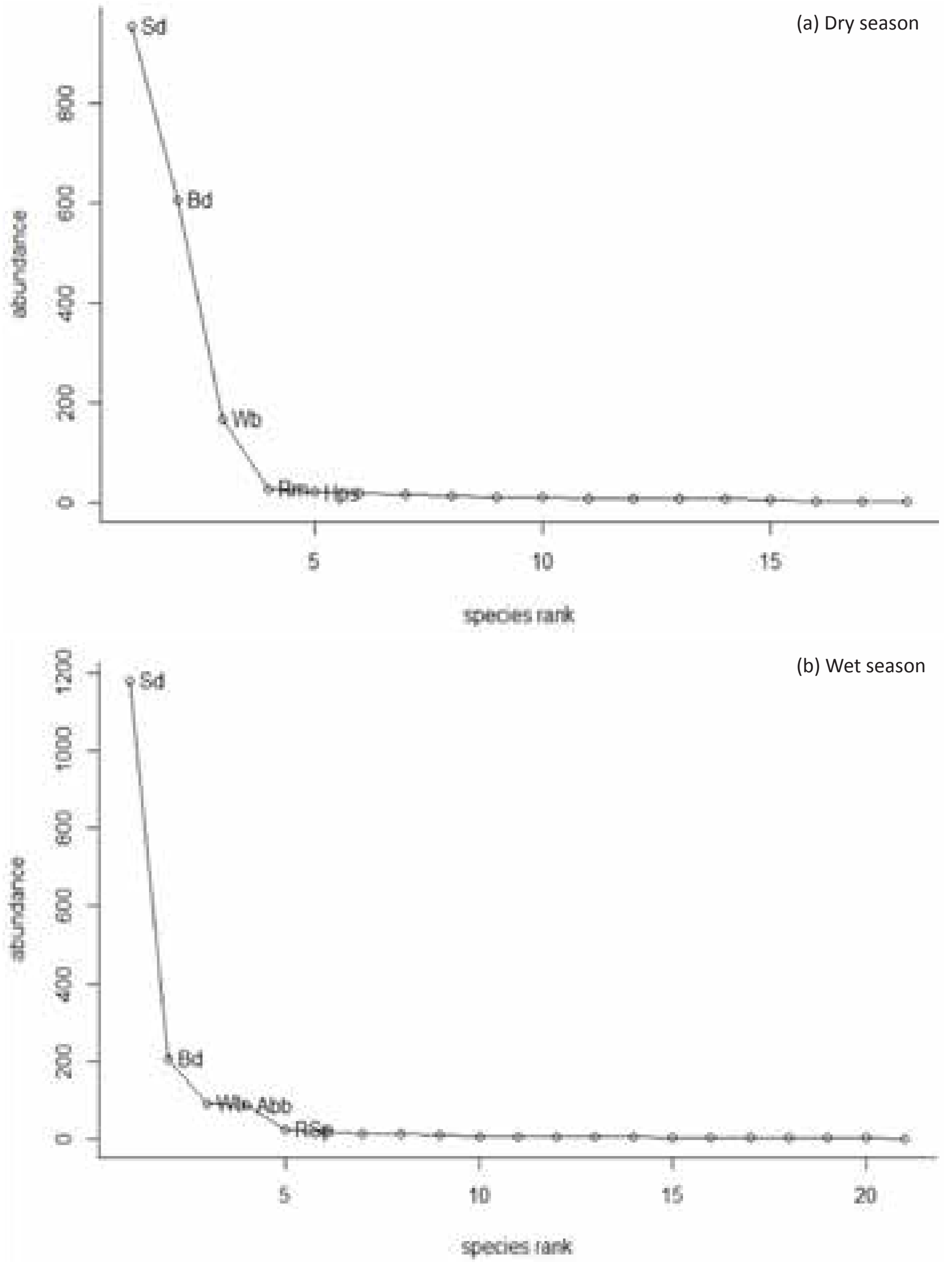

Figure 2. Graph showing species abundance of mammals in waterhole: a—dry season| b—wet season.
Sd—*Rusa unicolor* | Bd—*Muntiacus vaginalis* | Wb—*Sus scrofa* | Rms—*Macaca assamensis* | Hps—*Paguma larvata* | Abb—*Ursus thibetanus* | Rsp—*Niviventer* sp.

models for the dry and wet seasons, four waterhole parameters showed a significant impact on the use of waterholes by mammals, including canopy cover (Est. = -0.835, SE = 0.226, p = 0.000) and the presence of livestock (Est. = -0.619, SE = 0.225, p = 0.006) in the dry season. Conversely, in the wet season, more parameters showed significance: shrub density (Est. = -0.493, SE = 0.232, p = 0.03), distance from agricultural land (Est. = -0.548, SE = 0.243, p = 0.02), and altitude (Est. = -0.500, SE = 0.206, p = 0.01). Availability of water, salinity, and canopy cover showed a significant impact on mammal visits both in wet and dry seasons. Salinity, water availability, and the presence of agricultural land showed a positive impact on the animal visit to the waterhole whereas the presence of livestock, altitude, herb density, and canopy cover of the waterhole location showed a negative impact on the waterhole visit of mammal species.

As *Rusa unicolor*, *Sus scrofa*, and *Muntiacus vaginalis* exhibited the highest abundance at the studied waterhole, separate negative binomial regression

Table 2. Mammal species recorded from the waterholes and their seasonal visit.

Species		IUCN Red List	No. of visit	
Common name	Scientific name		Dry season	Wet season
Asian Black Bear	*Ursus thibetanus*	Vulnerable	19	86
Asian Golden Cat	*Catopuma temminckii*	Near Threatened	4	4
Assamese Macaque	*Macaca assamensis*	Near Threatened	27	19
Black Giant Squirrel	*Ratufa bicolor*	Near Threatened	-	2
Clouded Leopard	*Neofelis nebulosa*	Vulnerable	-	1
Dhole	*Cuon alpinus*	Endangered	9	4
Gaur	*Bos gaurus*	Vulnerable	-	12
Gee's Golden Langur	*Trachypithecus geei*	Endangered	2	5
Himalayan Goral	*Naemorhedus goral*	Near Threatened	-	1
Hoary-bellied Squirrel	*Callosciurus pygerythrus*	Least Concern	8	12
Indian Leopard	*Panthera pardus fusca*	Near Threatened	2	6
Mainland Leopard Cat	*Prionailurus bengalensis*	Least Concern	6	1
Mainland Serow	*Capricornis sumatraensis*	Vulnerable	6	-
Malayan Porcupine	*Hystrix brachyura*	Least Concern	9	10
Marbled Cat	*Pardofelis marmorata*	Near Threatened	2	-
Masked Palm Civet	*Paguma larvata*	Least Concern	20	3
Nepal Gray langur	*Semnopithecus schistaceus*	Endangered	15	-
Northern Red Muntjac	*Muntiacus vaginalis*	Least Concern	606	209
Rodent	*Niviventer* sp.	-	-	24
Sambar	*Rusa unicolor*	Vulnerable	959	1185
Small Indian Mongoose	*Urva auropunctata*	Least Concern	14	2
Wild Boar	*Sus scrofa*	Least Concern	167	90
Yellow-throated Marten	*Martes flavigula*	Near Threatened	8	7

Table 3. Summary of negative binomial model for dry season with model average coefficient, standard error (SE), Z- value and significant value expressed as hyper link with the coefficient (Signif. codes: 0 '*' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1).**

	Estimate	SE	z-value
Intercept	3.704 ***	0.177	20.955
Dissolved oxygen	-0.117	0.256	-0.456
Salinity	0.427 *	0.205	2.086
Water availability	0.582 *	0.279	2.088
Other waterhole	-0.184	0.208	-0.883
Altitude	-0.130	0.227	-0.575
Agricultural land	0.010	0.226	0.044
Settlements	0.334	0.193	1.737
Herb density	-0.276	0.214	-1.291
Shrub density	-0.230	0.227	-1.012
Crown cover	-0.835 ***	0.226	-3.699
Livestock	-0.619 **	0.225	-2.748

models were conducted for each of these three mammal species across both wet and dry seasons. The negative binomial regression model for *Rusa unicolor* revealed that parameters such as distance from settlements (Est. = 0.95, SE = 0.46, p = 0.039), shrub density (Est. = -1.29, SE = 0.64, p = 0.045), crown cover (Est. = -1.47, SE = 0. 0.48, p = 0.002), and water availability (Est. = 1.37, SE = 0.52, p = 0.008) significantly influenced the visitation rates of *Rusa unicolor* to the waterhole. Notably, shrub density (Est. = 1.15, SE = 0.54, p = 0.034) around the waterhole was found to be the most influential factor for *Sus scrofa*. *Sus scrofa* was found to prefer waterholes with higher shrub density, particularly during the dry season. *Muntiacus vaginalis* showed a significant impact on the waterhole parameters including dissolved oxygen (Est. = -0.62, SE = 0.27, p = 0.022), presence of livestock (Est. = -0.78, SE = 0.32, p = 0.014), and crown cover (Est. = -0.62, SE = 0.25, p = 0.011).

Table 4. Summary of negative binomial model for wet season with model average coefficient, standard error (SE), Z- value and significant value expressed as hyper link with the coefficient (Signif. codes: 0 '*' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1).**

	Estimate	SE	z-value
Intercept	3.253 ***	0.177	18.359
Dissolved oxygen	-0.277	0.226	-1.225
Salinity	0.494 *	0.210	2.351
Water availability	0.728 **	0.222	3.279
Other waterhole	-0.224	0.223	-1.003
Altitude	-0.500 *	0.206	-2.424
Distance from agricultural land	-0.548 *	0.243	-2.259
Distance from settlements	0.190	0.193	0.981
Herb density	-0.325	0.219	-1.479
Shrub density	-0.493 *	0.232	-2.123
Crown cover	-0.480 *	0.235	-2.045
Livestock	-0.075	0.229	-0.326

Table 5. Summary of negative binomial model for *Sus scrofa* in the dry season with model average coefficient, standard error (SE), Z- value, and significant value expressed as a hyper link with the coefficient (Significant codes: 0 '*' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1).**

	Estimate	SE	z value
(Intercept)	0.99 *	0.41	2.41
Dissolved oxygen	-0.74	0.59	-1.25
Salinity	-0.31	0.49	-0.63
Water availability	0.30	0.62	0.48
Other waterhole	0.04	0.48	0.09
Altitude	0.06	0.53	0.12
Distance from agricultural land	-0.24	0.66	-0.36
Distance from settlements	-0.24	0.50	-0.48
Herb density	0.99	0.71	1.39
Shrub density	1.15 *	0.54	2.11
Crown cover	-0.42	0.50	-0.84
Livestock	-0.71	0.53	-1.33

Table 6. Summary of negative binomial model for *Sus scrofa* in the wet season with model average coefficient, standard error (SE), Z- value, and significant value expressed as hyperlink with the coefficient (Significant codes: 0 '*' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1).**

	Estimate	SE	z value
(Intercept)	0.33	0.54	0.61
Dissolved oxygen	-1.05	0.72	-1.47
Salinity	-0.47	0.69	-0.68
Water availability	0.23	0.69	0.34
Other waterhole	0.29	0.66	0.43
Altitude	-0.81	0.71	-1.15
Distance from agricultural land	-0.31	0.77	-0.40
Distance from settlements	0.22	0.67	0.32
Herb density	0.40	0.91	0.44
Shrub density	0.30	0.74	0.41
Crown cover	-0.01	0.65	-0.02
Livestock	0.52	0.65	0.81

Table 7. Summary of negative binomial model for *Rusa unicolor* in dry season with model average coefficient, standard error (SE), Z- value and significant value expressed as hyper link with the coefficient (Significant codes: 0 '*' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1).**

	Estimate	SE	z value
(Intercept)	1.85 ***	0.41	4.56
Dissolved oxygen	0.33	0.61	0.55
Salinity	0.49	0.46	1.08
Water availability	0.54	0.64	0.85
Other waterhole	-0.32	0.45	-0.71
Altitude	-0.27	0.52	-0.52
Distance from agricultural land	0.80	0.62	1.29
Distance from settlements	0.95 *	0.46	2.06
Herb density	-0.63	0.67	-0.94
Shrub density	-1.29 *	0.64	-2.00
Crown cover	-1.47 **	0.48	-3.05
Livestock	-0.39	0.52	-0.76

DISCUSSION

This research was a preliminary study to understand the importance and utilization pattern of waterholes by mammals in the protected areas of Bhutan. The results of the study showed a fairly high species richness in the waterhole, recording a total of 23 mammal species from the waterholes studied (Table 2). Ungulate species were the frequent visitors to the waterhole (Figure 2) as their water requirements are relatively high compared to the other mammal species (Najafi et al. 2019). This can also be due to the higher densities of ungulates in general. The result of the paired sample t-test did not show any significant difference in the use of waterholes in the wet and dry seasons, which implies that more than a seasonal watering point, waterholes were utilized by the mammals regardless of the season. The significance of water availability in the waterhole in both seasons also back the following statement. The presence of water in the waterhole must be a concern as 52.7% (n = 16) of the waterholes studied were found to be without water at some point during the data collection, with

Table 8. Summary of negative binomial model for *Rusa unicolor* in wet season with model average coefficient, standard error (SE), Z- value and significant value expressed as hyper link with the coefficient (Significant codes: 0 '*' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1).**

	Estimate	SE	z value
(Intercept)	1.85 ***	0.40	4.65
Dissolved oxygen	-0.25	0.48	-0.52
Salinity	0.63	0.49	1.29
Water availability	1.37 **	0.52	2.62
Other waterhole	0.07	0.47	0.15
Altitude	-0.39	0.50	-0.79
Distance from agricultural land	0.07	0.56	0.12
Distance from settlements	0.44	0.50	0.88
Herb density	-0.82	0.68	-1.21
Shrub density	0.11	0.55	0.21
Crown cover	-0.86	0.48	-1.77
Livestock	-0.49	0.53	-0.93

Table 9. Summary of negative binomial model for *Muntiacus vaginalis* in the dry season with model average coefficient, standard error (SE), Z- value, and significant value expressed as hyperlink with the coefficient (Significant codes: 0 '*' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1).**

	Estimate	SE	z value
(Intercept)	2.66 ***	0.21	12.98
Dissolved oxygen	-0.03	0.29	-0.10
Salinity	0.36	0.24	1.50
Water availability	0.40	0.31	1.28
Other waterhole	-0.43 .	0.23	-1.85
Altitude	0.30	0.26	1.14
Distance from agricultural land	-0.23	0.32	-0.73
Distance from settlements	0.25	0.24	1.02
Herb density	-0.09	0.34	-0.26
Shrub density	-0.24	0.27	-0.88
Crown cover	-0.62 *	0.25	-2.52
Livestock	-0.78 *	0.32	-2.46

Table 10. Summary of negative binomial model for *Muntiacus vaginalis* in wet season with model average coefficient, standard error (SE), Z- value and significant value expressed as hyper link with the coefficient (Significant codes: 0 '*' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1).**

	Estimate	SE	z value
(Intercept)	1.34 ***	0.29	4.64
Dissolved oxygen	-0.62 *	0.27	-2.28
Salinity	-0.02	0.26	-0.08
Water availability	0.00	0.28	-0.01
Other waterhole	-0.26	0.27	-0.96
Altitude	-0.36	0.28	-1.27
Distance from agricultural land	-0.47	0.30	-1.53
Distance from settlements	0.41	0.26	1.56
Herb density	0.06	0.38	0.16
Shrub density	0.24	0.30	0.80
Crown cover	0.17	0.27	0.63
Livestock	-0.98	0.99	-0.99

two waterholes being completely dry throughout the dry season. The result of a separate negative binomial regression model performed for the most abundant mammal species (Table 8) also shows the close relationship of *Rusa unicolor* with water availability in the waterhole.

Regarding the water quality parameters of the waterhole, salinity showed a positive impact on the waterhole visit by the mammal species both in the wet and in the dry seasons. One-unit increase in the salinity showed a 53.3% increase in the animal visit in the dry season and a 63.7% in the wet season. Consistent with some previous studies on waterholes, the positive impact of animal visitation on water salinity in JSWNP may be to meet the mineral requirements of mammalian species (Adams et al. 2003). This can be one of the reasons why mammal species tend to prefer waterholes over the freshwater streams in the national park. Whether the waterhole in the national park is used by the mammals as an alternative source to meet their mineral requirements is still a question as the presence of the salt licks around the waterhole was not considered as one of the variables for the following study, which merits further research in the following topic.

The presence of livestock has been reported from the 13 of the waterholes monitored which had a significant negative impact on the waterhole visit of the mammal species, especially during the dry season (Table 3). *Muntiacus vaginalis* also exhibited a negative impact on the presence of livestock in waterholes (Table 9), particularly during the dry season when livestock activity is high in the forest areas of Bhutan (Buffum et al. 2009). Many studies showed the implications of sharing the same water source by wildlife and livestock, especially when it comes to the spreading of disease from livestock to wildlife species which shows a higher potential in stagnant water sources like waterhole (Cowie et al. 2016). Ungulate species as well as the livestock were camera-trapped defecating in the waterholes having high use pressure. The forest department needs to give much importance to the following situation in the protected areas of the country. In the wet season, there was no significant effect observed on the presence of livestock on the mammals (Table 4). Further research needs to be conducted for a better understanding of the following situation in the country.

The proximity of agricultural land to waterholes was found to have a significant positive impact on waterhole visitation rates by mammal species during the wet season. This positive impact was not observed during the dry season. The presence of farmers engaged in agricultural activities during the dry season may account for the non-significant effect during this period, particularly as the major agricultural activity in my study area is the cultivation of black cardamom, which involves significant fieldwork that occurs only two to three times a year. The negative binomial regression model for *Sus scrofa* indicated a strong association between *Sus scrofa* and waterholes characterized by higher shrub density (Table 5). In contrast, other mammals tended to prefer waterhole locations with lower shrub density. Most shrub species recorded around the waterholes monitored were non-palatable species. The dense shrub cover can limit visibility and potentially increasing predation risk (Sutherland et al. 2018). *Sus scrofa* preferred these bushy habitats to take advantage of the concealment they provide, which could help them minimize predation risk. In contrast, larger ungulate species may avoid waterholes with dense shrub patches due to their need for greater visibility to detect predators.

CONCLUSION

The following study shows that even in the presence of major running water sources, mammals tend to prefer waterholes for their water requirements. The results show that salinity may be the reason why the mammals prefer waterholes over the running water source in the national park. In addition to salinity, waterhole parameters including distance from agricultural land, altitude, herb density, canopy cover, livestock presence, and water availability also significantly impacted the waterhole visit by the mammal species. More importance needs to be given to the waterhole management practices in JSWNP. Currently, reliable data on the distribution of waterholes in the national park is lacking. The SMART (Spatial Monitoring and Reporting Tool) patrolling data of the waterhole also seems to be unreliable, which was the major challenge faced during the initial stages of research data collection (Wildlife Conservation Society). The preparation of accurate data base on waterhole distribution and water availability throughout the year will help in the better management of waterholes in the national park. This can also support future research on waterholes in the national park. Since salinity and water availability in the waterhole seem to be the most influential parameters for mammals regardless of seasons, it is recommended that more importance be given to waterholes with continuous water availability and presence of salinity when it comes to future waterhole management practice in the country. Stagnant water sources such as waterholes shared by livestock and wildlife, can be a medium for the spread of disease from livestock to wildlife. Therefore, the forest department needs to consider the presence of livestock in the waterhole to avoid further impacts. In the following context, the presence of disease-causing pathogens and antibiotic-resistant bacteria (AMR) in waterholes is the subject of further research.

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ARTICLE

Dietary composition of Black-necked Crane *Grus nigricollis* Przewalski, 1876 (Aves: Gruiformes: Gruidae) in its winter habitat: insights from fecal analysis in Bumdeling, Trashiyangtse, Bhutan

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Abstract: Gaining comprehensive insights into the dietary habits and food preferences of the Black-necked Crane (BNC) is crucial for developing effective conservation plans to safeguard this globally near-threatened species. The choice of habitats by these birds is primarily influenced by the availability of diverse food sources and overall environmental security. This study was conducted in 2019–2020 in Bumdeling, one of three wintering sites for BNC in Bhutan. It was prompted by concerns over a declining crane population, largely due to habitat alteration that threatens food sources. This study aimed to examine the dietary preferences of cranes by collecting and analyzing fecal samples from foraging and roosting sites. Results revealed that paddy-fields were the primary foraging areas. The presence of domestic grains after harvest, herbaceous plants, and invertebrates are crucial components of the food structure of cranes. Fecal samples contained 79 species from domestic crops, herbaceous plants, and invertebrates. Fecal dry weight exhibited significant differences from December to February compared to March, suggesting a decline in rice intake and an increase in invertebrate consumption, resulting in lower fecal weight. These results also showed that as the months progress rice decreases with a shift to a protein-rich diet of invertebrates before cranes migrate back to their summer grounds. Traces of plastics were found in feces from all feeding sites, highlighting the need for better waste management. Changes in agricultural practices have had significant impacts on the availability of food sources for cranes in Bumdeling. Collaboration among conservationists, local government, and communities is recommended to enhance winter habitats and provide food supplements when rice supplies start to diminish.

Keywords: Changing agricultural practices, conservation strategy, declining crane population, fecal dry weight, foraging and roosting behaviour, herbaceous plant, paddy-fields, protein-rich diet, winter habitat.

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INTRODUCTION

Black-necked Crane (BNC) *Grus nigricollis* is a migratory species in the Central Asian Flyway (CAF) that prefers high-elevation habitats for beeding in summer and low-elevation areas for foraging in winter (Image 1). The largest population occurs at the Tibetan-Qinghai Plateau in western China (Lhendup & Webb 2009; Dong et al. 2016), and a small population occurs in Ladakh in India. During winter, cranes typically migrate to a lower altitudes of 2,000–3,000 m (Harris & Mirande 2013), including Qinghai-Tibet and Yunnan-Guizhou Plateaus in China, Arunachal Pradesh in northeastern India, and Bhutan (BirdLife International 2020). Their wintering habitats are mainly attributed to food availability and favorable climatic conditions. BNC is a globally 'Near Threatened' species (BirdLife International 2024), listed on CITES Appendices I and II. Its habitats continue to accrue significant destruction (Li & Li 2012) and access to food sources continues to reduce due to anthropogenic activities (Dong et al. 2016). The knowledge about dietary habits, food preferences, and choice of habitats is important evidence that will help devise conservation plans for the management of this species effectively (Dong et al. 2016).

Bhutan has three main areas where the BNC winters: Phobjikha in the west, Bumdeling in the east, and Bumthang in the center (Lhendup & Webb 2009; Namgay & Wangchuk 2016). In these wintering grounds, BNC typically feed on domestic crops like paddy, wheat, barley, buckwheat, potatoes, turnips, and cereals where conventional agriculture is practiced by local communities, however, elsewhere outside Bhutan grassland constitutes primary foraging areas (Bishop et al. 1998; Dong et al. 2016). Birds feed on herbaceous plants, especially the soft shoots found on roots, dwarf bamboo, tubers, and seeds, and also on invertebrates such as snails, and earthworms, which are crucial for their survival and health (Dong et al. 2016). They roost in shallow water, on riverbanks, or in small ponds. The population is threatened by significant changes in agricultural practices, industrial development, climate change, habitat loss (Lhendup & Webb 2009; Namgay & Wangchuk 2016), and predation (Choki et al. 2011). The world population totals over 10,000 birds (Li 2014). Bhutan hosts more than 600 individuals annually during the winter season between October and March (Phuntsho & Tshering 2014). The BNC population in Bumdeling declined steadily between 1980–2020 while it increased in Phobjikha (Namgay & Wangchuk 2016; BNC 2021). If this trend persists, the BNC may gradually abandon Bumdeling as a wintering area as there were few instances reported in the distant past from Samtengang, Tshokana, Gongkhar (Lhendup & Webb 2009), Gaytsa, and Rodhungthang (Namgay & Wangchuk 2016). The decrease in BNC numbers can be attributed

Image 1. Black-necked Crane *Grus nigricollis* feeding. © Tshering Chophel.

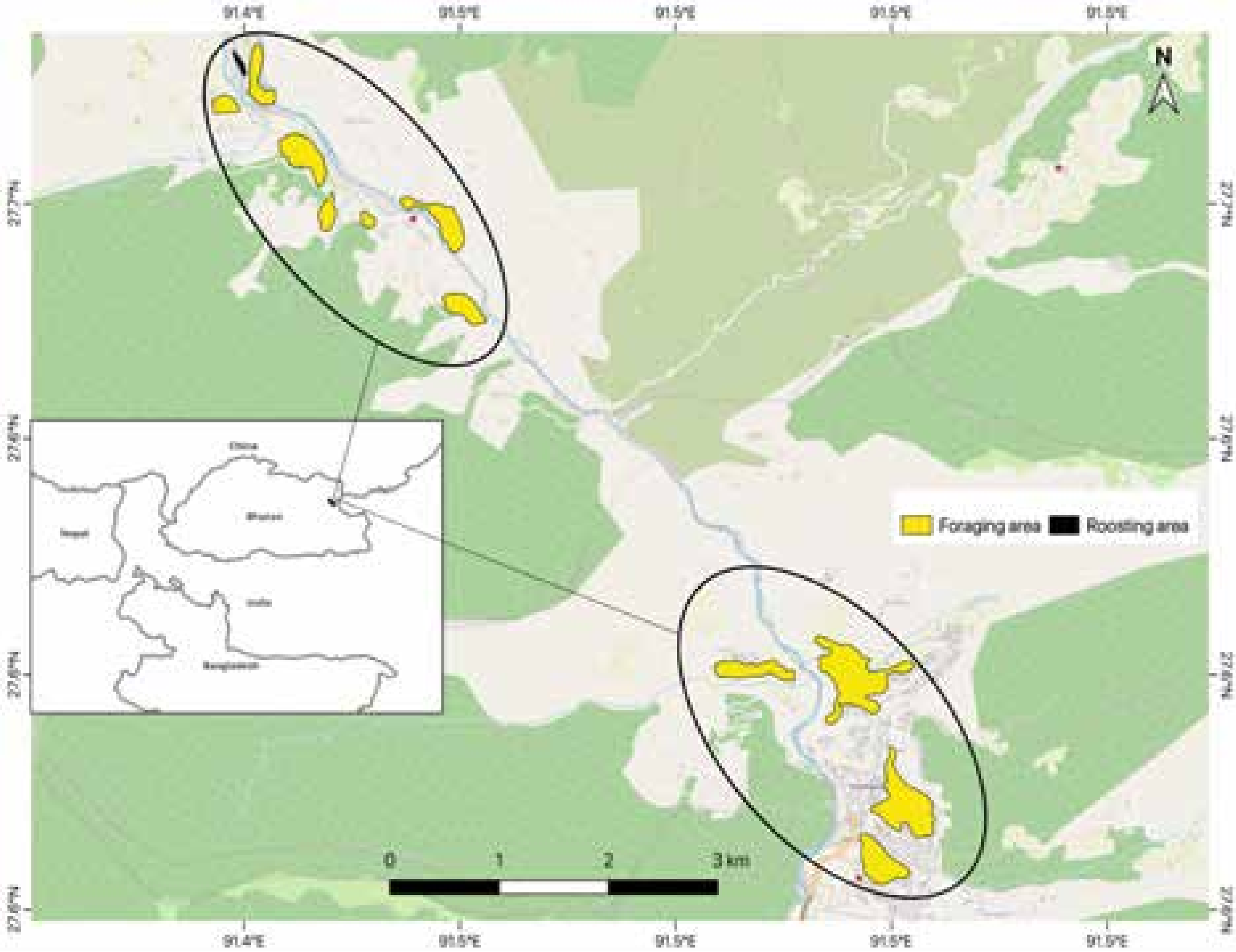

Figure 1. Map showing the study area, consisting foraging and roosting sites in Bumdeling and Yangtse, in Trashiyantse District.

to both anthropogenic activities, such as infrastructure development, and a series of natural events such as flash floods in Bumdeling in 1999, 2003, 2005, and 2007 (NCHM 2018), which have disrupted their feeding and roosting grounds. On the other hand, it is likely that the cultivation of winter crops in recent years after the rice harvest has reduced the availability of critical foraging and roosting areas which may have resulted in fewer BNCs visiting the sites.

The BNC plays a vital role in wetland ecosystems by regulating the population of invertebrates at cascading trophic levels. Culturally, these birds are considered sacred and believed to bring blessings, which helps to protect their habitats. Conservation efforts, including the designation of RAMSAR sites, habitat restoration, research on migration and habitat preferences, and the integration of community agricultural practices are being implemented. However, there is a lack of study on the dietary habits of BNC during winter months at their foraging and roosting sites. This study aims to address this gap by analyzing the dietary composition using fecal samples of BNC from their wintering grounds. By determining dietary needs and preferred food types, these findings are expected to enhance understanding of their habitat interactions and contribute to the development of long-term conservation plans (Dong et al. 2016) in Bhutan.

MATERIALS AND METHODS

Study area

The study was conducted in Bumdeling Wildlife Sanctuary (BWS) which falls within the northeastern part of Trashiyangtse District, Bhutan. The Sanctuary covers an area of 1,545 km^2 encompassing parts of the Lhuntse, Trashiyangtse, and Mongar districts (Figure 1). It shares international borders with the Tibetan region of China in the north and India in the north-east. Our study area is limited to Trashiyangtse, where the site is used as the wintering grounds by BNC. The sites include seven crane foraging areas: Bayling, Baychen, Batsemang, Gilingbo, Maidung, Tshaling, and Yangteng, and one roosting area: Dewalingjuk, scattered along Bumdeling valley. The study area has an altitudinal range of 1,785–1,921 m. The mean temperature varies 15–25 ^{0}C. The annual rainfall received in the area measures 2,000–3,000 mm. The study area covered all the foraging and roosting sites used by the BNC in the locality. The foraging site is located on farmland, where the main food crops grown by the local communities are rice, maize, millet, potatoes, and chillies. The roosting area consists of a shallow braided river with several pools and grasslands.

Sampling design and data collection

Local forest officials and resident communities were consulted to locate BNC annual foraging sites before starting fieldwork. Seven foraging sites and one roosting site were identified for fecal sample collection. Consultation of local people, observation, and involvement of local forest officials were key to site selection, and the transect method was employed for collecting fecal samples from the foraging and roosting sites.

We collected 350 and 40 fecal samples from the foraging and roosting sites, respectively. A transect walk was conducted from December 2019 to March 2020. BNCs start to arrive in their winter habitats by the end of November and leave for their summer habitats by March each year. The first 10 fresh fecal samples (intact) were collected from seven foraging and one roosting site. The fecal samples were sun-dried and wrapped in paper, and transported to the laboratory in zip-lock bags. While collecting, safety gear such as masks, hand gloves, and sanitizer were used to avoid fecal contamination and transfer of avian zoonotic diseases. At each collection site, a quadrat measuring 1 m^2 was laid on where the feces were observed. Firstly, at the foraging sites, surface-dwelling invertebrates were identified and counted, followed by herbs enumeration within the plot. Those unidentified invertebrates' specimens were collected and later identified in the laboratory. Secondly, within a 1 m^2 quadrat, a 10 cm^2 plot with a depth of 10 cm was dug and the invertebrates were identified and counted. Thirdly, at the roosting sites, freshwater invertebrate samples from the pools, runs, and riffles were collected using a kick net measuring 30 X 30 cm with a mesh size of 500 μm, and taxa were recorded.

Fecal analysis

Fecal sample analysis was carried out in the laboratory. Samples were oven-dried for three hours at 60^{o}C to eliminate moisture content and avoid fungal growth. We measured the dry sample weight of all the fecal samples using a digital weighing scale and then stored them at room temperature. Samples to be analyzed were put in petri dishes and soaked in water overnight, and the next morning, the contents were gently stirred to separate the plant fiber and invertebrate components. The supernatant of the fecal mixture was decanted into other petri dishes as invertebrate components remained afloat, and heavier invertebrate parts were also hand-picked with forceps. This method was adopted from Ralph et al. (1985) and Moreby (1988). The samples were repeatedly diluted and decanted until the undigested fecal materials (fibers, seeds, husk, invertebrate parts) were thoroughly cleaned and became identifiable under a microscope. The parts of undigested fiber and exoskeleton were placed on a glass slide and examined using a microscope, photographed, and identified. For the identification of undigested plant fiber, the method was adapted from Fengshan et al. (1997) and Liu et al. (2014), while for the identification of the exoskeleton of invertebrates, we used established methods by Moreby (1988), Ralph et al. (1985), and Liu et al. (2019). Depending on the size of the undigested fecal fragments, identifications were made to their taxonomic order, family, and species. The taxa names identified from fecal fragments, quadrat sampling, and kick net sampling were validated and confirmed by a national botanist and an entomologist. Soft-bodied organisms that may have been fully digested were beyond the scope of our study, however, those observed were included in our checklist.

Data analysis

To analyze the dietary compositions from fecal samples, both descriptive and inferential statistics were employed. For descriptive analysis, we calculated the percent composition of different diet components, including herbaceous plants, invertebrates, and domestic crops. For inferential analysis, we used Kruskal-Wallis tests in R software to compare diet composition and fecal dry weight across various months and sites. To compare diet composition and fecal dry weight between roosting and foraging sites, we applied the Mann-Whitney U test (also known as the Wilcoxon Rank Sum test). Given the non-normality of the data and unequal group size, we used a non-parametric effect size measure Cliff's delta to compare fecal weight data between March (Group 1) and each of the other months (December, January, February) treating each as group 2 in separate comparisons. We calculated Cliff's delta

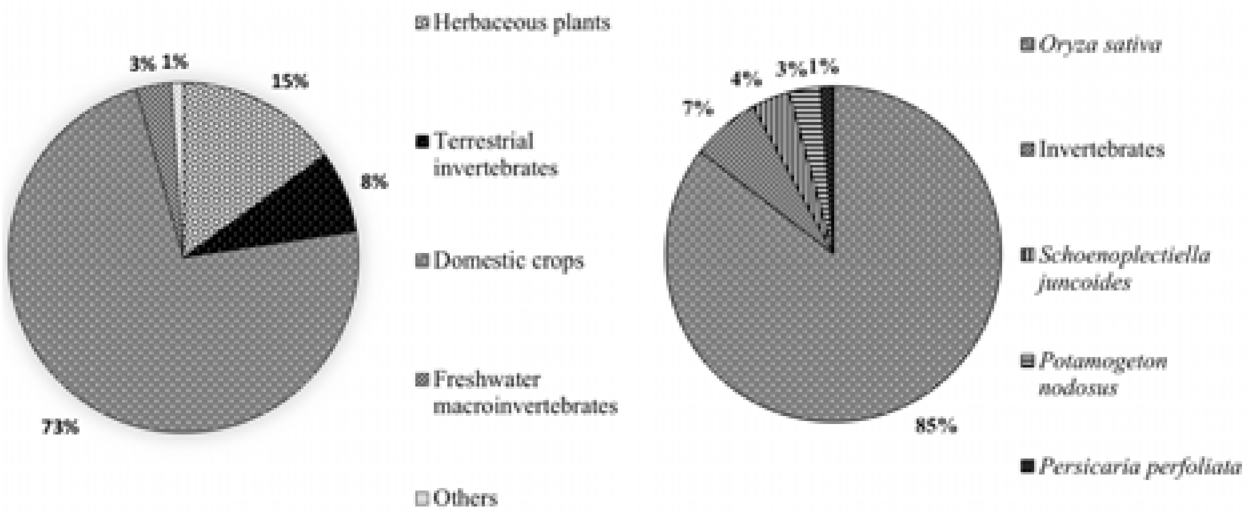

Figure 2. Left—Primary composition of food sources of the BNC | Right—five major diet constituents of the BNC.

(1993) using the equation: $\delta = (D-U)/(n1 * n2)$. In this D is the number of instances where a score from group 1 is greater than a score from group 2, U is the number of scores from group 1 that are smaller than group 2, and n1 and n2 are the number of observations in respective groups. The values of 1 are given when a score from group 1 is greater than group 2, -1 when it is smaller, and 0 when they are equal.

RESULTS

Dietary composition of BNC

A total of 3014 fragments of ingested materials were counted from 390 fecal samples constituting 79 different types of dietary sources, mainly herbaceous plants (41), followed by invertebrates (30), and domestic crops (4) respectively, apart from small traces of plastics, fine pebbles (2–4 mm diameter), feathers of birds, and fish scales were also evident in the fecal samples (Table 1). However, in terms of composition, rice constitutes the highest food source. This is certainly obvious as the remains of rice grains are readily available in the farmland after the harvest. The results show that domestic crops, herbaceous plants, and invertebrates constituted the main dietary structure of the BNC. Domestic crops comprised the highest proportion (70%) of the diet, followed by herbaceous plants (14%) and invertebrates (13%). About 1% constitutes other diatary components such as bird feathers, fish, plastics, and pebbles (Figure 2). The occurrences of plastic waste, pebbles, and bird feathers were circumstantial, however, plastic traces were present at almost all the feeding sites.

The main diet of BNC during the wintering months appeared to be rice *Oryza sativa*, followed by herbaceous plants and invertebrates. Data on diet composition in winter from December 2019 to March 2020 showed insignificant differences in the Kruskal-Wallis rank sum test; H = 1.269 (3), p = 0.05. The composition of diet content appears to have a similar pattern throughout the months. The diet composition exhibited no variation across different sites; H = 11.337 (7), p = 0.124. This showed that all sites had similar composition of dietary sources chiefly rice grains from paddy land. The top five food sources constitute *Oryza sativa*, invertebrates, *Schoenoplectiella juncoides*, *Potamogeton nodosus*, and *Persicaria perfoliata* (Figure 2). *Oryza sativa* is an essential dietary source followed by invertebrates which are attributed to the higher number of fragments in feces samples. However, it should be noted that most fragments which were not identifiable due to ingestion were grouped together.

Dietary composition at roosting and foraging sites

Dietary sources in roosting and foraging sites are likely to have differences, the former being in the braided river and island, and the latter in cultivated paddy-fields. Our in-depth analysis showed that roosting sites had species that were not present in other sites. This is primarily attributed to the composition of aquatic plants (*Cladophora* sp. *Dicranum viride, Digitaria sanguinalis, Marsupella emarginata, Eriochloa villosa, Seleginella* sp, and *Urochloa ramosa*) and freshwater invertebrates (Aeshnidae, Athericidae, fish, Hydropsychidae, Hydroptilidae, and Scirtidae) which were observed only from the roosting sites. On the other hand, foraging

Table 1. The percentage composition of species in the dietary intake and the remnants of identical parts present in the Black-necked Crane's fecal samples.

	Family	Species	Part of organ	Frequency of fragments	Percentage
		Herbaceous plants			
1	Adoxaceae	*Viburnum* sp.	Leaf	1	0.033
2	Asteraceae	*Chromolaena corymbosa*	Seed pod	3	0.100
3	Asteraceae	*Bidens tripartita*	Seed	9	0.299
4	Brassicaceae	*Cardamine hirsuta*	Leaves, stem	3	0.100
5	Ceratophyllaceae	*Ceratophyllum demersum*	Needle leaves with stem	1	0.033
6	Cladophoraceae	*Cladophora* sp.	Undigested filaments of algae	16	0.531
7	Commelinaceae	*Commelina* sp.	Whole plant, leaf, stem	4	0.133
8	Cyperaceae	*Carex* sp.	Flower, seed, seed pod	23	0.763
9	Cyperaceae	*Schoenoplectiella juncoides*	Seed	94	3.119
10	Dicranaceae	*Dicranum viride*	Leaf	2	0.066
11	Equisetidae	*Equisetum* sp.	Stem	3	0.100
12	Eriocaulaceae	*Eriocaulon nepalense*	Petal	27	0.896
13	Fabaceae	*Trifolium hybridum*	Seed	7	0.232
14	Funariaceae	*Funaria hygrometrica*	Seed and leaves	10	0.332
15	Gymnomitriaceae	*Marsupella emarginata*	Leaf	2	0.066
16	Hydrocharitaceae	*Elodea densa*	Leaf	7	0.232
17	Hydrocharitaceae	*Hydrilla verticillata*	Leaf	6	0.199
18	Juncaceae	*Juncus effusus*	Naked seed	4	0.133
19	Lamiaceae	*Pogostemon stellatus*	Leaf, stem	9	0.299
20	Lamiaceae	*Pogostemon erectus*	Leaf	2	0.066
21	Lythraceae	*Rotala cordata*	Twigs, leaves, stem	13	0.431
22	Lythraceae	*Rotala indica*	Flower, twig	18	0.597
23	Nostocaceae	*Nostoc* sp.	Alike jelly fungus	1	0.033
24	Plantaginaceae	*Plantago asiatica*	Leaf	2	0.066
25	Poaceae	*Alopecurus aequalis*	Seed pod	2	0.066
26	Poaceae	*Poa annua*	Seed with cover	5	0.166
27	Poaceae	*Poa pratensis*	Seed	17	0.564
28	Poaceae	*Setaria italica*	Seed, seed pod	12	0.398
29	Poaceae	*Panicum* sp.	Seed pod, seed	5	0.166
30	Poaceae	*Eriochloa villosa*	Seed	1	0.033
31	Poaceae	*Digitaria sanguinalis*	Seed	5	0.166
32	Poaceae	*Urochloa ramosa*	Seed with case	1	0.033
33	Polygonaceae	*Polygonatum aviculare*	Sheath	12	0.398
34	Polygonaceae	*Persicaria perfoliata*	Stem with spike	32	1.062
35	Potamogetonaceae	*Potamogeton nodosus*	Leaf	77	2.555
36	Araliaceae	*Hydrocotyle sibthorpioides*	Leaf	6	0.199
37	Selaginellaceae	*Selaginella* sp.	Stem and leaf	1	0.033
38	Xyridaceae	*Xyris capensis*	Awn	1	0.033
39	Xyridaceae	*Xyris* sp.	Seed, seedpod, flower	7	0.232
40	Zygnemataceae (Algae)	*Spirogyra* sp.	Leaf	2	0.066
		Domestic crop			
41	Amaranthaceae	*Amaranthus hybridus*	Seed	5	0.166

	Family	Species	Part of organ	Frequency of fragments	Percentage
42	Poaceae	*Oryza sativa*	Husk, seed, sheath, leaf, stem digested remains	2182	72.395
43	Poaceae	*Triticum aestivum*	Seed	1	0.033
44	Poaceae	*Eleusine coracana*	Seed	13	0.431
	Terrestrial invertebrates				
45	Acrididae	Acrididae	Legs	12	0.398
46	Agriolimacidae	*Deroceras* sp.	Whole body (Observed)	2	0.066
47	Carabidae	*Bradycellus* sp.	Elytra and legs	4	0.133
48	Carabidae	Harpalinae	Elytra and legs	5	0.166
49	Carabidae	*Stenolophus* sp.	Elytra and legs	2	0.066
50	Carabidae	*Platynus* sp.	Elytra	5	0.166
51	Cerambycidae	Cerambycidae	Legs, exoskeleton, ommatidium	8	0.265
52	Chrysomelidae	*Altica* sp.	Elytra	1	0.033
53	Chrysomelidae	*Chrysolina* sp.	Legs	2	0.066
54	Dermaptera	Dermaptera	Exoskeleton	1	0.033
55	Fanniidae	*Fannia* sp.	Exoskeleton	7	0.232
56	Lucanidae	*Lucanidae*	Elytra	2	0.066
57	Lumberculidae	Lumbriculidae	Whole body (Observed)	8	0.265
58	Ptinidae	*Stegobium paniceum*	Full body	1	0.033
59	Invertebrates	Invertebrates	Elytra, exoskeleton, legs, Mesonotum, scutellum,	169	5.607
	Freshwater invertebrates				
60	Aeshinidae	Aeshnidae	Exoskeleton	1	0.033
61	Athericidae	Athericidae	Whole body (Observed)	2	0.066
62	Aphelocheiridae	*Aphelocheirus* sp.	Elytra	2	0.066
63	Blepharicidae	Blephariceridae	Exoskeleton	1	0.033
64	Belostomatidae	*Diplonychus* sp.	Legs and wings	3	0.100
65	Chironomidae	*Chironomidae* (red)	Exoskeleton	10	0.332
66	Corixidae	*Hesperocorixa interrupta*	Wavy leopard pattern elytra	21	0.697
67	Dytiscidae	*Rhantus* sp.	Dotted leopard pattern elytra	19	0.630
68	Hydropsychidae	Hydropsychidae	Femur	1	0.033
69	Hydroptilidae	Hydroptilidae	Case with insect	1	0.033
70	Lymnaeidae	*Orientogalba ollula*	Part of shell	9	0.299
71	Potamidae	Potamidae	Legs, carapace, exoskeleton	16	0.531
72	Psychomyiidae	Psychomyiidae	Trochatin	2	0.066
73	Scirtidae	Scirtidae	Exoskeleton	1	0.033
74	Sphaeriidae	*Pisidium* sp.	Shell	5	0.166
75	Tipulidae	Tipulidae	Whole body	3	0.100
	Others				
76		Birds	Feather	2	0.066
77		Fish	Scale/skin	2	0.066
78		Plastics	With different colors: White, red, pink, yellow, green, blue	17	0.564
79		Pebbles	With color and patterns: black stripe, white, and yellow	13	0.431
				3014	100.00

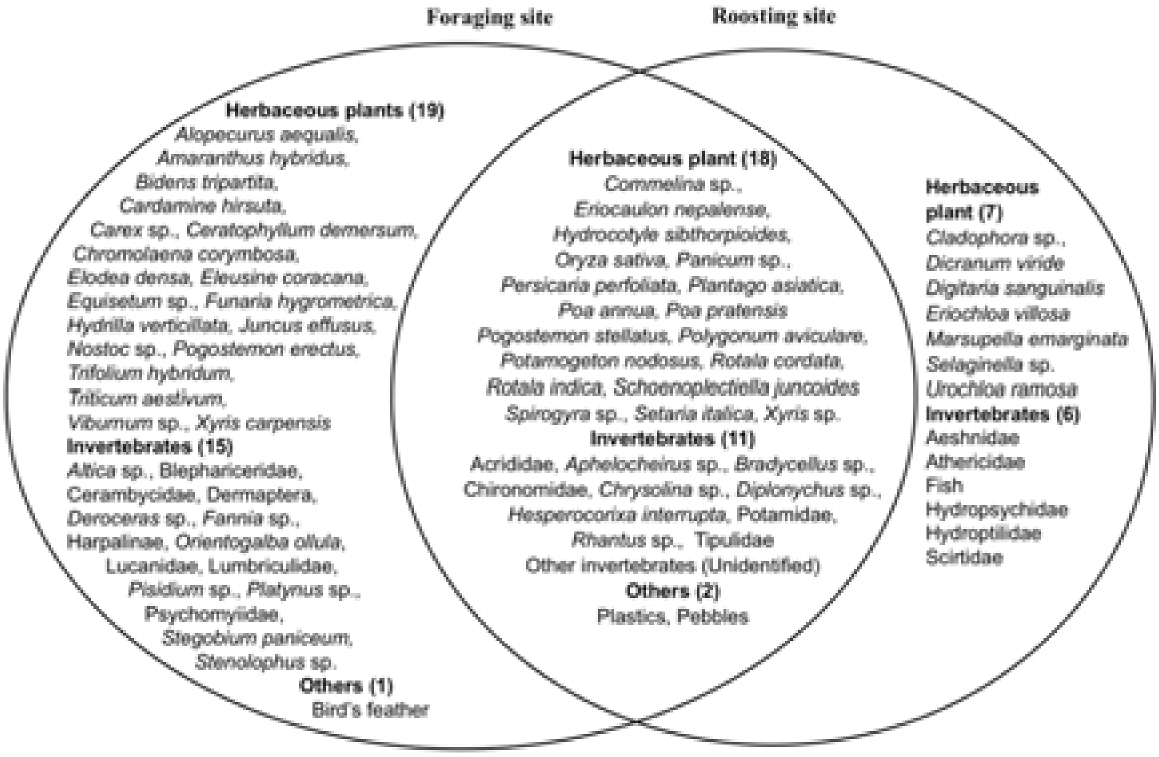

Figure 3. Dietary sources identified at roosting and foraging sites, indicating common dietary preferences and variations. The bold text represents major diet groups of the Black-necked Crane.

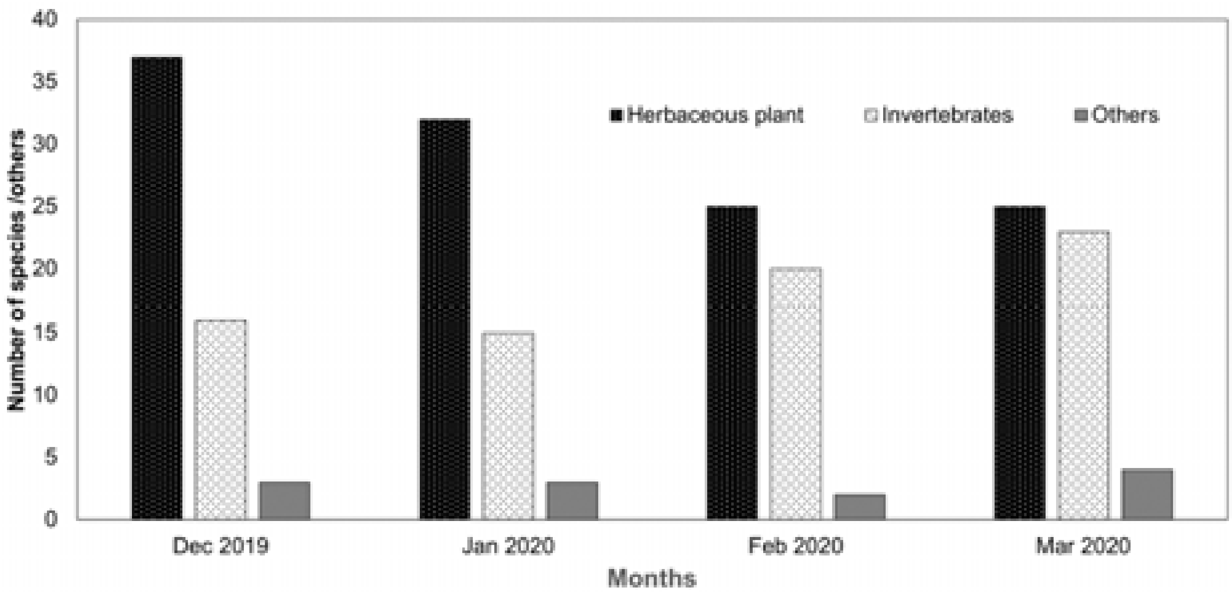

Figure 4. Number of species within taxonomic groups identified in the feces of Black-necked Crane across different months.

sites had the highest species composition and richness, possibly because these sites comprised seven localities (Figure 3). To understand the difference between the roosting sites (Dewalingjuk) and the foraging sites, a Wilcoxon rank sum test revealed significant differences in two of the seven site pairs; Batsemang vs Roost, W = 2491.5, p = 0.016, δ = 0.05 and Tshaling vs Roost site, W = 2397, p = 0.001, δ = 0.10. The other five pairs had

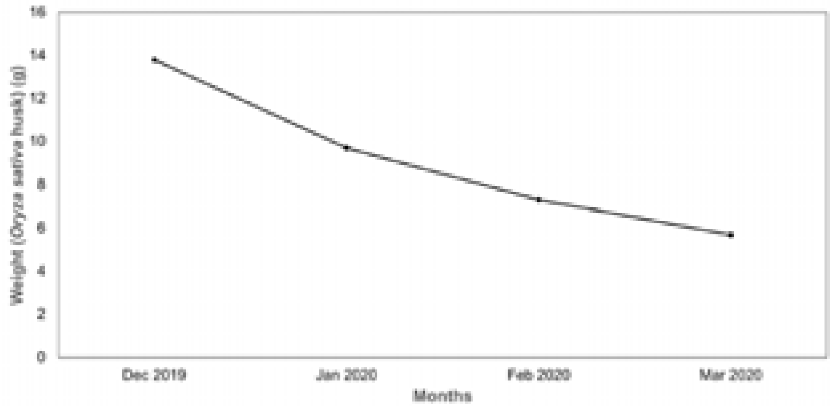

Figure 5. Dried weight of *Oryza sativa* residues in the feces of Black-necked Crane during different months.

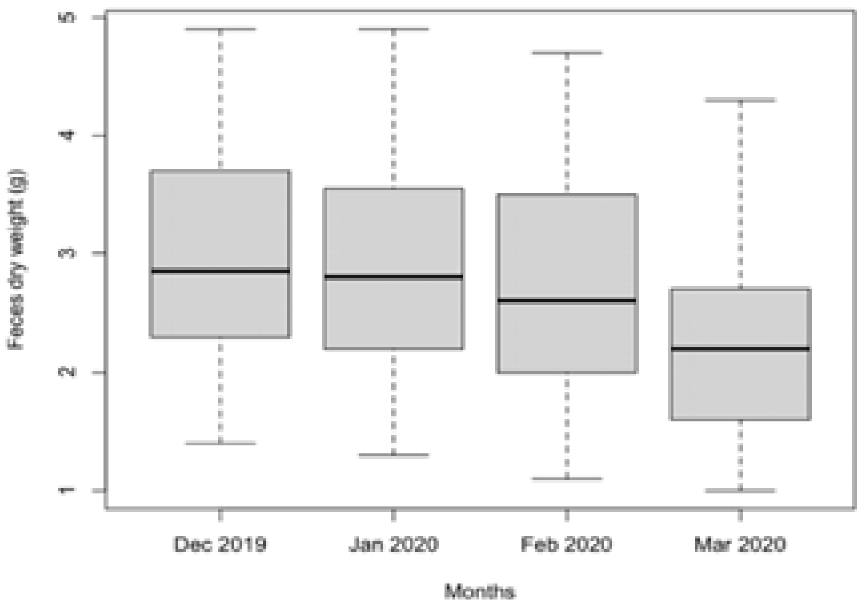

Figure 6. Variation in the dry weight of Black-necked Crane fecal samples during the winter months.

no significant differences; Roost site vs Maidung, W = 2736, $p = 0.150$; Bayling vs Roost site, W = 2999.5, $p = 0.651$; Choetenkora vs Roost site, W = 2889.5, $p = 0.390$; Gilingbo vs Roost site, W = 2937.5, $p = 0.491$ and Roost site vs Yangteng, W = 2720.5, $p = 0.132$. Cliff's delta effect size (≤ 0.1) in the significant comparisons suggests that the difference between the two groups was small.

Monthly variation of food

All 390 samples showed the presence of herbaceous plants when pooled with domestic crops and plants. Undigested materials from invertebrates were found in 281 samples, while 17 samples contained traces of plastics, pebbles (13), feathers of birds (2), and fishes (2). Species richness varied slightly over the four months, with December 2019 having the highest number of species. However, there was a steady decline in the following month before increasing in March 2020 (Figure 4). The cranes had access to more food sources at the time of their arrival in December, while access to food resources declined in the following months after they fed on them. Before migrating, the crane prefers invertebrates to store more energy for their long flight to their summer grounds. The Poaceae family was the most dominant species among the herbaceous plants, while Coleoptera was the most abundant food constituent in the invertebrate group. Overall, species richness slightly fluctuates over the four months, with herbaceous plant species decreasing and invertebrate species increasing.

Dry weight of feces and rice grains across different months

Of the 390 samples collected, 311 contained *Oryza sativa* which is the primary food source for the BNC. An in-depth analysis was conducted to determine the weight of undigested rice remains, including husk, stem, and seeds, and it was found that the fecal weight decreased over the months (Figure 5). In December, when BNC arrived at their wintering grounds, there was a large amount of rice residuals (~14 g) that had been harvested a month earlier. Over the following months, the availability of rice grains gradually decreased, reaching a low point (~6 g) just before the cranes left for their summer habitat. The decrease in rice intake was probably compensated by an increase in the consumption of invertebrates.

The dry fecal weight corroborates the food availability and access for BNC. The weight of BNC feces was highest in December, then gradually decreased from January to February, with a sharp drop in March, indicating reduced food availability due to repeated foraging in the area (Figure 6). The mean dry weight per dropping of the BNC is 2.70 ± 1.06 g and they gain more energy by feeding on invertebrates before flying back to their summer habitat. The Kruskal-Wallis rank sum test revealed that dry weight data from December 2019 to March 2020 had significant differences among the months H = 34.657 (3), p = 0.001. To determine which specific months had contributed to differences in dry weight, a post-hoc test was performed. The months of December 2019, January 2020, and February 2020, when compared to March 2020, exhibited significant differences based on the Wilcoxon rank sum test. These significance pairs were evaluated to understand the magnitudes and strength of effect size between independent paired months for March 2020 vs December 2019, W = 4612.5, p = 0.001, δ = 0.42; March 2020 vs January 2020, W = 4427.5, p = 0.001, δ = 0.43; and March 2020 vs February 2020, W = 3837, p = 0.001, δ = 0.32. The main observed differences with all three comparisons have positive data values indicating second months (December 2019, January 2020, and February 2020) have higher values than the first group (March 2020) respectively. However, the effect sizes are relatively small (0.3–0.4). This can be attributed to the fecal dry weight in March 2020, with an increased intake of invertebrates, which have higher protein content and constitute less indigestible material compared to plant matter. Conversely, for the other months, no significant differences were exhibited December 2019 vs January 2020, W = 3384.5, p = 0.052; December 2019 vs February 2020, W = 3514.5, p = 0.061, January 2020 vs February 2020, W = 3357, p = 0.20. These results were largely due to the crane's higher preference for herbaceous plants and lower intake of invertebrate diet during these months consistent with the earlier results.

DISCUSSION

In this study, the diet of BNC comprises 44 plant species, 31 invertebrate species, and four other food sources. Of the combined 87 herbaceous plant species reported elsewhere in the cranes-inhabiting regions by various authors Fengshang et al. (1997) (48 species), Dejun et al. 2011 (5 species), and Lui et al. 2014 (43 species); and *Plantago* sp., *Trifolium* sp., *Poa annua*, *Polygonum* sp., *Epilobium* sp., *Carex* sp., *Eriochloa villosa*, *Juncus effusus*, *Potamogeton* sp. *Hydrilla verticillata*, and *Polygonatum* sp. were also found in the feces samples of BNC from the present study. These species are largely grown on the edge of the terraces and are occasionally found growing along with the *Oryza sativa.* The primary diet of the BNC in the Bumdeling consisted of domestic crops, particularly *Oryza sativa*. The high food quantity and density of paddy seeds in the farmland, where residues are left after the harvest is the main reason why the cranes have established their wintering grounds in this locality.

Several studies have documented that the diet of cranes consists of fish, young birds, clams, shrimps, amphibians, molluscs, and invertebrates (Chacko 1992; Han 1995, Li et al. 1997; Li & Li 2005; Liu et al. 2014a,b, 2019). In this study, we report one fish species and two other molluscs (*Deroceras* sp. and *Orientogalba ollula*). The roosting sites characterized by shallow water provide the best habitat for cranes to feed on fish. The slightly marshy wetlands left after the harvest of paddy-fields support molluscs which is a food source for cranes in the locality.

The invertebrate taxa consumed by the BNC, identified at various taxonomic levels, include Coleoptera, Hymenoptera, Diptera, Lepidoptera, and Araneae (Di-jun et al. 2011; Liu et al. 2019), along with specific species such as *Chorthippus hsiai* and *Geotrupes* sp. (Wu 2007). In our study, we report several invertebrates identified down to the lowest possible taxa levels, from terrestrial and freshwater systems that were limited in previous studies. The fecal analysis revealed the presence of 16 freshwater and 15 terrestrial invertebrate species. Taxa such as Lumbriculidae, Tipulidae, Athericide, and Diplonychus sp. are soft-bodied and were recorded through field observations. In contrast, others, largely comprising Coleopterans (Liu et al. 2019), were discovered from the crane feces. Undigested fragments that were not identifiable were grouped under invertebrates, which may constitute multiple species. Although Coleopterans appear to be a supplementary food source for BNC, they form an important food source after herbaceous plants. Fragments of *Hesperocorixa interrupta* and *Rhantus* sp. were quite common compared to other species. However, this list is underestimated, as many digested soft tissues were difficult to examine and could not be accounted for. Although feces provide an easy method for analyzing diet, completely digested soft-bodied fragments and smaller indigestible particles make identification more challenging. This highlights the need for future studies to incorporate eDNA methods to improve accuracy.

The main factors that determine the arrival and departure of cranes are influenced by the availability of food in the farmland after the harvest. In December, just after the harvest, droppings of paddy grains are most abundant and gradually decrease in the following months. Animal matter, including protein- and fat-rich invertebrates from soil and freshwater habitats (Liu et al. 2014a), is crucial for cranes, with higher intake observed before migration to their summer grounds. Over the years, the gradual decline in visiting BNC in the localities may be attributed to the decrease in foraging areas, as nearby open spaces, including some agricultural land, have been colonized by vegetation. Additionally, food availability has decreased as the land used for rice production has been cultivated following the paddy harvest, resulting in a reduction of the food supply. Studies conducted elsewhere have shown that BNC forages in meadow habitats are rich in calcareous food resources. Grazing effects in the meadows provide a wide range of food for invertebrates, which are the main food source for BNC (Horgan 2002). However, in our study area, a foraging area solely consists of paddy-fields, where cranes depend on the dropping of a variety of rice grains. Occasional foraging has also been observed in the farmlands of localities where communities grow food grains such as *Eleusine coracana*.

Several challenges are causing degradation of habitat for BNC, with issues emerging such as the discovery of plastics in the feces of BNC from the study area. Different ingested plastic colors, such as white, green, and blue, were evident in the feces. Plastics, though present in small traces (<1%), were detected in feces across all sites and throughout the study months. Such evidence is likely to affect the health of the cranes and the surrounding environment in the long run. This highlights the need for decision-makers to develop effective habitat management and conservation strategies to address the increasing waste in crane foraging areas.

CONCLUSIONS

We found that the Black-necked Crane prefers cultivated land near human settlements, which provides them with easy access to grains left on the ground after harvest. Their preferred winter foraging habitat is closely tied to the local rice cultivation, which is crucial for crane survival. Future changes in cropping patterns for rice cultivation may impact crane wintering habitats. Localized rice cultivars that yield more paddy seeds and drop a sufficient quantity of seeds to support cranes must be prioritized. The crane spends the night in shallow streams, ponds, and marshy areas, separated from the rest of the localities, allowing them to remain secure from predators, which is important for their safety. The fate of the crane population is intertwined with human activities and their continued existence of wintering habitats in the study area depends on agricultural practices. Changing farming practices and colonization of foraging areas by trees would be a challenge for crane habitats in the future. We recommend the collaboration of conservationists, agriculturalists, and local communities to develop a suitable strategy that can enhance the winter habitats of the BNC and supplement food gains for the cranes when their rice supplies start to diminish.

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Author contribuions: JIGME WANGCHUK designed, gathered and analyzed the data, and prepared and reviewed the manuscript; UGYEN TENZIN collected, processed, and analyzed fecal samples in the laboratory; KARMA WANGDI gathered data; TSHETHUP TSHERING collected data, identified fecal fragments and reviewed manuscript; SANGAY DRUKPA, TSHERING CHOPHEL, and UGYEN WANGMO gathered the field data. JIGME TSHEING planned the study, secured funding, and conducted the internal review. DR. SHERUB planned, designed, collected fecal samples, conducted the internal review, and analyzed results. He played a pivotal role in providing the overall supervision for the achievement of this study. All authors contributed to finalizing the manuscript.

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ARTICLE

Checklist of forensically significant Rove beetles (Coleoptera: Staphylinidae: Staphylininae: Staphylinini) from India

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Abstract: Beetles play a substantial role in calculating the postmortem interval (PMI) during the later stages of decomposition of a carcass. The dominant families are Silphidae, Dermestidae, Histeridae, Tenebrionidae, Trogidae, and Staphylinidae. For accuracy in PMI calculations based on insect fauna, it becomes imperative to catalogue the insect diversity of an area. Herein, we provide checklist of forensically important rove beetles from India belonging to subfamily Staphylininae of family Staphylinidae.

Keywords: Beetle diversity, carcass, forensic entomology, Staphylininae, Rove beetles.

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Author contributions: The authors contributed equally in the preparation of the manuscript.

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INTRODUCTION

Diptera and Coleoptera are the major insect orders which help forensic entomologists in solving homicidal cases (Catts & Haskell 1990). Generally, dipteran flies are the first to arrive and colonize a carcass thereby acting as key players in calculating the post-mortem interval of a body (Bharti & Singh 2003). Beetles, on the other hand, are attracted to a carcass during the advanced stage of its decomposition. Silphidae (Carrion beetles or burying beetles) lay eggs in the burrows created under the carrion and uses carrion as a resource to complete its life history, Staphylinidae (Rove beetles), Histeridae (Clown beetles) are predacious and prefer to feed on fly larvae and dead flies present on the carcass, whereas Dermestid beetles prefer skin of the carcass, and Trogidae feed on dried remains (Weidner et al. 2021).

Of all the forensically important families of beetles, Staphylinidae is the most diverse family of rove beetles with 35 subfamilies encompassing 4,038 genera and 66,928 species (https://www.catalogueoflife.org/). Subfamily Staphylininae with 9,071 species is the third largest subfamily and comprises of nine tribes (Arrowinini, Coomaniini, Diochini, Maorothini, Othini, Platyprosopini, Staphyliini, Thayeralinini (extinct), and Xantholiini) of which Staphyliini constitutes the most hyperdiverse group with 6,377 species (Brunke et al. 2019). Its members prefer to feed on fungi, dead organic matter, carrion making them a potential candidate in solving PMI cases. A lot has been done to catalogue the forensically important beetles (Pajni & Kumar 1977; Kulshrestha & Satpathy 2001; Bharti & Singh 2003; Dekeirsschieter et al. 2013; Sharma et al. 2018; Al-Zahrani et al. 2023; Benny & Suleiman 2023; Luo & Meng 2023) but there is a dearth of comprehensive checklist of forensically important rove beetles from India. Cameron (1943, 1944) initiated the work on Staphylinidae from India, followed by inputs from Scheerpeltz 1933; Coiffait 1982, 1984; Schillhammer 2001, 2003. But the change in taxonomic status of many taxa, additions of new records and species in recent times (Smetana 1975, 1988; Herman 2001; Assing 2008; Zyla & Solodovnikov 2019; Tihelka et al. 2020), has left the data on rove beetles fragmented and confusing. Thus, in the light of above stated facts, an updated checklist of forensically important rove beetles from India belonging to subfamily Staphylininae of family Staphylinidae is provided.

RESULTS AND DISCUSSION

A total of nine tribes of Staphylininae (including extinct tribe Thayeralinini) are known from the World. Cameron (1943) divided Indian Staphylininae into three tribes namely Staphylinini, Xantholinini, and Quediini but phylogenetic analysis revealed Quediini as polyphyletic assemblage of species belonging to different subtribes within Staphylinini (Solodovnikov 2006; Chatzimanolis et al. 2010; Salnitska & Solodovnikov 2018; Brunke et al. 2019). Currently, Staphylininae is represented by tribes Othiini, Staphylinini, and Xantholinini from India. Tribe Othiini is represented by five genera, 152 species; tribe Staphylinini by 247 genera, 6377 species and tribe Xantholini by 146 genera and 2352 species from the world (https://www.catalogueoflife.org/). From India, tribe Othiini is represented by genus *Othius*; Staphylinini by *Philonthus*, *Quedius*, *Platydracus*, *Belonuchus*, *Bisnius*, *Heterothops*, *Staphylinus*, *Creophilus*, *Ontholestes* and *Neobisnius* where as Xantholinini by *Indolinus* and *Indomorphus*. Following is the list of forensically significant rove beetles of subfamily Staphylininae from India.

Subfamily: Staphylininae Latreille, 1802

1802. Staphylininae Latreille, *Familles naturelles des genres*. Vol. 3. F. Dufart, Paris. xii + 13-467 pp.

Tribe: *Othiini* Thomson, C.G., 1859

1859. Othiini Thomson, C.G., *Berlingska Boktryckeriet*, Lund 290 pp.

1957. Atrecini Hatch, *University of Washington Publications in Biology* 16(2).

Genus: *Othius* Stephens, 1829

1829. *Othius* Stephens, *Baldwin and Cradock*, London, 68 pp.

1906. *Othiellus* Casey, *Transactions of the Academy of Science of St. Louis*.

1926. *Othius apicalis* Cameron, *Transactions of the Entomological Society of London,* 1925: 341–372.

Distribution: India (Sikkim: Darjeeling, Uttar Pradesh), Nepal.

***Othius cachemiricus* Coiffait, 1982**

1982. *Othius cachemiricus* Coiffait, *Entomologica Basiliensia*, 7: 231–302.

Distribution: India (Kashmir).

***Othius flavocaudatus* Cameron, 1926**

1926. *Othius flavocaudatus* Cameron, *Transactions of the Entomological Society of London,* 1925: 341–372.

Distribution: India, Nepal.

***Othius kashmiricus* Cameron, 1943**

1943. *Othius kashmiricus* Cameron*, Proceedings of the Royal Entomological Society of London* (B), 12(1): 127–132.
Distribution: India (Kashmir).

***Othius monticola* Cameron, 1943**

1943. *Othius monticola* Cameron, *Proceedings of the Royal Entomological Society of London* (B), 12(1): 127–132.
Distribution: India (Darjeeling).

***Othius pokharensis* Coiffait, 1983**

1983. *Othius pokharensis* Coiffait, *Nouvelle Revue d'Entomologie*, 13(2): 161–172.
Distribution: India (Sikkim: Darjeeling), Nepal.

***Othius ruficornis* Cameron, 1928**

1928*. Othius ruficornis* Cameron, *Annals and Magazine of Natural History*, 2(12) : 558–569.
Distribution: India (Sikkim).

***Othius sinuosus* Assing, 1998**

1998*. Othius sinuosus* Assing, *Beiträge zur Entomologie*, 48(2): 343–351.
Distribution: India, Pakistan (Karakorum).

***Othius uttaricus* Assing, 2008**

2008. *Othius uttaricus* Assing*, Koleopterologische Rundschau*, 78: 245–263.
Distribution: India (Uttarakhand).

***Othius yusmargensis* Coiffait, 1982**

1982**.** *Othius yusmargensis* Coiffait, *Entomologica Basiliensia*, 7: 231–302.
Distribution: India (Kashmir).

Tribe: Staphylinini Latreille, 1802

1802. Staphylinini Latreille, *Familles naturelles des genres*. Vol. 3. F. Dufart, Paris. xii + 13–467pp.

Genus: *Belonuchus* Nordmann, 1837

1837. *Belonuchus* Nordmann, *Academiae Caesareae Scientiarum, Petropoli* [St.
Petersburg], 167 pp.

***Belonuchus aeneipennis* Fauvel, 1895**

1895. *Belonuchus aeneipennis* Fauvel, *Revue d'Entomologie*, 14(6–7): 180–286.
Distribution: Throughout India, Myanmar, Malaysia (Melaka, Sarawak), Singapore, Indonesia (Borneo, Sumatra, Moluccas).

***Belonuchus punctifrons* (Cameron, 1926)**

1926. *Philonthus punctifrons* Cameron, *Transactions of the Entomological Society of London*, 1925: 341–372.
Distribution: India (Himachal Pradesh, Uttar Pradesh), Thailand, China (Shaanxi, Sichuan, Yunnan), Malaysia (Pahang), Indonesia (Sumatra).

Genus: *Bisnius* Stephens, 1829

1829. *Bisnius* Stephens, *Baldwin and Cradock*, London, 68 pp.
1859. *Gefyrobius* Thomson, C.G., *Berlingska Boktryckeriet,* Lund, 290 pp.

***Bisnius deuvei* (Coiffait, 1982)**

1982. *Bisnius deuvei* (Coiffait), *Entomologica Basiliensia*, 7: 231–302.
Distribution: India (Kashmir)

***Bisnius diversus* (Schubert, K., 1906)**

1906. *Bisnius diversus* (Schubert, K.,), *Deutsche Entomologische Zeitschrift*, (2): 378–383.
1906. *Philonthus diversus* Schubert, K., *Deutsche* Entomologische Zeitschrift, (2): 378–383.
Distribution: India (Kashmir), Mongolia.

***Bisnius fimetarius* (Gravenhorst, 1802)**

1802. *Bisnius fimetarius* (Gravenhorst), *Brunsuigae [Braunschweig].* lxvi + 206 pp
1802. *Staphylinus fimetarius* Gravenhorst, *Brunsuigae [Braunschweig]*. lxvi + 206 pp.
1802. *Staphylinus rigidicornis* Gravenhorst*, Brunsuigae [Braunschweig].* lxvi + 206 pp.
1858. *Gabrius longulus* Motschulsky, *Bulletin de la Société Impériale des Naturalistes de Moscou,* 31(2): 634–670.
1859. Philonthus xanthomerus Kraatz, *Archiv für Naturgeschichte,* 25(1): 1–96.
1860. *Philonthus interpunctatus* Hochhuth, *Bulletin de la Société Impériale des Naturalistes de Moscou*, 33(2): 539–588.
1861. *Philonthus stenoderus* Reiche*, Annales de la Société Entomologique de France*, (4)1: 201–210.
Distribution: India (Arunachal Pradesh, Uttar Pradesh, Uttarakhand), Europe, Russia (European, Siberia, Far East), Armenia, Georgia, Morocco, Algeria, Tunisia, Libya, Egypt, Turkey, Iran, Kazakhstan China (Ningxia), Taiwan, Canada.

***Bisnius nichinaiensis* (Coiffait, 1982)**

1982. *Bisnius nichinaiensis* (Coiffait), *Senckenbergiana Biologica,* 62: 21–179.
1982. *Philonthus nichinaiensis* Coiffait, *Senckenbergiana Biologica,* 62: 21–179.
Distribution: India (Kashmir), China (Yunnan).

***Bisnius protenus* (Schubert, K., 1906)**

1906. *Bisnius protenus* (Schubert, K.,) *Deutsche Entomologische Zeitschrift*, (2): 378–383.
1906. *Philonthus protenus* Schubert, K., *Deutsche Entomologische Zeitschrift*, (2): 378–383.
1908. *Philonthus signifrons* Schubert, K, *Deutsche Entomologische Zeitschrift,* (5): 609–625.
1911. *Philonthus simlaensis* Bernhauer, *Entomologische Blätter,* 7(2–3): 199–200.
1928. *Philonthus yatungensis* Cameron, *Annals and Magazine of Natural History*, 2(12): 558–569.
Distribution: Pakistan, India (Kashmir, Himachal Pradesh, Uttar Pradesh), Nepal, China (Tibet).

Bisnius schawalleri **(Coiffait, 1982)**

1982. *Bisnius schawalleri* (Coiffait), *Senckenbergiana Biologica*, 62: 21–179.
1982. *Philonthus schawalleri* Coiffait, *Senckenbergiana Biologica*, 62: 21–179.
Distribution: India (Kashmir).

Genus: *Creophilus* Leach, 1819

1819. *Creophilus* Leach*, Thomas Boys,* London*,* 496 pp.
1839. *Creophagus* Streubel*, Isis von Oken, (2).*
1839. *Saprophilus* Streubel*, Isis von Oken, (2).*

Creophilus flavipennis **(Hope, 1831)**

1831. *Creophilus flavipennis* (Hope), *The Zoological Miscellany,* 1: 21–32.
1859. *Creophilus villipennis* Kraatz, *Archiv für Naturgeschichte*, 25(1): 1–96.
1878. *Emus violaceus* Fauvel, *Annali del Museo Civico di Storia Naturale di Genova*, 12: 171–315.
1879. *Emus insularis* Fauvel, *Annali del Museo Civico di Storia Naturale di Genova*, 15: 63–121.
Distribution: Northern India, Ryukyu Islands, Nepal, Sri Lanka, Myanmar, Thailand, China (Qinghai, Yunnan), Taiwan, Laos, Vietnam, Malaysia (Sarawak), Philippines, Indonesia (Sumatra, Kalimantan, Lombok, Ceram, Buru, Moluccas, Nais, Tanimbar); New Guinea.

Creophilus maxillosus **(Linnaeus, 1758)**

1758. *Creophilus maxillosus* (Linnaeus), *Editio decima, reformata. Tomus I. L. Salvii, Holmiae.* 824 pp.
1758. *Staphylinus maxillosus* Linnaeus, *Editio decima, reformata. Tomus I. L. Salvii, Holmiae.* 824 pp.
Distribution: Throughout India, Canada, USA, Mexico, Guatemala, Honduras, Galapagos Is., Cuba, Isla de Pinos, Jamaica, Iran, Pakistan, Azores, Canary Islands, Madeira, Iceland, Greenland, St. Helena, Bhutan, Taiwan, Ryukyu Islands, China, Hawaiian Islands, Brazil, Chile, Argentina, Peru.

Creophilus maxillosus **maxillosus (Linnaeus, 1758)**

1874. *Creophilus imbecillus* Sharp, *Transactions of the Entomological Society of London*, (1): 1–103.
1899. *Creophilus pulchellus* Meier, *Entomologische Nachrichten,* 25: 97–102.
1908*. Creophilus canariensis* Bernhauer, *Münchener Koleopterologische Zeitschrift*, 3(3): 320–335.
1927. *Creophilus sikkimensis* Wendeler*, Neue Beiträge zur Systematischen Insektenkunde,* 4(1): 1–2.
Distribution: India (Sikkim), Açôres, Canary Islands, Madeira, Iceland, China, Greenland, Brazil, Chile, Argentina, Bolivia, Peru.

Genus: *Heterothops* Stephens, 1829

1829. *Heterothops* Stephens, *Baldwin and Cradock,* London*,* 68 pp.
1837.*Trichopygus* Nordmann, *Academiae Caesareae Scientiarum*, Petropoli [St. Petersburg], 167 pp.

Heterothops dissimilis **(Gravenhorst, 1802)**

1802*. Heterothops dissimilis* (Gravenhorst), C. Reichard, *Brunsuigae [Braunschweig],* lxvi + 206 pp.
1876. *Heterothops paradoxus* Mulsant & Rey*, Annales de la Société d'Agriculture Histoire Naturelle et Arts Utiles de Lyon,* 4(8J 145–856.
1977. *Heterothops fraudulenta* Coiffait*, Nouvelle Revue d'Entomologie*, 7(2): 133–143.
1977. *Heterothops armeniaca* Coiffait, *Nouvelle Revue d'Entomologie*, 7(2): 133–143.
1802. *Tachyporus dissimilis* Gravenhorst, *C. Reichard, Brunsuigae [Braunschweig],* 206 pp.
Distribution: India (Kashmir), Greece, Canary Islands, Morocco, Algeria, Tunisia, Libya, Armenia, Azerbaijan, Turkey, Iran, Kazakhstan, Europe.

Heterothops franzi **Coiffait, 1982**

1982. *Heterothops franzi* Coiffait, *Senckenbergiana Biologica*, 62: 21–179.
Distribution: India, Nepal.

Heterothops hindustanus **Cameron, 1932**

1932. *Heterothops hindustanus* Cameron, *Taylor & Francis, London*. xiii + 443 pp.
Distribution: India (Tamil Nadu: Nilgiri hills).

Heterothops indicus **Cameron, 1926**

1926. *Heterothops indicus* Cameron, *Transactions of the Entomological Society of London*, 1925: 341–372.
Distribution: Throughout India.

Heterothops khairo **Smetana, 1988**

1988. *Heterothops khairo* Smetana, *Quaestiones Entomologicae*, 24(2): 163–464.
Distribution: India (Uttar Pradesh).

Heterothops oculatus **Fauvel, 1895**

1895*. Heterothops oculatus* Fauvel, *Revue d'Entomologie*, 14(6–7): 92–127.
Distribution: India, Pakistan, Nepal, Myanmar, Taiwan.

Heterothops persimilis **Cameron, 1932**

1932*. Heterothops persimilis* Cameron, *Taylor & Francis, London*, xiii + 443 pp.
Distribution: India, Nepal, Myanmar.

Heterothops pusillus **Coiffait, 1982**

1982. *Heterothops pusillus* Coiffait, *Senckenbergiana Biologica*, 62: 21–179.
Distribution: India (Himachal Pradesh, Uttar Pradesh), Nepal.

Heterothops saano **Smetana, 1988**

1988. *Heterothops saano* Smetana, *Quaestiones Entomologicae*, 24(2): 163–464.
Distribution: India (Kashmir).

Genus: *Neobisnius* Ganglbauer, 1895

1895. *Neobisnius* Ganglbauer, *Carl Gerold's Sohn***,** Vienna.

vi + 881 pp.

Neobisnius cameroni **Wendeler, 1928**

1928. *Neobisnius cameroni* Wendeler, *Deutsche Entomologische Zeitschrift*, 1928: 37.

1926. *Neobisnius fraternus* Cameron, *Transactions of the Entomological Society of London*, 1925: 341–372.

Distribution: India.

Neobisnius praelongus **(Gemminger & Harold, 1868)**

1868. *Neobisnius praelongus* (Gemminger & Harold), E.H. Gummi, *Monachii [Munich].* pp. 425–752.

1859. *Philonthus longulus* Kraatz, *Archiv für Naturgeschichte*, 25(1): 1–96.

Distribution: India (Bihar, Nagaland, Sikkim, Uttar Pradesh, West Bengal, Andaman Island), Sri Lanka, Myanmar, Thailand, Cambodia, Vietnam, Malaysia, Indonesia, Philippines, Taiwan, China (Zhejiang).

Genus: *Ontholestes* Ganglbauer, 1895

1833. *Trichoderma* Stephens, *Baldwin and Cradock*, London. iv + 134 pp.

1895. Ontholestes Ganglbauer, *Carl Gerold's Sohn,* Vienna. vi + 881 pp.

Ontholestes aurosparsus **(Fauvel, 1895)**

1895. *Ontholestes aurosparsus* (Fauvel), *Revue d'Entomologie,* 14(6–7): 92–127.

1895. *Leistotrophus aurosparsus* Fauvel, *Revue d'Entomologie*, 14(6–7): 92–127.

1936. *Ontholestes ophthalmicus* Kirshenblat, *Trudy Zoologicheskogo Instituta Akademii Nauk SSSR*, 3: 551–566.

1944. *Ontholestes assamensis* Cameron, *Proceedings of the Royal Entomological Society of London* (B), 13(1–2): 104–108.

Distribution: India (Kashmir, Assam, Uttar Pradesh), Nepal, Myanmar, China (Fujian, Guangxi, Shandong).

Ontholestes tenuicornis **(Kraatz, 1859)**

1859*. Ontholestes tenuicornis* (Kraatz), *Archiv für Naturgeschichte*, 25(1): 1–96.

1859. *Leistotrophus tenuicornis* Kraatz, *Archiv für Naturgeschichte*, 25(1): 1–96.

Distribution: India (West Bengal: Chakrata District), Nepal, China (Fujian).

Genus: *Philonthus* Stephens, 1829

1829. *Philonthus* Stephens, *Baldwin and Cradock*, London, 68 pp.

1968. *Endeius* Coiffait & Sáiz, *Centre National de la Recherche Scientifique,* Paris*,* 472 pp.

1977. *Philonthus (Parambigus)* Marcuzzi, *Quaderni di Ecologia Animale*, 12.

Philonthus **(*Onychophilonthus*) *anepsius* Cameron, 1926**

1926. *Philonthus anepsius* Cameron, *Transactions of the Entomological Society of London*,1925: 341–372.

Distribution: India (Himachal Pradesh).

Philonthus **(*Onychophilonthus*) *funeralis* Cameron, 1943**

1943. *Philonthus funeralis* Cameron, *Proceedings of the Royal Entomological Society of London* (B), 12(1): 127–132.

Distribution: India (Sikkim: Darjeeling).

Philonthus **(*Onychophilonthus*) *kashmiranus* Bernhauer, 1915**

1915. *Philonthus kashmiranus* Bernhauer, *Coleopterologische Rundschau*, 4(3): 49–60.

Distribution: India (Kashmir), Nepal.

Philonthus **(*Philonthus*) *aberrans* Cameron, 1932**

1932. *Philonthus aberrans* Cameron, *Fauna of British India, including Ceylon and Burma. Taylor & Francis, London*. xiii + 443 pp.

Distribution: India (Uttar Pradesh).

Philonthus **(*Philonthus*) *acroleucus* Kraatz, 1859**

1859. *Philonthus acroleucus* Kraatz, *Archiv für Naturgeschichte*, 25(1): 1–96.

Distribution: India, Sri Lanka, Philippines, Indonesia (Sumatra), China (Hong Kong).

Philonthus **(*Philonthus*) *adversus* Bernhauer & K.Schubert, 1914**

1914. *Philonthus adversus* Bernhauer & K. Schubert, *Coleopterorum Catalogus, Pars 57.* W. Junk, Berlin, 289–408 pp.

1925.*Philonthus adversus* Cameron, *Catalogue of the Indian Insects*, 126 pp.

Distribution: India (Sikkim), Myanmar.

Philonthus **(*Philonthus*) *aeger* Eppelsheim, 1895**

1895.*Philonthus aeger* Eppelsheim, *Wiener Entomologische Zeitung*, 14(3): 53–70.

Distribution: India (Himachal Pradesh, Manipur, Uttar Pradesh), Nepal, Bhutan, China (Sichuan), Vietnam.

Philonthus **(*Philonthus*) *aeneipennis* Boheman, 1858**

1858.*Philonthus aeneipennis* Boheman, *Insecta*, 1–112.

1908.*Philonthus kuluensis* Schubert, K., *Deutsche Entomologische Zeitschrift*, 1908 (5): 609–625.

1983. *Philonthus arachosicus* Coiffait, *Bonner Zoologische Beiträge*, 34: 477–483.

Distribution: India, Saudi Arabia, Iran, Afghanistan, Pakistan, Nepal, Bhutan, Andaman Is., Vietnam, China, Taiwan, Ryukyu Is., Philippines, Indonesia, Japan (Honshu, Kyushu, Shikoku), Korea (S), Ogasawara Is., New Guinea, Yemen, Tanzania, Senegal, Mauritius.

Philonthus **(*Philonthus*) *aeripennis* Cameron, 1943**

1943. *Philonthus aeripennis* Cameron, *Proceedings of the Royal Entomological Society of London (B)*, 12(1): 127–132.

Distribution: India (Darjeeling).

Philonthus **(*Philonthus*) *aliquatenus* Schubert, K., 1908**

1908. *Philonthus aliquatenus* Schubert, K., *Deutsche Entomologische Zeitschrift*, 1908 (5): 609–625.

Distribution: India (Kashmir, Himachal Pradesh, Manipur, Uttar Pradesh), Nepal, Bhutan, China (Yunnan).

***Philonthus* (*Philonthus*) *amplitarsis* Schillhammer, 2001**
2001. *Philonthus amplitarsis* Schillhammer, *Koleopterologische Rundschau*, 71: 59–61.
Distribution: India (Uttar Pradesh).

***Philonthus* (*Philonthus*) *assamensis* Cameron, 1932**
1932.*Philonthus assamensis* Cameron, *Taylor & Francis, London*. xiii + 443 pp.
Distribution: India (Assam, Manipur, Meghalaya, Sikkim, Tripura, Uttarakhand).

***Philonthus* (*Philonthus*) *atricoxis* Cameron, 1943**
1943.*Philonthus atricoxis* Cameron, *Proceedings of the Royal Entomological Society of London* (B), 12(1): 127–132.
Distribution: India (Kashmir).

***Philonthus* (*Philonthus*) *azuripennis* Cameron, 1928**
1928.*Philonthus azuripennis* Cameron, *Annals and Magazine of Natural History*, (10) 2(12): 558–569.
1982.*Philonthus trisulensis* Coiffait, *Senckenbergiana Biologica*, 62: 21–179.
Distribution: India (Sikkim), Nepal, Bhutan, China (Gansu, Qinghai, Shaanxi, Sichuan, Yunnan, Xizang).

***Philonthus* (*Philonthus*) *batotensis* Cameron, 1932**
1932.*Philonthus batotensis* Cameron, *Taylor & Francis, London*. xiii + 443 pp.
Distribution: India (Kashmir), Afghanistan.

***Philonthus* (*Philonthus*) *beesoni* Cameron, 1926**
1926.*Philonthus beesoni* Cameron, *Transactions of the Entomological Society of London*, 1925: 341–372.
Distribution: India (Himachal Pradesh, Uttar Pradesh), Afghanistan, Pakistan, Nepal.

***Philonthus* (*Philonthus*) *bengalensis* Bernhauer, 1911**
1911. *Philonthus bengalensis* Bernhauer, *Entomologische Blätter*, 7(2–3): 199–200.
Distribution: India (Bihar, Tamil Nadu, Uttar Pradesh).

***Philonthus* (*Philonthus*) *birmanus* Fauvel, 1895**
1895. *Philonthus birmanus* Fauvel, *Revue d'Entomologie*, 14(6–7): 92–127.
Distribution: India, Myanmar, China (Xizang), Vietnam, Indonesia (Sumatra).

***Philonthus* (*Philonthus*) *brevithorax* Bernhauer, 1934**
1934. *Philonthus brevithorax* Bernhauer, *Entomologisches Nachrichtenblatt (Troppau)*, 8(1): 1–20.
Distribution: India (Himachal Pradesh, Uttar Pradesh), Nepal, Bhutan, China (Sichuan).

***Philonthus* (*Philonthus*) *carbonarius* (Gravenhorst, 1802)**
1802. *Philonthus* (*Philonthus*) *carbonarius* (Gravenhorst), *C. Reichard, Brunsuigae [Braunschweig]*. lxvi + 206 pp.
1832. *Philonthus nigroaeneus* Stephens, *Mandibulata*, Vol. 5. Baldwin & Cradock, London, 240 pp.
1857. *Philonthus nemorosus* Gistel, *Schorner'schen Buchhandlung, Straubing*, 94 pp.
1905.*Philonthus shetlandicus* Poppius, *Öfversigt af Finska Vetenskaps-Societetens Förhandlingar*, 47(17): 1–19.
1933. *Philonthus menetriesi* Kirshenblat, *Entomologicheskoe Obozrenie*, 25(1–2).
1952. *Philonthus vinohradensis* Dvořák, R. & Havelka, *Bulletin de la Société Entomologique de Mulhouse*, 41.
Distribution: India, Europe, Russia (European, eastern & western Siberia, Far East), Algeria, Canary Islands, Armenia, Georgia, Turkey, Iran, Kazakhstan, Kyrgyzstan, Uzbekistan, Nepal, Mongolia, China (Heilongjiang), Canada, USA.

***Philonthus* (*Philonthus*) *caucasicus* Nordmann, 1837**
1837. *Philonthus caucasicus* Nordmann*, Academiae Caesareae Scientiarum, Petropoli* [St. Petersburg]. 167 pp.
1851. *Philonthus rutilipennis* Hochhuth*, Bulletin de la Société Impériale des Naturalistes de Moscou*, 24(2): 3–58.
1900. *Philonthus apicalis* Leinberg, *Meddelanden af Societas pro Fauna et Flora Fennica*, 26: 79–80.
1913. *Philonthus heinemanni* Bernhauer, *Coleopterologische Rundschau*, 2(8–9): 130–134.
Distribution: India (Kashmir), Europe, Russia (European, eastern & western Siberia), Armenia, Georgia, Turkey, Syria, Iraq, Iran, Afghanistan, Kazakhstan, Tajikistan, Turkmenistan, Uzbekistan, Mongolia, Canada, USA.

***Philonthus* (*Philonthus*) *chatterjeei* Cameron, 1926**
1926.*Philonthus chatterjeei* Cameron, *Transactions of the Entomological Society of London*, 1925: 341–372.
Distribution: India (Uttar Pradesh, Uttarakhand).

***Philonthus* (*Philonthus*) *christiei* Bernhauer, 1920**
1920. *Philonthus christiei* Bernhauer, *Archiv für Naturgeschichte*, 84(A)(10): 177–184.
1926. *Philonthus masuriensis* Cameron, *Transactions of the Entomological Society of London*, 1925: 341–372.
Distribution: India (Himachal Pradesh, Uttar Pradesh).

***Philonthus* (*Philonthus*) *cinctipennis* Fauvel, 1875**
1875.*Philonthus cinctipennis* Fauvel, *F. le Blanc-Hardel, Caen*, 3: 1–38.
Distribution: India, Egypt, Oman, Iraq, Ethiopia, Somalia, Myanmar, Vietnam, Indonesia (Sumatra), Philippines.

***Philonthus* (*Philonthus*) *cinctulus* (Gravenhorst, 1802)**
1802. *Philonthus* (*Philonthus*) *cinctulus* (Gravenhorst), *Brunsuigae [Braunschweig]*. lxvi + 206 pp.
Distribution: India (Uttar Pradesh, Uttarakhand, West Bengal), Pakistan, Nepal, Sri Lanka, Myanmar, Vietnam.

***Philonthus* (*Philonthus*) *cliens* Eppelsheim, 1890**
1830. *Philonthus cliens* Eppelsheim, *Wiener Entomologische Zeitung*, 9(10): 217–229.
1960. *Philonthus lindemanni* Scheerpeltz, *Opuscula Zoologica* (München), 51: 1–7.
Distribution: India, Pakistan, Nepal, Botswana, Senegal, Tanzania.

***Philonthus* (*Philonthus*) *cognatus* Stephens, 1832**
1832. *Philonthus cognatus* Stephens, *Mandibulata, Vol. 5.*

Baldwin & Cradock, London, 240pp.
1832. *Philonthus melanopterus* Stephens, *Mandibulata, Vol. 5. Baldwin & Cradock, London*, 240 pp.
1832. *Philonthus nigripennis* Stephens, *Mandibulata, Vol. 5. Baldwin & Cradock, London*, 240 pp.
Distribution: India (Kashmir), Algeria, Morocco, Russia (European, eastern & western Siberia), Tunisia, Madeira, Turkey, Armenia, Iran, Kazakhstan, Kyrgyzstan, Tajikistan, Pakistan, Nepal, China (Jilin), Sri Lanka, Canada, USA.

***Philonthus (Philonthus) concinnus* (Gravenhorst, 1802)**
1802. *Philonthus* (*Philonthus*) *concinnus* (Gravenhorst), *Brunsuigae [Braunschweig].* lxvi + 206 pp.
1830. *Staphylinus irregularis* Mannerheim, Précis d'un nouvel arrangement de la famille des brachélytres, de l'ordre des insectes coléoptères. St. Petersbourg, 87 pp.
1876. *Philonthus melanarius* Mulsant & Rey, *Annales de la Société d'Agriculture Histoire Naturelle et Arts Utiles de Lyon*, 4(8): 145–856.
1895. *Philonthus minor* Ganglbauer, *Carl Gerold's Sohn, Vienna*. vi + 881 pp.
1910. *Philonthus ochripennis* Gerhardt, *Deutsche Entomologische Zeitschrift*, (5): 554–557.
Distribution: India (Sikkim), Europe, Algeria, Morocco, Libya, Azores, Canary Islands, Russia (Eastern & western Siberia, Far East), Armenia, Georgia, Turkey, Lebanon, Israel, Iran, Afghanistan, Kazakhstan, Kyrgyzstan, Tajikistan, Uzbekistan, Mongolia, Canada, USA.

***Philonthus* (*Philonthus*) *congruens* Cameron, 1932**
1932. *Philonthus congruens* Cameron, *Taylor & Francis, London*. xiii + 443 pp.
Distribution: India (Uttar Pradesh).

***Philonthus* (*Philonthus*) *convalescens* Eppelsheim, 1890**
1890. *Philonthus convalescens* Eppelsheim, *Wiener Entomologische Zeitung,* 9(10): 161–172.
Distribution: India (Himachal Pradesh, Sikkim, Uttar Pradesh), Nepal, China (Xizang).

***Philonthus* (*Philonthus*) *crassicornis* Fauvel, 1895**
1895. *Philonthus crassicornis* Fauvel, *Revue d'Entomologie*, 14(6–7): 92–127.
Distribution: India (Tamil Nadu, Uttar Pradesh, Uttarakhand), Sri Lanka, Myanmar, Vietnam, Singapore, Indonesia (Java, Sumatra), Taiwan, Madagascar, Mauritius, Philippines.

***Philonthus* (*Philonthus*) *cruentatus* (Gmelin, 1790)**
1790. *Philonthus* (*Philonthus*) *cruentatus* (Gmelin), *G. E. Beer, Lipsiae*, 1(4): 1517–2224.
1900. *Philonthus extinctus* Bernhauer, *Wiener Entomologische Zeitung*, 19(2–3): 46–55.
1924. *Philonthus immaculatus* Gusmann, *Entomologische Blätter*, 20(3): 248–252.
Distribution: India (Uttar Pradesh), Europe, Russia (Eastern & western Siberia, Far East), Georgia, Armenia, Algeria, Morocco, Canary Islands, Turkey, Lebanon, Iran, Kazakhstan, Kyrgyzstan, Afghanistan, Tajikistan, Uzbekistan, Mongolia, Japan, Canada, USA, Mexico.

***Philonthus* (*Philonthus*) *cyanelytrius* Kraatz, 1859**
1859. *Philonthus cyanelytrius* Kraatz, *Archiv für Naturgeschichte*, 25(1): 1–96.
1926. *Hesperus gridellii* Cameron, *Transactions of the Entomological Society of London*, 1925: 341–372.
Distribution: India (Kashmir, Himachal Pradesh, Meghalaya, Uttar Pradesh), Nepal, Vietnam.

***Philonthus* (*Philonthus*) *dejectus* Cameron, 1932**
1932. *Philonthus dejectus* Cameron, *Taylor & Francis, London*. xiii + 443 pp.
Distribution: India (Uttar Pradesh), Nepal.

***Philonthus* (*Philonthus*) *delicatulus* Boheman, 1858**
1858. *Philonthus delicatulus* Boheman, *Insecta,* 1–112.
1858. *Philonthus lativentris* Motschulsky, *Bulletin de la Société Impériale des Naturalistes de Moscou,* 31 (2): 204–264.
1859. *Philonthus subirideus* Kraatz, *Archiv für Naturgeschichte*, 25(1): 1–96.
Distribution: India (Uttarakhand), China (Hong Kong), Sri Lanka, Myanmar, Vietnam, Singapore, Indonesia (Java, Sumatra); Philippines, Taiwan.

***Philonthus* (*Philonthus*) *densus* Cameron, 1926**
1926. *Philonthus densus* Cameron, *Transactions of the Entomological Society of London*, 1925: 341–372.
Distribution: India (Uttar Pradesh), Afghanistan, Nepal, China (Yunnan).

***Philonthus* (*Philonthus*) *distincticornis* Cameron, 1932**
1932. *Philonthus distincticornis* Cameron, *Taylor & Francis, London*. xiii + 443 pp.
1932. *Philonthopsis antennalis* Cameron, *Taylor & Francis, London*. xiii + 443 pp.
1991. *Philonthus cyaneonitens* Schillhammer, *Koleopterologische Rundschau*, 61: 51–56.
Distribution: India (Sikkim, Uttar Pradesh), Nepal.

***Philonthus* (*Philonthus*) *donckieri* Bernhauer, 1915**
1915. *Philonthus donckieri* Bernhauer, *Entomologische Blätter*, 11(10–12): 251–258.
1919. *Philonthus tripunctatus* Cameron, *Entomologische Blätter*, 11(10–12): 251–258.
1931. *Philonthus crebrior* Bernhauer, *Entomologische Zeitung*, 48(3): 125–132.
Distribution: India (Goa, Himachal Pradesh, Tamil Nadu, Uttar Pradesh), Nepal, Sri Lanka, Laos, Vietnam, China (Fujian, Guangdong, Hong Kong, Jiangxi, Sichuan).

***Philonthus* (*Philonthus*) *explorator* Cameron, 1932**
1932. *Philonthus explorator* Cameron, *Taylor & Francis, London*. xiii + 443 pp.
Distribution: India (Tamil Nadu: Nilgiri Hills), Nepal, Thailand, Taiwan, China (Shanghai).

Philonthus (Philonthus) *flavipes* Kraatz, 1859
1859. *Philonthus flavipes* Kraatz, *Archiv für Naturgeschichte*, 25(1): 1–96.
Distribution: India (Sikkim: Darjeeling, Uttarakhand, Manipur, Tamil Nadu), China (Fujian, Hong Kong, Yunnan, Zhejiang), Taiwan, Ryukyu Islands, Sri Lanka, Myanmar, Thailand, Vietnam, Indonesia (Sumatra), Brunei, Samoa, Réunion, Mauritius, Philippines.

Philonthus (Philonthus) *flavocinctus* Motschulsky, 1858
1858. *Philonthus flavocinctus* Motschulsky, *Bulletin de la Société Impériale des Naturalistes de Moscou*, 31(2): 204–264.
1859. *Philonthus rufo-marginatus* Kraatz, *Archiv für Naturgeschichte*, 25(1): 1–96.
Distribution: India (West Bengal), Israel, China (Hong Kong), Taiwan, Ryukyu Islands, Ogasawara Islands, Sri Lanka, Myanmar, Vietnam, Singapore, Indonesia (Sumatra), New Caledonia, Sudan, Réunion, Mauritius, Réunion, Rodriguez; Philippines, Senegal, Madagascar.

Philonthus (Philonthus) *fletcheri* Cameron, 1943
1943. *Philonthus fletcheri* Cameron, *Proceedings of the Royal Entomological Society of London (B),* 12(1): 127–132.
Distribution: India (Kashmir).

Philonthus (Philonthus) *foetidus* Cameron, 1932
1932. *Philonthus* (*Philonthus*) *foetidus* Cameron, *Taylor & Francis, London*. xiii + 443 pp.
Distribution: India (Himachal Pradesh, Uttar Pradesh), Nepal, Myanmar, Thailand, Taiwan, China (Shanghai).

Philonthus (Philonthus) *fuscatus* Kraatz, 1859
1859. *Philonthus fuscatus* Kraatz, *Archiv für Naturgeschichte*, 25(1): 1–96.
Distribution: India, Iraq, Sri Lanka, China.

Philonthus (Philonthus) *gardneri* Cameron, 1932
1932. *Philonthus gardneri* Cameron, *Taylor & Francis, London*. xiii + 443 pp.
Distribution: India (Sikkim, Uttarakhand).

Philonthus (Philonthus) *gemellus* Kraatz, 1859
1859. *Philonthus gemellus* Kraatz, *Archiv für Naturgeschichte*, 25(1): 1–96.
Distribution: India (Uttar Pradesh, West Bengal), Pakistan, China (Beijing, Hong Kong), Ryukyu Islands (Ishigaki), Sri Lanka, Singapore, Indonesia (Java), Réunion, Mauritius, Madagascar.

Philonthus (Philonthus) *geminus* Kraatz, 1859
1859. *Philonthus geminus* Kraatz, *Archiv für Naturgeschichte*, 25(1): 1–96.
Distribution: Throughout India, China (Hong Kong, Yunnan), Ryukyu Islands (Amami-Oshima), Sri Lanka, Myanmar, Thailand, Malaysia, Vietnam, Singapore, Indonesia.

Philonthus (Philonthus) *gentilicius* Cameron, 1926
1926. *Philonthus gentilicius* Cameron, *Transactions of the Entomological Society of London*, 1925: 341–372.
Distribution: India (Himachal Pradesh, Uttar Pradesh).

Philonthus (Philonthus) *gulmargensis* Coiffait, 1982
1982. *Philonthus gulmargensis* Coiffait, *Senckenbergiana Biologica*, 62: 21–179.
Distribution: India (Kashmir).

Philonthus (Philonthus) *humilis* Cameron, 1932
1932. *Philonthus humilis* Cameron, *Taylor & Francis, London*. xiii + 443 pp.
Distribution: India (Uttar Pradesh).

Philonthus (Philonthus) *idiocerus* Kraatz, 1859
1859. *Philonthus idiocerus* Kraatz, *Archiv für Naturgeschichte*, 25(1): 1–96.
Distribution: India (Uttar Pradesh), Afghanistan, Sri Lanka, Nepal, Myanmar, Thailand, Vietnam, China (Hong Kong, Macao, Yunnan); Indonesia, Philippines.

Philonthus (Philonthus) *incultus* Cameron, 1932
1932. *Philonthus incultus* Cameron, *Taylor & Francis, London*. xiii + 443pp.
Distribution: India (Uttar Pradesh).

Philonthus (Philonthus) *industanus* Fauvel, 1903
1903. *Philonthus industanus* Fauvel, *Revue d'Entomologie*, 22: 149–163.
1911. *Philonthus bipunctatus* Bernhauer, *Entomologische Blätter*, 7(2–3): 86–93.
1919. *Philonthus pubipennis* Cameron, *Entomologist's Monthly Magazine*, 55: 251–255.
Distribution: India (Punjab, Sikkim, Tamil Nadu, Uttarakhand, West Bengal), Nepal, Sri Lanka, Vietnam, China (Hong Kong), w Malaysia, Indonesia (Sumatra).

Philonthus (Philonthus) *kashmiricus* Cameron, 1932
1932. *Philonthus kashmiricus* Cameron, *Taylor & Francis, London*. xiii + 443 pp.
Distribution: India (Kashmir), Nepal.

Philonthus (Philonthus) *kempi* Cameron, 1924
1924. *Philonthus* (*Philonthus*) *kempi* Cameron, *Records of the Indian Museum*, 26(1): 115–122.
Distribution: Pakistan, India (Meghalaya, Uttar Pradesh), Myanmar.

Philonthus (Philonthus) *kotgarhensis* Cameron, 1932
1932. *Philonthus* (*Philonthus*) *kotgarhensis* Cameron, *Taylor & Francis, London*. xiii + 443 pp.
Distribution: India (Himachal Pradesh, Uttar Pradesh).

Philonthus (Philonthus) *lidarensis* Cameron, 1932
1932. *Philonthus* (*Philonthus*) *lidarensis* Cameron, *Taylor & Francis, London*. xiii + 443 pp.
Distribution: India (Kashmir).

Philonthus (Philonthus) *madurensis* Bernhauer, 1915
1915. *Philonthus madurensis* Bernhauer, *Entomologische*

Blätter, 11(10–12): 251–258.
Distribution: India (Tamil Nadu), Taiwan.

***Philonthus* (*Philonthus*) *maindroni* Fauvel, 1903**
1903. *Philonthus maindroni* Fauvel, *Revue d'Entomologie*, 22: 149–163.
1924. *Philonthus annandalei* Cameron, *Records of the Indian Museum*, 26(1): 118–119.
Distribution: India (Assam, Meghalaya, Sikkim, Tamil Nadu, Uttar Pradesh, Uttarakhand), Myanmar, Taiwan.

***Philonthus* (*Philonthus*) *minutus* Boheman, 1848**
1848. *Philonthus* (*Philonthus*) *minutus* Boheman, *Officina Norstedtiana, Holmiae.* viii + 625 pp.
1874. *Philonthus mutans* Sharp, *Transactions of the Entomological Society of London*, (1): 1–103.
1878. *Philonthus rufocinctus* Fauvel, *Bulletin de la Société Linnéenne de Normandie*, 3(2): 83–162.
1879. *Philonthus longiceps* Fauvel, *Annali del Museo Civico di Storia Naturale di Genova*, 15: 63–121.
Distribution: India, Spain, Morocco, Algeria, Tunisia, Egypt, Saudi Arabia, Canary Islands, Pakistan, Korea (North & South), Japan, Senegal, Ethiopia, Kenya, Zaire, Mozambique, South Africa, Sri Lanka, Myanmar, Vietnam, Malaysia, Indonesia, China, Taiwan, New Guinea, Australia, Iran.

***Philonthus* (*Philonthus*) *montivagans* Cameron, 1943**
1943. *Philonthus montivagans* Cameron, *Proceedings of the Royal Entomological Society of London (B*), 12(1): 127–132.
Distribution: India (Sikkim: Darjeeling).

***Philonthus* (*Philonthus*) *nigricoxis* Cameron, 1928**
1928. *Philonthus (Philonthus) nigricoxis* Cameron, *Annals and Magazine of Natural History*, 2 (10): 558–569.
Distribution: India (Kashmir, Sikkim), Nepal, China (Xizang).

***Philonthus* (*Philonthus*) *obsoletus* Eppelsheim, 1895**
1895. *Philonthus obsoletus* Eppelsheim, *Wiener Entomologische Zeitung*, 14(3): 53–70.
1977. *Philonthus bhutanicus* Coiffait, *Entomologica Basiliensia*, 2: 205–242.
1982. *Philonthus analokus* Coiffait, *Senckenbergiana Biologica*, 62: 21–179.
Distribution: India (Himachal Pradesh), Nepal, Bhutan, Myanmar, China (Xizang).

***Philonthus* (*Philonthus*) *paederoides* (Motschulsky, 1858)**
1858. *Philonthus (Philonthus) paederoides* (Motschulsky), *Bulletin de la Société Impériale des Naturalistes de Moscou*, 31(2): 204–264.
1859. *Philonthus bellus* Kraatz, *Archiv für Naturgeschichte*, 25(1): 1–96.
1922. *Philonthus obscuricollis* Bernhauer, *Archiv für Naturgeschichte*, 88 (A) (10): 147–159.
Distribution: India (Manipur, Tamil Nadu, West Bengal), Afghanistan, Pakistan, Sri Lanka, Nepal, Myanmar, Thailand, Cambodia, Vietnam, China (Hong Kong, Yunnan), Taiwan, Indonesia, Philippines; Malaysia (Sarawak).

***Philonthus* (*Philonthus*) *paradoxus* Cameron, 1932**
1932. *Philonthus paradoxus* Cameron, *Taylor & Francis, London*. xiii + 443 pp.
Distribution: India (Uttar Pradesh).

***Philonthus* (*Philonthus*) *peregrinus* Fauvel, 1866**
1866. *Philonthus peregrinus* Fauvel, *Annales de la Société Entomologique de France*, 4(6): 293–340.
Distribution: India (Kashmir, Uttar Pradesh), Nepal, São Tomé, Senegal, Sierra Leone, Liberia, Ivory Coast, Benin, Cameroon, Central African Republic, Ethiopia, Uganda, Rwanda, Burundi, Zaire, Kenya, Tanzania, Namibia, South Africa, Madagascar, Réunion, Mauritius, Seychelles, Comoros.

***Philonthus* (*Philonthus*) *persimilis* Cameron, 1926**
1926. *Philonthus persimilis* Cameron, *Transactions of the Entomological Society of London,* 1925: 341–372.
Distribution: India (Himachal Pradesh, Uttar Pradesh), Afghanistan.

***Philonthus* (*Philonthus*) *politus* (Linnaeus, 1758)**
1758. *Philonthus* (*Philonthus*) *politus* (Linnaeus), *Tomus I.L. Salvii, Holmiae*, 824 pp.
1887. *Cafius amblyterus* Olliff, *Proceedings of the Linnean Society of New South Wales*, (2) 2(3): 471–512.
1923. *Quedius ohiaensis* Broun, *New Zealand Institute*, Bulletin No. 1: 667–708.
1987. *Philonthus temperei* Coiffait, *Nouvelle Revue d'Entomologie*, 3(4): 497–498.
2005. *Philonthus rubroelytratus* Whitehead, *Entomologist's Monthly Magazine*, 141.
Distribution: India (Karnataka), Europe, Africa, Canary Islands, Madeira, Azores, Iceland, Russia, Armenia, Azerbaijan, Georgia, Turkey, Iran, Turkmenistan, Kazakhstan, Mongolia, China, Canada, USA, Mexico, Venezuela, Chile, Argentina, Australia, New Zealand, Chatham Islands.

***Philonthus* (*Philonthus*) *productus* Kraatz, 1859**
1859. *Philonthus* (*Philonthus*) *productus* Kraatz, *Archiv für Naturgeschichte*, 25(1): 1–96.
1931. *Philonthus sulciceps* Bernhauer, *Wiener Entomologische Zeitung*, 48(3): 125–132.
Distribution: India (Uttar Pradesh), Sri Lanka, Malaysia, China (Hong Kong, southwest), Taiwan, Ryukyu Islands (Okinawa, Ishigaki, Yonaguni).

***Philonthus* (*Philonthus*) *purpuripennis* Reitter, 1887**
1887. *Philonthus* (*Philonthus*) *purpuripennis* Reitter, *Horae Societatis Entomologicae Rossicae*, 21: 201–234.
1933. *Philonthus magnificus* Bernhauer, *Entomologisches Nachrichtenblatt* (Troppau), 7(2): 39–54.
Distribution: India (Andhra Pradesh), Nepal, China (Gansu, Hubei, Qinghai, Shaanxi, Sichuan, Yunnan, Xinjiang, Xizang).

***Philonthus* (*Philonthus*) *remotus* Fauvel, 1895**

1895. *Philonthus* (*Philonthus*) *remotus* Fauvel, *Revue d'Entomologie*, 14(6–7): 264.
1920. *Philonthus nilgiriensis* Cameron, *Entomologist's Monthly Magazine*, 56: 214–220.
Distribution: India (Himachal Pradesh, Uttar Pradesh), Myanmar, Indonesia (Java), China (Hong Kong).

***Philonthus* (*Philonthus*) *riparius* Cameron, 1926**

1926. *Philonthus* (*Philonthus*) *riparius* Cameron, *Transactions of the Entomological Society of London,* 1925: 341–372.
Distribution: India (Himachal Pradesh, Uttar Pradesh), Afghanistan, Bhutan, China (Xizang).

***Philonthus* (*Philonthus*) *rivularis* Cameron, 1932**

1932. *Philonthus* (*Philonthus*) *rivularis* Cameron, *Taylor & Francis, London*. xiii + 443 pp.
Distribution: India (Kashmir, Himachal Pradesh, Uttar Pradesh).

***Philonthus* (*Philonthus*) *rotundicollis* (Ménétriés, 1832)**

1832. *Philonthus* (*Philonthus*) *rotundicollis* (Ménétriés), *Académie Impériale des Sciences, St. Pétersbourg*, 271 pp.
1840. *Philonthus scutatus* Erichson, *F.H.Morin, Berlin,* 954 pp.
1860. *Philonthus duplopunctatus* Motschulsky, *Bulletin de la Société Impériale des Naturalistes de Moscou*, 33(2): 539–588.
1916. *Philonthus nigropolitus* Bernhauer, *Neue Beiträge zur Systematischen Insektenkunde*, 1(4): 26–28.
Distribution: India, Europe, Russia (Siberia, Far East), Turkey, Georgia, Iran, Turkmenistan, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan, Afghanistan, Pakistan, Mongolia, Japan (Hokkaido), Korea (North & South), China (Heilongjiang, Qinghai, Shaanxi, Xinjiang).

***Philonthus* (*Philonthus*) *rubricollis* Motschulsky, 1858**

1858. *Philonthus* (*Philonthus*) *rubricollis* Motschulsky, *Bulletin de la Société Impériale des Naturalistes de Moscou,* 31(2): 204–264.
1859. *Philonthus erythrostictus* Kraatz, *Archiv für Naturgeschichte*, 25(1): 1–96.
1935. *Philonthus obscuricollis* Bernhauer, *Entomologisches Nachrichtenblatt (Troppau)*, 9(1): 4–14.
Distribution: India (Bihar: Katihar), Myanmar, China (Fujian, Guangxi, Hong Kong).

***Philonthus* (*Philonthus*) *semiaenescens* Bernhauer, 1920**

1920. *Philonthus (Philonthus) semiaenescens* Bernhauer, *Archiv für Naturgeschichte*, 84 (A)(10): 177–188.
Distribution: India (Uttar Pradesh, Uttarakhand), Myanmar.

***Philonthus* (*Philonthus*) *simpliciventris* Bernhauer, 1933**

1933. *Philonthus* (*Philonthus*) *simpliciventris* Bernhauer, *Entomologisches Nachrichtenblatt (Troppau)*, 7(2): 39–54.
1859. *Philonthus proximus* Kraatz*, Archiv für Naturgeschichte*, 25(1): 1–96.
1939. *Philonthus explanipes* Tottenham, *Entomologist's Monthly Magazine*, 75: 218–224.
Distribution: India (Kashmir, Himachal Pradesh, Uttar Pradesh), Nepal, China (Beijing, Fujian, Gansu, Shaanxi, Shanxi, Sichuan, Yunnan), Taiwan, Vietnam.

***Philonthus* (*Philonthus*) *siwalikensis* Cameron, 1926**

1926. *Philonthus* (*Philonthus*) *siwalikensis* Cameron, *Transactions of the Entomological Society of London,* 1925: 341–372.
Distribution: India (Himachal Pradesh, Uttar Pradesh).

***Philonthus* (*Philonthus*) *speciosus* Cameron, 1926**

1926. *Philonthus* (*Philonthus*) *speciosus* Cameron, *Transactions of the Entomological Society of London*, 1925: 341–372.
Distribution: India (Uttar Pradesh), Oman, Turkey.

***Philonthus* (*Philonthus*) *subjectus* Cameron, 1932**

1932. *Philonthus (Philonthus) subjectus* Cameron, *Taylor & Francis, London*. xiii + 443 pp.
Distribution: India (Sikkim).

***Philonthus* (*Philonthus*) *succicola* Thomson, C. G., 1860**

1860. *Philonthus* (*Philonthus*) *succicola* Thomson, *C. G., Berlingska Boktryckeriet, Lund*, 304 pp.
1835. *Staphylinus nigritus* Runde, *Ploetzianis, Halae*, 32 pp.
1952. *Philonthus wohlgrothi* Dvořák, R., *Bulletin de la Société Entomologique de Mulhouse*, 1952: 41.
Distribution: India (Himachal Pradesh), Europe, Tunisia, Russia (Siberia, Far East, Kuriles), Armenia, Georgia, Iran, Kazakhstan, Mongolia, Nepal, China (Heilongjiang, Jilin, Liaoning).

***Philonthus* (*Philonthus*) *terminipennis* Tottenham, 1939**

1939. *Philonthus* (*Philonthus*) *terminipennis* Tottenham*, Proceedings of the Royal Entomological Society of London* (B), 8(12): 227–237.
1932. *Philonthus apicipennis* Cameron, *Taylor & Francis, London*. xiii + 443 pp.
Distribution: India (Himachal Pradesh, Uttar Pradesh), Nepal.

***Philonthus* (*Philonthus*) *tricoloris* Schubert K., 1908**

1908. *Philonthus* (*Philonthus*) *tricoloris* Schubert, K., *Deutsche Entomologische Zeitschrift*, (5): 609–625.
Distribution: India (Himachal Pradesh, Uttar Pradesh), Nepal, Myanmar, Pakistan.

***Philonthus* (*Philonthus*) *varians* (Paykull, 1789)**

1789. *Philonthus* (*Philonthus*) *varians* (Paykull), *Johann. Edman, Upsaliae* [Uppsala], 81pp.
Distribution: India, Europe, Russia, Armenia, Georgia, Turkey, Syria, Iran, Kazakhstan, Kyrgyzstan, Uzbekistan, Mongolia, Japan, Africa, Afrotropical, South Africa, Madagascar, Myanmar, Tahiti, Canada, USA, Cuba, St. John, St. Vincent, Venezuela, Argentina, Chile.

***Philonthus* (*Philonthus*) *variipennis* Kraatz, 1859**

1859. *Philonthus* (*Philonthus*) *variipennis* Kraatz, *Archiv für*

Naturgeschichte, 25(1): 1–96.
1953. *Philonthus ilus* Tottenham, *Annals and Magazine of Natural History*, 12(6): 143–148.
1979. *Philonthus ledouxi* Coiffait, *Annales de la Société Entomologique de France*, 14: 551–569.
1981. *Philonthus arabicus* Coiffait, *Fauna of Saudi Arabia*, 3: 236–242.
1987. *Philonthus falcozi* Coiffait, *Nouvelle Revue d'Entomologie*, 3(4): 497–498.
Distribution: India (Uttar Pradesh), Egypt, Saudi Arabia, Afghanistan, Japan (Shikoku), Ryukyu Is. (Amami-Oshima, Kikai, Kita Daito), Sri Lanka, Thailand, Cambodia, Vietnam, Malaysia, Indonesia, Philippines, China (Hong Kong), Taiwan.

***Philonthus amplicollis* Schillhammer, 2003**
2003. *Philonthus amplicollis* Schillhammer, *Koleopterologische Rundschau*, 73: 85–136.
Distribution: India (Uttarakhand: Kumaon), Nepal.

***Philonthus andrewesi* Cameron, 1920**
1920. *Philonthus andrewesi* Cameron, *Entomologist's Monthly Magazine*, 56: 141–148, 214–220.
Distribution: India (Tamil Nadu).

***Philonthus atkinsoni* Cameron, 1932**
1932. *Philonthus atkinsoni* Cameron, *Taylor & Francis, London*. xiii + 443 pp.
Distribution: India.

***Philonthus cameroni* Scheerpeltz, 1933**
1933. *Philonthus cameroni* Scheerpeltz, *Coleopterorum Catalogus*, Pars 129. W. *Junk, Berlin*.
1926. *Philonthus fraternus* Cameron, *Transactions of the Entomological Society of London*, 1925: 341–372.
Distribution: India.

***Philonthus castaneus* Gemminger & Harold, 1868**
1868. *Philonthus castaneus* Gemminger & Harold, *E. H. Gummi, Monachii [Munich]*. pp. 425–752.
1858. *Gabrius badius* Motschulsky, *Bulletin de la Société Impériale des Naturalistes de Moscou*, 31(2): 204–264.
Distribution: India (Karnataka, Kerala, Manipur, Uttarakhand, West Bengal).

***Philonthus chandigarhensis* Pajni & Kohli, 1977**
1977. *Philonthus chandigarhensis* Pajni & Kohli, *Oriental Insects*, 11(4): 513–519.
Distribution: India (Punjab).

***Philonthus differens* Cameron, 1932**
1932.*Philonthus differens* Cameron, *Taylor & Francis, London*. xiii + 443 pp.
Distribution: India.

***Philonthus dohertyi* Cameron, 1932**
1932. *Philonthus dohertyi* Cameron, *Taylor & Francis, London*. xiii + 443 pp.
Distribution: India (Uttarakhand), Myanmar.

***Philonthus flavohumeralis* Schillhammer, 2003**
2003. *Philonthus flavohumeralis* Schillhammer, *Koleopterologische Rundschau*, 73: 85–136.
Distribution: India, (Sikkim: Darjeeling), Nepal.

***Philonthus fulvitarsis* Motschulsky, 1860**
1860. *Philonthus fulvitarsis* Motschulsky, *Études Entomologiques*, 8: 25–118.
Distribution: India, Sri Lanka.

***Philonthus indicus* Cameron, 1920**
1920. *Philonthus indicus* Cameron, *Entomologist's Monthly Magazine*, 56: 214–220.
Distribution: India.

***Philonthus leptocerus* Fauvel, 1895**
1895. *Philonthus leptocerus* Fauvel, *Revue d'Entomologie*, 14(6–7): 92–127.
1927.*Philonthus pseudooculatus* Bernhauer, *Arkiv för Zoologi*, 19: 1–28.
Distribution: India (Uttarakhand), Myanmar, Cambodia, Vietnam, Indonesia (Sumatra).

***Philonthus maculatus* Cameron, 1920**
1920. *Philonthus maculatus* Cameron, *Entomologist's Monthly Magazine*, 56: 141–148, 214–220.
Distribution: India.

***Philonthus malcolmi* Herman, 2001**
2001. *Philonthus malcolmi* Herman, *Bulletin of the American Museum of Natural History*, 264: 1–82.
1977. *Philonthus cameroni* Pajni & Kohli, *Oriental Insects*, 11(4): 513–519.
Distribution: India (Punjab).

***Philonthus modestus* Cameron, 1932**
1932. *Philonthus modestus* Cameron, *Taylor & Francis, London*. xiii + 443 pp.
Distribution: India, Sri Lanka.

***Philonthus peliomerus* Kraatz, 1859**
1859. *Philonthus peliomerus* Kraatz, *Archiv für Naturgeschichte*, 25(1): 1–96.
Distribution: India (Assam, Uttarakhand), Sri Lanka, Japan, China (Sichuan), Myanmar, Indonesia, French Equatorial Africa, Réunion, Mauritius, Seychelles, Madagascar, Philippines.

***Philonthus perniger* Bernhauer, 1920**
1920. *Philonthus perniger* Bernhauer, *Archiv für Naturgeschichte*, 84(10): 177–188.
Distribution: India (Tamil Nadu: Madurai).

***Philonthus schuhi* Schillhammer, 2003**
2003. *Philonthus schuhi* Schillhammer, *Koleopterologische Rundschau*, 73: 85–136.
Distribution: India, Nepal, Myanmar, Thailand, Laos, Vietnam, Malaysia (Penang).

Philonthus suturorubineous Pajni & Kohli, 1977
1977. *Philonthus suturorubineous* Pajni & Kohli, *Oriental Insects*, 11(4): 513–519.
Distribution: India (Punjab).

Philonthus tamulus Cameron, 1932
1932. *Philonthus tamulus* Cameron, *Taylor & Francis, London*. xiii + 443 pp.
Distribution: India.

Genus: _Platydracus_ Thomson, C.G., 1858
1858.*Platydracus* Thomson, C. G., *Öfversigt af Kongliga Vetenskaps-Akademiens Förhandlingar,* 15*.*

Platydracus (_Platydracus_) _asemus_ (Kraatz, 1859)
1859. *Platydracus* (*Platydracus*) *asemus* (Kraatz), *Archiv für Naturgeschichte*, 25(1): 1–96.
1911. *Staphylinus aeneicollis* Bernhauer, *Entomologische Blätter*, 7(2–3): 199–200.
Distribution: India (Meghalaya, Uttar Pradesh, West Bengal, Sikkim: Darjeeling).

Platydracus (_Platydracus_) _birmanus_ (Fauvel, 1895)
1895. *Platydracus* (*Platydracus*) *birmanus* (Fauvel), *Revue d'Entomologie*, 14(6–7): 180–220.
Distribution: India, Myanmar, Bhutan.

Platydracus (_Platydracus_) _brevipennis_ Smetana & Davies, 2000
2000. *Platydracus* (*Platydracus*) *brevipennis* Smetana & Davies, *American Museum Novitates*, 3287: 1–88.
1859.*Staphylinus brachypterus* Kraatz, *Archiv für Naturgeschichte*, 25(1): 1–96.
Distribution: India.

Platydracus (_Platydracus_) _dudgeoni_ (Cameron, 1932)
1932. *Platydracus* (*Platydracus*) *dudgeoni* (Cameron), *Taylor & Francis, London*. xiii + 443pp.
Distribution: India (Punjab).

Platydracus (_Platydracus_) _goryi_ (Laporte de Castelnau, 1835)
1835. *Platydracus* (*Platydracus*) *goryi* (Laporte de Castelnau), *Méquignon-Marvis Père et Fils, Paris,* 159pp.
1859. *Staphylinus auripennis* Kraatz, *Archiv für Naturgeschichte*, 25(1): 1–96.
Distribution: India.

Platydracus (_Platydracus_) _indicus_ (Kraatz, 1859)
1859. *Platydracus* (*Platydracus*) *indicus* (Kraatz), *Archiv für Naturgeschichte*, 25(1): 1–96.
1859. *Ocypus lineatus* Walker, *Annals and Magazine of Natural History*, 3(3): 370–376.
Distribution: India, Sri Lanka, Malaysia.

Platydracus (_Platydracus_) _lomii_ (Cerruti, 1951)
1951. *Platydracus* (*Platydracus*) *lomii* (Cerruti), *Rivista di Biologia Coloniale*, 10: 15–22.
Distribution: India (Punjab).

Platydracus (_Platydracus_) _maculipennis_ (Kraatz, 1859)
1859. *Platydracus* (*Platydracus*) *maculipennis* (Kraatz), *Archiv für Naturgeschichte*, 25(1): 1–96.
Distribution: India, Pakistan, China (Hong Kong).

Platydracus (_Platydracus_) _marginatus_ (Cameron, 1944)
1944. *Platydracus* (*Platydracus*) *marginatus* (Cameron), *Proceedings of the Royal Entomological Society of London* (B), 13(1–2): 104–108.
Distribution: India (Sikkim: Darjeeling).

Platydracus (_Platydracus_) _parvulus_ Smetana & Davies, 2000
2000. *Platydracus* (*Platydracus*) *parvulus* Smetana & Davies, *American Museum Novitates*, 3287: 1–88.
Distribution: India (Assam).

Platydracus (_Platydracus_) _semipurpureus_ (Kraatz, 1859)
1859. *Platydracus* (*Platydracus*) *semipurpureus* (Kraatz), *Archiv für Naturgeschichte*, 25(1): 1–96.
1868. *Staphylinus semicupreus* Gemminger & Harold, *E. H. Gummi, Monachii [Munich]*. pp. 425–752.
Distribution: India.

Platydracus (_Platydracus_) _sparsus_ (Cameron, 1932)
1932. *Platydracus* (*Platydracus*) *sparsus* (Cameron), *Taylor & Francis, London.* xiii + 443pp.
Distribution: India (Sikkim: Darjeeling).

Platydracus (_Platydracus_) _submarmorellus_ (Schubert, K., 1908)
1908. *Platydracus* (*Platydracus*) *submarmorellus* (Schubert, K.), *Deutsche Entomologische Zeitschrift*, (5): 609–625.
Distribution: India (Himachal Pradesh), Bhutan.

Platydracus (_Platydracus_) _yolensis_ (Cerruti, 1951)
1951. *Platydracus* (*Platydracus*) *yolensis* (Cerruti), *Rivista di Biologia Coloniale*, 10: 15–22.
Distribution: India (Punjab).

Platydracus basicornis (Fauvel, 1895)
1895. *Platydracus basicornis* (Fauvel), *Revue d'Entomologie*, 14(6–7): 92–127.
Distribution: India, Myanmar.

Platydracus bengalensis (Bernhauer, 1914)
1914. *Platydracus bengalensis* (Bernhauer), *Verhandlungen der Kaiserlich-Königlichen Zoologisch-Botanischen Gesellschaft in Wien*, 64: 76–109.
1914. *Staphylinus bengalensis* Bernhauer, *Verhandlungen der Kaiserlich-Königlichen Zoologisch-Botanischen Gesellschaft in Wien,* 64: 76–109.
Distribution: India (West Bengal).

Platydracus curticornis (Fauvel, 1895)
1895. *Platydracus curticornis* (Fauvel), *Revue d'Entomologie*, 14(6–7): 92–127.
Distribution: India, Myanmar.

***Platydracus maculicollis* (Fauvel, 1895)**
1895. *Platydracus maculicollis* (Fauvel), *Revue d'Entomologie*, 14(6–7): 92–127.
Distribution: India (Assam, Manipur), Myanmar.

***Platydracus purpurascens* (Cameron, 1920)**
1920. *Platydracus purpurascens* (Cameron), *Entomologist's Monthly Magazine*, 56: 94–99.
Distribution: India (Karnataka).

***Platydracus virgulatus* (Fauvel, 1895)**
1895. *Platydracus virgulatus* (Fauvel), *Revue d'Entomologie*, 14(6–7): 92–127.
Distribution: India (West Bengal), Myanmar.

Genus: *Quedius* Stephens, 1829
1829. *Quedius* Stephens, *Baldwin and Cradock*, London, 68 pp.

***Quedius* (*Distichalius*) *chatterjeei* Cameron, 1926**
1926. *Quedius (Distichalius) chatterjeei* Cameron, *Transactions of the Entomological Society of London*, 1925: 341–372.
Distribution: India.

***Quedius* (*Distichalius*) *deceptor* Cameron, 1944**
1944. *Quedius (Distichalius) deceptor* Cameron, *Proceedings of the Royal Entomological Society of London (B*), 13(1–2): 104–108.
Distribution: India (Sikkim: Darjeeling, Uttar Pradesh), Nepal.

***Quedius* (*Distichalius*) *kashmirensis* Cameron, 1944**
1944. *Quedius* (*Distichalius*) *kashmirensis* Cameron, *Proceedings of the Royal Entomological Society of London (B)*, 13(1–2): 104–108.
Distribution: India (Kashmir, Uttar Pradesh), Nepal.

***Quedius* (*Distichalius*) *taruni* Smetana, 1988**
1988. *Quedius* (*Distichalius*) *taruni* Smetana, *Quaestiones Entomologicae*, 24(2): 163–464.
Distribution: India, Nepal.

***Quedius* (*Microsaurus*) *adjacens* Cameron, 1926**
1926. *Quedius* (*Microsaurus*) *adjacens* Cameron, *Transactions of the Entomological Society of London*, 1925: 341–372.
Distribution: India (Kashmir, Himachal Pradesh, Uttar Pradesh), China (Hunan, Sichuan, Shaanxi), Vietnam.

***Quedius* (*Microsaurus*) *antennalis* Cameron, 1932**
1932. *Quedius* (*Microsaurus*) *antennalis* Cameron, *Taylor & Francis, London*. xiii + 443pp.
Distribution: India (Sikkim: Darjeeling), Myanmar, China (Fujian, Gansu, Ghizhou, Hainan, Henan, Hubei, Shaanxi, Sichuan), Laos, Vietnam.

***Quedius* (*Microsaurus*) *apicicornis* Eppelsheim, 1895**
1895. *Quedius* (*Microsaurus*) *apicicornis* Eppelsheim, *Deutsche Entomologische Zeitschrift*, (2): 53–70.
Distribution: India (Sikkim: Darjeeling), Nepal, Bhutan.

***Quedius* (*Microsaurus*) *beesoni* Cameron, 1932**
1932. *Quedius* (*Microsaurus*) *beesoni* Cameron, *Taylor & Francis, London*. xiii + 443 pp.
Distribution: India (Sikkim: Darjeeling, Uttar Pradesh), Nepal, China (Chongqing, Fujian, Guangxi, Guizhou, Hubei, Shaanxi, Shanghai, Sichuan, Yunnan, Zhejiang), Taiwan.

***Quedius* (*Microsaurus*) *cruentus* (Olivier, A. G., 1795)**
1795. *Quedius* (*Microsaurus*) *cruentus* (Olivier A.G.), *Coléoptères*, *Lanneau, Paris*, 557 pp.
1832. *Quedius erythropterus* Stephens*, Mandibulata, Baldwin & Cradock, London*. 240 pp.
1835. *Quedius analis Stephens*, *Mandibulata, Baldwin & Cradock, London*. pp. 369–477.
1857. *Philonthus putridarius* Gistel, *Coléoptères*, *Lanneau, Paris*, 557 pp.
1870. *Quedius virens* Rottenberg, *Berliner Entomologische Zeitschrift*, 14(1–2): 11–40.
1913. *Quedius obscurus* Lokay, *Časopis České Společnosti Entomologické*, 10: 136–140.
Distribution: India, Albania, Austria, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Finland, France, Great Britain, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Spain, Sweden, Switzerland, Ukraine, Armenia, Turkey, Morocco, Algeria, Tunisia, Massachusetts, Maine, Michigan, New Jersey, New York, Ohio, Pennsylvania.

***Quedius* (*Microsaurus*) *dui* Smetana, 1988**
1988. *Quedius* (*Microsaurus*) *dui* Smetana, *Quaestiones Entomologicae*, 24(2): 163–464.
Distribution: India (Himachal Pradesh).

***Quedius* (*Microsaurus*) *flavocaudatus* Cameron, 1944**
1944. *Quedius* (*Microsaurus*) *flavocaudatus* Cameron, *Proceedings of the Royal Entomological Society of London* (B), 13(1–2): 104–108.
Distribution: India (Uttar Pradesh), Nepal.

***Quedius* (*Microsaurus*) *franzi* Smetana, 1975**
1975. *Quedius* (*Microsaurus*) *franzi* Smetana, *Oriental Insects*, 9(3): 323–342.
Distribution: India (Sikkim: Darjeeling), Nepal.

***Quedius* (*Microsaurus*) *franzi najik* Smetana, 1992** (subspecies of *Quedius (Microsaurus) franzi.*
1992. *Quedius (Microsaurus) franzi najik* Smetana, *Stuttgarter Beiträge zur Naturkunde (A: Biologie)*, 487: 1–11.
Distribution: India (Sikkim: Darjeeling).

***Quedius* (*Microsaurus*) *fulgidus* (Fabricius, 1792)**
1792. *Quedius (Microsaurus) fulgidus* (Fabricius), *C. G. Proft*, *Hafniae*, 538pp.
Distribution: India, Canary Islands, Madeira, Iceland, Libya,

Tunisia, Algeria, Turkey, Indonesia, Peru, Chile, Australia, New Zealand, Chatham Islands.

***Quedius* (*Microsaurus*) *inquietus* (Champion, 1925)**

1925. *Quedius (Microsaurus) inquietus* (Champion), *Entomologist's Monthly Magazine*, 61: 6–11.

Distribution: India (Sikkim: Darjeeling, Uttar Pradesh), Nepal, China (Hubei, Shaanxi, Sichuan, Yunnan), Vietnam.

***Quedius* (*Microsaurus*) *milansaar* Smetana, 1988**

1988. *Quedius* (*Microsaurus*) *milansaar* Smetana, *Quaestiones Entomologicae*, 24(2): 163–464.

Distribution: India (Himachal Pradesh).

***Quedius* (*Microsaurus*) *ochripennis* (Ménétriés, 1832)**

1832. *Quedius* (*Microsaurus*) *ochripennis* (Ménétriés), *Académie Impériale des Sciences, St. Pétersbourg*, 271pp.

1835. *Emus floralis* Lacordaire, *Méquignon-Marvis, Père et Fils, Paris*, 696pp.

1835. *Staphylinus laetus* Faldermann, *Nouveaux Mémoires de la Société Impériale des Naturalistes de Moscou,* 4: 1–310.

1876. *Quedius assecla* Mulsant & Rey, *Annales de la Société d'Agriculture Histoire Naturelle et Arts Utiles de Lyon*, (4)8: 145–856.

Distribution: India (Himachal Pradesh), Ukraine, Russia (s European), Armenia, Georgia, Azerbaijan, Turkey, Syria, Lebanon, Israel, Algeria, Iran, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan, Afghanistan, Pakistan.

***Quedius* (*Microsaurus*) *placidus* Cameron, 1932**

1932. *Quedius* (*Microsaurus*) *placidus* Cameron, *Taylor & Francis, London*. xiii + 443 pp.

Distribution: India (Sikkim: Darjeeling), Nepal, Bhutan.

***Quedius* (*Microsaurus*) *ripicola* Cameron, 1926**

1926. *Quedius* (*Microsaurus*) *ripicola* Cameron, *Transactions of the Entomological Society of London*, 1925: 341–372.

Distribution: India (Himachal Pradesh, Sikkim, Uttar Pradesh, Uttarakhand, West Bengal), Nepal.

***Quedius* (*Microsaurus*) *spectabilis* Kraatz, 1859**

1859. *Quedius* (*Microsaurus*) *spectabilis* Kraatz, *Archiv für Naturgeschichte*, 25(1):1–96.

Distribution: India.

***Quedius* (*Microsaurus*) *stevensi* Cameron, 1932**

1932. *Quedius* (*Microsaurus*) *stevensi* Cameron, *Taylor & Francis, London*. xiii + 443 pp.

Distribution: India (Sikkim, Uttarakhand), Nepal, China (Yunnan).

***Quedius* (*Raphirus*) *anomalus* Cameron, 1926**

1926. *Quedius* (*Raphirus*) *anomalus* Cameron, *Transactions of the Entomological Society of London*, 1925: 341–372.

Distribution: India.

***Quedius* (*Raphirus*) *assamensis* Cameron, 1932**

1932. *Quedius* (*Raphirus*) *assamensis* Cameron, *Taylor & Francis, London*. xiii + 443 pp.

Distribution: India (Meghalaya, Nagaland), Nepal, China (Yunnan).

***Quedius* (*Raphirus*) *aureiventris* Bernhauer, 1915**

1915. *Quedius* (*Raphirus*) *aureiventris* Bernhauer, *Coleopterologische Rundschau*, 4(3): 49–60.

Distribution: India (Kashmir, Himachal Pradesh, Uttar Pradesh, Uttarakhand), Nepal, Bhutan, Pakistan.

***Quedius* (*Raphirus*) *daksumensis* Coiffait, 1982**

1982. *Quedius* (*Raphirus*) *daksumensis* Coiffait, *Entomologica Basiliensia*, 7: 231–302.

Distribution: India (Kashmir), Nepal.

***Quedius* (*Raphirus*) *durgaa* Smetana, 1988**

1988. *Quedius* (*Raphirus*) *durgaa* Smetana, *Quaestiones Entomologicae*, 24(2): 163–464.

Distribution: India (Sikkim: Darjeeling).

***Quedius* (*Raphirus*) *fluviatilis* Cameron, 1926**

1926. *Quedius* (*Raphirus*) *fluviatilis* Cameron, *Transactions of the Entomological Society of London*, 1925: 341–372.

Distribution: India (Kashmir, Himachal Pradesh, Uttar Pradesh).

***Quedius* (*Raphirus*) *himalayicus* Bernhauer, 1915**

1915. *Quedius* (*Raphirus*) *himalayicus* Bernhauer, *Coleopterologische Rundschau*, 4(3): 49–60.

Distribution: India (Sikkim: Darjeeling, Himachal Pradesh, Nagaland, Uttar Pradesh, Uttarakhand), Nepal.

***Quedius* (*Raphirus*) *kaalo* Smetana, 1988**

1988. *Quedius* (*Raphirus*) *kaalo* Smetana, *Quaestiones Entomologicae*, 24(2): 163–464.

Distribution: India (Uttar Pradesh, western Almora), Nepal.

***Quedius* (*Raphirus*) *muscicola* Cameron, 1932**

1932. *Quedius* (*Raphirus*) *muscicola* Cameron, *Taylor & Francis, London*. xiii + 443 pp.

Distribution: India (Sikkim: Darjeeling, Himachal Pradesh, Uttar Pradesh), Nepal, Myanmar, China (Gansu, Guizhou, Hubei, Shaanxi, Sichuan, Yunnan), Vietnam.

***Quedius* (*Raphirus*) *pahelo* Smetana, 1992**

1992. *Quedius* (*Raphirus*) *pahelo* Smetana, *Stuttgarter Beiträge zur Naturkunde (A: Biologie*), 487: 1–11.

Distribution: India (Sikkim: Darjeeling).

***Quedius* (*Raphirus*) *paschim* Smetana, 1988**

1988. *Quedius* (*Raphirus*) *paschim* Smetana, *Quaestiones Entomologicae*, 24(2): 163–464.

Distribution: India (Uttar Pradesh), Nepal.

***Quedius* (*Raphirus*) *rugosus* Cameron, 1921**

1921. *Quedius* (*Raphirus*) *rugosus* Cameron, *Entomologist's Monthly Magazine*, 57: 270–274.

Distribution: India (Sikkim: Darjeeling, Nagaland, Uttar Pradesh), Nepal, Myanmar.

***Quedius* (*Raphirus*) *tonglu* Smetana, 1988**

1988. *Quedius* (*Raphirus*) *tonglu* Smetana, *Quaestiones Entomologicae*, 24(2): 163–464.

Distribution: India (Sikkim: Darjeeling), Nepal.

***Quedius aureipilis* Cameron, 1932**

1932. *Quedius (Raphirus) aureipilis* Cameron, *Taylor & Francis, London*. xiii + 443 pp.

Distribution: India.

***Quedius chlorophanus* Erichson, 1840**

1840. *Quedius chlorophanus* Erichson, *F. H. Morin, Berlin*, pp. 401–954.

Distribution: India (Bengal).

Genus: *Staphylinus* Linnaeus, 1758

1758. *Staphylinus Linnaeus*, Systema naturae Edidito decima, reformata, 824+iiipp.

1886. *Ouchemus Gozis*, Imprimerie Herbrin, Montlucon 36pp.

***Staphylinus dimidiaticornis* Gemminger, 1851**

1851. *Staphylinus dimidiaticornis* Gemminger, *Ein Beitrag zu den Localfaunen Deutschlands. Jena: Friedrich Mauke*, 65 pp.

1903. *Staphylinus parumtomentosus* Stein, G. R., *Entomologische Zeitung*, 22(4–5): 128.

1913. *Staphylinus ernesti* Bernhauer, *Entomologische Blätter*, 9(9–10): 219–224

1940. *Staphylinus brunneimaculatus* Tottenham, *Entomologist's Monthly Magazine*, 76: 129–130.

Distribution: India (Kashmir), Austria, Belgium, Bulgaria, Belarus, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Great Britain, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Slovenia, Spain, Sweden, Switzerland, Ukraine.

Figure 1. Representation of tribes of subfamily Staphylininae.

Tribe: Xantholinini Erichson, 1839

1837. Gyrohypnidae Kirby, *Fauna Boreali-Americana*, xxxix + 325 + [1]pp.

1839. Xantholinini Erichson, *Genera et species staphylinorum insectorum coleopterorum familiae*, F. H. Morin, Berlin, 400 pp.

1957. Gyrohypnini Hatch, *University of Washington Publications in Biology*, 16 (2).

Genus: *Indolinus* Bordoni, 2002

2002. *Indolinus* Bordoni, *Monografie, Museo Regionale di Scienze Naturali, Torino*, 33.

***Indolinus mitomorphoides* (Coiffait, 1984)**

1984. *Xantholinus mitomorphoides* Coiffait, *Annales de la*

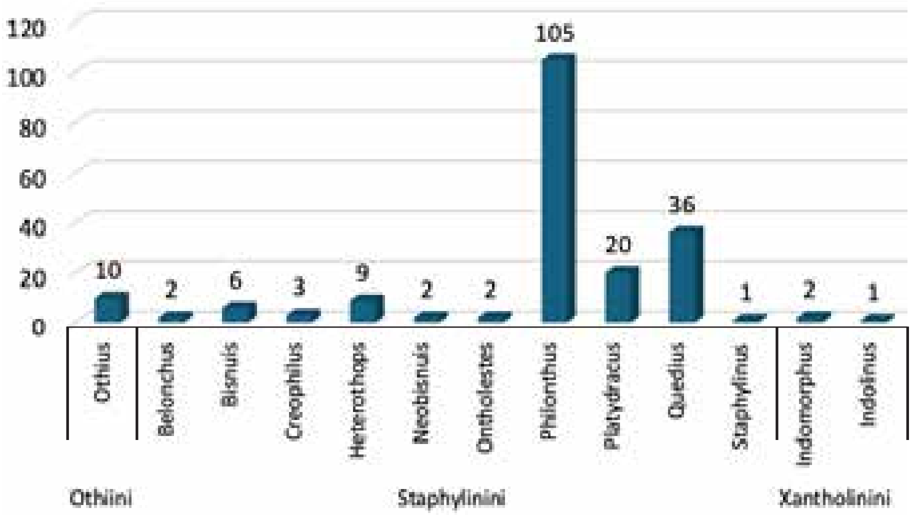

Figure 2. Generic diversity of tribes of subfamily Staphylininae.

Société Entomologique de France, 20(4): 373–387.
Distribution: India (Meghalaya, Uttarakhand, West Bengal), Nepal, Bhutan, Myanmar, Thailand, Laos.

Genus: *Indomorphus* Bordoni, 2002
2002. *Indomorphus* Bordoni, *Monografie, Museo Regionale di Scienze Naturali*, Torino, 33.

***Indomorphus parcus* (Eppelsheim, 1895)**
1895. *Xantholinus parcus* Eppelsheim, *Deutsche Entomologische Zeitschrift*, (2): 385–408.
1982. *Xantholinus bhutanicus* Coiffait, *Entomologica Basiliensia*, 7: 231–302.
Distribution: India (Uttar Pradesh), Nepal, Bhutan, Myanmar, China (Sichuan, Yunnan).

***Indomorphus shavrini* Bordoni, 2013**
2013. *Indomorphus shavrini* Bordoni, *Fragmenta Entomologica*, 45(1–2): 59–63.
Distribution: India (Uttarakhand).

Thus, a total of 199 species belonging to 13 genera of subfamily Staphylininae have been reported out of which Staphylinini is the most speciose with 93% of the known species, followed by Othiini and Xantholinini (Figure 1). Moreover, 73 species belonging to genera *Othius* (6), *Bisnius* (2), *Heterothops* (4), *Neobisnus* (1), *Philonthus* (36), *Platydracus* (12), *Quedius* (11), *Indomorphus* (1) have only been reported from India constituting around 36.68% of the catalogued rove beetle diversity. At generic level, *Philonthus*, a lineage of specialized predators, is the most diverse group of rove beetles with 105 species followed by *Quedius* (36) and *Platydracus* (20) (Figure 2). Holarctic genus *Quedius* is mainly restricted to higher altitude regions of India namely in the states of Kashmir, Himachal Pradesh, Manipur, Meghalaya, Sikkim, Uttarakhand and West Bengal. *Platydracus*, on the other hand, is a group of large rove beetles, which prefer to predate on other insects feeding on the dead decaying matter. All the three genera together constitute 80% of the recorded diversity so far.

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ARTICLE

Distribution and habitat suitability of *Amorphophallus gigas* with MaxEnt modeling in north Sumatra, Indonesia

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Abstract: *Amorphophallus gigas* is exclusively found in community agroforestry gardens within the northern Sumatra region, Indonesia. This species faces various threats including land conversion and tuber extraction for economic purposes. Despite its unique habitat characteristics, the conservation status remains unrecorded on the IUCN Red List. Effective conservation requires comprehensive data, including distribution and habitat conditions in the field. Therefore, this study aimed to analyze the variables affecting the distribution of *A. gigas* in northern Sumatra and predict the size of the area with the potential for spread. The variables examined included height, slope, slope direction, climatic conditions, and land cover. Coordinate points were taken directly in the field using GPS, while Maximum Entropy (MaxEnt) modeling was used to predict the suitability of the habitat of the species. MaxEnt modeling of variables affecting the distribution of *A. gigas* showed that soil type played an important role (contribution 55%), followed by the average monthly temperature range (16%), and altitude (7.9%). The most suitable area was found to be located in the southern part of the province. The results of this research are useful for formulating conservation strategies for *A. gigas*.

Keywords: Alismatales, altitude, Araceae, conservation strategy, corpse flower, distribution modelling, monthly temperature, population ecology, soil type, spatial ecology.

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INTRODUCTION

The Indonesian flora is part of the Malesian flora, renowned for its rich biodiversity (Latifah et al. 2021). The Malesian region covers Indonesia, Malaysia, the Philippines, Papua New Guinea, and parts of Thailand and southeastern Asia. A prominent plant family within this region is Araceae, which includes the genus *Amorphophallus* (Van et al. 2020). Northern Sumatra Province, covering an estimated forest area of ±3,010,160.89 ha (approximately ± 41.25% of the total land area), hosts diverse flora and fauna, including *Amorphophallus* species. With over 200 species distributed from western Africa to tropical Asia and northern Australia, these plants are notable for their large size and the foul odor emitted during flowering, resembling decaying animals (Shirasu et al. 2017; Yuzammi et al. 2018).

Several species of *Amorphophallus* hold economic value and are cultivated in tropical and subtropical regions worldwide (Mutaqin et al. 2020). These species contribute quite significantly to food security due to their high glucomannan content, a polysaccharide widely used in the food, pharmaceutical, and chemical industries (An et al. 2010; Chua et al. 2010). Historically, the tubers and flowers of *Amorphophallus* have been utilized as food and medicine for over 2,000 years ago by the ancient southeastern Chinese people (Handayani et al. 2020). In northern Sumatra, the tubers were harvested primarily for their economic value rather than for direct consumption or medicinal use. I In regions such as Java, *Amorphophallus* was incorporated into the diet (Mutaqin et al. 2020; Widyastuti et al. 2020) and used to treat diabetes (Sutriningsih & Ariani 2017). Similarly, in East Nusa Tenggara, the shoots and leaves of *Amorphophallus muellerii* are consumed and used for medicinal purposes, including stimulating breastmilk production and as an astringent and analgesic (Santosa & Sugiyama 2016).

In Indonesia, 25 *Amorphophallus* species have been identified, including the iconic *Amorphophallus titanum* (Becc.), listed in the IUCN Red List (Yuzammi et al. 2018), and *Amorphophallus gigas* Teijsm. & Binn., naturally occurring in agroforestry areas in northern Sumatra (Rambey et al. 2021, 2022). Despite the ecological and economic importance, *Amorphophallus* species remain underexplored in northern Sumatra. These species play vital roles in biodiversity maintenance and nutrient cycling within forest ecosystems (Singh & Gadgil 1995; Wahidah et al. 2022). Threats such as land conversion for agriculture and human activities pose serious risks to their survival. *A. titanum*, as one of the largest inflorescences in the world, is vulnerable due to its restricted distribution and long maturation period. Public awareness of the conservation status and ecological significance of these species remains low, further jeopardizing their preservation (Yudaputra et al. 2022). Although *A. gigas* has not been officially classified as a protected species, the plant is rarely documented when it blooms in fields or forests. The habitat of the species is also at risk of degradation or loss due to its coexistence with agroforestry practices or human interference.

Conservation of *Amorphophallus* species has been prioritized through the strategic action plan spanning from 2015 to 2025 (Yuzammi et al. 2015). One important aspect to support conservation efforts is a systematic assessment of *A. gigas* populations in the wild, specifically in habitats that are in contact with human activities. It is important to understand that not all human activities directly inhibit growth and endanger the conservation status of this species. In the field, the reality is that complex agroforestry planting patterns serve as a harmonious strategy crucial for protecting and sustainably using *A. gigas*. Previous studies have reported the potential of wild cultivation and utilization of *Amorphophallus* spp. as edible crops and ethnomedicinal materials in northern Sumatra (Rambey et al. 2022a). This is evident in the discovery of various species growing around forests and agroforestry land, including *Amorphophallus gigas*, *Amorphophallus titanum, Amorphophallus paeoniifolius*, *Amorphophallus prainii*, and *Amorphophallus beccarii* (Supriati 2016). Based on initial surveys, data collected from 2019 to 2021 indicate substantial exploitation of *A. gigas* and *A. titanum* in the field, primarily for export purposes. In Sumatra, the population of *A. titanum* has declined significantly due to overharvesting of its tubers (Yudaputra et al. 2022). In 2018, exports of *Amorphophallus* tubers amounted to 254 t, generating IDR 11.3 billion, and were shipped to countries including Japan, Vietnam, China, and Australia, among others (Utami 2021). Given the scarcity of information regarding the habitat suitability for *A. gigas*, it is essential to assess whether natural populations of this species are still conserved.

The habitat suitability of *A. gigas* was modelled in this study using ecological niche modeling with Maximum Entropy (MaxEnt). This method aims to evaluate and predict habitats or areas with the potential to become distribution locations that meet the growth requirements for this species (Saputra & Lee 2021). In the data analysis process, MaxEnt requires various data sets representing the location of species occurrences and environmental information (Phillips & Dudík 2008). Environmental data included six variables: distance from roads, distance from rivers, slope, altitude, topography, and annual bioclimate. These variables were chosen for their known influence on habitat suitability and species distribution, providing insight into how landscape and climate affect *Amorphophallus* populations, particularly in areas facing land conversion (Rahman et al. 2019). Suitability of land use is used as a basis for planning and decision making in rational land management. In several studies, geographic information systems (GIS) have been commonly used to analyze land suitability (Rahmawaty et al. 2020). Investigations into the land suitability of *Amorphophallus* have been undertaken by both Wahyu et al. (2022) and Komsiati & Achyani (2021). The identified locations of *A. gigas* were found on slopes ranging between 30% and 60%, classifying them under the steep terrain category. Effective management strategies must prioritize conservation while allowing sustainable use, ensuring biodiversity and long-term availability of this valuable genus. Despite the presence of *Amorphophallus* species in northern Sumatra, including *A. gigas*, research on their distribution remains limited. This study aims to fill this gap by using MaxEnt to evaluate habitat suitability, providing a foundation for future conservation initiatives.

METHODS

Study Area

This study was conducted in 2023 in north Sumatra, including southern Labuhanbatu, northern Padang Lawas, southern Tapanuli, northern Tapanuli, and Mandailing Natal Regency. Northern Sumatra is located between 0.568–4.305 N and 97.059–100.424 E (Figure 1). According to climatic data provided by Statistics Indonesia of northern Sumatra (https://sumut.bps.go.id/) in 2023, temperatures in the region fluctuate between 13.4°C and 33.9°C, with humidity ranging from 78% to 91%. Annual precipitation varies between approximately 800 mm and 4,000 mm. Over the past five years, observable climate change phenomena in northern Sumatra include a documented increase in temperature and erratic precipitation patterns. Northern Sumatra's land cover shows that most of the area is dominated by forest cover and agroforestry area. The point sample of species locations was found in community agroforestry areas for rubber, durian, and cacao. Agroforestry in almost all regions had a complex pattern resembling a forest. *Amorphophallus gigas* in northern Sumatra is found at an altitude of 40 to 950 m. The survey of *Amorphophallus* was conducted in all forest locations, both natural forests and agroforestry areas. In the Northern Padang Lawas District, *Amorphophallus gigas* was found at the edges of the Barisan Hills forest at various elevations. In the southern Tapanuli District, *Amorphophallus* was located in agroforestry gardens adjacent to natural forests. In both the southern Tapanuli and northern Tapanuli Districts, *Amorphophallus* coexists with natural forests. The exploratory findings revealed that the distribution of *A. gigas* in southern Tapanuli and northern Tapanuli is at elevations below 1,000 m, which are predominantly agroforestry lands owned by the community. Elevations above 1,000 m are natural forests managed by the government's conservation agency, the Natural Resources Conservation Agency. Surveys in the natural forests of southern Tapanuli and northern Tapanuli Districts at elevations above 1,000 m revealed a different species, *Amorphophallus beccarii*. In the Mandailing Natal District, *A. gigas* was found in limited production forests that are adjacent to natural forests.

Data Collection

The materials used were thematic maps including topography, land cover, climate, soil types, roads, rivers, and villages, as well as community socio-economic data. These data were chosen due to the high contribution of each variable (altitude, slope aspect, distance from river, distance from road, and 19 bioclimates) to the species distribution in the model after the first running of the MaxEnt model. Distance from road indicates the potential of human activity to this species' potential distribution, while distance from river shows the correlation between water bodies to the species' location to distribution across the area. For image processing and analysis, a licensed ArcMap 10.8, DivaGIS version 7.5.0, JavaScript, and MaxEnt application version 3.4.1 are available in the Universitas Sumatra Utara.

Several steps were undertaken to predict the distribution of *A. gigas*, including the collection of primary and secondary data. Primary data were collected through field observations using purposive sampling, where sample locations were identified by local communities or through direct findings in the field. Distribution data were recorded using a Global Positioning System (GPS) across various regions in northern Sumatra. After confirming the presence of *A. gigas*, the geographic coordinates were recorded. A total of 34 point locations were included in the MaxEnt analysis, with 24 points used for training and 10 points

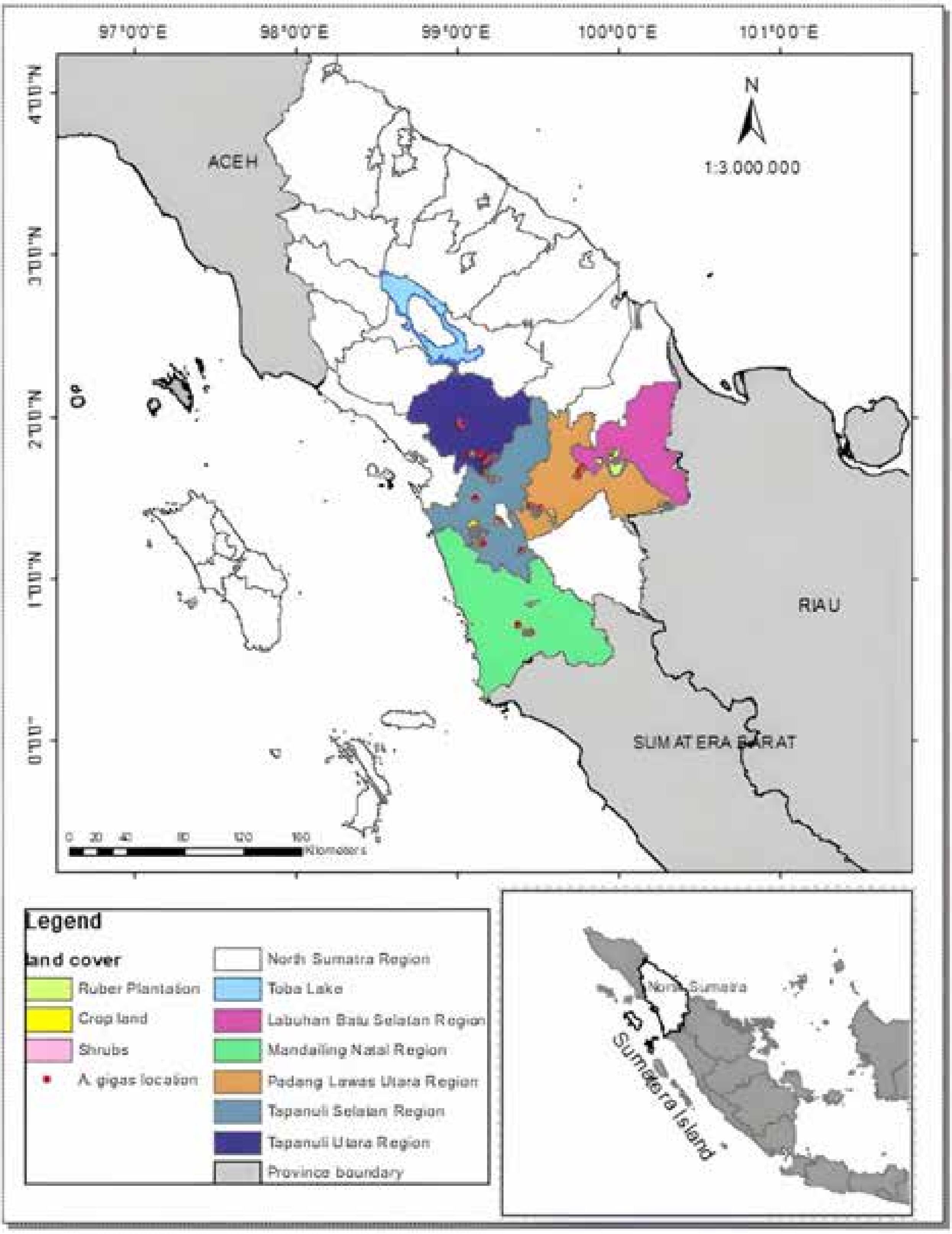

Figure 1. Map showing study sites, distribution coverage, and land cover of *Amorphophallus gigas* habitats.

for testing.

Secondary data supporting this study included information on topography, slope, elevation, soil type, and land cover obtained from DEMNAS (Indonesian Geospatial Portal). Additional data, such as area boundary shapefiles, road networks, and river networks, were sourced from geospatial websites. Bioclimatic and geospatial data from BIG (Indonesia) were acquired from the WorldClim.org website, along with general information about the study area's conditions. Table 1 provides an overview of the data, sources, and types in this study.

Construction of Environmental Variables Mapping

Maps of road and river distances in this study were processed using ArcGIS 10.8 and distance analysis was carried out with the Euclidean distance method in the Arc ToolBox ArcGIS option. Distance map data from roads and rivers were downloaded from the Indonesian Earth Rupa map in shapefile form on the INA Geospatial Portal. The road and river distance maps were created from the road and river networks respectively in the northern Sumatra Province region. Altitudinal class maps were created with DEMNAS data using the ArcGIS 10.8 application.

Height map data was downloaded in grid form, and the digital elevation model (DEM) data obtained from the DEMNAS Indonesia Geospatial Portal was adjusted to the study location. The conversion of vector data to raster form was carried out by equalizing the resolution units of the extract by mask projection. Slope maps were created with a similar procedure for creating a height map. The analysis used a base elevation map, which was then processed in the Arc Toolbox to produce a percentile map projection. Class division referred to the decree issued by the director general of Watershed Management and Social Forestry regarding Technical Instructions for Compiling Critical Land Spatial Data, Number: P.4/v-set/2013.

Soil maps showed physical and chemical properties such as pH, texture, organic matter content, depth, etc. in line with the FAO (Food and Agriculture Organization of the United Nations) soil classification at a resolution of 30 m. The soil type data was obtained from the FAO Soil Classification portal dataset. These maps were generally used for agricultural purposes, environmental engineering, natural resource conservation, and land use planning. Soil maps usually include information such as soil type, depth, water capacity, organic matter content, soil structure, and nutrient content. This information can be used to understand the quality and land use method that best suits soil characteristics. The map was downloaded from the Indonesian Geospatial Portal website, and then the data were processed by adjusting to the study location.

All data were assimilated into the projection unit, and the extension was extracted with a mask in the raster. Interpretation of land cover/vegetation was divided into three main classifications, namely forest, no forest, and no data, each of which was further classified. The land cover classes included vegetative land (forest, plantations, shrubs, grass), open land, as well as settlements and water bodies (Saputra & Lee 2019). The 2019 land cover map data was obtained from the Indonesian Geospatial Portal website by downloading the overall land cover classification map file in the form of dry primary forest land, bushes, bare land, dry land secondary forest, regional industrial forest plantations (HTI), rice fields, primary mangrove and ancient swamp forests, swamp bushes/grass, settlements, agricultural land interspersed with shrubs, ponds, swamps, mangrove and swamp secondary forests. The data were then processed by cutting out the area required for the search.

Bioclimate data was obtained from the WorldClim website (https://www.worldclim.org/data/worldclim21.html), which provided 19 climate variables, including annual trends in the form of average temperature and rainfall, as well as seasonality namely coldest and hottest seasons or the wettest and driest. This variable explained the impact of climate on the distribution of species in spatial data (O'Donnell & Ignizio 2012). It is commonly used in HR analysis both for current and future distribution predictions. In MaxEnt analysis, a sample layer comprising discovery coordinates and an environmental layer in raster form including elevation, slope and terrain (aspect), soil type, distance from roads and rivers, land cover, and 19 bioclimatic variables (Fick 2017) were used with a spatial resolution of 30 arc s or the equivalent of around 1 km^2 (Hijmans et al. 2005).

The MaxEnt model estimates a target probability distribution by calculating the probability distribution of maximum entropy which makes it well-suited for species distribution modelling. The processed environmental data were collected and adjusted to the northern Sumatra region with the same resolution, area, and geographic coordinate system. The environment layer was converted into an Actionscript Communication (ASC) file implemented in MaxEnt analysis. For sample classes, the analysis used the CSV (Comma Separated Values) format. Subsequently, in the post-analysis process, the distribution analysis output of *A. gigas* was overlaid on the district administrative map. Figure 2 shows a flowchart illustrating the study procedure for analyzing the distribution and habitat suitability of *A. gigas* using MaxEnt and ArcMap tools.

Data Analysis

Amorphophallus gigas habitat suitability in this study was modelled using Ecological Niche Modeling with MaxEnt. This method aims to evaluate and predict the most suitable habitat in the study area. All environmental variables were combined with data points showing the presence of *A. gigas* and analyzed to determine the most influencing factors.

MaxEnt analyzed species presence data in the field directly in the form of historical data, and the probability of existence. Various areas with environmental information were examined, using a probability range of 0–1 with three observation samples including, environmental variables, future scenarios, and the extent of one suitability map (Saputra et al. 2019). The model used 10 replicates with one regularization multiplier and 30 % of random test data of *A. gigas* occurrence data. The model runs for 5,000 maximum iterations. The higher the number, the higher the chance of the species appearing. Probability numbers were classified into five groups. Areas with a probability greater than or equal to 0.4 were considered suitable and others unsuitable. Classification of habitat suitability of *A. gigas* with probability values is presented in Table 2.

The goal of MaxEnt is to estimate a target probability distribution by finding the maximum entropy probability distribution (Phillips et al. 2006). The perfect formula for Species Distribution Models with presence and absence data represented as follows (Phillips & Dudik 2008):

$$P(y = 1|x) = \frac{P(y = 1|x)\ P(y = 1)}{P(x)} \quad (1)$$

Where P (y = 1|x) is the probability of existence of the species at location x (y ranges from 0 to 1), P(x|y = 1) is the current observation or distribution realization in area x annotated as π (x) , P(y = 1) is the probability of presence, and P(x) = 1/|X| is the area-wide probability of location X. Similarly

$$P(y = 1|x) = \pi\ (x)\ P(y = 1)|X| \quad (2)$$

Where s

$$q_\lambda(x) = \frac{\exp(\sum_{i=1}^{n} \lambda j\ f j(x))}{Z\lambda} \quad (3)$$

Where qλ(x) is the MaxEnt distribution, exp$(\sum_{i=1}^{n} \lambda j\ f j(x))$ is the exponential parameterized with feature vector (f) and (λ), and Zλ is a normalization constant that ensures the values of qλ(x) add up to unity over the entire area. The formula is calculated as follows:

$$H = \sum q\lambda(x) ln(q\lambda(x)) \quad (4)$$

Where H is the maximum entropy, and qλ(x) is the Maxent distribution from Equation (3). After obtaining an estimate of qλ, sufficient information is obtained to calculate the probability distribution P(y = 1|x), as shown by Equation (5)

$$P(y = 1|x) = \frac{e^H q_\lambda(x)}{1+e^H q_\lambda(x)} \quad (5)$$

Where qλ is the estimated probability of presence with maximum entropy π, and H is the entropy qλ.

The MaxEnt model was evaluated using the area under the curve (AUC), calculated from the receiver operating characteristic (ROC) curve. The ROC curve is a graph that shows the performance of a classification model at all thresholds. It consists of a sensitivity on the y-axis and a specificity of one on the x-axis for all possibilities. Sensitivity describes the accuracy of the model predicting presence, while specificity shows its effectiveness in predicting habitat suitability. To assess the model performance, MaxEnt used cross-validation to evaluate possible errors in the predictive output. The resulting AUC values ranged from 0.5 to 1.0, where values above 0.7 show appropriate model fit (Prasetyo et al. 2021). The accuracy of model performance based on AUC values is described in Table 3.

RESULTS

MaxEnt analysis of *A. gigas* distribution

Thirty-four distribution points of *A. gigas* were identified, spanning various districts in northern Sumatra, including southern Labuhanbatu Regency (eight points), northern Padang Lawas Regency (six points), southern Tapanuli Regency (six points), northern Tapanuli Regency (10 points), and Mandailing Natal Regency (Four points). The sample species was documented as featured in Image 1.

Habitat suitability analysis was conducted using MaxEnt with a distance resolution limit of 1 km^2 on the map. Among the 34 result points, MaxEnt covered 24 distribution points and the remaining 10 were used as sample points for testing. The remaining distribution points were then combined with the environmental variable map. Figure 4 shows MaxEnt results for *A. gigas* habitat in northern Sumatra with a range of 0–1, and 3b depicts the potential distribution in five suitability classifications. The red colour showed a highly suitable habitat with a probability range of 0.8–1, while the orange and yellow colours represented suitability

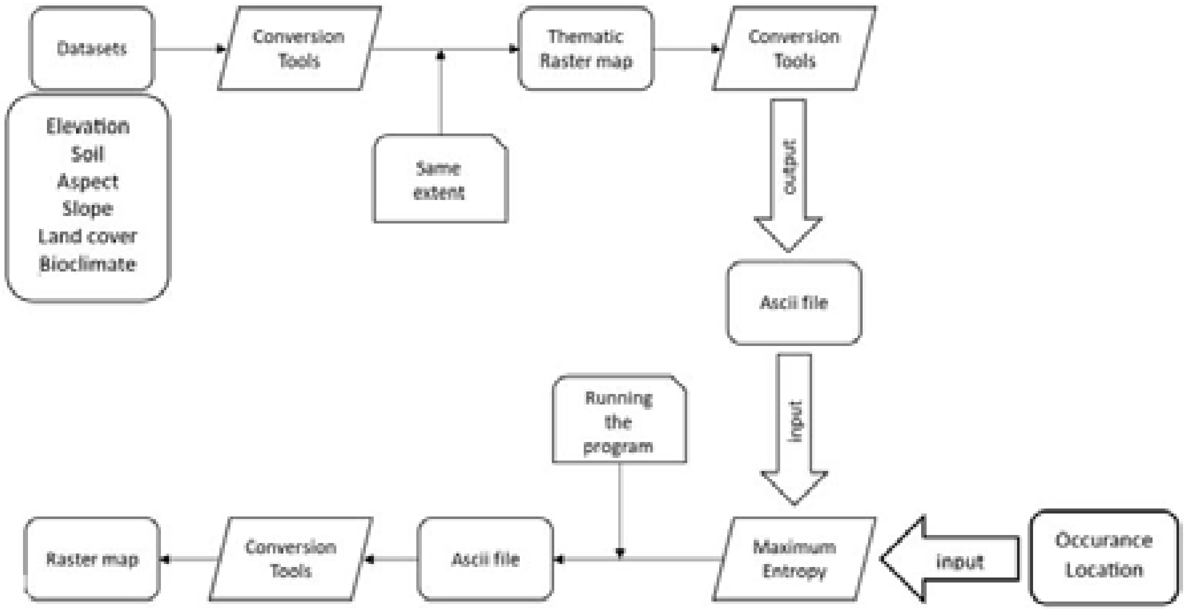

Figure 2. Type distribution mapping analysis procedure using MaxEnt and ArcMap tools.

Table 1. Data source or environmental variables for distribution modelling of *Amorphophallus gigas*.

	Data	Source	Type	Year
1	Digital Elevation Model (DEM)	www.earthexplorer.usgs.gov	.tif	2010
2	Soil Type	http://www.fao.org/soils-portal	.asc	2000
3	Aspect	Derived from DEM Data	.tif	2010
4	Slope	Derived from DEM Data	.tif	2010
5	Land cover	www.appgis.dephut.go.id	.kml	2000
6	Climate	www.worldclim.org	.bil	1980-2000

Table 2. Classification of habitat suitability of *Amorphophallus gigas* with probability of occurrence values

Main classification	Subclassification	Probability of occurrence
Suitable	Highly suitable	0.8–1
	Moderately suitable	0.6–0.8
	Marginally suitable	0.4–0.6
Not Suitable	Currently not suitable	0.2–0.4
	Permanently not suitable	0–0.2

class corresponding to a range of 0.6–0.8 and 0.4–0.6, respectively. The light blue colour showed areas not suitable for *A. gigas* with a probability range of 0.2–0.4 and the dark green colour implied areas very unsuitable with a probability range of 0–0.2.

Validation Model of *A. gigas* Habitats

The AUC test value was obtained from testing 30% of samples taken randomly. The higher the value, the better the accuracy of the data model. In this range, the AUC value fell into the good category from 0.8 to 1 by 0.971 for training data and 0.897 for test data. The model validation results are shown in Figure 5.

MaxEnt-derived models of *A. gigas* based on environmental variables

Environmental variables that contributed to MaxEnt analysis included elevation, slope, aspect, soil type, land cover, distance from roads, distance from rivers, average annual temperature (bio1), average monthly range (bio2), rainfall annual (bio12), and warmest quarterly rainfall (bio18). The modelling analysis results of habitat suitability showed that soil type, altitude, and average monthly temperature range had the highest contribution. The percentage contribution is shown in Table 4.

Jackknife analysis was used to calculate the importance of each environmental variable in the model and the results are shown in Figure 6. The green colour showed MaxEnt results without the variable included in the model, the blue colour showed the results obtained using only the variable, and the red colour implied the optimal results with all environmental variables. Soil type 20 (alluvial humic) has the highest impact on the

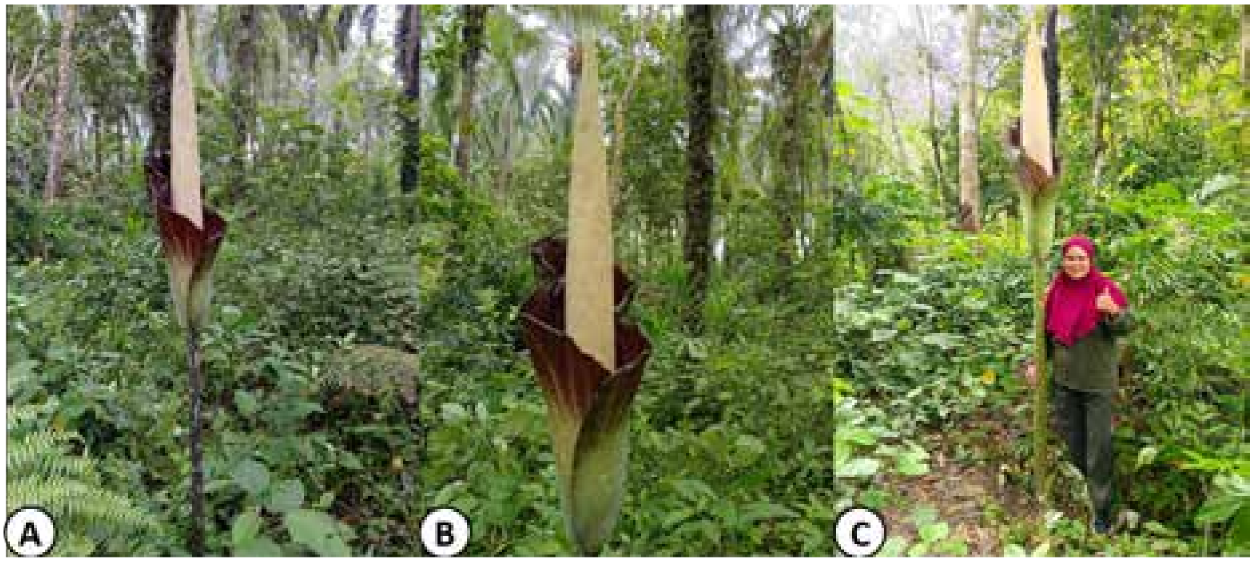

Image 1. An image series of *Amorphophallus gigas* includes: a—a close-up view | b—blossoming phase | and c—a depiction of the proportional height of *A. gigas* in comparison to a human. © Ridahati Rambey.

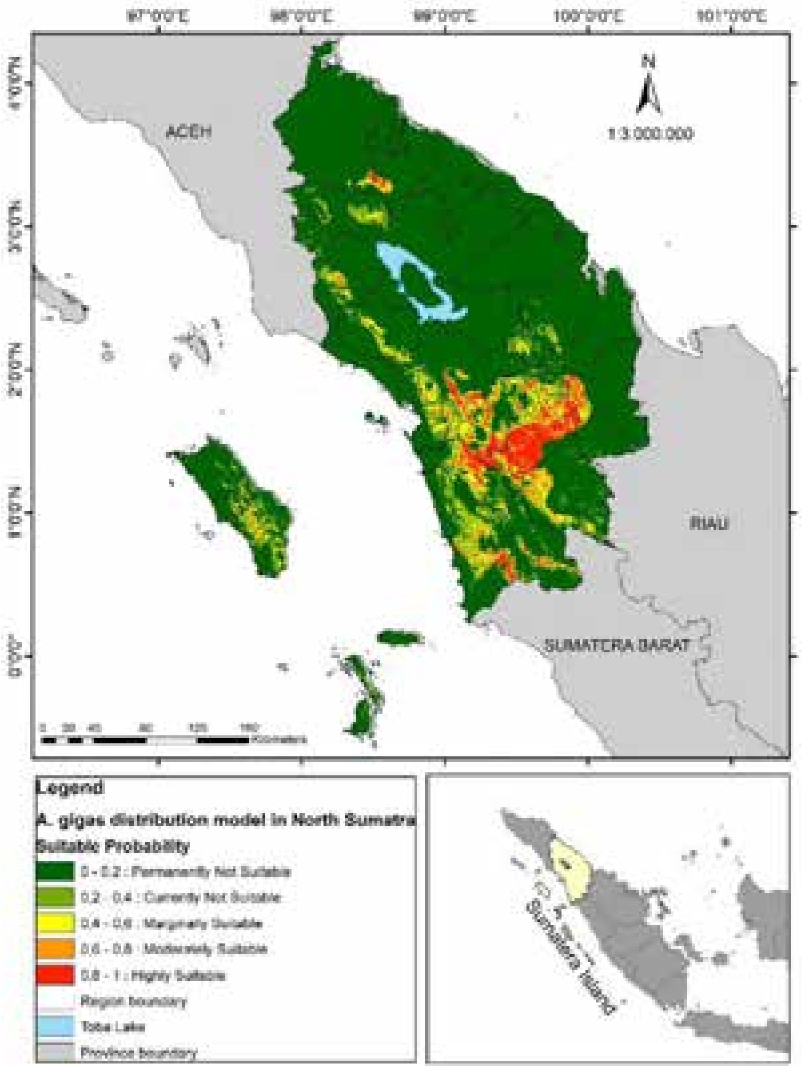

Figure 3. MaxEnt output map illustrating the *Amorphophallus gigas* habitat in northern Sumatra.

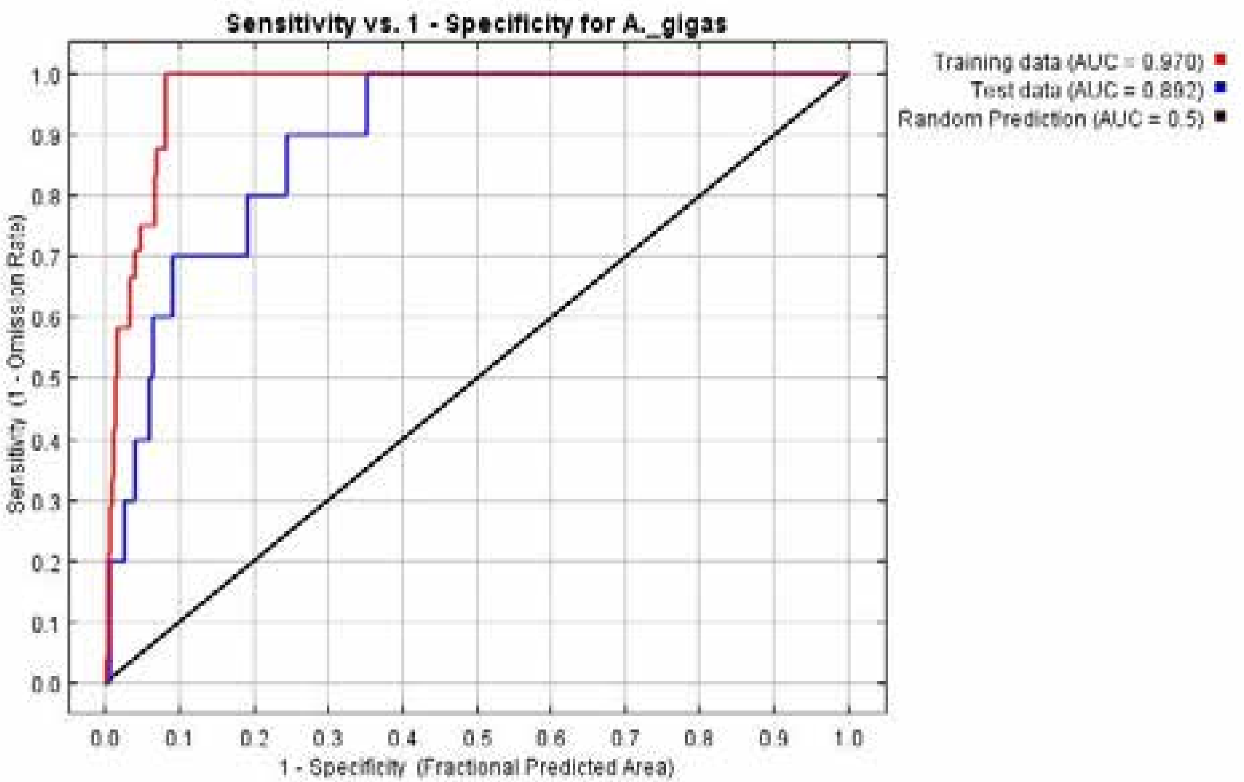

Figure 4. ROC graph showing sensitivity and specificity for *Amorphophallus gigas* distribution model. A higher AUC value shows the reliability of the model.

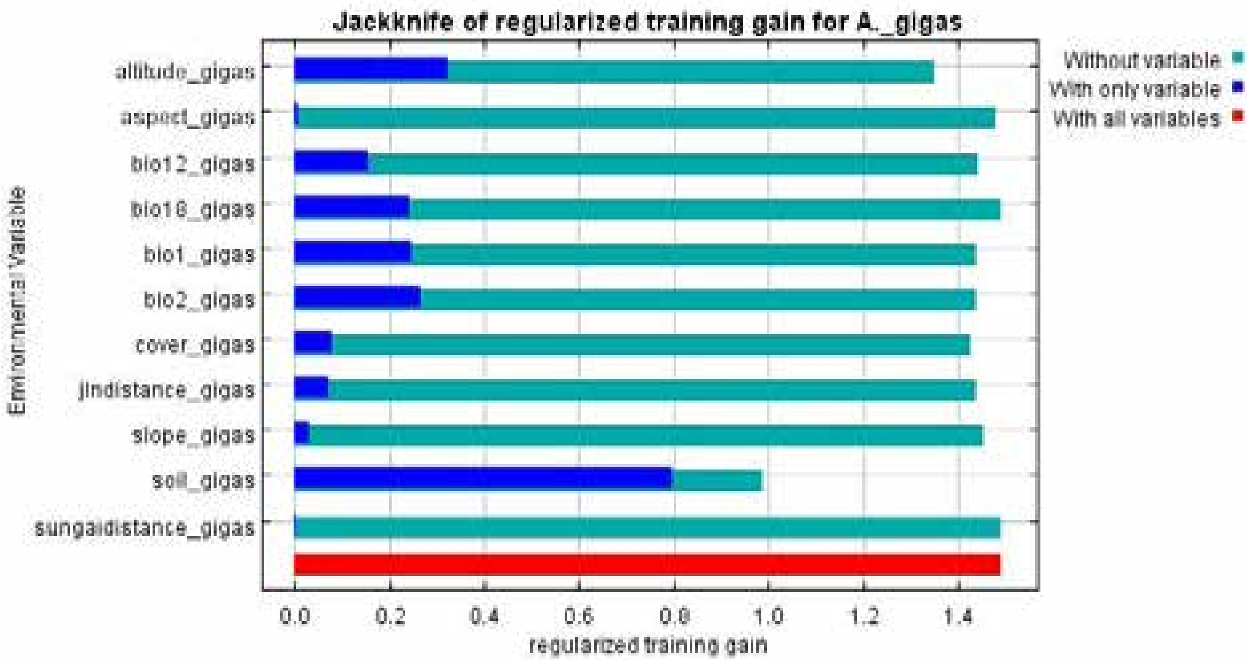

Figure 5. Jackknife analysis of *Amorphophallus gigas* for the importance of each environmental variable in the model.

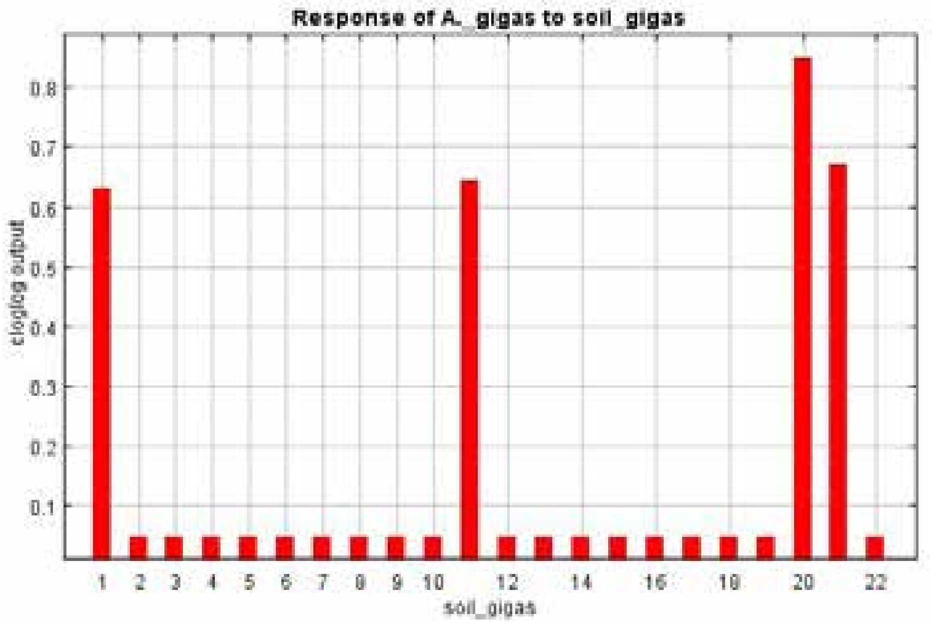

Figure 6. Response of *Amorphophallus gigas* to soil type variables.

Table 3. Model performance accuracy based on AUC values.

AUC Value	Model Performance
0.6 – ≤ 0.7	Not accurate
> 0.7 – ≤ 0.8	Moderately
> 0.8–0.9	Accurate

distribution of *A. gigas*. The response of *A. gigas* to soil-type variables is shown in Figure 7. The response of *A. gigas* the most significant contribution stemming from soil type 1: Ah27-2/3c (Humic Acrisols), 11: Th17-2c (Humic Andosol), 20: Jd 9-2/3a (District Fluvisols), and 21: Bh 17-2bc (Humic cambisols).

The response of *A. gigas* to the environmental variables of altitude and the difference between the annual average maximum and minimum temperatures are shown in Figure 8. Height from 400 to 600 m was classified as the highest probability distribution with a value above 0.5. Regarding the difference in annual average maximum and minimum temperatures, the range of 10–10.5^{0}C had the highest probability. In other words, *A gigas* would be found less frequently when the difference between the maximum and minimum temperatures in the annual average exceeds 10.5 or falls below 10^{0}C.

Distribution of *A. gigas* in the northern Sumatra Region

MaxEnt results in Figure 9 showed that 15 regions in northern Sumatra were suitable for the distribution of *A. gigas* with varying areas, ranging from 175.19 ha to 43,248.57 ha. This was less than 30% of the total land area in the province, and the most suitable area was located in the southern part. The results of the map modelling showed that the most suitable areas for the growth of *A. gigas* were in the northern Padang Lawas (113,916.34 ha), southern Tapanuli (43,248.57 ha), southerns Labuhanbatu (17,759.81 ha), Mandailing Natal (17,735, 23 ha), and northern Tapanuli Regency (16,305.74 ha). For the distribution of *A. gigas* based on land cover types, the majority is located in cropland or dry land agriculture, accounting for 52.78% of its presence. Meanwhile, agroforestry areas constitute 33% of its habitat, and forested areas make up 13.2%. It appears that *A. gigas* favors environments where the canopy cover is relatively sparse, as evidenced by its prevalence in agroforestry and crop areas, which typically feature less dense vegetation.

DISCUSSION

The map modeling results indicate that the most suitable habitats for *A. gigas* growth are concentrated in specific regions with favorable geographical conditions. These areas likely possess suitable environmental factors, such as soil type, elevation, and climate, supporting the species' growth and distribution. Furthermore, based on the analysis results, the variables that influenced the habitat suitability of *A. gigas* included soil type, monthly

Table 4. Percentage contribution of the three highest environmental variables in MaxEnt *Amorphophallus gigas* model.

	Variable	Variable code	Percent contribution (%)
1	Type of soil	soil_gigas	55
2	Average monthly temperature range	bio2_gigas	16.2
3	Elevation	altitude_gigas	7.9
4	Distance from road	jlndistance_gigas	5.3
5	Average annual temperature	bio1_gigas	4.4
6	Land use and land cover	cover_gigas	4.3
7	Warmest quarterly rainfall	bio18_gigas	3.4
8	Slope	slope_gigas	1.8
9	Aspect	Aspect_gigas	0.8
10	Annual rainfall	bio12_gigas	0.8
11	Distance from the river	Sungaidistance_gigas	0

temperature, and altitude (Figure 4). A machine learning ensemble model employing Random Forest and Artificial Neural Network methods identified slope and distance to the nearest river as the two most significant variables correlated with the growth of *A. titanum* in Sumatra (Yudaputra et al. 2022). The most suitable area for the growth of *A. gigas* was at an altitude of 400–600 m (Figure 6).

The land suitability analysis indicated the highest potential growth point for *Amorphophallus* at 438 m and the lowest at 24 m in the Kokok Tojang sub-watershed in eastern Lombok (Wahyu et al. 2022). Another study explored the habitat characteristics of *A. titanum* populations in Lampung across seven locations, including three in the TNBBS, two in protected forests, and two in community forests (Munawaroh et al. 2017). Additionally, a study on the distribution of *porang* (*Amorphophallus muelleri*) based on regional topography in Malang Raya, utilizing Quantum GIS software, revealed that the species was found at varying heights ranging from 34 to 931 m and 100 to 1,100 m (Alifianto et al. 2013). The findings indicated that *A. gigas* generally flourished in agroforestry stands, aligning with previous studies that reported the plant's wild growth in various regions across northern Sumatra (Rambey et al. 2021). Furthermore, *A. gigas* was observed under rubber stands in northern Padang Lawas Regency, Indonesia. The plant was identified in Sabungan Village and Langgapayung Village, southern Labuhanbatu Regency, thriving under *Hevea brasiliensis* stands (Yudaputra et al. 2022; Rambey et al. 2022b).

The validation results of all selected variables showed

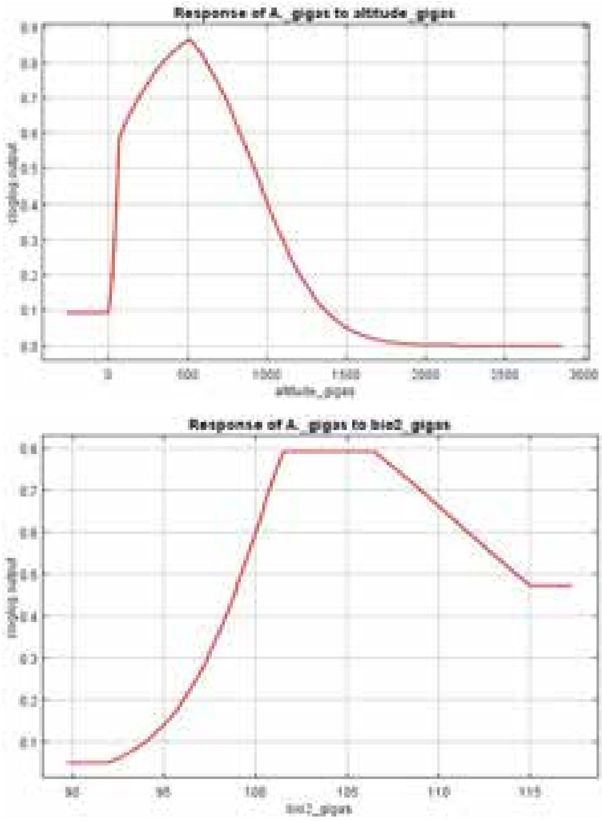

Figure 7. Response of *Amorphophallus gigas* to altitude and to the difference in annual average maximum and minimum temperature.

that the AUC value for *A. gigas* habitat suitability model was 0.970. This shows the model created can be used and has high accuracy (Pradhan & Setyawan 2021). The AUC method, employed in the validation process, is a standard technique for assessing the validity of a model. It also offers advantages for users by helping to avoid subjectivity in the boundary selection process (Lobo et al. 2008). MaxEnt modelling showed three main variables determining the distribution of *A. gigas* in northern Sumatra, with the soil variable having the most significant contribution. Based on the results, Fluvisol, Andosol, Acrisol, and Cambisols soils were found to be suitable as habitats. Humic Acrisols are characterized by acid soils with layers of clay accumulation. According to the modified legend, this class consists only of clays with low cation exchange capacity. Andosol represents dark soil formed from volcanic material with little horizon development. Fluvisols comprise alluvial and floodplain soils with little profile development, while Cambisol is soil with little profile development and not dark in colour (Soil Survey Staff 2010, 2014). As a member of the Araceae family, the *Amorphophallus* species can grow in almost all types of soil, but optimal growth and

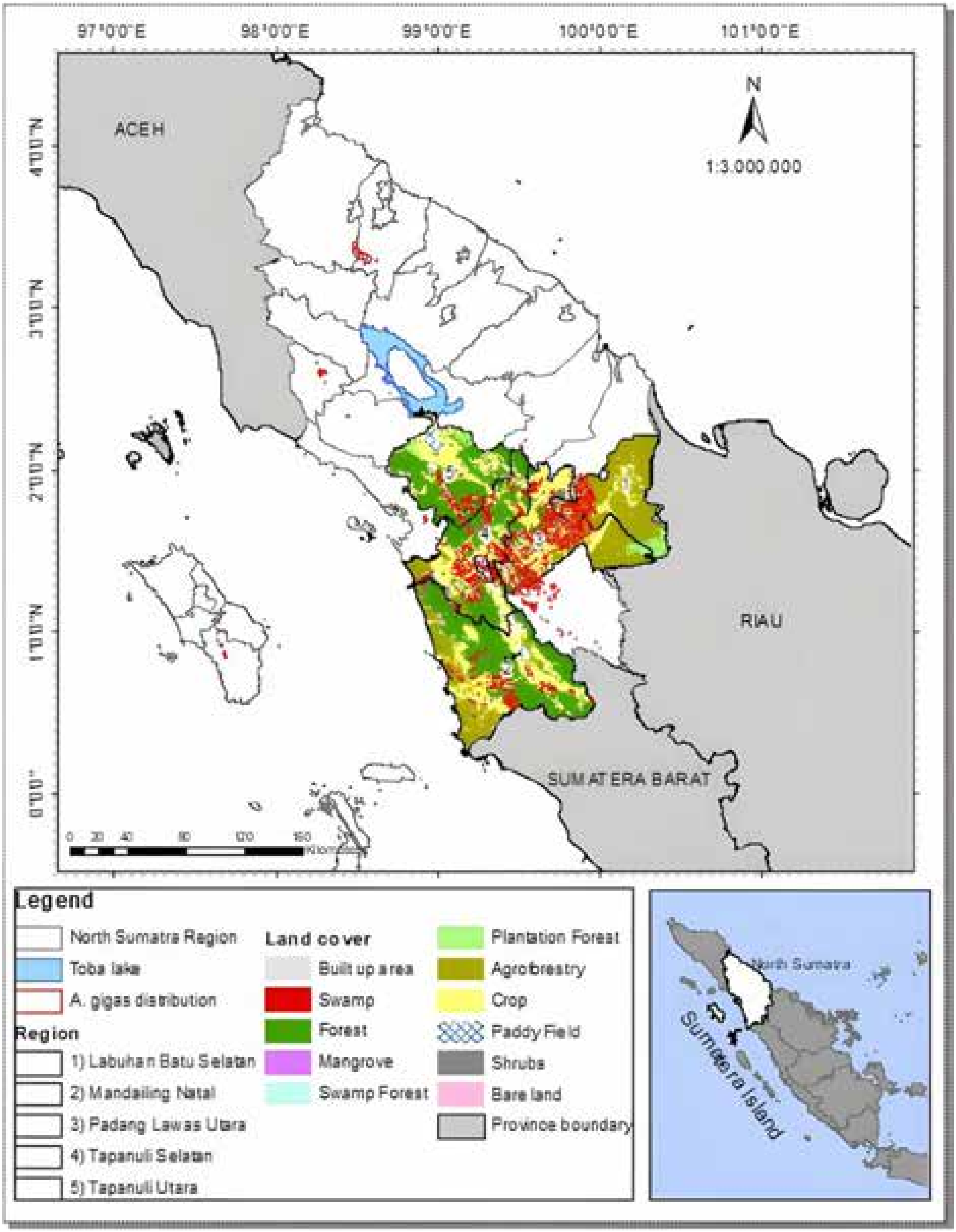

Figure 8. Potential distribution and extent of *Amorphophallus gigas* in northern Sumatra in various land covers.

development are achieved in loose soil, with a neutral pH and good drainage (Santosa et al. 2008). In general, *Amorphophallus* grows optimally in soil having a pH of 6.07.5 with a light texture (sandy clay or loose), rich in nutrients, and high in humus content (Shenglin et al. 2020). This is in line with the modelling results showing neutral pH and high humus in the preferred soils. In the section analyzed, there were many types of alluvial, andosol, and podzolic soils with relatively high levels of soil fertility.

In MaxEnt analysis, temperature played a crucial role as a tuning parameter, impacting the complexity of the model. The addition of environmental variables can also affect the value of the "regularization multiplier" parameter and the number of background points used in modelling. The addition of environmental variables such as temperature increased the ability of the MaxEnt model to predict the possibility of species existence (Elith et al. 2011). The Jackknife AUC test used the height on the graph as an important indicator of environmental variables influencing species modelling. Altitudes signify the importance of a variable in influencing species existence, while slope indicates the sensitivity of the model to that specific variable (Bradie & Leung 2017). *Amorphophallus* species thrives in lowland areas up to 1,000 m with a monthly rainfall range of 300–500 mm during the growth period. The optimal air temperature for *A. gigas* falls within the range of 20–30 °C. Exceeding 35 °C may result in leaf burning, while low temperatures might induce dormancy. To ensure high production, it is recommended to provide 50–60% shade (Nugrahaeni et al. 2021).

Amorphophallus species are known to grow and disperse from lowland areas up to 1,000 m, with optimal temperatures ranging between 25–35°C and monthly rainfall between 300–500 mm during the growth period (Puspitaningtyas & Ariati 2016). This finding is consistent with our MaxEnt analysis, which shows the species' presence at altitudes of approximately 500 m, within a broader range of 100–1,000 m. The temperature variation between annual maximum and minimum averages is approximately 10°C (Figure 6). Similarly, Wulandari et al. (2022) highlight the impact of temperature on the distribution of *A. gigas*, noting that it is predominantly found at elevations of 200 to 500 m. These studies underscore the importance of understanding the bioecology and distribution patterns of *Amorphophallus* species, which is essential for supporting effective conservation efforts (Nursanti et al. 2019; Mutaqin et al. 2022).

In addressing the conservation needs of *A. gigas* in northern Sumatra, several strategic measures are recommended. Firstly, the establishment of protected areas is crucial to protect the habitat from degradation. These protected regions could be strategically designated within existing agroforestry lands, encompassing conservation zones or buffer zones around critical habitats to mitigate impacts from adjacent land uses. Implementing regulations to manage land use effectively can prevent habitat destruction and promote the persistence of *A. gigas* populations. Moreover, the adoption of sustainable forestry practices is essential to balance ecological health with economic activities. This strategy includes maintaining ecological functions while allowing for controlled agroforestry operations that do not compromise the habitat integrity of *A. gigas*. Ongoing ecological monitoring and regular surveys should be conducted to track the population dynamics, distribution, and occurrence of *A. gigas*. This data is invaluable for evaluating the effectiveness of conservation interventions and adapting strategies as necessary. Finally, fostering collaborations with international organizations, research institutions, and conservation groups can enhance the conservation output for *A. gigas*. By sharing knowledge, resources, and best practices, these partnerships can amplify efforts and innovate conservation approaches tailored to the unique ecological context of northern Sumatra. This integrated approach will not only contribute to the conservation of *A. gigas* but also support the broader biodiversity and ecological health of the region.

CONCLUSION

The distribution suitability of *A. gigas* varied, ranging 175.19–113,916.34 ha, with less than 30% of the land area in northern Sumatra being suitable. The most suitable area was identified in the southern part of the province. In conclusion, almost all districts in northern Sumatra were found to be suitable for the growth of *A. gigas*, with the largest areas situated in the altitude range of 400–600 m. The data generated from this study could serve as a basic reference in conservation and propagation efforts to harness the numerous benefits.

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Abstrak: *Amorphophallus gigas* hanya ditemukan di kebun agroforestri masyarakat di wilayah Sumatra bagian utara, Indonesia. Spesies ini menghadapi berbagai ancaman terhadap populasinya, termasuk konversi lahan dan pengambilan umbi untuk tujuan ekonomi. Meskipun memiliki karakteristik habitat yang unik, status konservasinya belum tercatat dalam IUCN *Red List*. Konservasi yang efektif memerlukan data komprehensif, termasuk distribusi dan kondisi habitat di lapangan. Oleh karena itu, penelitian ini bertujuan untuk menganalisis variabel-variabel yang memengaruhi distribusi *A. gigas* di Sumatra bagian utara serta memprediksi luas area potensial penyebarannya. Variabel yang dikaji meliputi ketinggian, kemiringan, arah lereng, kondisi iklim, dan tutupan lahan. Titik koordinat diambil langsung di lapangan menggunakan GPS, sedangkan pemodelan MaxEnt (*Maximum Entropy*) digunakan untuk memprediksi kesesuaian habitat spesies ini. Pemodelan MaxEnt menunjukkan bahwa tipe tanah memiliki kontribusi terbesar terhadap distribusi *A. gigas* (55%), diikuti oleh kisaran suhu rata-rata bulanan (16%), dan ketinggian (7,9%). Area dengan kesesuaian habitat tertinggi ditemukan di bagian selatan provinsi. Hasil penelitian ini bermanfaat sebagai rumusan dalam perancangan strategi konservasi bagi *A. gigas*.

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ARTICLE

Taxonomy, distribution, and ecology of *Impatiens violacea* (Balsaminaceae) a steno-endemic species in Pettimudi, an area of endemism in southern Western Ghats, India

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Abstract: *Impatiens violacea* is a steno-endemic species in a valley in Pettimudi forest adjacent to Eravikulam National Park, Kerala, India. Taxonomic treatment, morphology, vertical distribution, ecology, phenology, ethnobotany, threats, and conservation status of the species are provided. *Impatiens violaceae* is a threatened species under the 'Vulnerable' category with substantial anthropogenic stress. The present study on endemic species in Pettimudi forest revealed 13 endemic species of the southern Western Ghats reside at area of (1.87 km^2) in a U-shaped valley within the forest of Pettimudi, of which three species, namely, *Impatiens violacea*, *I. johnii*, and *Cnemaspis anamudiensis* were exclusively endemic to this valley whereas *I. pandurananii* to the Pettimudi forest. The findings suggest that the u-shaped valley in Pettimudi forest is an area of endemism (AoE) and a 'hot speck' within the Western Ghats, recognised as one of the global hotspots. Based on the study result, the authors recommend the u-shaped valley in Pettimudi forest be attached to the Eravikulam National Park territory to conserve the endemic species.

Keywords: Anthropogenic stress, conservation, endemic species, habitat fragmentation, hot speck, tropical montane cloud forest, vertical distribution.

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INTRODUCTION

The Western Ghats-Sri Lanka is one of the hottest hotspots with 4,780 plant species having 2,180 endemic species, which is 17.5% of the global endemic plant community (Myers et al. 2000). In India, the Western Ghats extends from southern Gujarat and run approximately 1,600 km and end up in Kanyakumari in the southernmost tip of India (Singh et al. 2019). The southern Western Ghats lies between south Canara of Karnataka and Kanyakumari of Tamil Nadu with a 30–40 km discontinuation called Palghat Gap at Kerala (Nair 1991; Augustine 2018). One of the unique features of the southern Western Ghats is the presence of tropical montane cloud forests, which occurs at 1,400–2,400 m, popularly known as shola forests and this high-elevation cloud forest habitat hosts a high level of endemism (Robin & Nandhini 2012; Singh et al. 2019).

Endemism is the term for a species' exclusive existence in a designated geographic area. Since the endemism idea is purely phenomenological, various taxa may be endemic to the same region as a result of disparate historical processes (Fattorini 2017). Areas where the distributions of at least two taxa overlap are called areas of endemism (AoE) (Quijano-Abril et al. 2006). Endemic areas or areas of endemism are the foundation of comparative biogeography, and identifying areas of endemism is essential for biogeographical regionalisation (Parenti & Ebach 2009). Local endemism and hot specks are observed within the Western Ghats-Sri Lanka biodiversity hotspot (Cherian 1996; Bossuyt et al. 2004). Hot specks are small niches within the biodiversity hotspots with a high concentration of diverse species including endemic ones. Identification of hot specks or small local hot spots is requisite for extensive conservation management (Trivedi & Bharchula 2023; Harris et al. 2005; Murray-Smith et al. 2009) and endemic species are most convenient to identify biodiversity hotspots (Myers et al. 2000; Mittermeier et al. 2005; Orme et al. 2005). For the identification of the area of endemism, the study based on endemic flora and fauna is very helpful in locating such hot specks for regional conservation management.

The genus *Impatiens* of the family Balsaminaceae is a highly diversified genus with more than 900 species distributed in tropical Africa, Madagascar, southern India, Sri Lanka, the eastern Himalaya, and southeastern Asia (Bhaskar 2012). The most striking features of this genus are the high degree of endemism and regional endemism. The genus *Impatiens* in southern India and Sri Lanka has c. 95% of endemism (Grey-Wilson 1980). In India, more than 210 species of *Impatiens* have been reported and from southern India 106 species and 13 varieties, of which 103 species and 13 varieties were endemic to the Western Ghats (Hareesh et al. 2015). From parts of the Western Ghats in Kerala, 88 taxa of *Impatiens* were reported within which 73 taxa were endemic to this region (Bhaskar 2012; Sasidharan 2013). Many new species are still being described in this region (Narayanan 2013). Kumar & Sequeira (2001) first described *Impatiens violacea* as an endemic epiphytic parrot-billed *Impatiens* from the shola forest of Pettimudi near Eravikulam National Park, Kerala.

In the Pettimudi forest, only very few studies on flora and fauna have taken place (Ramasubbu et al. 2011; Prabhukumar et al. 2017; Cyriac et al. 2018; Prasad et al. 2018). In the present study, the aim is to extend the knowledge of morphology, ecology, and spatial distribution including the vertical distribution and threats of a vascular epiphyte *Impatiens violacea*. The paper also focused on the habitats that have received less conservation and research attention by identifying endemic species of flora and fauna in Pettimudi forest and thus gaining insight into the degree of endemism in that area and the need for conservation.

MATERIALS & METHODS

Study Area

The study was conducted in a u-shaped valley at Pettimudi forest which lies in the north 10.175^{0}N, 76.995^{0}E, south 10.163^{0}N, 76.991^{0}E, west 10.172^{0}N, 76.984^{0}E and east 10.171^{0}N, 76.998^{0}E (Image 1). The area comes under the reserve forest located adjacent to the south-west periphery of Eravikulam National Park, Idukki, Kerala. This area comes under the Munnar Territorial Forest Division of the Kerala Forest Department. This valley faces towards the west and the elevation of the valley varies 1,450–1,900 m. To examine the distribution of *I. violaceae*, the type locality and surrounding areas including the Pettimudi forest and the Eravikulam National Park were investigated. The vegetation is composed of a tropical montane cloud forest surrounded by steep mountains with a single narrow corridor (Image 1) and a few small and large perennial streams flowing west towards the Edamalayar Dam. Therefore, the tribal people refer to this large patch of shola forest as "Valiyathoducholai." (Valiya – large, thodu – creek, cholai – shola). Pettimudi forest receives heavy rainfall during the south-west (June/July) and retreating (October/November) monsoons, and has

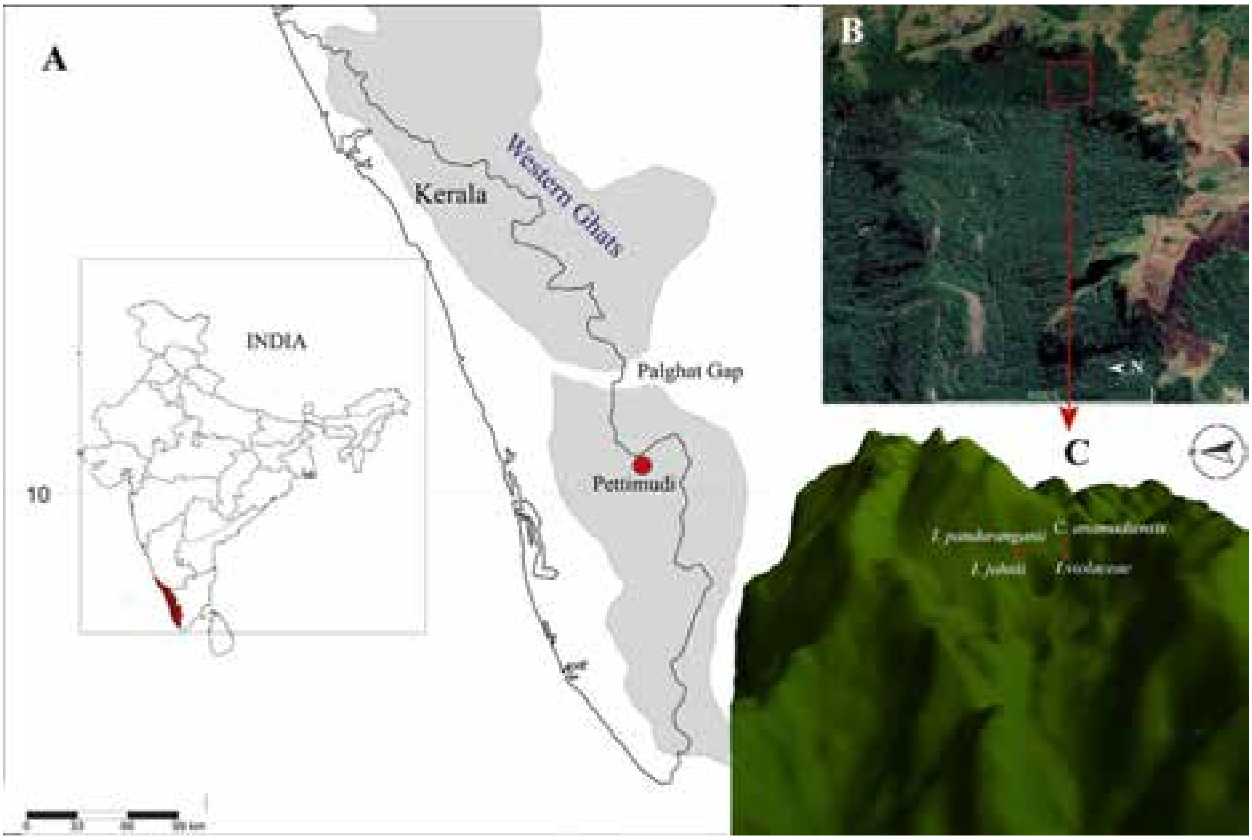

Image 1. A—location map of Pettimudi Forest in the Western Ghats, Kerala | B—u-shaped valley in Pettimudi Forest with type locality area of steno endemic species (red square) (Source: Google Earth) | C—enlarged type locality area of *Impatien s violacae*, *I. johnii, I. pandurangani,* and *Cnemaspis anamudiensis* (red circles) in u-shaped valley in Pettimudi Forest (GIS image).

an annual rainfall average of 5,500 mm making it one of the wettest places in Kerala with the ever-recorded highest rainfall of 61.6 cm/day on 6 August 2020 (Achu et al. 2021). The temperature varies 10–24 °C with the lowest temperature from December to January and the highest in April and May. The average humidity during the winter season is above 80%.

Sampling

Field studies were conducted from August 2020 to November 2022. The study site location was noted using the geographic positioning system (GPS) including exact altitude with latitude and each tree (phorophyte) having *I. violacea* species were selected. Each selected tree was divided up into five vertical tree zones according to Johanson (1974) and Krömer & Gradstein (2016) (Figure 1). These zones were categorized as the base (Z 1; from the ground to 2 m), trunk (Z 2; 2 m above the ground to the first bifurcation), Zone 2 is subdivided into a humid lower part of the trunk (Z 2a) and a dryer upper part (Z 2b). Inner canopy (Z 3; the inner third of the branches in the crown), mid-canopy (Z 4; the middle third branches of the crown) and (Z 5; the outer third of the branches of the crown (Figure 1). The epiphytes were classified into one of three ecological groups (Acebey et al. 2003; Krömer & Kessler 2006; Krömer et al. 2007)**:** habitat generalists (occurring in three or more zones) and habitat specialists (occurring only in one or two zones or three continuous ones); the latter were further subdivided into canopy epiphytes (occurring (> 90% in Zones Z3–5) and trunk epiphytes (> 90% in understory and Zones Z1–2). Within each tree zone, the occurrence of *I. violacea* was observed along with abiotic factors such as relative humidity, temperature, light, and wind using Lutron LM 800A. Binoculars were used for the observation of *I. violacea* anchoring in the canopy branches and if necessary climbing the host trees were also done using single and double rope techniques (Lowman & Moffett 1993). Detailed morphological studies were done using a Leica EZ4W stereomicroscope. Herbarium specimens were prepared as per the standard method (Jain & Rao 1976). Voucher specimens were deposited at St. Albert's College Herbarium (SAC). For the distribution of endemic species of plants and animals in the study area we conducted a field survey along with the details available from literature and other zoological records.

RESULTS & DISCUSSIONS

Taxonomic Treatment

Impatiens violacea M.Kumar & Sequeira, Sida 19: 798. 2001; N.C. Rathakr. et al. in P.Daniel, Fl. Kerala 1: 563. 2005. (Figure 1, Image 2).

Types: INDIA. Kerala: Idukki Dt., Munnar, Pettimudi, Way to Edamalakudy, Sequeira 20731 (holotype KFRI**!** isotypes MH).

Perennial succulent, epiphytic herbs, up to 15 cm or higher. Suffrutescent stems woody at the bottom, herbaceous above, 1–2.5 cm dia., leaf-scare prominent, succulent, glabrous. Leaves crowded at the top of the stem, whorled, glabrous, asymmetric 2–6 by 1.4–4 cm, base obtuse to round, apex acute or obtuse, margins scalloped, sinus of the crenation with cilia, venation eucamptodromous, usually 4. Inflorescence 1–4 cm flowered raceme, terminal; peduncle 1.5–2 cm, cylindrical green, glabrous with sparingly flowered; pedicel 2–4 cm cylindrical, violet. Flowers violet, bisexual, zygomorphic. lateral sepals small, flat linear-lanceolate, glabrous, green 1.2 x 0.4 mm; lower sepal large, bag-shaped, spurred, 1.75–2 × 0.6–1.1 cm, violet, glabrous, wrinkled, with a short prominent hook at the mouth; dorsal petal erect, 0.9 × 0.95 mm, yellowish-green, gland-dotted, deeply hooded, hood dark green; lateral petals fleshy, 0.8 × 1.2 mm, 3-lobed. Androecium 1.9 mm long, stamens 5 in number, filaments short; anthers 0.16–0.19 × 0.18–0.2 mm dithecous, dehiscent transversely. Ovary elliptic-ovate, glabrous, 0.6 × 1.40 mm; style short; stigma obtuse. Capsule fusiform with five valves, glabrous, loculicidal dehiscence. Seed oblong to ovate, brownish 0.45 × 0.85 mm diam, wrinkled with dense tuft hairs on both ends.

Vernacular name: Neelakondrapoo (Muthuvan tribal language) (Neela – Blue, Kondra – prawn shaped, poo – flower)

Phenology: Flowering period is limited to three months (August–October), coinciding with the two main monsoon periods. The fleshy stems effectively close down, lose their leaves, and shrink in diameter throughout the dry summer months. When the rainy season finally arrives, the stems swell to their previous size. The stems end up looking like a string of beads as a result of this. All of the Indian epiphytic species belonging to *Impatiens* including *I. parasitica*, *I. jerdonia*, and *I. viridiflora* have this type of moniliform growth pattern. This trait may aid the epiphytic species in surviving dry, droughty conditions and can be considered an ecological adaptation for epiphytism.

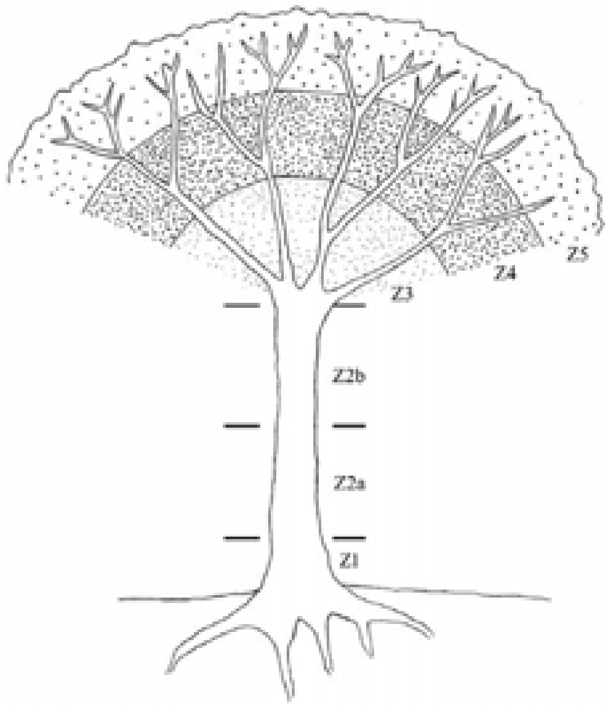

Figure 1. Illustration of vertical zones: Z1—trunk base | Z 2a/b—lower/upper part of the trunk | Z3—lower canopy | Z4—middle canopy | Z5—outer canopy. This figure shows the adapted version of the system, where the trunk is divided into two separate zones (Steege & Cornelissen 1989).

Ethno-medical uses: *Impatiens violacea* have been used as medicine for the treatment of paralysis. The entire plant is ground into the paste and applied to the affected part. This tribal medical practice is recorded in the oral tradition of Muthuvan tribes.

Specimens examined: India, Kerala, Idukki District, Pettimudi, 2,000 m, 25 August 1998, Sequeira 20731 (Holotype KFRI!); Pettimudi, 10.167^{0}N, 76.997^{0}E, 1,836 m, 25 October 2020, Arjun & Jameson 572,573 (SAC!).

Distribution and ecology of *I. violacea*

During the present study, *I. violacea* was recorded and collected only from the Pettimudi forest valley (1,836 m; 10.167^{0}N, 76.997^{0}E) in the Idukki district of Kerala, India (Image 1B). The habitat of *I. violacea* was fragmented into two by a long gravel forest road from Pettimudi towards Edamalakkudy, a tribal Gram panchayat consisting of 25 settlements inhabited by Muthuvan tribes, one of the isolated indigenous tribes

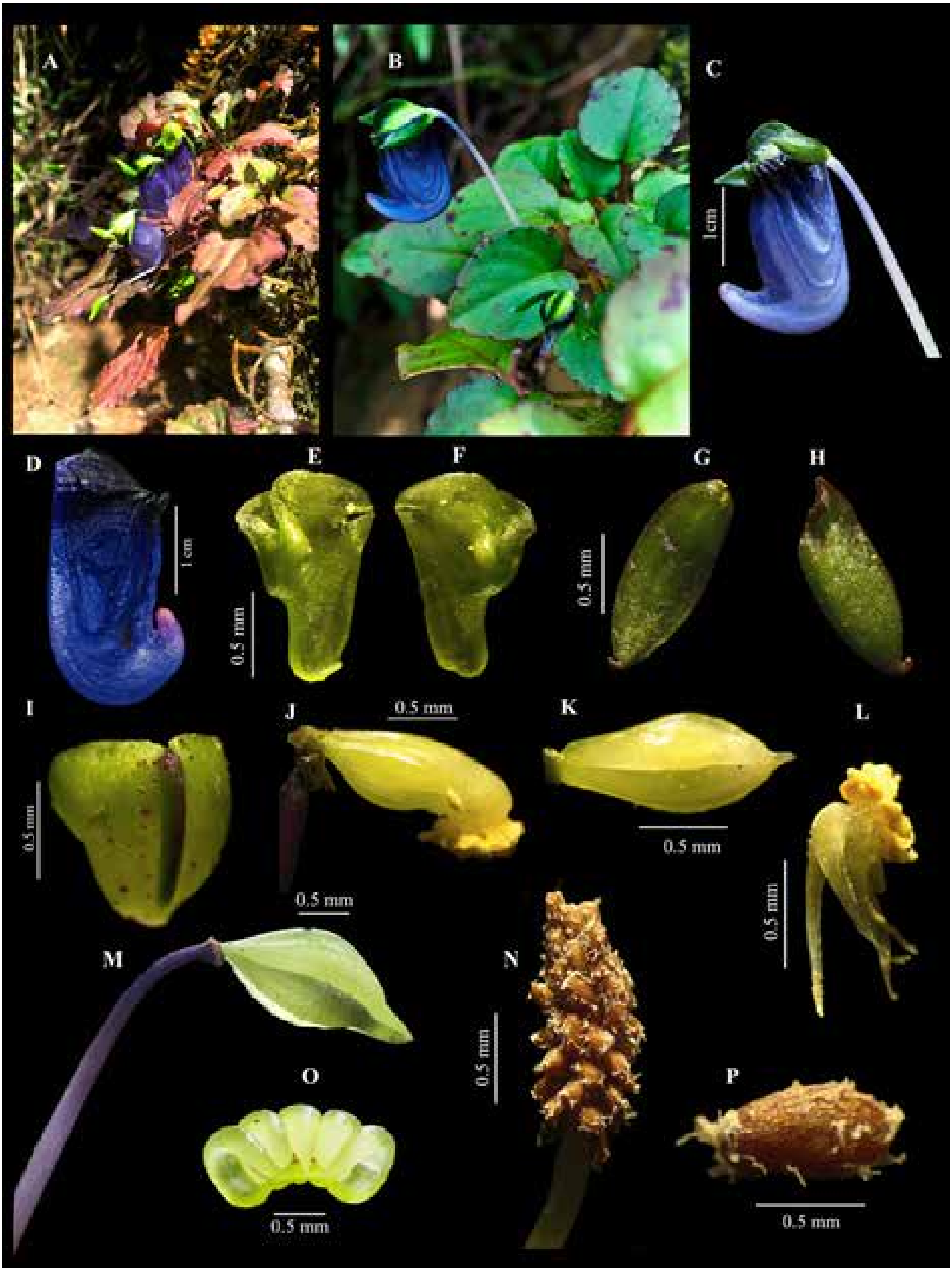

Image 2. ***Impatiens violacea*****: A&B—plant habit | C—a flower | D—lower sepal | E&F—lateral petals | G&H—lateral sepals | I—dorsal petal | J—column | K—gynoecium | L—androecium | M—capsule | N—Infructescence | O—dehisced capsule | P—seed. © A. Thomas.**

of the Western Ghats. This epiphyte can be regarded as a true epiphyte because it remains detached from the forest floor and the phorophyte's vasculature during its whole existence. This species was found distributed on the trees with closed canopy located on both sides of this forest road at an altitude of 1,800–1,900 m. Even though the valley is very closely connected to Eravikulam National Park (ENP), the species was observed only at a u-shaped valley in Pettimudi forest indicating the ineffectiveness of seed dispersal along with heavy and few numbers of seeds compared (Image 2) to the minute and numerous seeds of successful epiphytes such as orchids and ferns (Grey 1980). *I. violacea* possesses explosive ballistic dispersal with a high likelihood of reaching an unfavorable place for the seed to germinate, which is a crucial stage in the life cycle of plants. Another element influencing the limited dispersion may be the valley surrounded by steep mountains highly humid conditions and very low or null wind inflow inside a closed canopy.

The plant species were vertically distributed on phorophytes in three tree zones from Z3 to Z5 and were more prevalent in mid-canopy (Zones 3 and 4). This epiphytic species can be considered an ecological group, habitat generalists (Occurring in three or more zones).

Abiotic factors such as temperature, relative humidity, light intensity, and wind at each vertical zone of phorophytes having *I. violacea* were observed. Microhabitats in the phorophyte reveal a model of vertical change where abiotic factors such as temperature, and light availability increase with the height of the phorophyte, while humidity simultaneously decreases with height and wind velocity are null to calm. Another contrasting observation in the habitat of *I. violacea* was the close association with non-vascular epiphytes. All *I. violacea* individuals were observed in moss-covered bark of phorophytes and none of them were observed on bare bark.

The vertical distribution pattern observed in this study can be associated with the ecological adaptation of *I. violacea*. This true epiphyte is vertically distributed from phorophyte (Z3–Z5), these zones receive maximum light with low humidity. The distribution pattern of abiotic factors such as temperature and humidity in our study was in accordance with studies of (Walsh 1996; Freiberg 1997) where temperature increases from the ground level to the canopy, while air humidity decreases. The most important parameters determining epiphyte placement are humidity and temperature (Benzing 2008). This drought-avoider epiphyte has desiccation-prone foliage with a woody tuberous stem to withstand canopy zones with maximum light along with low humidity and dry seasons. This species found only on the moss and humus-covered bark of phorophytes may be a result of the lack of specialized root systems that may anchor to the phorophyte's bare bark. According to numerous findings, epiphytic bryophytes help vascular epiphytes establish themselves, survive and coexist (Van Leerdam et al. 1990; Tremblay et al. 1998; Zotz & Vollrath 2003; Thomas & Jameson 2020). Especially in tree species with smooth bark, bryophytes may improve seed anchoring and result in a more dependable water supply during germination, but they may also lessen the severity of drought in later ontogenetic phases. This impact is anticipated to be a diminishing function of plant size (Zotz et al. 2001), which may be attributed to the *I. violaceae* having a variety of small- to large-sized plants. In montane forests, the constant presence of humidity can be favourable for the specialization of microhabitats of epiphytic plants (Gentry & Dodson 1987).

Threats and Conservation status of *I. violacea*

The population is estimated to be 87 individuals (mature – 60 and juvenile – 27) where all are observed only from the type locality. Moreover, the type locality of this species is in a landslide-prone area. A catastrophic landslide event occurred at the windward slope of this valley mountain in August 2020 due to heavy downpours (Achu et al. 2021). A major anthropogenic threat observed was habitat fragmentation; a gravelled forest road fragmenting the habitat into two and the government's new proposed project to make this gravel road motorable from Pettimudi to Eddalipparakkudy will severely affect the survival of this beautiful species in the wild. Habitat fragmentation in plants can potentially impact a huge number of progenies in the quantity of progeny produced, but also the genetic and biological quality (Aguilar et al. 2019). It has been observed that this threatened species is illegally harvested and traded in the national and international markets. In general, the illegal plant trade threatens and destroys numerous species, and important natural resources, and can cause phytosanitary risks (Lavorgna & Sajeva 2021). The whole plant part used by Muthuvan tribals for ethnomedical purposes also makes this plant reduce in number of individuals. All these threats altogether make the remaining populations in this valley face in an uncertain future. Being a steno-endemic species to Pettimudi Valley, very restricted distribution in the upper montane cloud forest (shola forest) with small population size in the wild and high risk of natural and anthropogenic stress makes the species threatened and can be classified as

Table 1. List of endemic taxa from U-shaped valley in Pettimudi Forest. TMCF—tropical montane cloud forest | WG-SRI Western Ghats–Sri Lanka | WG—Western Ghats | SWG—southern Western Ghats | VU—Vulnerable | EN—Endangered | CR—Critically Endangered | NE—Not Evaluated.

Scientific name	Family	Habitat	Categories	Endemic
Impatiens violaceae M.Kumar & Stephen Sequiera	Balsaminaceae	Herb (Epiphytic in TMCF)	VU	Pettimudi
I. pandurangani K.M.P.Kumar, R.Jagad. & G.Prasad	Balsaminaceae	Herb (Lithophyte in TMCF)	CR	Pettimudi
I. johnii Barnes	Balsaminaceae	Shrub (Lithophyte in TMCF)	EN	Pettimudi
I. platyadena C.E.C.Fisch.	Balsaminaceae	Shrub in TMCF	CR	SWG
I. phoenicea Bedd	Balsaminaceae	Herb (Suffruticose in TMCF)	EN	SWG
I. modesta Wight	Balsaminaceae	Herb (Lithophytes / epiphyte in TMCF & EGF)	NE	SWG
I. leschenaultii (DC.) Wall. ex Wight & Arn	Balsaminaceae	Shrub (Lithophyte in TMCF)	NE	WG
I. latifolia L.	Balsaminaceae	Shrub - TMCF	NE	WG-SRI
I. disotis Hook.f	Balsaminaceae	Herb (Terrestrial/ epiphytic in TMCF & EGF)	NE	SWG
I.coelotropis C.E.C.Fisch.	Balsaminaceae	Terrestrial/ epiphyte	VU	SWG
I. parasitica Bedd.	Balsaminaceae	Herb (Epiphyte/ on wet rocks)	NE	SWG
Henckelia macrostachya (E.Barnes) A.Weber & B. L.Burtt.	Gesneriaceae	Herb (Lithophyte in TMCF)	EN	SWG
Cnemaspis anamudiensis Cyriac, Johny, Umesh & Palot	Gekkonidae	Reptile. Crevices of rock boulders	NE	Pettimudi

Vulnerable under criterion D2 (VU D2) under the IUCN Red List Categories and Criteria.

Endemic species in Pettimudi forest

The single-patch shola of Pettimudi forest is surrounded by steep mountains harboured by endemic flora and fauna. In the study, the u-shaped valley of Pettimudi forest (1.87 km^2) consists of 12 endemic plant species and one reptile species. The type locality and distribution of three steno-endemic taxa were located within an area of 0.023 km^2 within this valley. This includes a species of geckos (*Cnemaspis anamudiensis)* and two species of *Impatiens (I. violacea* & *I. johnii*) along with *I. pandurangani* which is endemic to Pettimudi forest (Image 1) (Prabhukumar et al. 2017; Cyriac et al. 2018). Barnes described *Impatiens johnii* from Kallar Valley adjacent to Pettimudi forest in 1931. The plant was believed to be extinct until it was rediscovered by Biju & Kumar (1999) after 67 years from Pettimudi forest. A recent study on the distribution pattern of *I. johnii* revealed that the plant is restricted only to less than 5 km^2 in Pettimudi Valley (Prasad et al. 2018). A similar result was observed in our study, with the population of *I. johnii* near *I. violaecae*.

A detailed list of endemic species from Pettimudi forest is mentioned in Table 1. Areas of endemism (AoE) are places where the ranges of at least two taxa overlap (Quijano-Abril et al. 2006). Therefore, the U-shaped valley in Pettimudi forest with three steno endemic species can be considered as an area of endemism. Our results on the distribution of endemic taxa in this valley indicate that there are 13 endemic species here, making it a hotspot within the Western Ghats. A study by Shajitha et al. (2016) confirmed that southern Western Ghats species of *Impatiens* including *I. violacea* have belonged to recent lineages, so *I. violacae* can be considered as steno-endemic taxa, evolved recently, constrained by steep mountains of Pettimudi with no sufficient time to expand its range. The tropical forests of the Western Ghats are considered 'refugia' harbouring highly diverse endemic taxa and montane habitats, particularly acting as 'species pumps' (Johnson et al. 2022). According to Kumar & Sequeira (1996), the Western Ghats is a region of speciation of the genus *Impatiens.* This assessment was consistent with our observations which favour the presumption that this small valley in Pettimudi forest is a cradle of speciation. The molecular phylogeny study of the genus *Impatiens* indicates that southern Western Ghats species of *Impatiens* were colonized from southeastern Asia by two independent dispersal events, i.e., once by a southeastern Asian ancestor and another time by an ancestor with African affinities. The phylogeny and biogeography study of *I. parasitica* and *I. latifolia* showed African affinities (Yuan et al. 2004) and *I. violacea* and *I. johnii* have a southeastern Asian relationship (Sajitha et al. 2016).

In the case of endemic reptile *Cnemaspis anamudiensis* of the genus *Cnemaspis* Strauch, 1887 is one of the most species-rich genera of the family Gekkonidae which is distributed from Africa to southeastern Asia (Sayyed et al. 2018). According to Kier et al. (2009), the endemic richness of plants and vertebrates is correlated. The topography of the valley surrounded by steep mountains was complex. A large mountain with topographic complexity, isolation, and different microclimatic conditions promotes endemism and biodiversity (Badgley et al. 2017; Noroozi et al. 2019).

CONCLUSION

In the current investigation, it was found that *I. violacea* is a threatened species that is currently Vulnerable. Due to its steno-endemic status to Pettimudi forest, rare distribution at the upper montane cloud forest (shola forest) along with its low wild population size puts it in significant danger of near extinction in the wild in the future due to multiple anthropogenic stresses**.** Our results indicated that the u-shaped valley in Pettimudi forest is an area of endemism and can be strongly considered a 'hot speck' where it is a hot spot within the southern Western Ghats hotspot and a cradle of speciation. This study highlights our understanding of the endemic diversity of the Pettimudi forest, which is essential for understanding the biogeographic relationships among the recognised areas of endemism (AoEs). Considering the relevance of the Pettimudi forest's unique endemic diversity, public policies for the conservation of this region need to be generated. Also, a proposal that recommends this u-shaped mountain valley in Pettimudi forest to be attached to the Eravikulam National Park territory. This research emphasizes the importance of comprehending the endemic biodiversity of the Pettimudi forest to better grasp the biogeographic connections between recognised AoE. Given the significance of the unique endemic biodiversity in the Pettimudi forest, it is imperative to formulate public policies for the conservation of this region. In addition, a proposal suggesting the incorporation of the U-shaped Mountain valley in the Pettimudi forest into the territory of the Eravikulam National Park is recommended.

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COMMUNICATION

Assessing the conservation status of *Elaphoglossum stigmatolepis* (Fee) T.Moore (Dryopteridaceae), an endemic fern in the Western Ghats of India

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Abstract: *Elaphoglossum stigmatolepis*, a fern species endemic to the semi-evergreen or evergreen forests of the Western Ghats of India, has recently garnered attention due to its precarious status within its native habitat. Thriving within the unique microclimates of these regions, this fern has been assessed for the first time. The results of this assessment are concerning, as the species has been classified as Endangered under the IUCN Red List Categories and Criteria 3.1. The limited population of *E. stigmatolepis* underscores its vulnerability, highlighting the pressing need for dedicated conservation efforts. This assessment represents a pivotal step in acknowledging and addressing the threats faced by *E. stigmatolepis*, emphasizing the urgency of implementing measures to ensure its survival and safeguarding the biodiversity of the Western Ghats.

Keywords: Biodiversity, endangered, epiphyte, GeoCAT, habitat, holodimorphic, population, species information assessment (SIS), survival, threat.

சுருக்கம்: *Elaphoglossum stigmatolepis*, இந்தியாவின் மேற்குத் தொடர்ச்சி மலைகளின் அரை-பசுமை அல்லது பசுமையான காடுகளுக்குச் சொந்தமான ஒரு டெரிடோபைட் இனம், அதன் சொந்த வாழ்விடத்திற்குள் அதன் ஆபத்தான நிலை காரணமாக சமீபத்தில் கவனத்தை ஈர்த்துள்ளது. இந்த பிராந்தியங்களின் தனித்துவமான மைக்ரோக்ளைமேட்டுகளுக்குள் செழித்து, இந்த டெரிடோபைட் முதல் முறையாக மதிப்பிடப்பட்டுள்ளது. இயற்கை பாதுகாப்புக்கான சர்வதேச ஒன்றியம் சிவப்பு பட்டியல் வகைகள் மற்றும் அளவுகோல் 3.1 இன் கீழ் இனங்கள் அழிந்து வரும் நிலையில் வகைப்படுத்தப்பட்டுள்ளதால், இந்த மதிப்பீட்டின் முடிவுகள் கவலையளிக்கின்றன. *E. stigmatolepis* மட்டுப்படுத்தப்பட்ட மொத்த எண்ணிக்கை அதன் பாதிப்பை அடிக்கோடிட்டுக் காட்டுகிறது, அர்ப்பணிப்புள்ள பாதுகாப்பு முயற்சிகளின் அவசரத் தேவையை எடுத்துக்காட்டுகிறது. இந்த மதிப்பீடு *E. stigmatolepis* எதிர்கொள்ளும் அச்சுறுத்தல்களை அங்கீகரிப்பதில் மற்றும் நிவர்த்தி செய்வதில் ஒரு முக்கிய படியை பிரதிபலிக்கிறது, மேற்குத் தொடர்ச்சி மலைகளின் பல்லுயிரியலைப் பாதுகாப்பதற்கும் அதன் உயிர்வாழ்வை உறுதி செய்வதற்கும் நடவடிக்கைகளை செயல்படுத்துவதற்கான அவசரத்தை வலியுறுத்துகிறது.

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Author contributions: AB conducted the field surveys, analyzed the data, provided photographs, location details, and revised the initial draft. SP conceived and designed the study and authored the initial draft of the manuscript. RM contributed to data interpretation. All three authors reviewed and approved the final manuscript.

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INTRODUCTION

The *Elaphoglossum* genus, originating from Schott's initial description and later revised by John Smith, stands as one of the most diverse genera within the fern family, boasting around 600 species. Interestingly, the bulk of these species find their home in the New World. According to the Pteridophyte Phylogeny Group I (PPG I) classification, this species belongs to the family Dryopteridaceae. Approximately, 13 species of *Elaphoglossum* inhabit India (Fraser-Jenkins et al. 2021). Among all the above species *E. beddomei* Sledge, *E. nilgiricum* Krajina ex. Sledge, and *E. stigmatolepis* (Fee) Moore are endemic to the southern Western Ghats. Madhusoodanan (2015) observed only two species—*E. nilgiricum* and *E. beddomei* in Kerala. Rajagopal & Bhat (1998) reported the presence of only *E. nilgiricum*, while a more recent study by Tripathi et al. (2016) confirmed the existence of *E. stigmatolepis* in Karnataka and Tamil Nadu (Manickam & Irudayaraj 2003). The species' distribution is restricted to a few specific localities within these states, making it susceptible to habitat fragmentation and other environmental threats.

The present study aimed to assess the status of *E. stigmatolepis* using the IUCN Red List Categories and Criteria which involves a thorough analysis of the species' extent of occurrence (EOO) and area of occupancy (AOO) from field data and secondary sources. This evaluation is crucial for understanding the conservation needs of this species and formulating effective strategies to ensure its continued survival amidst the growing threats of habitat degradation and climate change in the Western Ghats. In some earlier assessments of *E. stigmatolepis* it was considered as 'rare' even though some effective attempts were made by the authors Chandra et al. (2008), Ebihara et al. (2012), Fraser-Jenkins (2012), and Benniamin et al. (2021); it may not be fully in accordance with the IUCN criteria.

Through rigorous scientific investigation and proactive conservation measures, the goal is to mitigate the risks facing this unique and ecologically significant fern species, safeguarding its presence for future generations and preserving the rich biodiversity of the Western Ghats ecosystem. The work also forms a baseline for ecologists, conservation biologists, and applied researchers for conservation and sustainable utilization of the species.

METHODS

Study area

The study focused on the Western Ghats in general with particular reference to Kudremukh National Park, located in the Chikkamagalur District of Karnataka (13.0169–13.4880 N & 75.1527–75.4169 E). Among various sites within the park, Kadambi Falls was selected as a key location for its rich biodiversity. At this site, researchers found and collected a specimen of *E. stigmatolepis*, a rare epiphytic fern, growing exclusively on a *Memecylon* tree. This fern, observed in a single patch on the tree, highlights the park's unique and diverse plant life.

Methodology

Extensive field exploration formed the cornerstone of the data collection process. Geographical coordinates were meticulously recorded using a geographical positioning system (GPS) during field expeditions to capture accurate location data of *E. stigmatolepis* populations. These field excursions provided us with primary data crucial for understanding the distribution and habitat preferences of the species. Supplementing our primary data collection efforts, secondary data were gathered from various herbaria such as the Central National Herbarium (CNH) Botanical Survey of India, Western Regional Centre (BSI), and digital herbaria namely Flora of Peninsular India, Digital Flora of Karnataka, CALI (Calicut University Herbarium) & XCH (St. Xavier's College, Palayamkottai). Additionally, a preliminary search in the GBIF showed some odd and wrong records under the name '*E. stigmatolepis*' from Reunion (Africa), and iNaturalist (2024) which yielded results with zero observation. The reviewed published literature further enriched the understanding of the geographic locations of Benniamin et al. (2020, 2021), Rajagopal & Bhat (1998), Manickam & Irudayaraj (2003), and ecological characteristics of *E. stigmatolepis*. To systematically organize the compiled data, essential parameters such as distribution, localities, state, collector names, date of collection, basis of record, altitude, latitude, longitude, and habitat were recorded in an Excel spreadsheet (Table 1). Subsequently, this data was imported and processed for analysis. Utilizing open-source online software, specifically the Geospatial Conservation Assessment Tool (GeoCAT) developed by Bachman et al. (2011), available at http://geocat.iucnredlist.org (Image 1). The area of occupancy (AOO) and extent of occurrence (EOO) values were calculated based on the recorded location points. These metrics

Image 1. Evaluation of area of occupancy and extent of occurrence of *Elaphoglossum stigmatolepis* (Fee) T.Moore in India by using GeoCAT.

provided crucial insights into the spatial distribution and extent of the species' range. To ensure comprehensive documentation of the findings, the Species Information Service (SIS) portal was utilized to detail various aspects of *E. stigmatolepis*, including species attributes, geographic range, AOO, EOO, number of locations, elevation occurrence, population information, habitat and ecology, threats, conservation strategies, ecosystem services, and Red List assessment. By employing a multidimensional approach encompassing fieldwork, data synthesis from diverse sources, and advanced analytical tools, the methodology aimed to provide a robust assessment of the threatened status of *E. stigmatolepis*. This systematic methodology lays the foundation for informed conservation strategies tailored to safeguarding this endemic fern species and its fragile habitat in the Western Ghats ecosystem.

RESULTS

Elaphoglossum stigmatolepis (Fee) T.Moore, Index Fil. 16. 1857; Sledge in Bull. Brit. Mus. (Nat. Hist). Bot. 4: 86. 1967; Nayar & Kaur, Comp. Bedd. Hand., 97. 1974; Dixit, Census 166. 1984; Manickam & Irudayaraj Pterid. Fl. West. Ghats 287. 1992. *Acrostichum stigmatolepis* Fee, Mem. Fam. Foug. 2: 62 t. 24 f. 2. 1845. *Elaphoglossum conforme* sensu Bedd. FSI 67 t. 198 (1864) & Handb. 416 t. 247 (1883) pro parte (non J. Sm.). *Acrostichum conforme* sensu Clarke in Trans. Linn. Soc. London II Bot. 1: 576. 1880 pro parte. *Elaphoglossum ballardianum* K. Biswas in Bull. Misc. Inf. Kew. 1939: 239. 1939.

Rhizome long creeping, 3–4 mm thick, densely scaly; scales ovate-lanceolate, attenuate, brown at the base, blackish-brown above. Stipes scattered, deep brown, 8–11 cm long. Lamina simple, dark green, lanceolate, 8–18 cm long, 1.5–2.0 cm wide, apex acute. The upper and lower–halves of the lamina gradually narrowed, with an entire margin with a cartilaginous border. The midrib is slightly raised on both sides and shallowly grooved above; veins immersed; the underside of the lamina and midrib covered by minute, fimbriate scales. Fertile fronds approximately 12–14 cm long and 1–1.5 cm wide, oblanceolate, much compressed, with a moderately longer stipe and revolute margin. Sori acrostichoid; spores monolete, reniform, dark brown (Image 2).

Habitat and Ecology: It is an epiphytic fern thriving in the semi-evergreen and evergreen forests that characterize this region. It typically grows on tree trunks under the dense forest canopy, which provides the shaded, humid environment essential for its survival. This fern prefers elevations ranging 1,000–2,650 m, where the cool, moist conditions of the montane regions are ideal for its growth.

Specimen examined: Karnataka, Kadambi Falls, Kudremukh National Park, 24.xi.2015, coll. Devendra Tripathi, 197952, BSI (Image 3).

Distribution: Tamil Nadu and Karnataka. Endemic to southern India.

DISCUSSION

Elaphoglossum stigmatolepis is placed under the Endangered (EN) category in the present assessment as the species is restricted to only two states in India, i.e., Karnataka and Tamil Nadu. The EOO for the species was estimated to be 7,808.857 km^2 which is more than

Table 1. Distribution of *Elaphoglossum stigmatolepis* in the Western Ghats.

	Basis of records	Collection no.	Collection date	Altitude (m)	Name of collectors	State	Locality	Habitat	Data source
1	Preserved specimen	197952	24.xi.2015	1,350	Deventra Tripathi & A. Benniamin	Karnataka	Kudremukha National Park, Kadambi Falls.	Epiphyte exclusively on *Memecylon* tree (one patch).	BSI (Botanical Survey of India, Western Regional Centre) Pune.
2	Preserved specimen	RHT 32615	02.v.85	2,200	VSM & KMM	Tamil Nadu	Madurai (Anna), Kodaikanal, Palni Hills, Gundar Shola.	Epiphyte.	XCH (St. Xavier's College, Palayamkottai).
3	Preserved specimen	RHT 34438	16.ii.86	1,850	VSM & KMM	Tamil Nadu	Coimbatore, Valparai, Anaimalai Hills, Grass Hill- Periyar Path.	Epiphyte on forest trees.	XCH (St. Xavier's College, Palayamkottai).
4	Preserved specimen	XCH 410 (2)	24.x.91	2,650	VSM	Tamil Nadu	Nilgiri, Dodabetta Road.	Occasional epiphyte in the forest interior.	XCH (St. Xavier's College, Palayamkottai).
5	Preserved specimen	XCH 436	24.x.91	2,650	VSM	Tamil Nadu	Nilgiri, Dodabetta Road.	Rare epiphyte locally abundant in shola interior.	XCH (St. Xavier's College, Palayamkottai).
6	Preserved specimen	XCH 456	25.x.91	2,200	VSM	Tamil Nadu	Nilgiri, Forest Bungalow of Terrace Estate.	Epiphyte, occasional and locally abundant.	XCH (St. Xavier's College, Palayamkottai).
7	Preserved specimen	XCH 568	27.x.91	2,300	VSM	Tamil Nadu	Nilgiri, Sholas Between T.R. Bazaar And Belluve.	Epiphyte. Rare.	XCH (St. Xavier's College, Palayamkottai).
8	Preserved specimen	XCH 583	28.x.91	2,300	VSM	Tamil Nadu	Nilgiri, Shola On The Short Cut From The T.R. Bazaar To Naduvattum.	Occasional epiphyte. Sterile.	XCH (St. Xavier's College, Palayamkottai).
9	Preserved specimen	XCH 855	06.xii.91	2,100	VSM	Tamil Nadu	Nilgiri, Avalanchi Forest.	Epiphyte in shola; rare.	XCH (St. Xavier's College, Palayamkottai).
10	Preserved specimen	XCH 900 (2)	07.xii.91	2,100	VSM	Tamil Nadu	Nilgiri, Avalanchi Forest.	Rare, in the forest interior; sterile.	XCH (St. Xavier's College, Palayamkottai).
11	Preserved specimen	XCH 933	08.xii.91	2,200	VSM	Tamil Nadu	Nilgiri, Round Road on the Plateau, Upper Bhavani (Manjoor).	Rare, epiphyte in the shola.	XCH (St. Xavier's College, Palayamkottai).

the threshold value for the Endangered category, so it's not applicable for category assignment. The AOO was calculated based on the cell size of (2 × 2 km) recommended by IUCN and it was estimated to be 32 km^2 which meets criterion B2 for the Endangered category. Field experiences and data collected from secondary sources indicate that the species is reported from five localities, namely, Palani Hills, Nilgiris, Anamalais Hills, Kodaikanal (Gundar Shola) in Tamil Nadu, and Kadambi Falls in Kudremukh National Park, Karnataka, this aligns with sub-criterion 'a' for the endangered category, as the number of locations are five.

The species is facing multiple threats across its distribution range, leading to a continuous decline in habitat quality and population size. In Kudremukha National Park, infrastructure development such as road construction and increased tourism activities have further degraded its habitat. Additionally, invasive plant species like *Lantana camara* and *Chromolaena odorata* are outcompeting native vegetation, reducing the availability of suitable microhabitats. The climate crisis exacerbates the situation by altering rainfall patterns and microclimatic conditions essential for the species' growth and reproduction. Intrinsic factors, such as poor spore viability, low germination rates, and limited genetic diversity due to declining population size, further jeopardize its survival. These cumulative threats not only reduce the extent of suitable habitat but also impact the species' ability to regenerate, qualifying it for listing under the Endangered category based on sub-criterion 'b (iii)'.

Among seven species of *Elaphoglossum* in India,

Image 2. Habitat of *Elaphoglossum stigmatolepis* (Fée) T.Moore – Kadambi Falls, KNP, Karnataka. © A. Benniamin & Devendra Tripathi.

only *E. stigmatolepis* and *E. stelligerum* are with holodimorphic fronds and the remaining five species are with weak or hemidimorphic fronds. It is possible that the relative costs of this reproductive system are offset by increased spore dispersal (Watkins et al. 2016). Most of the species in the related lomariopsidoid genus *Bolbitis* are with strictly holodimorphic fronds (Hennipman 1977). In general, frond dimorphism may influence the reproductive successfulness of that particular fern, at least to some extent by the production of a low number of spores which may be released within a short span of time this might be the reason for continuous reduction in a number of mature individuals which qualify the species for the Endangered category under sub-criteria 'b (v)'.

In Kudremukh National Park, the primary threats to *Elaphoglossum stigmatolepis* include habitat loss due to deforestation for agricultural expansion and tree cutting, which significantly impacts its association with *Memecylon* species. Increased infrastructure development, such as road construction, has fragmented the habitat, isolating subpopulations and limiting dispersal. In Nilgiris, tourism-related activities, including trekking and recreational pursuits, lead to habitat disturbances like soil compaction and trampling, which degrade the forest floor and reduce the availability of suitable microhabitats. In Kodaikanal hills, the conversion of forested areas into plantations has caused severe habitat modification and population declines. Across these locations, climate change intensifies these issues, with altered rainfall patterns and rising temperatures further reducing habitat quality and the species' ability to regenerate. These localized threats collectively contribute to a decline in both the extent of habitat and the size of subpopulations, justifying its endangered status.

Elaphoglossum stigmatolepis, an endemic fern of the Western Ghats, is reported from Karnataka and Tamil Nadu with an EOO of 7808.857 km² and an AOO of only 32 km², calculated using GeoCAT and a 2 × 2 km grid. The species is restricted to five locations, with a reported continuous decline in the number of locations, mature individuals, and habitat quality due to threats such as deforestation, road expansion, urbanization, and other anthropogenic pressures. The limited AOO, small number of locations, and ongoing decline in population

Image 3. Herbarium specimen of *Elaphoglossum stigmatolepis* (Fee) T.Moore. © Sakshi Pandey.

and habitat quality justify its assessment as Endangered under the IUCN Red List criterion B2ab(iii,v).

In light of these findings, a comprehensive conservation strategy for the endangered endemic fern E. *stigmatolepis*, utilizing both in vivo and in vitro methods is strongly recommended. Existing research, such as studies by Johnson et al. (2015) and Johnson & Shibila (2018), highlights the potential of in vitro spore culture. Effective conservation strategies should include habitat protection, ecological restoration, continuous monitoring, community engagement, and climate change adaptation efforts. Addressing these diverse challenges is essential to safeguarding *E. stigmatolepis* and securing the long-term survival of this unique fern species in the Western Ghats.

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REVIEW

Management challenges in marine protected areas: a field note from the Malvan Marine Sanctuary, India

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Abstract: Marine protected area (MPA) is an umbrella term for the protection and conservation of coastal biodiversity. MPAs are expected to work as an effective tool for marine biodiversity conservation and fishery management. As India has an extensive coastline of 7,517 km that supports approximately 250 million people for their livelihood, the existence of prosperous coastal and marine ecosystems is imperative for the sustainable economic growth of the country. In India, MPA is part of the protected area network notified under the Wildlife Protection Act, of 1972. In view of the socio-economic angle of the MPA, conserving the specific marine habitat and sustaining commercial activities like fishing pose tremendous challenges in achieving conservation goals. In this context, this paper evaluates the management challenges of the Malvan Marine Sanctuary located in Maharashtra State of India and subsequently discusses the possible solutions for effectively managing the sanctuary.

Keywords: Coastal ecosystem, corals, fishery management, government policy, legislation, mangroves, management, marine biodiversity, marine conservation, sustainable management, wildlife.

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INTRODUCTION

A marine protected area (MPA) refers to a designated coastal /marine area backed by legislation or other effective means aimed at its long-term conservation. Some MPAs are designed to exclude all anthropogenic activities including fishing, while others are managed with a specific objective such as fishery management, species conservation, or for recreational activities (Day et al. 2012). MPAs are expected to work as an effective tool for marine biodiversity conservation (Agardy et al. 2011). Scientific studies confirmed that well-managed marine protected areas can significantly increase the population density and biomass of several species (Halpern 2003; Selig & Bruno 2010). Unfortunately, over-exploitation of marine resources, pollution, unsustainable fishery, ocean acidification, and global warming put such a peculiar ecosystem under tremendous pressure (Dardi & Shanthakumar 2023). Hence, the conservation of marine ecosystems has become a global priority now. Interestingly, Aichi Biodiversity target 11 under the Convention on Biological Diversity (CBD) proposed to conserve 10 % of coastal and marine areas by 2020 (CBD 2020). Countries are presently working on conserving at least 30 % of their land, fresh waters, and oceans by 2030 as well (HAC 2021) also referred to as the 30 x 30 initiative.

India has an extensive coastline with a length of 7,517 km, supporting approximately 250 million people for their livelihood and integrated development (UNISDR/UNDP 2012). Healthy and prosperous coastal and marine ecosystems are imperative for the sustainable economic growth of the country. India's coastal and marine ecosystems are under threat (Sivakumar et al. 2012). Unsustainable fishing, poor anchoring practices, and unregulated tourism impose severe harm to marine biodiversity. India's protected area network comprises national parks, sanctuaries, conservation reserves and community reserves. MPAs are also part of these protected area networks notified under the Wildlife Protection Act, 1972. Likewise, the Environment (Protection) Act, 1986 was enacted to protect the environment and prevent pollution. Coastal Regulation Zone Notification (Years—1991, 2011, & 2019) issued under the provision of the Environment (Protection) Act, categorized India's coastal areas into various zones as CRZ I to IV of which, CRZ 1A, referred to as ecologically sensitive areas (ESA) are demarcated to conserve and protect coastal areas and marine waters. MPAs are placed under CRZ IA as ESA along with four ecosystems, three habitats, two geomorphological features, and the archaeological and heritage sites. Similarly, the Biological Diversity Act of 2002 and subsequent Biological Diversity Rules, 2004, and the guidelines thereof ensure the conservation of marine biodiversity, sustainable use, and equitable sharing of its components, protecting traditional knowledge, and the intellectual property rights of dependent communities. This includes biodiversity heritage sites (BHS), areas designated for their unique and rich biodiversity that require conservation to maintain their ecological significance. The Wildlife (Protection) Act, 1972 protects at the species level and the landscape level. Species enlisted in schedules I–IV of this act are being protected irrespective of their location. All species are being equally protected within the notified protected areas. The act provides stringent regulation by restricting unnecessary human interference inside the national parks and sanctuaries. Given the socio-economic angle of the MPA, protecting the specific marine habitat, and sustaining commercial activities like fishing pose tremendous challenges in achieving conservation goals, particularly in a thickly populated country like India. Nonetheless, zoning in MPAs like core zones, buffer zones, and critical wildlife habitats ensures legitimate interaction with humans and marine living without compromising the conservation priorities. In this context, this review paper will highlight the management challenges and discuss the possible solutions for the effective management of the Malvan Marine Sanctuary located in Maharashtra State of India. For writing this research paper, information from numerous sources was utilized. These include the field interactions that the author had with various stakeholders of the sanctuary; available secondary sources of information on the sanctuary; and lastly, the management plan of the Malvan Marine Sanctuary.

Malvan Marine Sanctuary

Malvan Marine Sanctuary (MMS) represents a unique combination of some of the richest and most varied marine ecosystems on the western coast of India. It is identified as one of the Critically Vulnerable Coastal Areas (CVCA) in the Coastal Regulation Zone (CRZ) notifications 2011 and 2019. The notification of the MMS was issued in the year 1987 by the state government of Maharashtra. It is located at 16.006 N & 73.466 E in Malvan Taluka of Sindhudurg District of Maharashtra. The sanctuary has a 'Core Zone' of 3.182 km^2 comprising the seascape, Sindhudurg Fort, and Padmagad Island which demands stringent protection. The rest of the 25.940 km^2 area falls under the 'Buffer Zone' category where restricted activities are permitted.

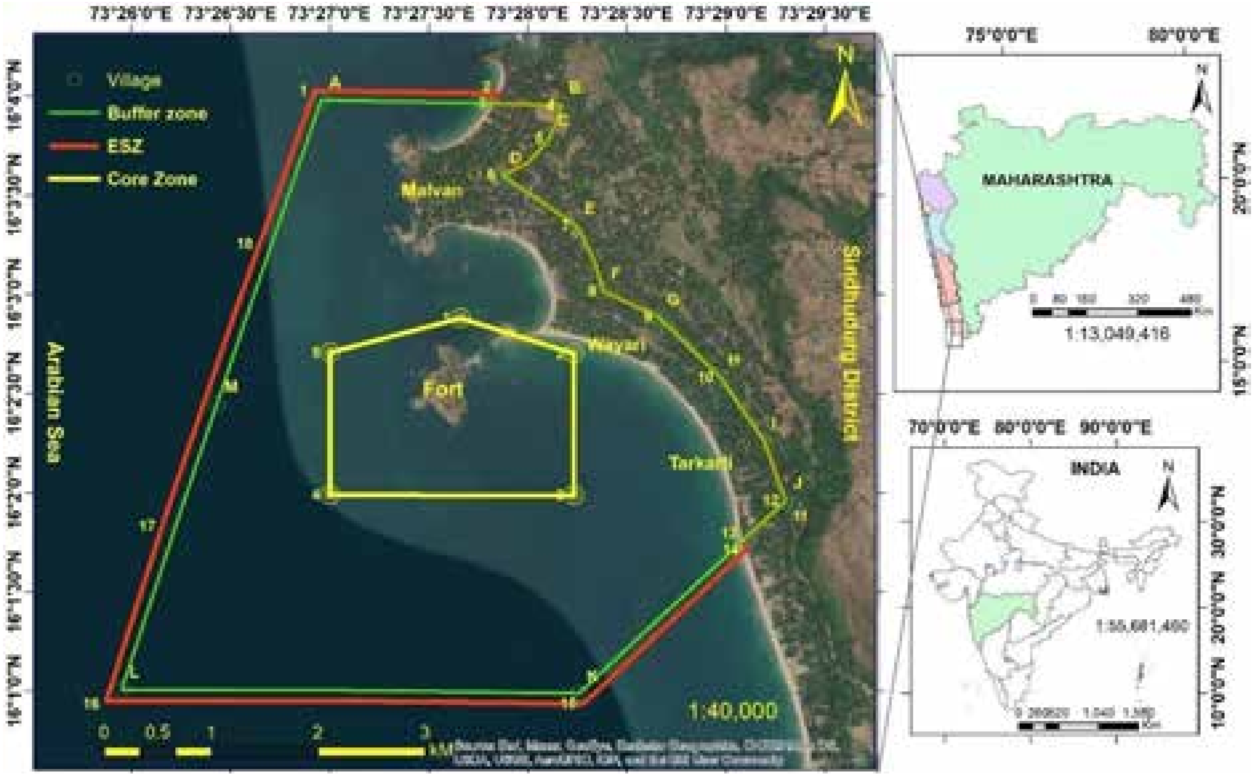

Image 1. Map of Malvan Marine Sanctuary (Source: Malvan Marine Sanctuary Management Plan 2020).

The sanctuary borders Malvan Port on the northeastern side, sandy beaches on the eastern side, Mandal Rock of the Malvan Port on the southern side, and Malvan Rock on the western side.

Climate

Malvan falls in a tropical monsoon region with less variation in the temperature during the day and throughout the season. December is the coldest month with a mean daily maximum temperature at 32.7 °C and a mean daily minimum temperature of 18.7°C. On the other hand, April is the hottest month (34°C). The relative humidity during the south-west monsoon is very high (86–90 %). The annual average rainfall is 2,916 mm. The average wind speed in the region is in the range of 6.6–17.9 kmph. The coastal currents are clockwise or shoreward from February to September, while anti-clockwise from November to January and transitional in October.

Marine biodiversity

MMS has a relatively rich distribution of corals. There are more than 25 species of both reef-building and non-reef-building corals recorded in and around the MMS (SDMRI & BNHS 2017). The corals are mostly slow-growing species that belong to genera like *Porites*, *Pavona*, and *Leptastrea*. Malvan Sanctuary is home to more than 32 species of seaweeds including 12 species of Rhodophyceae, 11 species of Chlorophyceae, and nine species of Phaeophyceae (Rode & Sabale 2015). Phytoplankton forms the primary source of the marine food chain. A study conducted by Hardikar et al. (2017) observed 57 phytoplankton species falling under five classes namely diatoms (40 spp.), dinoflagellates (9 spp.), Chlorophyceae (5 spp.), Cyanophyceae (2 spp.), and Dictyochophyceae (1 sp.).

There are seven species of sea snakes such as Beaked Sea Snake *Hydrophis schistosus*, Short Sea Snake *H. curtus*, Annulated Sea Snake *H. cyanocinctus*, Malacca Sea Snake *H. caerulescens*, Pelagic Sea Snake *Pelamis platurus*, Viper-headed Sea Snake *H. viperinus*, and Little File Snake *Acrochordus granulatus* found in the Malvan seascape (Dakshin Foundation 2016). They are often caught as bycatch in fisheries leading to large mortalities. Sea snakes are a protected species in India and are listed under Schedule IV of the Wildlife (Protection) Act, 1972. Of the total seven species of sea turtles found globally, four species are known to occur in the MMS region, namely, Green turtle *Chelonia mydas*, Hawksbill *Eretmochelys imbricata*, Loggerhead *Caretta caretta*, and Olive Ridley *Lepidochelys olivacea* are known to regularly nest along the coast of the Sindhudurg District

(Somaraj 2020).

The presence of seven species of marine mammals has been recorded directly and indirectly along the Malvan shore. Indian Ocean Humpback Dolphin *Sousa plumbea* and Indo-Pacific Finless Porpoise *Neophocaena phocaenoides* are the frequently sighted marine mammals within the sanctuary area. In addition to these, Bottlenose Dolphin *Tursiops truncates*, Spinner Dolphin *Stenella longirostris*, Bryde's Whale *Balaenoptera edeni*, Blue Whale *B. musculus*, and Sperm Whale *Physeter macrocephalus* have been reported around the sanctuary by Konkan Cetacean Research Team (KCRT) as a part of the Government of India- Global Environment Facility-United Nations Development Programme (GoI-GEF-UNDP) project in 2014–15 (KCRT 2015).

Barman et al. (2007) recorded 108 species of fish belonging to 48 families in 13 orders in MMS. Among them, four 'Vulnerable' species—*Congresox talabonoides*, *Muraenesox cinereus*, *Tenualosa ilisha*, and *Arius thalassinus*— and two 'Near Threatened' species—*Chiloscyllium griseum* and *Scoliodon laticaudus*—are found in the sanctuary. The fishes of the family Carangidae are the dominating group among the important edible fishes.

Congregation of Whale Sharks is also reported from Malvan waters (Premjothi et al. 2016). Though good diversity of mangroves is observed in the Malvan region along the creeks, only two species of mangroves namely *Avicennia marina* and *Sonneratia alba* have been observed in the sanctuary area, particularly at Sindhudurg Fort and Rock Garden. As the sanctuary area is an abode to both terrestrial and migratory birds, it is designated as an Important Bird Area (IBA) by Birdlife International and BNHS, Mumbai.

Management challenges

1. Legal Status: The sanctuary was notified under the Wildlife Protection Act, of 1972. As a matter of legal procedures prescribed in the Act, all the existing rights inside the notified area had to be settled before proceeding with the final notification. Since the core zone of the sanctuary includes both the Sindhudurg Fort and the Padmagad Island, private rights over 17.68 ha of land have to be acquired by the government within two years from the date of notification of the sanctuary. Such acquisition of the private land and settlement of rights did not happen due to strict opposition from the affected local communities. Fishermen community marked strong dissent against the creation of the sanctuary as they fear it will take away their traditional fishing rights and livelihood options existing in the area. Apart from this, the prior concurrence of the union government is also required since the sanctuary is created in the territorial waters. Furthermore, the limits of the area of the territorial waters to be included in the sanctuary shall be determined in consultation with the chief naval hydrographer of the union government after adopting adequate measures to protect the livelihood interests of the local fishermen. This is yet to be done due to the pending settlement process. As a result, the boundary of the core and buffer zone is not properly demarcated in the field. This poses a major impediment to enforcing the regulatory measures in the sanctuary area for the authorities.

People's apprehensions about the sanctuary are still not faded away as was demonstrated while implementing the GOI-GEF-UNDP project in Sindhudurg in the year 2012. The sanctuary opponents viewed any conservation activities of the forest department with suspicion and considered it a covert attempt to impose restrictions on the sanctuary. The locals even do not want any signage of the Forest Department which establishes the existence of the MMS in Malvan. Strong protest without any dilution in its severity was observed even while proposing an eco-sensitive zone (EEZ) around the sanctuary in 2020 and the UNDP-GCF Project in 2022. Consequently, any implementation of the Wildlife (Protection) Act 1972 in its appropriate form has not materialized in the sanctuary other than prohibiting the killing/ hunting of any protected species in the sanctuary.

2. Livelihood dependency: The buffer zone of the sanctuary is extended to the Gram Panchayats of Tarkarli and Wayari and Malvan Nagar (town) Parishad. The sphere of influence includes seven villages, i.e., Dhuriwada, Gawandiwada, Rajkot, Makarebag-Medha, Dandi, Wayari, Tarkarli, and their seaward side. In the seven villages falling under the sanctuary area as mentioned above, the per capita income of the district is INR 1,30,987 (as per the 2011 census) against the Maharashtra State's average of INR 2,15,000 (District Statistical Department 2015). The average income of a fisherman can vary between INR 1,500 and INR 50,000 per month based on the catch and method of fishing (Somaraj 2020). The middlemen earn more than the active fishermen. At present, there are 19 fishery societies with 14,779 active members. The total population of Malvan city is 18,648 as per the 2011 census. Fishing and tourism are key drivers of the rural economy in Malvan with its dependence on natural resources viz., coral reefs, dolphins, and turtles. The fishing communities

Image 2. A diver with ghost net. © Rohit Sawant.

Image 3. Traditional fishing (Rampan) in the Malvan Marine Sanctuary. © Rohit Sawant.

have over-reliance on the sanctuary as Malvan is a major fishing harbour. The buffer zone of the sanctuary includes transport routes and approaches to Malvan harbour. The traditional fishing practices observed in the sanctuary are shore seine (Rampan) and Cast Net (Shendi). Mechanized fishing gear such as gill nets, hooks, and line are also in use. More destructive fishing using Trawl nets and Purse Seine operates outside the sanctuary with adherence to the Maharashtra Marine Fisheries Regulation Act, 1981. Fishing has provided livelihood for boat owners, drivers, 'tandel' (navigator), 'khalashi' (labour), traders, transport service providers, ice manufacturers, supplier, and marketers. A sizable number of fisherwomen population is also involved in post-harvest operations of fishery produce, i.e., salting and drying of fish. They use the beaches in the buffer zone of the sanctuary for fish drying (Rajagopalan 2008).

As the fish catch was depleting over a period, fishermen started migrating to the tourism sector. It provides multiple job opportunities in SCUBA diving, snorkelling, dolphin safari, and other water sports (De et al. 2020). Besides, boat owners, shopkeepers, and restaurants also depend upon tourism along Malvan Beach. The data retrieved from the Maharashtra Maritime Board (MMB) revealed that more than four lakh tourists visited Malvan annually in 2018–19 (Somaraj 2020). Unlike fishery, tourism service providers earn higher economic returns with less amount of actual effort once the line of business is established well. Thus, the majority of the people have resource dependency on the sanctuary area for fishing and tourism. This makes regulating the entry and movement of people within the sanctuary difficult.

3. Management: The sanctuary is managed by the Maharashtra State Forest Department. It is under the administrative control of the Mangrove Cell of Maharashtra. It is managed by the range forest officer (RFO), Mangrove Cell who also has jurisdiction in the entire Sindhudurg District. Considering the extent of the sanctuary and threats, more manpower and logistics are required for the effective management of the area. The lack of skilled staff equipped for the management of marine ecosystems is a constraint since forest field personnel are traditionally trained to manage terrestrial landscapes. Moreover, they are bound to departmental transfers and it makes a fresh start for the administrator recurrently. Strict implementation of the wildlife-related laws in the sanctuary prohibits fishing, trespassing of boats (fishing and tourism), anchoring of fishing vessels, and functioning of Malvan Port. People residing in the core area need to be rehabilitated outside. Hence, local communities and people's representatives have been regularly agitating for the de-notification of this sanctuary due to reservations about restricted movement and livelihood opportunities. The affected communities demanded written consent from the park management for their free movement and commercial activities which cannot be fulfilled legally.

4. Lack of clarity: There are no specific laws for the administration of the MPA in India. Both marine and terrestrial protected areas are on the same pedestal under the Wildlife Act. Usually, the MPA is located at the intersection between fishery activities and biodiversity conservation. Hence, the scope of management in a marine landscape is not similar to that in a terrestrial area. Moreover, the absence of distinct measurable management objectives in the MPA under the existing wildlife laws creates confusion and dilemmas among various stakeholders. Hence implementation of the activities for example, boundary demarcation, proper zonation as core and buffer zones, and imposing restrictions are far more challenging in the sanctuary due to the lack of cooperation from the communities and coordination with other public departments.

RECOMMENDATIONS

1. Rationalization of the Boundary

On account of People's agitation and the suggestions given in the management effectiveness evaluation (MEE) report of the Ministry of Environment Forest and Climate Change, the administration decided to carry out a feasibility study to understand the status of marine biodiversity in and around the sanctuary to identify the potential areas to be included in the sanctuary. Accordingly, Shinde et al. (2023) reported the following outcomes:

· The study area along Malvan beach is classified under three categories, i.e., potential protected areas (PAs), conservation priority areas, and sensitive areas based on biodiversity richness and anthropogenic threats.

· Areas with relatively high biodiversity richness and less degree of threats such as Kawda complex, seven rock complex, and lighthouse complex are included in the potential PAs. Similarly, Chiwla Beach Complex and Sargassum Forest Complex are classified under the conservation priority areas due to high anthropogenic pressure. Sensitive areas are under severe threat and hence currently have low species richness. King's Garden area near the Sindhudurg Fort which is part of the core area of the Malvan sanctuary is classified under the sensitive areas.

· Potential PAs may be considered for the re-notification as a sanctuary and the conservation priority area may be incorporated as a buffer zone or eco sensitive zone to check the unregulated fishing and water-based tourism activities. On the other hand, sensitive areas can be excluded from the sanctuary to safeguard the occupational interests of the local communities.

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2. Habitat conservation and species recovery programs

· The coral reef ecosystem is highly fragile in Malvan Sanctuary due to coral bleaching and human disturbances. Coral transplantation, artificial reef deployment, establishing coral nurseries shall be explored for the restoration of this ecosystem. As a maiden attempt at coral transplantation as part of the UNDP-GOI project in 2014 was successful, a similar intervention is being planned in the GOI-GCF project in the sanctuary in the near term.

· Illegal harvesting and trade of scheduled species listed under the Wildlife Protection Act, 1972 shall be strictly prohibited.

· The stranding of marine mammals and sea turtles is frequent along the Malvan coast, particularly in the monsoon season. A well-trained rescue team and a temporary treatment centre for stranded animals need to be established in Malvan for the treatment and recovery of injured animals.

· Mandatory uses of bycatch reduction devices (BRD) inside the sanctuary help in the reduction of bycatch and thus save the juvenile fish fauna. Trials during the GOI-GEF-UNDP project in 2014–15 showed that on average about 5–6 l of diesel was saved during one-day trips with square mesh cod end, as compared with the traditional cod end.

· Sensitization of fishermen is necessary to avoid dumping ghost nets in the sea thereby reducing incidents of marine animals getting entangled in the ghost net and getting killed.

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3. Sustainable livelihood development

Local communities heavily depend on the sanctuary for fishing and for water-based tourism activities. Hence, they need to be well informed about the importance of the sanctuary for sustaining their livelihood. Local communities having a high sense of ownership can eventually decide the success and failure of the sanctuary.

· As an option for alternative income generation, creek-based aquaculture, i.e., fish cage culture, oysters and mussels farming, crab farming, and marine ornamental fish hatcheries should be encouraged among the locals with technical and budgetary support from the state government. Such projects have already been initiated at the village level under the GOI-GEF-UNDP projects of 2014 in the Sindhudurg District and were found to be beneficial to the rural economy. Similarly, the ongoing UNDP-GCF project aims to enhance the resilience of the coastal communities through sustainable livelihood opportunities and capacity building. These activities will not only improve the household income but will also help in developing harmony between people and the management.

· Permit system for snorkelling and scuba diving should be strictly followed in the sanctuary area and a diving license should be issued to the shops by the district government authorities. Scuba diving needs to be permitted only in designated areas with adequate depth. The average depth in which scuba diving is presently practiced is less than 3–4 m which is not ideal for the same (IISDA 2017). New dive sites might be created outside the sanctuary by sinking wrecks in sandy patches. These wrecks would help in coral regeneration and act as FADs (fish aggregating devices).

· Dolphin watches and sea turtle festivals in the hatchery sites are gaining popularity. It should be allowed under the strict supervision of the park management or concerned department according to the norms and regulations. Trained villagers as hatchery watchers in hatching sites would help keep a check on people's interference in the turtle-hatching beaches.

4. Administration and Management

A dedicated team is required for the management of the sanctuary. Manpower should be increased by creating new posts such as a beat guard for looking after the protection as well as the ecotourism under the supervision of a forest round officer (RO) and a range forest officer (RFO). Specialized posts such as research officers, marine biologists, boat drivers, *etc*. can be recruited on a contractual basis. Joint patrolling with the help of the Fisheries Department, Police and Indian Coast Guard needs to be regularly done to check IUU (Illegal unregulated and unreported) fishing. Capacity building for the front-line staff on map reading, diving, surveying, and wildlife laws is also essential for better management. Adequate budgetary provisions need to be made in advance as roughly INR 4 crore (around USD 480,000) is required for the management of the sanctuary annually after the reorganization (Somaraj 2020).

5. Modification of the existing laws

Conservation objectives are different in terrestrial protected areas and in MPA. The nature of resource dependency in terrestrial and MPA is also beyond comparison. Hence parallels cannot be drawn between terrestrial and marine sanctuaries/ marine national parks. There should be clear guidelines and management objectives for the MPA which should address both the socio-economic and ecological dimensions of the protected area. Hence an amendment in the Wildlife (Protection) Act, 1972 is required to incorporate specific administrative frameworks for the MPA in India.

CONCLUSION

MMS is met with reluctance from the affected local communities and leads to outright objection in the present scenario. It is mainly attributable to their feeling of victimization and alienation due to the prohibitory nature of wildlife laws. Recently implemented sustainable livelihood programs and capacity building of the stakeholders have helped in changing their perception to a certain extent. Any landscape conservation effort will be fruitful only with community participation and in this case, it will happen only if the boundaries of the sanctuary are reorganized efficiently after consultation with the stakeholders. Such efforts are under the active consideration of the Maharashtra State Government, and it is going to be a win-win situation for both the government and the affected communities. Needless to say, instead of a total ban on commercial activities, a consensus-based 'seascape approach' in MPA in India can win the trust of local communities. Thus, amendments in the Wildlife Protection Act, of 1972 with regard to the MPA are imperative for a sustainable future.

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SHORT COMMUNICATION

A preliminary checklist of butterflies (Lepidoptera: Rhopalocera) of Dhorpatan Valley, Dhorpatan Hunting Reserve, Nepal

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Abstract: Butterfly species were studied in the Dhorpatan Valley, situated in the western region of Nepal, during the pre-monsoon and monsoon seasons of 2021 and 2022. This preliminary study documented forty-three species of butterflies from five families Lycaenidae, Pieridae, Nymphalidae, Papilionidae, and Hesperiidae. A purposive sampling method was applied to locate various butterfly species across elevations ranging 2,846–4,000 m. This study recorded *Polyommatus nepalensis*, an endemic species and *Polyommatus stoliczkanus*, a rare species. No reports have been made of this endemic butterfly from eastern region of Nepal.

Keywords: Distribution, elevation, endemic, family, habitat, plots, rare, sampling, seasons, species.

The IUCN Butterfly and Moth Specialist Group estimates that there are approximately 18,000 butterfly species and 160,000 moth species globally. Insects make up more than half of the world's faunal diversity, which plays a crucial role in the functioning of the earth's ecosystem. Butterflies are the best-studied group throughout Nepal (Smith 1994, 1997). These insects are widely distributed in Nepal and 18% of butterflies in the mid-hills are threatened (BPN 1996; Bhusal & Khanal 2008; Thapa & Bhusal 2009). The country's various bio-climatic zones reflect the niches for a wide variety of flowers that offer ideal habitats for butterfly diversity.

Six-hundred-and-sixty species under 263 genera of butterflies have been reported in Nepal (Smith 2010). Based on Smith (2010) and Subedi et al. (2021), the most recent count of butterfly species in Nepal is 678. Since, no previous studies on invertebrate fauna, such as butterflies and moths, have been conducted in this region, this research aims to provide important information on the butterfly species inhabiting the higher elevations of Nepal. This preliminary checklist of butterfly species in this region could also help explore habitat preferences, particularly in relation to larval host plants such as *Rumex nepalensis*, *Berberis aristata*, *Duchesnea indica*, *Anaphalis* spp., and *Pedicularis* spp. This information contributes to initiating conservation

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efforts, particularly in protected areas of Nepal like Dhorpatan Hunting Reserve.

Study area

Dhorpatan Valley is the part of Dhorpatan Hunting Reserve (DHR) located in Baglung District, Gandaki Province, western region of Nepal (28.490 ^{0}N, 83.027 ^{0}E) (Figure 1, Image 1). This reserve was established to protect a variety of Himalayan flora & fauna, represented by alpine, sub-alpine, and high temperate vegetation. According to the DHR (2019), the features include extensive highland pastures mostly above 3,800 m and east-west ridges that make north and south slopes suitable for summer and winter habitats. Forest covers different vegetations like blue pine *Pinus wallichiana*, fir *Abies spectabilis*, rhododendron (*Rhododendron ferrugineum*, *R. campanulatum*), Hemlock *Tsuga dumosa*, Birch *Betula utilis*, Juniper *Juniperus indica*, Spruce *Picea smithiana*, and oak *Quercus semicarpifolia*. This is the only one hunting reserve of Nepal that supports sport hunting of Jharal *Hemitragus jemlahicus* and Blue Sheep *Pseudois nayaur*. The map of the study area was drawn using Arc GIS 10.5.1. The survey of butterfly was conducted in the Dhorpatan Valley of the Dhorpatan Hunting Reserve (DHR), where the altitude ranges 2,846–4,000 m. The diverse physiographic conditions of this valley, including seasonal meadows, various water bodies, and a wide range of shrubs & herbs, provide preferred habitats and

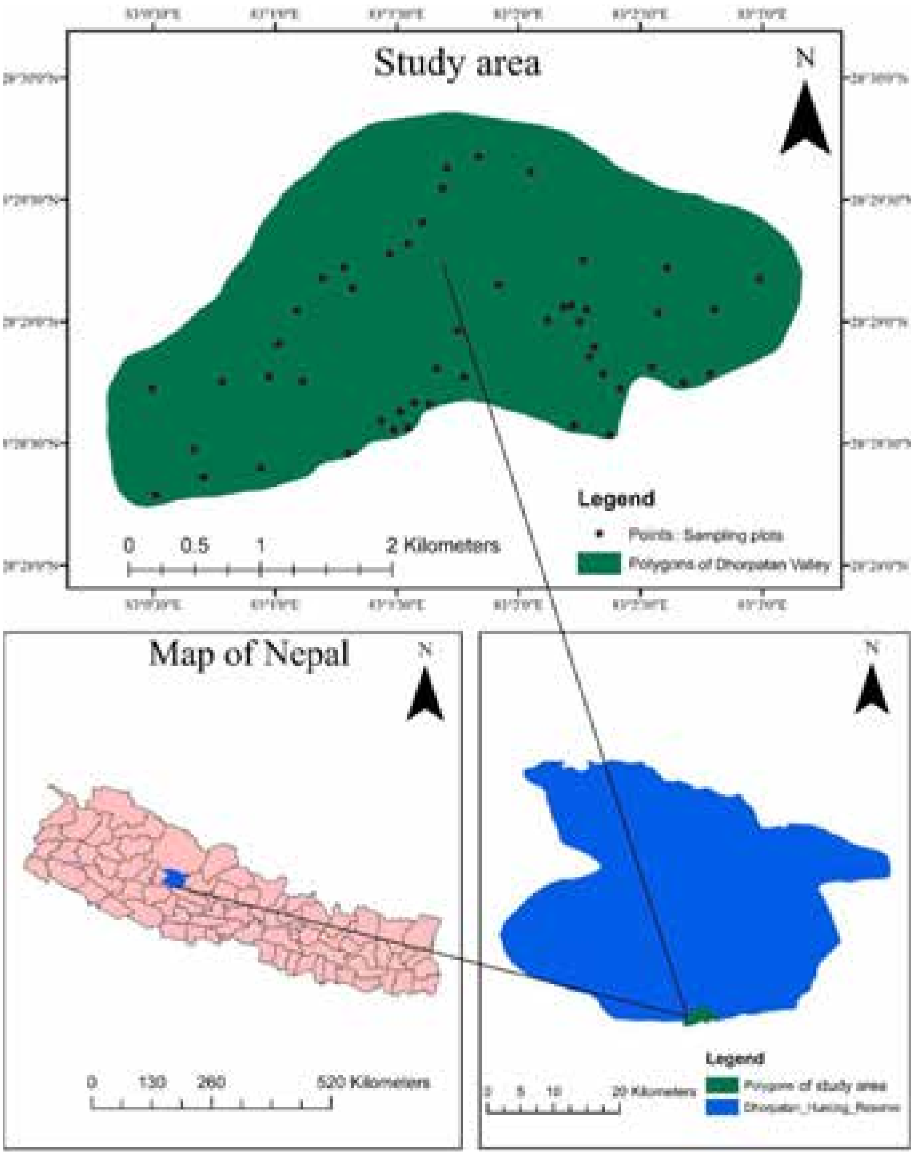

Figure 1. Map showing the study area of Dhorpatan Valley, Dhorpatan Hunting Reserve (DHR), Nepal.

food for butterflies & moths, supporting the pollination of floral species, and contributing to overall ecosystem health & biodiversity.

Materials and Methods

Butterfly species were recorded from 50 plots with a plot size of 50 × 20 m^2 in the study area of Dhorpatan Valley. This research was conducted over two months during the pre-monsoon season (25 March–23 April, 2021) and the monsoon season (19 June–18 July, 2022). The Pollard (1977) method was followed, where butterflies were surveyed between 1045 h and 1545 h on sunny days with temperatures (>17 °C, or 13–17 °C). The butterflies were observed and recorded from the sampling plots for five hours per day throughout the study period using purposive sampling. Most of the species were photographed using a Nikon D-7500 camera, and only a few confusing or unidentifiable species were collected. Different relevant literatures (Khanal & Smith 1997; Smith 2011) were consulted for identification.

Table 1. A preliminary checklist of butterfly species found in the Dhorpatan Valley of Dhorpatan Hunting Reserve, Nepal. The list includes family, names of the species, and their local status.

Family	Scientific name	Common name	Local status
1. Pieridae	1. *Catopsilia pyranthe* Linnaeus, 1758	Mottled Emigrant	C
	2. *Colias erate* Esper, 1805	Eastern Pale Clouded Yellow	C
	3. *Colias fieldii* Ménétriés, 1855	Dark Clouded Yellow	C
	4. *Delias belladonna* Fabricius, 1793	Hill Jezebel	C
	5. *Eurema hecabe* Linnaeus, 1758	Oriental Common Grass Yellow	C
	6. *Gonepteryx nepalensis* Linnaeus, 1758	Common Brimstone	C
	7. *Pieris brassicae* Linnaeus, 1758	Large Cabbage White	C
	8. *Pieris canidia* Sparrman, 1768	Indian Cabbage White	C
2. Nymphalidae	9. *Aglais cashmirensis* Kollar, 1844	Indian Tortoiseshell	FC
	10. *Argynnis kamala* Moore, 1857	Common Silverstripe	FC
	11. *Aulocera brahminus* Blanchard, 1853	Narrow-banded Satyr	UC
	12. *Lethe sidonis* Hewitson, 1863	Common Woodbrown	C
	13. *Issoria issaea* Doherty, 1886	Queen of Spain Fritillary	C
	14. *Junonia orithya* Linnaeus, 1758	Blue Pansy	C
	15. *Lasiommata schakra* Kollar, 1844	Common Wall	C
	16. *Melitaea arcesia* Bremer, 1861	Blackvein Fritillary	C
	17. *Neptis hylas* Linnaeus, 1758	Common Sailor	VC
	18. *Parantica sita* Kollar, 1844	Chestnut Tiger	LC
	19. *Junonia iphita* Cramer, 1779	Chocolate Pansy	C
	20. *Rhaphicera moorei* Butler, 1867	Small Tawny Wall	C
	21. *Vanessa cardui* Linnaeus, 1758	Painted Lady	C
	22. *Vanessa indica* Herbst, 1794	Indian Red Admiral	VC
3. Lycaenidae	23. *Celastrina argiolus* Linnaeus, 1758	Hill Hedge Blue	C
	24. *Celastrina gigas* Hemming, 1928	Silvery Hedge Blue	C
	25. *Everes lacturnus* Godart, 1824	Indian Cupid	FC
	26. *Everes argiades* Pallas, 1771	Tailed Cupid	C
	27. *Heliophorus epicles* Godart, 1824	Purple Sapphire	C
	28. *Heliophorus sena* Kollar, 1844	Sorrel Sapphire	UC
	29. *Lampides boeticus* Linnaeus, 1767	Pea Blue	C
	30. *Leptotes plinius* Fabricius, 1793	Zebra Blue	UC
	31. *Lycaena panava* Westwood, 1852	White-bordered Copper	LC
	32. *Lycaena phlaeas* Linnaeus, 1761	Common Copper	C
	33. *Polyommatus icarus* Rottemburg, 1775	Common Blue	UC
	34. *Polyommatus nepalensis* Forster, 1961	Nepal Meadow Blue	E
	35. *Polyommatus stoliczkanus* C. & R.Felder, 1865	Himalayan Meadow Blue	R
	36. *Pseudozizeeria maha* Kollar, 1844	Pale Grass Blue	FC
	37. *Udara albocaerulea* Moore, 1879	Himalayan Albocerulean	C
4. Papilionidae	38. *Graphium cloanthus* Westwood, 1841	Glassy Bluebottle	UC
	39. *Papilio machaon* Linnaeus, 1758	Common Yellow Swallowtail	C
	40. *Papilio protenor* Cramer, 1775	Spangle	C
	41. *Parnassius hardwickii* Gray, 1831	Common Blue Apollo	UC
5. Hesperiidae	42. *Pelopidas mathias* Fabricius, 1798	Small Branded Swift	C
	43. *Caltoris cahira austeni* (Moore, 1883)	Colon swift	C

C—Common | UC—Uncommon | LC—Locally Common | FC—Fairly Common | R—Rare | E—Endemic.

Image 1. This photo displays a portion of the Dhorpatan Valley within the Dhorpatan Hunting Reserve (DHR), Nepal.

Results and Discussion

This study records 43 species of butterflies (Images 2–47), categorization based on their availability relative to the total number of individuals recorded in this region. All the recorded species belong to 32 genera and five families, which include Lycaenidae (15 species), Pieridae (8 species), Nymphalidae (14 species), Papilionidae (4 species), and Hesperiidae (2 species). Single individuals of *Parnassius hardwickii*, *Papilio protenor*, *Everes lacturnus*, *Parantica sita*, *Argynnis kamala*, and *Neptis hylas* were recorded above 3,000 m in the Dhorpatan Valley. Inomata (1998) published an account of *Parnassius* of Nepal which includes 12 species from the Himalayan region. Only few studies provide information on the population status of Apollo species and their habitat preferences in different geographical regions of the world (Ali et al. 2019). *Aglais cashmirensis* was noted with the highest abundance records during the whole period of survey. This is one of the most common species, found in a wide range of habitats in India (Haribal 1990). *Polyommatus nepalensis*, an endemic species, and *Polyommatus stoliczkanus*, a rare species, were generally recorded as common in this geographic region.

We observed that the monsoon season, typically from June to July, is an optimal time for monitoring butterfly diversity in high-altitude regions like Dhorpatan Valley. The pre-monsoon season is typically dry so, few individuals of species like *Polyommatus icarus*, *Polyommatus nepalensis*, *Polyommatus stoliczkanus*, *Vanessa indica*, *Junonia iphita*, *Parnassius hardwickii,* *Everes argiades*, and *Udara albocaerulea* were mostly seen. Within this protected area, most butterfly species were recorded at lower elevations. The diverse habitats of this reserve support a wide variety of flora, fauna, and invertebrates, including butterflies, moths, and bees. As pollinators, butterflies & bees play a crucial role in maintaining floral diversity and enhancing the overall health of the ecosystem (Potts et al. 2010). This preliminary study fills a significant knowledge gap by providing the first comprehensive assessment of butterfly species in this region. The baseline data generated by this research will be instrumental in guiding future studies and conservation initiatives.

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Image 2. *Catopsilia pyranthe.* © Kiran Rayamajhi


Image 3. *Colias erate* (female). © Kiran Rayamajhi


Image 4. *Colias fieldii* (male). © Kiran Rayamajhi


Image 5. *Colias fieldii* (female). © Kiran Rayamajhi

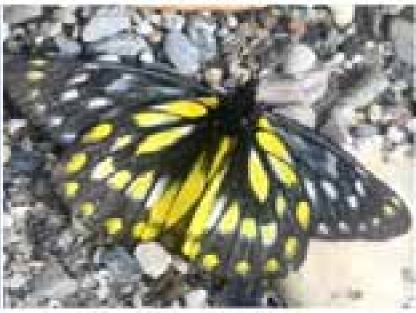
Image 6. *Delias belladonna.* © Kiran Rayamajhi

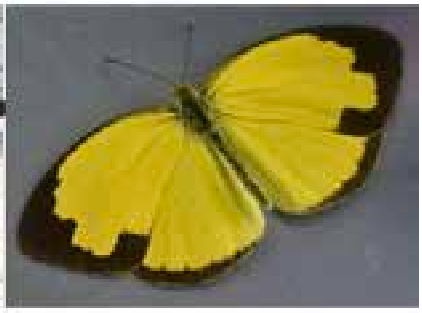
Image 7. *Eurema hecabe.* © Kiran Rayamajhi


Image 8. *Gonepteryx nepalensis.* © Kiran Rayamajhi


Image 9. *Pieris brassicae.* © Kiran Rayamajhi


Image 10. *Pieris canidia.* © Kiran Rayamajhi


Image 11. *Aglais cashmirensis.* © Kiran Rayamajhi


Image 12. *Argynnis kamala.* © Kiran Rayamajhi


Image 13. *Aulocera brahminus.* © Kiran Rayamajhi

Image 14. ***Lethe sidonis.*** **© Kiran Rayamajhi**

Image 15. ***Issoria issaea*** **(upperside). © Kiran Rayamajhi**

Image 16. ***Issoria issaea*** **(underside). © Kiran Rayamajhi**

Image 17. ***Junonia orithya.*** **© Kiran Rayamajhi**

Image 18. ***Lasiommata schakra.*** **© Kiran Rayamajhi**

Image 19. ***Melitaea arcesia.*** **© Kiran Rayamajhi**

Image 20. ***Neptis hylas.*** **© Kiran Rayamajhi**

Image 21. ***Junonia iphita.*** **© Kiran Rayamajhi**

Image 22. ***Rhaphicera moorei.*** **© Kiran Rayamajhi**

Image 23. ***Vanessa cardui.*** **© Kiran Rayamajhi**

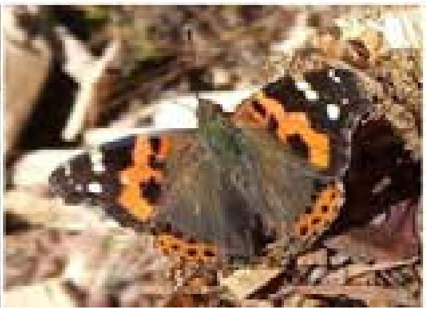

Image 24. ***Vanessa indica.*** **© Kiran Rayamajhi**

Image 25. ***Celastrina argiolus.*** **© Kiran Rayamajhi**

Image 26. ***Celastrina gigas.*** © Kiran Rayamajhi

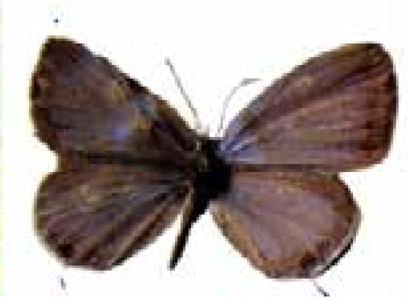

Image 27. ***Everes lacturnus.*** © Kiran Rayamajhi

Image 28. ***Everes argiades.*** © Kiran Rayamajhi

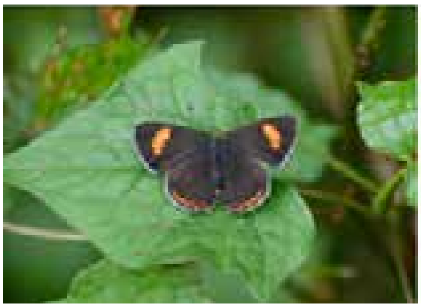

Image 29. ***Heliophorus epicles.*** © Kiran Rayamajhi

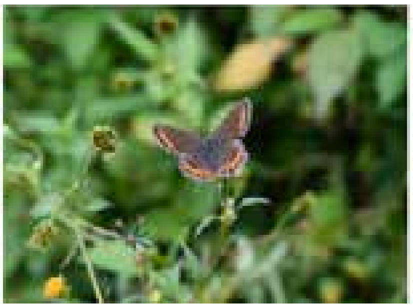

Image 30. ***Heliophorus sena.*** © Kiran Rayamajhi

Image 31. ***Lampides boeticus.*** © Kiran Rayamajhi

Image 32. ***Leptotes plinius.*** © Kiran Rayamajhi

Image 33. ***Lycaena panava.*** © Kiran Rayamajhi

Image 34. ***Lycaena phlaeas.*** © Kiran Rayamajhi

Image 35. ***Polyommatus icarus.*** © Kiran Rayamajhi

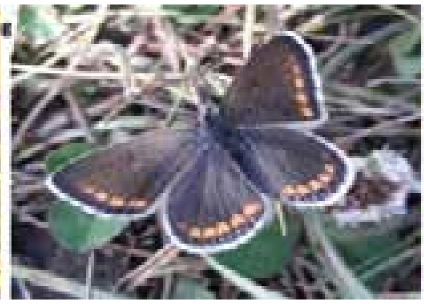

Image 36. ***Polyommatus nepalensis*** (female upperside). © Kiran Rayamajhi

Image 37. ***Polyommatus nepalensis*** (female underside). © Kiran Rayamajhi

Image 38. ***Polyommatus stoliczkanus*.** © Kiran Rayamajhi

Image 39. ***Pseudozizeeria maha*.** © Kiran Rayamajhi

Image 40. ***Udara albocaerulea*.** © Kiran Rayamajhi

Image 41. ***Graphium cloanthus*.** © Kiran Rayamajhi

Image 42. ***Papilio machaon*.** © Kiran Rayamajhi

Image 43. ***Papilio protenor*.** © Kiran Rayamajhi

Image 44. ***Parnassius hardwickii*** (female). © Kiran Rayamajhi

Image 45. ***Parnassius hardwickii*** (male). © Kiran Rayamajhi

Image 46. ***Pelopidas mathias*.** © Kiran Rayamajhi

Image 47. ***Caltoris cahira austeni*.** © Kiran Rayamajhi

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OPEN ACCESS

SHORT COMMUNICATION

New species records of sericine chafer beetles (Coleoptera: Scarabaeidae: Melolonthinae) from Goa and Maharashtra, India

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Abstract: The present study reports three species of sericine chafer beetles, *Maladera keralensis* (Frey, 1972), *Maladera burmeisteri alternans* (Frey, 1975), and *Neoserica gravida* Ahrens & Fabrizi, 2016 as new records for Goa state and *M. burmeisteri alternans* for Maharashtra state of India.

Keywords: Distribution, genitalia, new records, pests, phytophagous, scarab beetles, Scarabaeoidea, sericini, species diversity, Western Ghats.

Sericine chafer beetles belong to the subfamily Melolonthinae and is the biggest group of the family Scarabaeidae under the superfamily Scarabaeoidea. There are approximately 4,600 species of Sericine Chafer Beetles described in the world including 682 from India (Ahrens & Fabrizi 2016; Sreedevi et al. 2018, 2019; Bhunia et al. 2021, 2022; Chandra et al. 2021).

These beetles are unique in appearance and can be identified easily by the distinctive characteristics of their head, thorax, and abdomen and an elongated, cylindrical body. They are mainly reported and studied from the Himalaya (Ahrens 2004) and southern area (Ahrens & Fabrizi 2016). Some recent reports from other parts of the country like Manipur (Bhunia et al. 2023), Mizoram (Sreedevi et al. 2018), Nagaland (Sreedevi et al. 2019), Madhya Pradesh (Chandra et al. 2021) are published. In many regions of India, these important phytophagous pests remain either largely unexplored or have exist in old records. Identification of these beetles is challenging owing to their similar external morphology and uniform subtle brown colour in almost all species. Hence, the study of the external male genitalia is an important tool in species conformation of sericine chafer beetles.

While sorting and studying the unidentified sericine chafer beetles (SCB) present in the collections of the Western Regional Centre, Pune, some beetles were found to be new record to the Goa and Maharashtra states. A total of 210 specimens recorded from Maharashtra, Karnataka, and Goa were studied. This is the first report on SCB from Goa after Ahrens & Fabrizi (2016). The present work is an attempt to fill the gap in the SCB taxonomy and distribution in India.

Materials and Methods

A total of 210 specimens of SCB were sorted, pinned, and studied. The specimens were examined under the Leica S9i Stereo-zoom microscope. The identification

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Competing interests: The authors declare no competing interests.

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and terminologies used follow Ahrens & Fabrizi (2016). The specimen was studied under a Leica EZ 4 E stereozoom microscope with a photographic facility. The images were stacked using Combine ZP software and then processed with Adobe Photoshop CS Version 8. To study the males, the genitalia was carefully removed from the abdomen. Then, it was boiled in 10% KOH for 5–10 minutes to remove the adhered tissues and soft muscles and rinsed with distilled water. The genitalia was stored in separate vials containing 70% ethanol with the same catalogue number as the specimen. The identified specimens were duly labelled and deposited in the National Zoological Collections of the Zoological Survey of India, Western Regional Centre, Pune.

Results and Discussion

The three beetles identified in this study are *Maladera keralensis* (Frey, 1972), *Maladera burmeisteri alternans* (Frey, 1975), and *Neoserica gravida* Ahrens & Fabrizi, 2016.

Systematic account

Order Coleoptera Linnaeus, 1758
Superfamily Scarabaeoidea Latreille, 1802
Family Scarabaeidae Latreille, 1802
Subfamily Melolonthinae Leach, 1819
Tribe Sericini Kirby, 1837

Genus *Maladera* Mulsant & Rey, 1871

1. ***Maladera keralensis* (Frey, 1972)** (Image 1A–D)

Autoserica keralensis Frey 1972, *Entomologische Arbeiten aus dem Museum Frey* 23: 186.

Maladera keralensis: Krajcik, 2012, *Animma. X, supplement* 5: 154.

Maladera keralensis Ahrens & Fabrizi, 2016, *Bonn Zoological Bulletin* 65 (1 & 2): 197.

Material examined: Male, India, South Goa, Aranyak Nature campsite, 28.v.2023, coll. A.S. Kalawate (ZSI-WRC-ENT-1/4736); Male, India, Karnataka, Nagzari watch tower, KTR, Uttara Kannada, 08.vi.2022, coll. A.S. Kalawate (ZSI-WRC-ENT-1/4741); Male, India, Karnataka, Mandurli FRH, KTR, Uttara Kannada, 09.vi.2022, coll. A.S. Kalawate (ZSI-WRC-ENT-1/4742).

Male genitalia (Image 1): Length, 3.30 mm; width, 0.869 mm. Sclerotised; phallobase longer than parameres; Right distal phallobasal apodeme is solid invagination and hence the phallobase is not movable, position of placement of parameres medially.

Distribution: India: Goa (present study), Karnataka, Kerala, Maharashtra (Ahrens & Fabrizi 2016).

Remark: Endemic to India. New record to Goa.

2. ***Maladera burmeisteri alternans* (Frey, 1975)** (Image 2A–D)

Autoserica alternans Frey, 1975, *Entomologische Arbeiten aus dem Museum* Frey 26: 186.

Maladera alternans: Krajcik, 2012, *Animma. X, supplement* 5: 154.

Maladera burmeisteri alternans, Ahrens & Fabrizi, 2016, *Bonn zoological Bulletin* 65 (1 & 2): 186.

Material examined: Male, India, South Goa, Aranyak Nature campsite, 30-v-2023, coll. A.S. Kalawate (ZSI-

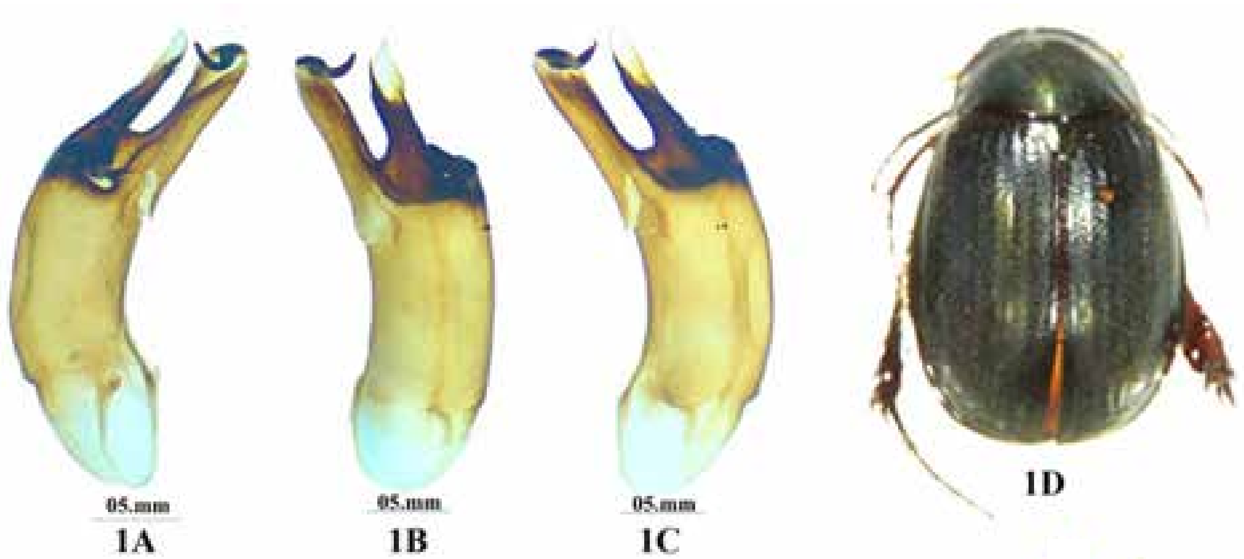

Image 1A–D. ***Maladera keralensis*: A—aedeagus in lateral view (left) | B—aedeagus in dorsal view | C—aedeagus in lateral view (right) | D—habitus, dorsal view adult. © Aparna Kalawate.**

WRC-ENT-1/4737); Male, India, Maharashtra, Waki, Yawal, Jalgaon, 22-vi-2021, coll. S.S. Talmale (ZSI-WRC-ENT-1/4738); Male, India, Maharashtra, Bhosgaon, Patan, Satara, 15-vii-2017, coll. A.S. Kalawate (ZSI-WRC-ENT-1/4739); Male, India, Maharashtra, Ambegaon, Pune, 23-vi-2017, coll. A.S. Kalawate (ZSI-WRC-ENT-1/4740); Male, India, Karnataka, Kulgi Nature Camp, Uttara Kannada, 10-vi-2022, coll. A.S. Kalawate (ZSI-WRC-ENT-1/4745); Male, India, Karnataka, Mandurli, FRH, KTR, Uttara Kannada, 09-vi-2022, coll. A.S. Kalawate (ZSI-WRC-ENT-1/4746); Male, India, Karnataka, Kumberli, Phansoli range, Nala, Uattara Kannada, 11-vi-2022, coll. A.S. Kalawate (ZSI-WRC-ENT-1/4747); Male, India, Karnataka, Nagzari watch tower, KTR, Uttara Kannada, 08-vi-2022, coll. A.S. Kalawate (ZSI-WRC-ENT-1/4748); Male, India, Maharashtra, Karanjpani, Yawal, Jalgaon, 21-vi-2021, coll. S.S. Talmale (ZSI-WRC-ENT-1/4749); Male, India, Maharashtra, Dhebewadi, FRH, Bhosgaon, Satara, 02-iii-2017, coll. S.R. Patil (ZSI-WRC-ENT-1/4750).

Male genitalia (Image 2): Length, 2.65 mm; width, 1.11 mm. Sclerotised; phallobase broader towards the apex and narrowed towards the base; distal median lobe of phallobase fused with the more basal portion of the phallobase; basally left paramere not widened.

Distribution: India: Goa (present study), Maharashtra (present study), Karnataka, Kerala, Tamil Nadu (Ahrens & Fabrizi 2016), Madhya Pradesh (Chandra et al. 2021)); Nepal (Ahrens & Fabrizi 2016).

Remark: New Record to Goa and Maharashtra.

Genus *Neoserica* Brenske, 1894

3. ***Neoserica gravida* Ahrens & Fabrizi, 2016** (Image 3A–D)

Neoserica gravida Ahrens & Fabrizi, 2016, *Bonn Zoological Bulletin* 65 (1 & 2): 76–77.

Material examined. Male, India, South Goa, Aranyak Nature campsite, 30.v.2023, coll. A.S. Kalawate (ZSI-WRC-ENT-1/4735); Male, India, Karnataka, Nagzari watch tower, KTR, Uttara Kannada, 08.vi.2022, coll. A.S. Kalawate (ZSI-WRC-ENT-1/4743); Male, India, Karnataka, Mandurli FRH, KTR, Uttara Kannada, 09.vi.2022, coll. A.S. Kalawate (ZSI-WRC-ENT-1/4744).

Male genitalia (Image 3): Length, 5.00 mm; width, 1.90 mm. Extremely sclerotized; parameres are extremely sclerotised, long, slender, and sharp, without lateral teeth externally, and equal to the length of the phallobase.

Distribution: India: Karnataka (Ahrens & Fabrizi 2016), Goa (present study).

Remark: New record to Goa. Endemic to India.

Conclusions

From the studied specimens, two beetles, *Maladera keralensis* (Frey, 1972) and *Neoserica gravida* Ahrens & Fabrizi, 2016 are endemic to India. In the collections from the three states, *Maladera burmeisteri alternans* is found to be the most dominant beetle. Earlier records show that these species were mostly confined to southern India. It may due to less studies undertaken on this particular fauna from other regions of India. The

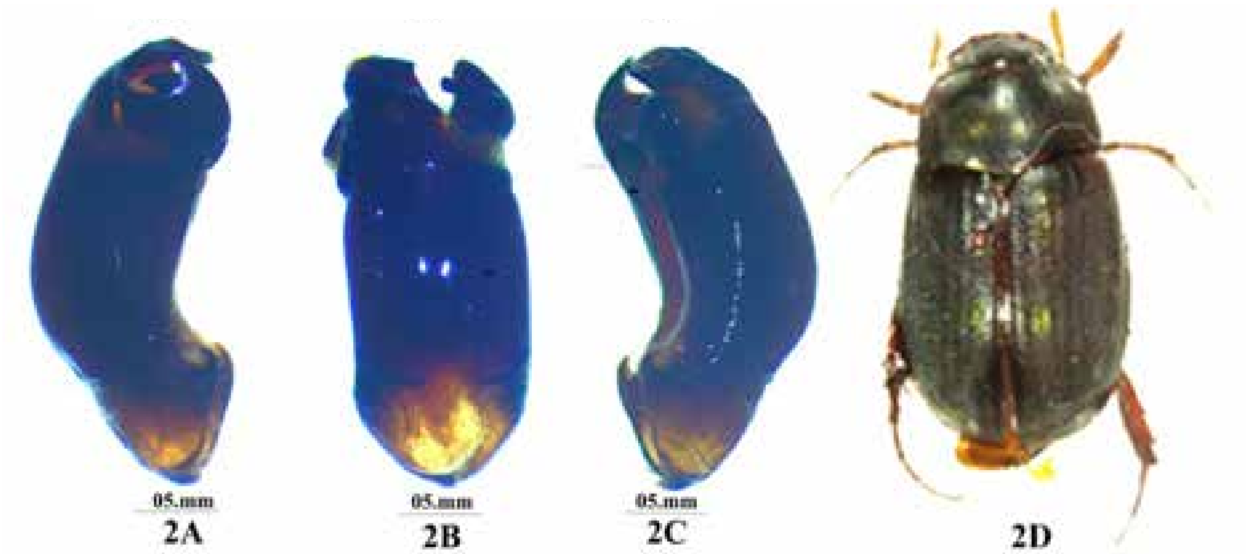

Image 2A–D. *Maladera burmeisteri alternans*: A—aedeagus in lateral view (left) | B—aedeagus in dorsal view | C—aedeagus in lateral view (right) | D—habitus, dorsal view adult. © Aparna Kalawate.

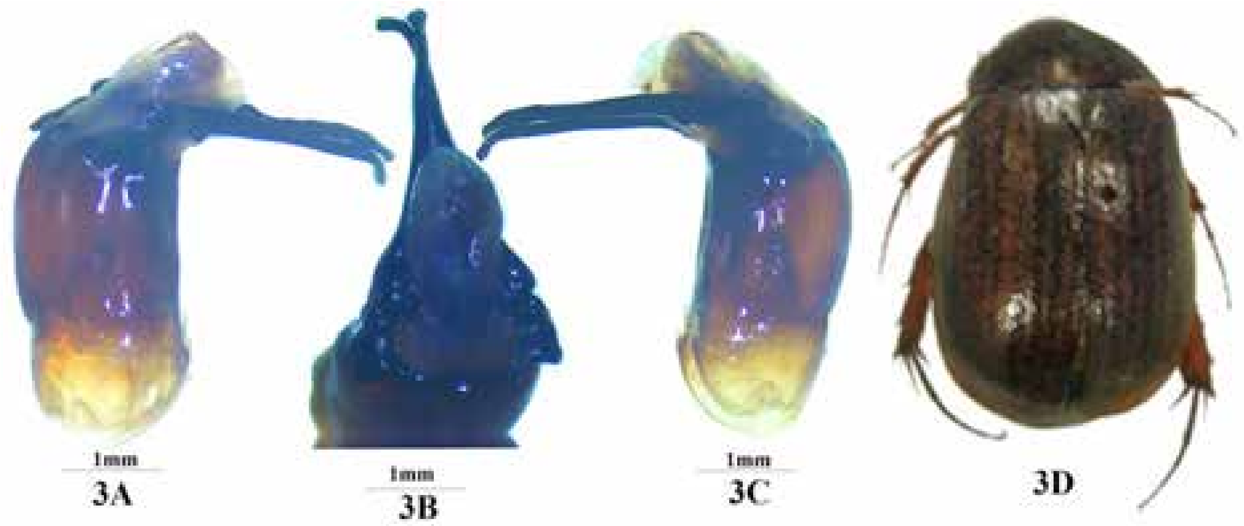

Image 3A–D. *Neoserica gravida*: A—aedeagus in lateral view (left) | B—aedeagus in dorsal view | C—aedeagus in lateral view (right) | D—habitus, dorsal view adult. © Aparna Kalawate.

reason behind this is the Linnean and the Wallacean Shortfall. The Linnean shortfall is created when there is lack of taxonomic work in a particular group. On the other hand, when a group of organism lacks its distribution data a Wallacean Shortfall is created. In case of SCB group both these shortfalls are responsible for less data. This paper is a small attempt towards filling the gap areas towards these shortfalls and to generate the data for the secondary users like agriculturist, farmers, students, and researchers as these beetles are phytophagous pest. Hence, the need of the hour is to increase the taxonomic studies, expeditions, and funding to undertake such studies.

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SHORT COMMUNICATION

Survey of Orthoptera in the Desert National Park, Rajasthan, India

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Abstract: Members of the insect order Orthoptera comprising grasshoppers, locusts, and crickets form a dominant and vital group of invertebrates in the arid environment. Orthopterans play an important role in grassland ecosystems and their species diversity and abundance in grasslands are much higher compared to those in the agricultural and scrubland areas. We attempt to create a comprehensive list of Orthopteran species from the Desert National Park (DNP) and its surrounding areas from the Thar Desert landscape of Rajasthan. This area constitutes one of the largest and few protected areas of arid biodiversity in India. In different enclosures of DNP sweep net sampling was done to sample the focal species in different seasons. 24 orthoptera species belonging to 20 genera and 11 subfamilies under 5 families were recorded.

Keywords: Grasshopper, grassland, habitat, insect, season, sweep net, Thar Desert.

Deserts are found on almost all the continents of the world and are characterized by dunes and interdunal valleys. These regions experience extremely hot summers, cold winters, and low, erratic rainfall. In India, the central parts of the desert are occupied by grasslands. Grassland ecosystems are severely threatened by agriculture and industrialization (White et al. 2000). Despite providing an assortment of ecosystem services, supporting human livelihoods, and harbouring endemic wildlife, grasslands in India have been largely ignored in development and conservation discourses (Dutta et al. 2010). In grasslands, insect diversity is usually linked to plant species composition and habitat structure (Roffey & Popov 1968).

Orthopteran insects, especially grasshoppers, have a substantial importance in the ecology of grassland ecosystems, being important primary herbivores and significantly contributing to the diet of the Great Indian Bustard, an endangered bird of Thar Desert (Dutta & Jhala 2021). Grasshoppers regularly indicate habitat quality and change, so they are commonly regarded as potential ecological indicator species for grasslands (Bazelet & Samways 2011).

The order Orthoptera is one of the significant insect orders, with about 29,530 species recorded worldwide (Cigliano et al. 2024). There are about 1,274 species or subspecies belonging to 442 genera and 23 families recorded from India (Chand et al. 2024). Some species of grasshoppers and locusts cause considerable loss to vegetation in agricultural ecosystems in particular, in

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many parts of the world due to their massive seasonal outbreaks (Klein et al. 2021).

In Thar Desert, the Desert National Park (DNP) is an important grassland ecosystem with vast expanses of grassland intermixed with shrubs and small trees. Earlier Rathore (2004) reported only 10 species of Orthoptera from DNP. There is paucity of information about the orthopteran species in the Thar landscape, specially the DNP, being the only prominent protected area representative of India's north-western arid biogeographic zone. Therefore, the aim of our study was to understand how many different type of orthopteran species are there.

Methods

The Thar Desert occupies nearly 385,000 km^2 and about 9% of the area of India (Islam & Rahmani 2004). Thar is occupied mainly by dry open grassland or grassland interspersed with trees and shrubs with broad topographic features like gravels, plains, sand-soil mix, dunes, and rocky hillocks (Sharma & Mehra2009). The Desert National Park (DNP); actually a Wildlife Sanctuary encompasses about 3,162 km^2 in the Jaisalmer District and another 1,262 km^2 in the Barmer Districts of Rajasthan. Several areas within the national park are protected by fencing where the human activity is restricted to conserve the habitat for important

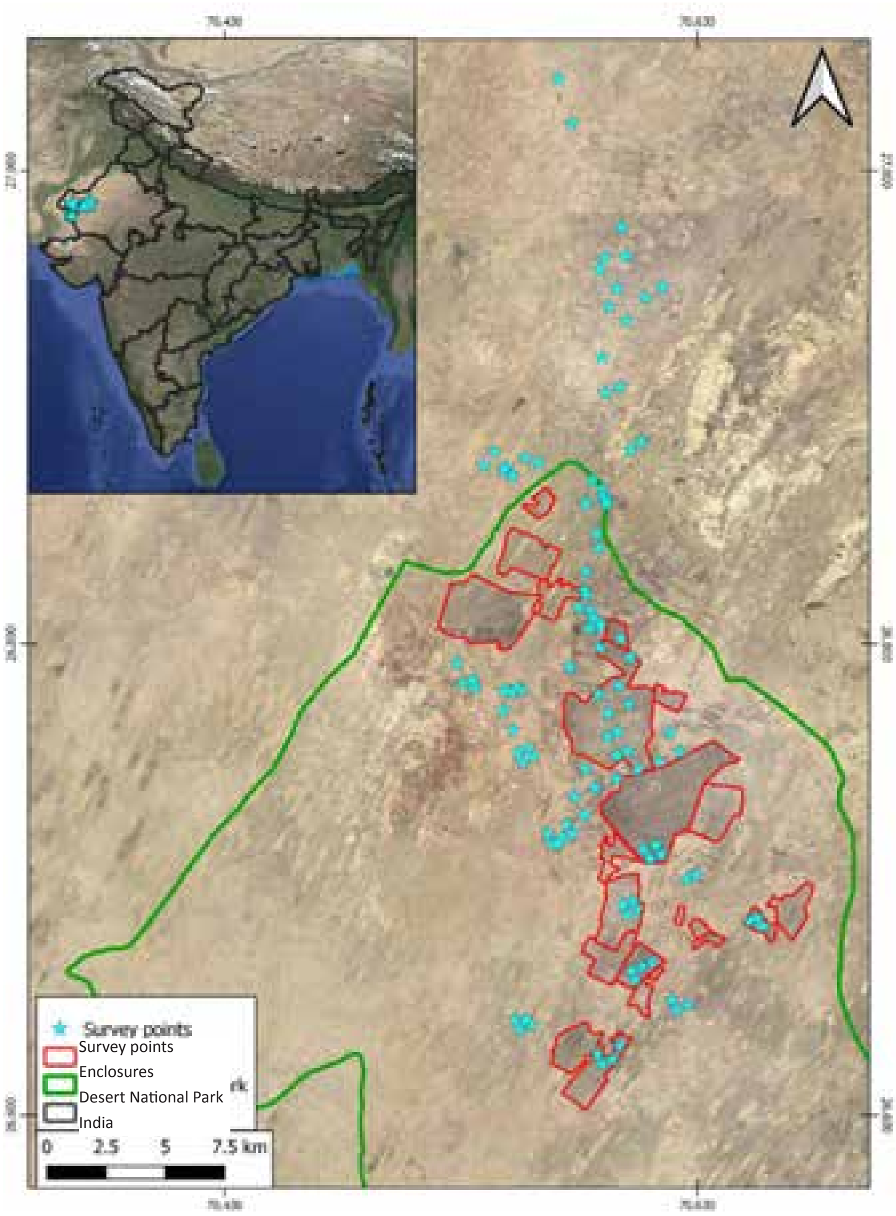

Image 1. Orthoptera sampling inside and outside Desert National Park, Rajasthan, India.

wildlife species like the Great Indian Bustard, where the vegetation is natural. Within the DNP several areas outside the enclosures experience unrestricted human interference and movements, where the vegetation of the few areas is natural and few areas are cultivated. The study was carried out in different enclosures and unprotected agro-pastoral areas of DNP (Image 1). The size of the enclosures are different, wherein, the minimum size of the survey enclosures are 3 km^2 and the maximum is 12 km^2. We surveyed these enclosures and adjoining unprotected areas in summer, monsoon and winter seasons from June 2021 to December 2023. We visited the sampling area multiple times in three monsoon, two winter and two summer seasons.

Sampling was done at random points generated inside the study area. Sweep netting (Rudd & Jensen 1977) was done in a 50 x 4 m^2 belt transect, following a standard approach of about 100 strokes and the samples were collected in a container after every 20 strokes. After that four adult individuals of different sexes of each species were collected from the sample container. Preservation of the collected specimen was done using wet and dry methods. For the dry preservation insects were pinned and kept in a storage box and (Image 2) for the wet preservation 70% ethanol were used. All the preserved insects were studied under Nikon stereozoom microscope and identified using taxonomic keys by Uvarov (1977). In addition, we also used the species identification information from the Orthoptera Species File (http://Orthoptera.SpeciesFile.org) last accessed on April 2024. The collected specimens are deposited in the Great Indian Bustard Conservation Breeding Center (Wildlife Institute of India), Pokhran, Rajasthan, India.

Results and Discussion

A total of 24 species of Orthoptera were recorded from different enclosures (Protected) and unprotected agro-pastoral areas. These species belong to five families, 11 subfamilies, represent 20 genera, and four subgenera (Table 1). Notably 12 species were recorded in summer (April & May) while 24 species were observed during monsoon (July & August) and eight species in winter (November & December). These species belong to four major types of habitats, viz., grassland, scrubland, agricultural land, and barren land (Image 3).

The DNP is mainly covered by grassland, and the dominant grass species include *Dactyloctenium aegyptium*, *Dactyloctenium scindicum*, *Aristida*

Image 2. Orthoptera specimen from the Desert National Park and associated areas of Thar landscape. © Anshuman Pati.

Table 1. Orthoptera from Desert National Park during 2021–2023.

Family	Subfamily	Genera	Subgenus	Species	Habitat
Acrididae	Acridinae	*Truxalis*		*Truxalis indica* (Bolívar, 1902)	Grassland, Scrubland
	Calliptaminae	*Acorypha*		*Acorypha glaucopsis* (Walker, 1870)	Grassland
	Cyrtacanthacridinae	*Schistocerca*		*Schistocerca gregaria* (Forskål, 1775)	Agriculture land, Grassland
		Anacridium		*Anacridium rubrispinum* Bey-Bienko, 1948	Grassland, Scrubland
	Eyprepocnemidinae	*Heteracris*		*Heteracris littoralis* (Rambur, 1838)	Scrubland
	Gomphocerinae	*Crucinotacris*		*Crucinotacris decisa* (Walker, 1871)	Grassland
		Leva		*Leva indica* (Bolívar, 1902)	Grassland
		Ochrilidia		*Ochrilidia geniculata* (Bolívar, 1913)	Grassland
				Ochrilidia gracilis (Krauss, 1902)	Grassland
				Ochrilidia hebetata (Uvarov, 1926)	Grassland
	Oedopodinae	*Acrotylus*		*Acrotylus humbertianus* Saussure, 1884	Grassland
				Acrotylus longipes (Charpentier, 1845)	Scrubland, Grassland, Agriculture land
		Oedaleus		*Oedaleus senegalensis* (Krauss, 1877)	Scrubland, Grassland
		Scintharista		*Scintharista notabilis* (Walker, 1870)	Barren land
		Sphingonotus	*Neosphingonotus*	*Sphingonotus* (*Neosphingonotus*) *paradoxus* Bey-Bienko, 1948	Barren land
			Sphingonotus	*Sphingonotus* (*Sphingonotus*) *rubescens* (Walker, 1870)	Barren land
	Catantopinae	*Diabolocatantops*		*Diabolocatantops pinguis* (Stål, 1861)	Scrubland
Pyrgomorphidae	Pyrgomorphinae	*Chrotogonus*	*Chrotogonus*	*Chrotogonus* (*Chrotogonus*) *trachypterus* (Blanchard, 1836)	Barren land
		Poekilocerus		*Poekilocerus pictus* (Fabricius, 1775)	Scrubland
		Pyrgomorpha	*Pyrgomorpha*	*Pyrgomorpha* (*Pyrgomorpha*) *bispinosa* Walker, 1870	Agriculture land
				Pyrgomorpha (*Pyrgomorpha*) *conica* (Olivier, 1791)	Agriculture land
		Tenuitarsus		*Tenuitarsus orientalis* Kevan, 1959	Barren land
Tetrigidae	Tetriginae	*Paratettix* Bolívar, 1887		*Paratettix* sp.	Grassland
Schizodactylidae	Schizodactylinae	*Schizodactylus*		*Schizodactylus monstrosus* (Drury, 1773)	Barren land
Tettigoniidae	Conocephalinae	*Euconocephalus*		*Euconocephalus incertus* (Walker, 1869)	Grassland

depressa, *Cenchrus biflorus*, *Lasiurus sindicus*; apart from these, a few shrub species are present comprising *Aerva pseudotomentosa*, *Crotalaria burhia*, *Dipterygium glaucum*, and *Fagonia cretica* (Charan & Sharma 2016). During the monsoon all the 24 species of Orthoptera were found which can be attributed to the availability of green vegetation compared to other seasons when the vegetation becomes predominantly dry. Acrididae was the most abundant family recorded during the study followed by Pyrgomorphidae, Tettigoniidae, Schizodactylidae, and Tetrigidae. The present study adds to the existing knowledge of the orthopteran fauna of DNP.

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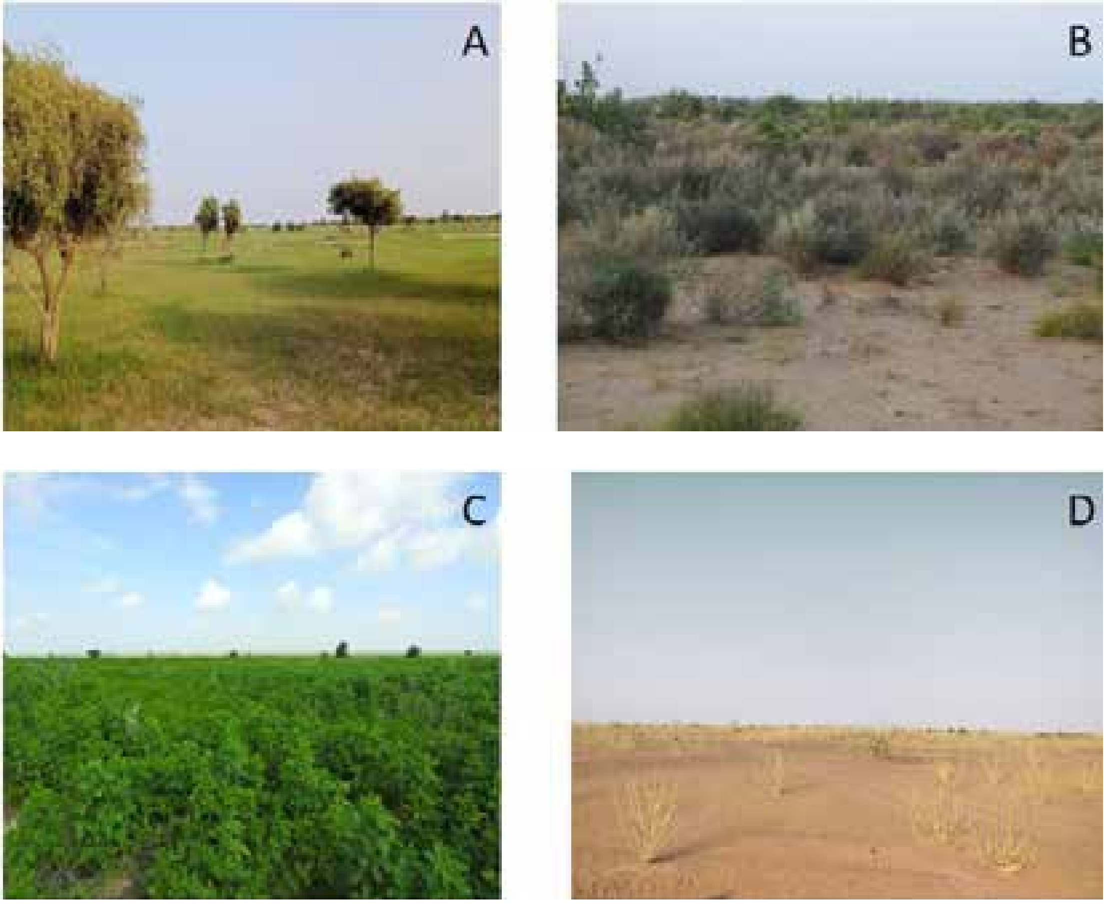

Image 3. Different major habitat of sampling area in Desert National Park: A—Grassland | B—Scrubland | C—Agriculture Land | D—Barren land. © Anshuman Pati

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SHORT COMMUNICATION

Phenology of *Rhododendron wattii* Cowan (Ericales: Ericaceae) - a threatened plant of Nagaland, India

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Abstract: The paper deals with the flowering phenology of *Rhododendron wattii* Cowan (Ericaceae family), a threatened and endemic plant from Nagaland, northeastern India. The study was conducted at Dzukou Valley, Kohima District of Nagaland, on a single tree of *R. wattii* growing at an elevation of 2,600 m with no other tree of the same species in the vicinity. Flowering occurs from the end of February to April, and fruiting is observed from April to December. The flowers present in trusses of 18–25 flowers are pink with darker flecks and purplish basal blotches. They are foraged and pollinated by the Fire-tailed Sunbird *Aethopyga ignicauda* and bumble bees (*Bombus* spp.). The only attractant for the foragers is the nectar secreted in the five nectaries at the base of the corolla tube. Catastrophes like frequent forest fires and anthropogenic activities are responsible for the disappearance of this species.

Keywords: *Aethopyga ignicauda*, *Bombus* spp., Dzukou Valley, endemic, nectaries, northeastern India, Vulnerable.

The genus *Rhododendron*, belonging to the Ericaceae family, is one of the largest, most fascinating genera, with immense horticultural importance for its beautiful flowers and foliage. The genus is popular in Europe, America, Canada, Australia, and New Zealand. It occurs at higher altitudes, having ecological and economic importance in addition to its graceful flowers (Paul et al. 2005). The flowers of Rhododendrons are also considered sacred and offered in temples and monasteries (Mao et al. 2001). They display a wide range of morphological characteristics in their sizes, which range from less than 10 cm high to trees taller than 20 m (Williams et al. 2011).

Rhododendrons play a vital role in ecosystem services as they grow in areas of high rainfall and high humidity on acidic soils, conditions under which few plants would survive. They stabilise slopes in hilly areas and provide the structure of plant communities which support a wealth of biodiversity (Gibbs et al. 2011). According to Mainra et al. (2010), rhododendrons have phenological sensitivity to climate change and play a vital role in the ecological stability of ecosystems and as indicators of forest health. Thus, rhododendrons play important roles in maintaining biodiversity, preserving water & soil, and stabilizing the ecosystem. In the current century, the genetic resources of wild rhododendrons have been damaged severely due to the constant increase in human, social, & economic activities and some species have become highly threatened (Ma et al. 2014). Rhododendrons growing in high altitudes face the impact of disturbances due to various natural and anthropogenic factors (Mao et al. 2010). Natural threats include landslides and forest fires, which affect the rich growth of rhododendrons. Anthropogenic threats include fuel wood collection,

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small-scale extraction of timber, and collection of plants by locals for their graceful and magnificent flowers.

There are over 1,000 species of Rhododendrons worldwide. In India, 132 taxa are recorded, out of which 129 taxa are recorded from northeastern India. Northeastern states support the luxuriant growth of Rhododendrons, including many endemic species (Mao et al. 2017). According to the IUCN Red List, *R. wattii* is 'Vulnerable' due to population fragmentation and area of occupancy less than 500 km^2 (Gibbs et al. 2011).

Rhododendron wattii was first collected by Sir George Watt from Japfu Hill ranges during his survey (1882–1885) of Manipur and Nagaland (Mao et al. 2018). It is endemic to the Indian states of Manipur and Nagaland. It is a small tree attaining a height of 6–7.6 m (20–25 feet). Flowering occurs from March to April, and fruiting from April to December. During a field survey in 2012–2013, a single tree of *R. wattii* was located in Dzukou Valley, Nagaland, reported by Mao & Gogoi (2007) and later the tree was felled by the locals for firewood. Another tree was located in the surrounding hills of Dzukou Valley which is the subject of the present study. No seedlings or saplings were observed in the vicinity during the study period. The quick disappearance of this species from its natural habitat due to anthropogenic activities and natural disasters accompanied by poor regeneration of seedling survivability and recruitment failure could be one of the reasons for population decline and dwindling of *R. wattii*, which made it critically endangered in its natural habitat (Mao et al. 2017). In the present communication, an attempt has been made to highlight flowering phenology to provide valuable information on its conservation.

Materials and Methods

The study was carried out during 2012–2013 on a single tree of *Rhododendron wattii* found growing in its natural habitat at Dzukou Valley, Kohima District, Nagaland situated at 25^{0}33.387 N, 94^{0}04.707 E at an altitude of 2,600 m (Image 1). Regular field trips were conducted during the entire flowering period (February–April) to study the flowering phenology, the timing of the onset and termination of flowering, and the development of the ovary, fruit, and seed. The different floral visitors were observed and recorded during the study period. The foraging behaviour of the floral visitors were observed at different hours of the day. Field photographs and videos were taken using the Canon digital still camera with 8MP resolution. The species *R. wattii* was identified and

Image 1. The study area in Kohima District, Nagaland.

Image 2. *Rhododendron wattii* Cowan: A—Landscape view of the study site | B—Inflorescence in truss | C—Habit of the plant. © Imtilila Jing.

Table 1. Phenology of *Rhododendron wattii*.

Parameters	**Observations (2012–2013)**
Leaf fall	Evergreen
Leaf renewal	Throughout the year
Flowering period i. Minimum ii. Maximum iii. Decline	 Last week of February The second week of March The first week of April
Initiation of fruits	April
Fruit maturation	December
Seed dispersal	January
Mode of seed dispersal	Wind

authenticated by consulting the Herbarium, Botanical Survey of India (BSI), ERC, Shillong, Meghalaya.

Results and Discussion

The observed *Rhododendron wattii* is a small tree of about 6–7.6 m in height (Image 2). The inflorescence is a terminal truss (Image 2); hypogynous and nectar pouches are present at the base of the corolla tube. The corolla has blotches or spots of darker colour, which is a typical feature of rhododendron flowers, and acts as a nectar guide. Leaves are obovate to oblong, apex rounded, apiculate, base rounded, glabrous above, with a sparse whitish felted indumentum beneath. The inflorescence bears 18–25 flowers per truss. The flowers are tubular-campanulate, corolla 6-lobed, pink with darker flecks and purplish basal patches. The stamens are 12 in number and unequal, anther lobes brown and dorsifixed and dehisce by apical pores. The ovary is densely pilose with brownish indumentum. The pollen grains remain in permanent clusters of four to form tetrads, which are

Image 3. *Rhododendron wattii* Cowan: A–D Floral visitors: A— Fire-tailed Sunbird *Aethopyga ignicauda* (male) | B—*Aethopyga ignicauda* (female) | C&D—Bumble bees (*Bombus* spp.) with pollens on their body | E&F—Young fruits | G&H—Old dehisced fruit capsules. © Imtilila Jing.

held together by viscin threads. The viscin threads play an important role in pollen removal from the anthers and its adhesion to pollinators for accurate pollen delivery to the stigma, increasing pollination efficiency (Hesse et al. 2000). The fruit is a capsule that is oblong, grooved, and dehisce from the top by longitudinal slits (Image 3). The seeds are fusiform and winged, which retain viability for about one year when stored at normal temperature and humidity (Williams et al. 2011). No seedlings were observed in its natural habitat.

Rhododendron wattii is an evergreen plant, and leaf renewal occurs throughout the year (Table 1). It was observed that the same branch did not bear flowers consecutively for two years. The fruits dehisce when still attached to the branch (Image 3). The plant grows on rocky hill slopes with other *Rhododendron* species *R. macabeanum*, and dwarf bamboo, mosses, and ferns. The flowers bloom in the last week of February, while peak flowering is observed in the second week of March and declines by the first week of April. Fruit initiation begins in April and matures by the month of December (Table 1). Fruit is a capsule dehiscing laterally, producing

Table 2. Visitor census in *Rhododendron wattii*.

Order	Family	Scientific name	Common name	Forage type		Duration of foraging per flower (in seconds)	Visiting hours
				Nectar	Pollen		
Passeriformes	Nectariniidae	*Aethopyga ignicauda*	Fire-tailed Sunbird	+	–	1–2	0900–1600 h
Hymenoptera	Apidae	*Bombus* spp.	Bumble bees	+	–	1–7	1200–1600 h

numerous seeds that are dispersed by wind. The onset of nectar secretion was observed already at the opening bud stage. The same observation has been made by Chwil & Chmielewska (2009).

The most dominant visitors to *R. wattii* were the passerine Fire-tailed Sunbird *Aethopyga ignicauda* (Image 3) followed by bumble bees *Bombus* spp. (Images 3). The duration of foraging by the Sunbird lasted for 1–2 seconds per flower and 1–7 seconds per flower in the case of bumble bees. Nectar and pollen grains are the main attractants for the floral visitors (Table 2). The nectars are secreted by the nectaries present at the base of the corolla tube. The pollen grains were found attached on the ventral surface of birds' necks during the foraging, whereas in *Bombus* spp. they were found on both the dorsal and ventral surfaces of the body. The pollen tetrads are present in lumps and bound with viscin threads to increase pollination efficiency, which is the characteristic feature of the family Ericaceae.

Conclusion

The main pollinators of *R. wattii* are Fire-tailed Sunbirds *Aethopyga ignicauda* and bumble bees (*Bombus* spp.), which forage for nectar and carry pollen. Natural regeneration of the plant species was found to be very low though the plants produce numerous seeds. Pornon & Doche (1995) have also reported that seedling recruitment is poor in many rhododendrons. For successful seedling establishment, the seeds require favourable microsites (Cross 1981; Plocher & Carvell 1987; Kohyama & Grubb 1994). Poor seedling survivability and recruitment failure may be another reason why the population of *R. wattii* is dwindling, making it highly threatened in its natural habitat, besides natural calamities and anthropogenic factors (Mao & Gogoi 2012; Mao et al. 2018). Thus, there is an urgent need to conserve this species by protecting its natural habitat.

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SHORT COMMUNICATION

Phalaenopsis wilsonii: a new addition to the orchid flora of Manipur, India

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Abstract: *Phalaenopsis* is a well-known Orchidaceae genus with significant ornamental value. There are eight *Phalaenopsis* species already reported in Manipur (India), with inclusion of *Phalaenopsis wilsonii* Rolfe as a new addition for the state, the species richness rises to nine. The species was found blooming during an orchid survey at Mao, Senapati District of Manipur. Description of the plant with detailed coloured images and distribution is presented.

Keywords: Biodiversity, conservation, Epiphytic, identification, Mao, morphology, new distribution report, northeastern India, Orchidaceae, taxonomy.

The genus *Phalaenopsis* Blume is represented by 80 accepted species globally (POWO 2024) of which 18 species are known from India (Gogoi et al. 2012b; Rao & Kumar 2018; BSI ENVIS 2020; Gogoi & Rinya 2020). In Manipur, eight species of *Phalaenopsis* have previously been documented, viz., *P. cornucervi* (Breda) Blume & Rchb.f., *P. fasciata* Rchb.f., *P. marriottiana* (Rchb.f.) Kocyan & Schuit., *P. mannii* Rchb.f., *P. parishii* Rchb.f., *P. pulcherrima* (Lindl.) J.J.Sm., *P. taenialis* (Lindl.) Christenson & Pradhan and *P. yingjiangensis* (Z.H.Tsi) Kocyan & Schuit. (ENVIS Hub Manipur 2015; Rao & Kumar 2018). This communication reports the addition of *Phalaenopsis wilsonii* Rolfe as a new record to the flora of Manipur. These species has been reported earlier from China, Myanmar, Nagaland of India, Tibet, and Vietnam (Tsai 2011; Kamba & Deb 2021; POWO 2024).

Field surveys were carried out in Chakumei Village, Mao, Senapati District, as one of the sites chosen for an orchid collection programme for conservation purposes. The GARMIN eTrex 20X GPS device was used to pinpoint the location (Image 1). The flower was in bloom, making it easier to confirm the specimen's identity through consultation with the protologue and other relevant literature (Christenson 2001; Kamba & Deb 2021; Chen & Wood 2009). Identification was substantiated with the type specimen available at K and Natural History Museum's data portal. One living specimen was brought to the Institute of Bioresources and Sustainable Development (IBSD) net-house for cultivation. Since a single living specimen was found, herbarium preparation will be performed following further propagation. The descriptions of the plant are presented along with a photographic illustration in Image 2 and prepared here in details.

Taxonomic treatment

***Phalaenopsis wilsonii* Rolfe, Bull. Misc. Inform. Kew 1909: 65 (1909)**

Polychilos wilsonii (Rolfe) Shim, Malayan Nat. J. 36: 27 (1982); *Kingidium wilsonii* (Rolfe) O. Gruss & Roellke, Orchidee (Hamburg) 47: 149 (1996).

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Type: China. Western China, Cliffs at 1,200 m. alt., without precise location, 07-1902, Ernest Henry Wilson 4576 (Holotype: K [K000891370 digital image!]; Isotype: BM [BM000534956 digital image!]).

Phalaenopsis minor F.Y. Liu, Acta Bot. Yunnan. 10: 119 (1988).

Type: Yunnan. Malipo, 1,500 m. alt., on tree, 04.iv.1981, S. Q. Bao 81001 (Typus KUN).

Phalaenopsis chuxiongensis F.Y. Liu, Acta Bot. Yunnan. 18: 411 (1996).

Type: Yunnan. Chuxiong, 1,990 m. alt., on the tree, 01.iv.1992, F. Y. Liu (Holotype KUN). *Doritis wilsonii* (Rolfe) T. Yukawa & K. Kita, Acta Phytotax. Geobot. 56 (2): 157 (2005).

Phalaenopsis wilsonii f. *azurea* Z.J. Liu & Z.Z. Ru, Orchidee (Hamburg) 57: 318 (2006).

Type: China. Sichuan. Wenchuan County, 1,800 m. alt., 04.i.2004, Z. J. Liu 2838.

Epiphytic monopodial herb with fleshy dark green, well-developed roots, flattened and unbranched, the surface appears to be rough with warty structures. Fasciculate roots arise from the base of the stem in clusters. The base of the stem appears to be dark purplish-green. Stem is short, about 1 cm and the leaf arises from the apex of the stem and bears a single green leaf. Leaf oblong-elliptic with symmetric acute apex, 7.5 cm, near the base at the time of collection. Leaves are deciduous, leathery, and fleshy with parallel venation, surface of the leaf bears purplish pigmented spots, more intense vertically at midrib and towards the base of the leaf. Pigmentations were more prominent in younger leaves. Pedicellate raceme inflorescence with simple erect peduncle, 25 cm long, and short pedicels, 3 ± 0.5 cm. Ovate and triangular bract, which is 0.4 cm. Only one

Image 1. Field survey site map and natural habitat of *Phalaenopsis wilsonii*.

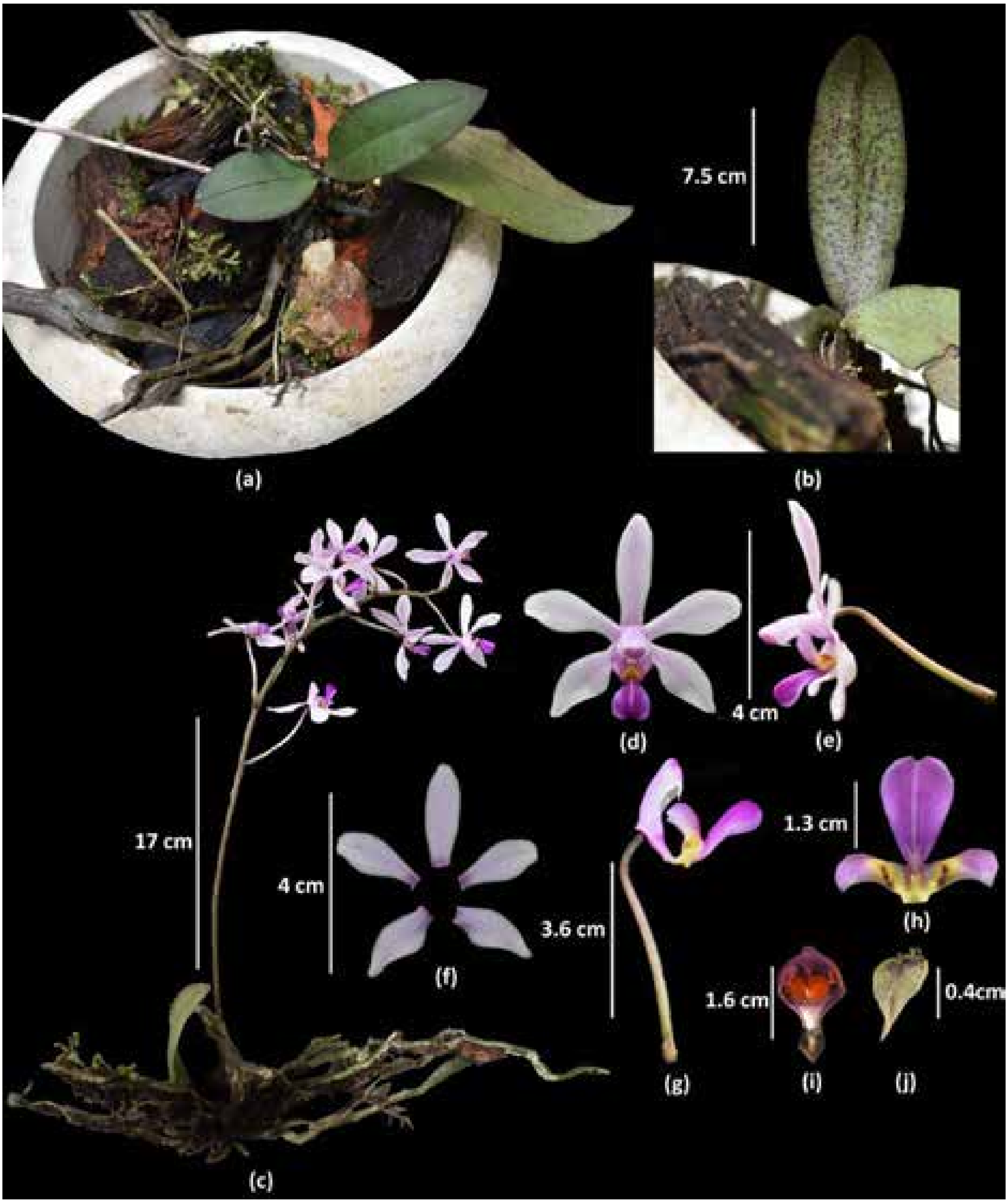

Image 2. Anatomized image of *Phalaenopsis wilsonii*: a—Collected sample grown in IBSD's nethouse | b—Young leaves with pigmentation | c—Plant with inflorescence | d—Ventral view of inflorescence | e— Lateral view of inflorescence | f—Petals and sepals | g—Pedicel with column and trilobed lip | h—Ventral view of trilobed lip-two lateral lobes and a midlobe | i—Pollina with anther cap | j—Bracts. © T.N. Khanganba.

unbranched arching inflorescence axis present bearing eleven flowers, white-purple ombre linearly more intense in the middle, widely open, petals and sepals are 0.3–0.5 cm spaced apart. Dorsal sepal narrowly oblong-elliptic, cuneate, acute, 1.7 cm x 0.5 cm; lateral sepals, obovate with acute apex, 1.6 cm x 0.5 cm; petals, elongated obovate with obtuse apex, 1.5 cm x 0.6 cm; lip base with a claw, trilobed lip, 1.3 cm, purplish pink, mid lobe oblong-obovate, 0.9 cm x 0.5 cm, fleshy, notched at apex, posterior raised median, adaxially bearing raised bilateral keel and two erect lateral lobes, 0.6 cm, falcate with obtuse apex, yellowish at the base, relatively smaller than mid lobe. Column, purplish white, 0.6 cm x 0.4 cm, erect, extended pedicellate ovary. Pollinia, 0.4 cm x 0.2 cm, two asymmetric pairs, covered with a 0.3 cm wide, anther cap.

Flowering: April to June.

Fruiting: May to July.

Ecology and Habitat: Solitary specimen found in the mixed deciduous sub-tropical forest of Chakumei, Mao, Senapati district at asl 1,648 m. Epiphytic on a tree branch of *Quercus* spp., covered by moss and liverworts. No observation of lithophytic growth was made but, the occurrence was reported in China (Chen & Wood 2009).

Specimens examined: India, Manipur, Senapati, Mao, Chakumei, 25.458 ^{0}N, 94.129 ^{0}E, 1,648 m, 18.v.2022 (Image 1).

Distribution: Native to India, southcentral China, southeastern China, Hainan, Myanmar, Tibet, Vietnam (POWO 2024), and Nagaland (Kamba & Deb 2021).

Conclusions

Phalaenopsis wilsonii was previously thought to be distributed only in China, Myanmar, Tibet, and Vietnam, but it has now been discovered to be growing in the Indian states of Manipur and Nagaland (Kamba & Deb 2021; POWO 2024). *Phalaenopsis wilsonii* shows resemblance with *Phalaenopsis braceana* and *Phalaenopsis taenialis* but comparative assessment shows slight morphological differences. The length of the inflorescence stalk in *P. wilsonii* is longer, bearing a higher number of flowers (10–15) as compared to *P. braceana* (4–6) and *P. taenialis* (6–8). Flower size appears larger in *P. wilsonii* (4–5 cm) as compared to *P. braceana* (2.5 cm) and *P. taenialis* (2 cm). Prominent spur is present at the junction of the labellum midlobe and sidelobes in *P. braceana* and *P. taenialis* while spur is neglible to a small nipple-shaped structure in *P. wilsonii*. The labellum midlobe of *P. taenialis* is flat, convex in *P. braceana,* while in *P. wilsonii* labellum midlobe is obtuse with a central apical fleshy knob (Christenson 2001; Gogoi et al. 2012a; Imchen et al. 2015; Qin et al. 2024). This unique moth-like orchid has high ornamental values and is an economical asset to the floriculture market. In terms of phytochemistry, the genus reports the presence of the alkaloid phalaenopsine (Teoh 2016) and pyrrolizidine (Anke et al. 2008), both of which play important roles in plant defence mechanisms. Teoh (2016) also described using the entire plant of *P. wilsonii* to treat headaches, common colds, and indigestions in children.

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NOTE

Confirmation of the presence of Red Pierrot *Talicada nyseus nyseus* (Lepidoptera: Lycaenidae) in Assam, India

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Assam, the second largest state in northeastern India, situated south of the eastern Himalaya along the Brahmaputra and Barak River valleys is a biological hotspot with many rare and endemic plant and animal species (Barooah & Sarma 2016). Guwahati, the largest metropolis in northeastern India and a part of the ecologically significant Indo-Burma global biodiversity hotspot is home to eight reserve forests (RF) (south Kalapahar RF, Fatasil RF, Jalukbari RF, Gotanagar RF, Hengrabari RF, Sarnai Hill RF, Garbhanga RF, and Rani RF) and two wildlife sanctuaries (WS) (Deepor beel WS and Amchang WS) (Bohra & Purkayastha 2021).

The monotypic genus *Talicada* Moore, 1881 (Type species: *Polyommatus nyseus* Guérin-Méneville) and its sole species, *Talicada nyseus* (Guérin-Méneville 1843) is a small lycaenid butterfly with distinctive white, black, and orange wing colouration. *Talicada nyseus* currently includes nine recognised subspecies, four of which are found in India: *T. n. nyseus* in southern India (Kunte 2000), *T. n. khasiana* in Khasi Hills (Evans 1925), *T. n. assamica* in Assam (Seitz 1927) and *T. n. delhiensis* in northern India (Kumar et al 2009; Lo et al. 2017). In India, the nominotypical subspecies *T. n. nyseus* (Figure 1) is known from Maharashtra to Kerala (Skaria et al. 1997), Delhi (Smetacek 2009), Himachal Pradesh (Mahendroo & Smetacek 2011), Uttarakhand and Uttar Pradesh (Varshney & Smetacek 2015), Manipur (Irungbam et al. 2020), Chhattisgarh (Singh et al. 2023), and Arunachal Pradesh (Upadhaya et al. 2024). In recent years, the reports of *T. n. nyseus* in the lower western Himalaya and northeastern India suggest its range expansion which could be an indicator of the changing environment (Singh 2005).

Observation: *Talicada nyseus nyseus* is a butterfly commonly encountered in Guwahati. Despite its widespread presence, the literature review indicates that there are no records of this subspecies from the state. Therefore, the present study provides the first record of this butterfly subspecies from the state based on the sightings in several places in Guwahati City (Table 1, Image 1).

The present record in Assam and neighbouring states Manipur (Irungbam et al. 2020) and, Arunachal Pradesh (Upadhaya et al. 2024) indicates its distribution

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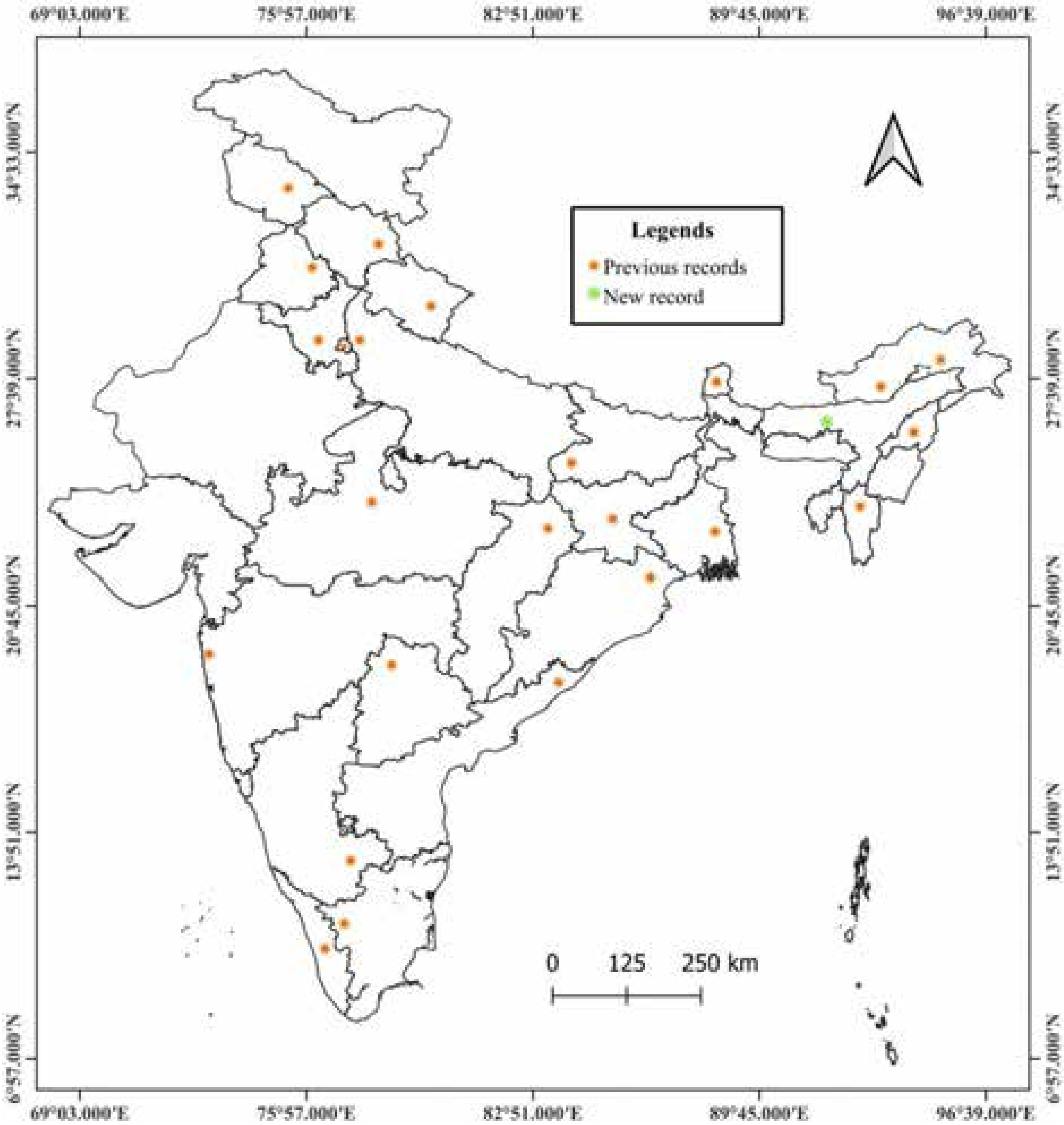

Figure 1. Records of *Talicada nyseus nyseus* from India.

expansion to northeastern India. Such range expansion of insects is often associated with climate change, globalisation, or anthropogenic activities (Lopez-Vaamonde et al. 2010; Pureswaran et al. 2018; de Boer & Harvey 2020). Leaf damage and the presence of eggs and pupae (Image 2) were also observed on the Cotton University campus on 6 June 2023 (26.187°N, 91.749°E) on the Kalanchoe plant. The egg was laid at the base of a leaf, while pupation was noted on less-damaged leaves, likely as a strategy to avoid predators. On campus, the host plants are found on both the ground floor and the first-floor balcony. Despite this distribution, butterflies predominantly selected ground-level host plants for oviposition. These butterflies were commonly observed in gardens near the host plant Kalanchoe, as well as nectaring plants such as *Melampodium* spp. and *Emilia sonchifolia* (L.).

Description: To aid in identification, two adults

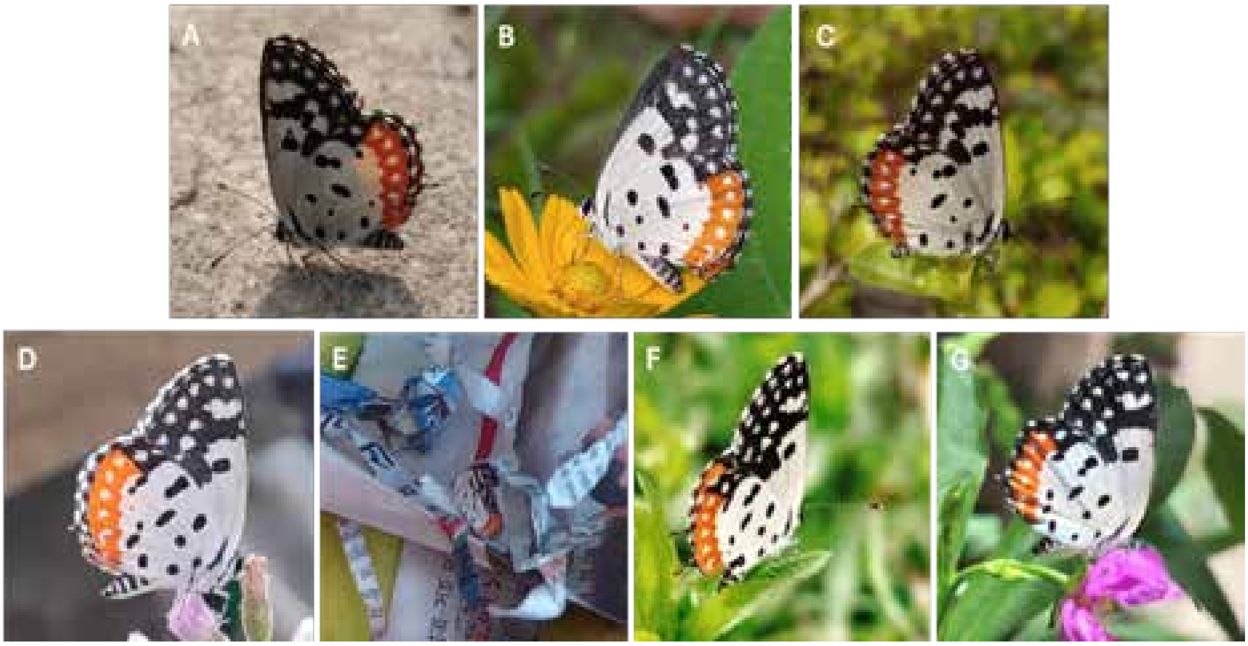

Image 1. Photographic evidence of *Talicada nyseus nyseus*: A–C—in Cotton University Campus | D—Geeta Nagar, Zoo Road | E—Ganeshguri market | F—Lankeshwar Temple | G—Gauhati University Campus, Guwahati, Assam. © Renu Gogoi & Bijay Basfore.

Image 2. A—Host plant *Kalanchoe* | B—Single egg at the base of the leaf | C—Pupa of *Talicada nyseus nyseus*. © Renu Gogoi.

Table 1. The sighting records of the *Talicada nyseus nyseus* in the Guwahati city area.

	Sighting locality	GPS co-ordinates	Date of sighting
1	Cotton University Campus	26.186°N, 91.749°E	02.ii.2023
2	Cotton University Campus	26.186°N, 91.749°E	03.ii.2023
3	Cotton University Campus	26.186°N, 91.749°E	30.v.2023
4	Zoo Road	26.175°N, 91.802°E	17.iii.2023
5	Ganeshguri Market	26.149°N, 91.785°E	04.vi.2023
6	Lankeshwar Temple	26.144°N, 91.647°E	26.v.2024
7	Gauhati University Campus	26.152°N, 91.655°E	23.vi.2024

were collected from the Cotton University campus and brought to the laboratory for taxonomic analysis. Head and eyes dark, antennae clubbed, black with white bands. The wingspan measured 3.8 cm, with the thorax and abdomen dorsally black, and ventrally white with lustrous hair. The underside of both wings is white with a prominent series of white spots at the end of each vein. Hindwing with a black basal spot; three sub-basal, three medial; wing tail is black, tipped with white lunules. Forewing with a broad black outer band, intersected by two submarginal series of white spots and a marginal lunular line: a black spot at the end of the cell. The upperside of both wings is blackish-brown except hindwing which displays a broad orange outer

Image 3. *Talicada nyseus nyseus*: A—Dorsal view | B—Ventral View. © Renu Gogoi.

band (Image 3).

The four sub-species reported from India can be distinguished based on the band and the spot pattern present on the wings.

Forewings: The underside of the forewings of *T. n. nyseus* and *T. n. delhiensis* have a broad black distal band that almost merges with the marginal band whereas in *T. n. khasiana* distal black band is narrow and in *T. n. assamica,* it is narrower than *khasiana* and this band is not merging with the marginal band in the latter two sub-species (Evans 1925; Seitz 1927; Kehimkar 2016). The gap between the marginal band and the distal band is wide in the case of *T. n. assamica* but narrow in the case of *T. n. khasiana.* The white spots in the discal region of the distal band form a clear broad chain in *T. n. assamica* (Seitz 1927) but in *T. n. khasiana* this chain of white spots is narrow and in *T. n. nyseus* and *T. n. delhiensis* the white spots do not form a continuous chain.

Hindwings: *T. n. nyseus* and *T. n. delhiensis* have a broad orange patch on the upperside of the hindwing whereas the same region is comparatively narrow in *T. n. assamica* and, *T. n. khasiana* (Evans 1925; Seitz 1927; Kehimkar 2016; Kumar et al. 2009). On the underside of the hindwings of *T. n. nyseus* and *T. n. delhiensis,* a few scattered black spots are present near the discal and basal region while in *T. n. assamica* and *T. n. khasiana* the number of spots is many. These spots are much larger in *T. n. khasiana* but small in *T. n. assamica*. The orange band in the margin on the underside is broader in *T. n. khasiana* than in the rest of the three subspecies where the band width appears almost the same. This orange band is almost continuous with the black marginal line in *T. n. nyseus, T. n. delhiensis,* and *T. n. khasiana* but there is a clear gap between the marginal line with that of the orange band in *T. n. assamica*.

These characters can be used to easily distinguish between *T. n. nyseus* and *T. n. delhiensis* from that of *T. n. assamica* and *T. n. khasiana* but no sufficient literature support exists to differentiate between *T. n. nyseus* and *T. n. delhiensis* except for the size differences. The wingspan of *T. n. nyseus*, *T. n. delhiensis*, and *T. n. khasiana* are reported to be 3.0 cm, 3.26 cm, and 3.0 cm, respectively (Kumar et al. 2009). It is seen that the *T. n. nyseus* of Assam are larger (3.8 cm) than the ones reported by Kumar et al. (2009) and slightly larger than the range of 3.0–3.6 cm suggested by Kehimkar (2016).

Conclusion: The earlier records of the butterflies from Assam (Gogoi 2013; Bhuyan et al. 2014; Deb et al. 2015; Modak et al. 2018; Bishaya et al. 2021; Bohra & Purkayastha 2021; Gogoi et al. 2023; Mahananda et al. 2023) do not have records of *T. n. nyseus*. The present records from Guwahati City, confirm the presence of this subspecies in Assam and its range expansion towards the eastern part of India.

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NOTE

A note on *Pterospermum obtusifolium* Wight ex Mast. (Malvaceae), a rare endemic evergreen tree of southern Western Ghats, India

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The genus *Pterospermum* Schreb. belonging to Malvaceae sensu lato family (formerly Sterculiaceae) comprises of 52 accepted and 25 unresolved species (POWO 2024). In India, it is represented by 11 species (Chandra 1993) of which eight species are distributed in southern India: *P. reticulatum* Wight & Arn., *P. obtusifolium* Wight ex Mast., *P. heyneanum* Wall. ex Wight & Arn., *P. diversifolium* Blume, *P. rubiginosum* Heyne, *P. suberifolium* (L.) Lam., *P. acerifolium* (L.) Willd. (Gamble & Fischer 1935), and *P. xylocarpum* (Gaertn.) Santapau & Wagh (Narasimhan & Sheeba 2021). Among them, *P. obtusifolium* Wight ex Mast., and *P. rubiginosum* Heyne are endemic to the southern Western Ghats, and are found growing in the evergreen forests (Gamble & Fischer 1935), the former is rare (Britto 2019) while the latter is common (Rao et al. 2019).

Pterospermum obtusifolium Wight ex Mast. is a tree, grows primarily in the wet tropical biome and its native range is southwestern India (WFO 2024). It was first collected by Robert Wight in 1838 from Courtallum (then Tirunelveli District), Tamil Nadu, and published in 1840 in 'Illustrations of Indian Botany'. Later, although, it has been reported from Karnataka, Kerala, and Tamil Nadu (Sasidharan 2011; Singh et al. 2015; Britto 2019; Rao et al. 2019), no new herbarium collections including fresh specimens images are available. Only six herbarium specimens of Robert Wight are available but none of them were found in Indian Herbaria, of which Wight 227 is well preserved at Kew [K000671799] and hence it was designated as lectotype and remaining as syntypes by Rekha et al. (2020) recently. During our revisionary work on *Pterospermum* species of peninsular India, the species was collected from its type locality in the year 2023.

Pterospermum obtusifolium Wight ex Mast. (Image 1) was collected from two locations (Chitaruvi and near Shri Shenbaga Devi Temple) in Courtallum, Sengottai Forest Division, Tenkasi District of Tamil Nadu and identified with the help of local flora, BSI publications, and consulting Virtual Herbarium, Kew. Required taxonomic characters including flowering and fruiting phenology were recorded for detailed botanical description and herbaria prepared. Data were also gathered from the literature for analysis. Ahmedullah & Nayar (1987) have reported that it is endemic to southern Western Ghats in Travancore, Tirunelveli, Coimbatore, Ramanathapuram and Tiruchirappalli. Based on this information, later workers like Rao et al. (2019), Britto (2019), and Narasimhan & Sheeba (2021) have documented only these areas for distribution of this species in their compilation works, without specifying exact collection localities. Similarly, Sasidharan (2011) too documented it

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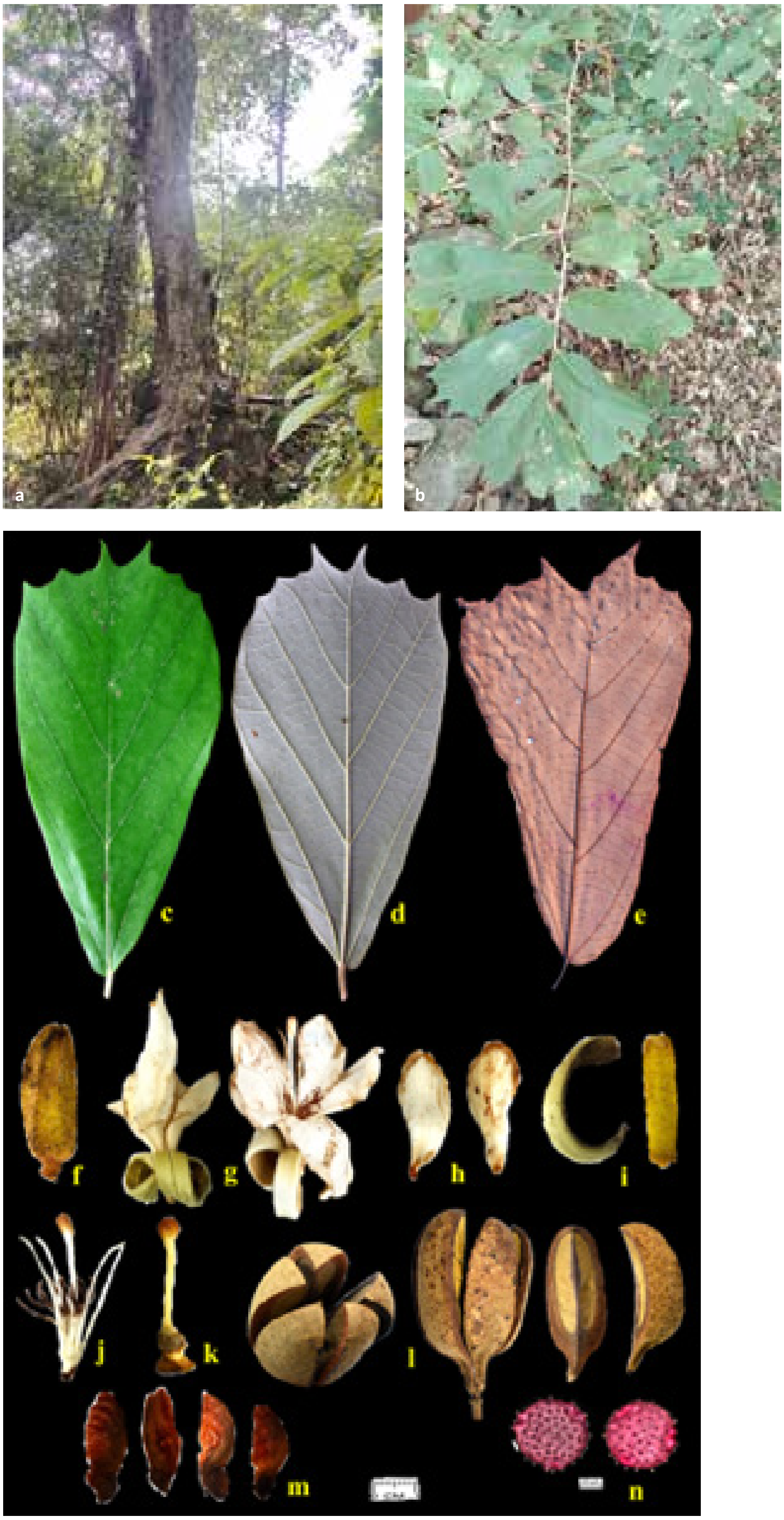

Image 1. *Pterospermum obtusifolium* Wight ex Mast.: A—Habit | b—A twig | c—Leaves upper surface | d—Leaves lower surface | e—Dried leaf showing venation | f—Flower bud | g—Flowers | h—Petals | i—Sepals | j—Androecium | k—Gynoecium | l—Fruits | m—Seeds | n—Pollens. © Narayanan & Abdul Kader.

for 'Flowering Plants of Kerala' without specifying exact collection localities. Therefore, it seems that none of them have collected this species again from these areas. Recently, Rekha et al. (2020) have lectotypified it using Wight's collections deposited at KEW. The prepared herbarium sheets (PCM KN09 dated 07.iv.2023) were deposited in Madras Presidency College (PCM), Madras Herbarium (MH) at BSI Coimbatore, and Fischer's Herbarium (FRC) at IFGTB Coimbatore.

Botanical description

Habit: a large evergreen tree (Figure 1), attaining more than c. 2.13 m GBH. Leaves: simple, alternate, petiolate (petiole 5–15 mm long), three-nerved at base, oblique, cuneate-obovate to cuneate-oblong, margin entire, base cuneate, either very broadly truncated at tip, somewhat obcordate, or irregularly two-lobed at tip, lobes coarsely toothed, upper surface green and glabrous (Image 1), lower surface glaucous pubescence (Figure 1), 5.9–17 cm × 3.1–8.2 cm, lateral veins 5–6 pairs (usually five pairs), prominent, distant (Image 1). Inflorescence: axillary cyme. Flowers: flower bud, oblong-angular, shortly-pedicellate, pedicel 4 mm long; medium-sized, white, fragrant, 4.0–4.5 cm across (Image 1). Calyx: sepals five, green, free, recurved, linear with round tip, 1 mm thick, stellate-tomentose, longer than the petals, 3.7 × 0.4–4.5 × 0.7 cm in size (Image 1). Petals: white, oblanceolate, thin, densely stellate-pubescent outside, 2.7 × 1.0–3.4 × 1.3 cm in size (Image 1). Androecium: staminodes five, 2.3 cm long, white; stamens 15, arranged in bundles of three each in between staminodes, filament white, short, 9 mm long; anthers 7 mm long (Image 1). Gynoecium: pistil white, ovary pentacarpellary, 5 × 4 mm in size; style 2 cm long, stigma 5 mm long (Image 1). Fruit: a woody dehiscent capsule, medium-sized, stalked, stalk 2–2.2 cm long, oblong, 6–6.5 cm × 2.8–3.5 cm, surface rough and tubercled, tip obtuse, 4–5-seeded (Image 1). Seed: brown, 5–13 mm long; wing brown, knife-shaped, tip round or acute, 1.5–3.1 cm × 5–11 mm (Image 1).

Flowering: March–April.

Fruiting: April–May.

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