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Journal of Threatened Taxa

Open Access

10.11609/jott.2024.16.1.24451-24614
www.threatenedtaxa.org

26 January 2024 (Online & Print)
16(1): 24451–24614
ISSN 0974-7907 (Online)
ISSN 0974-7893 (Print)

ISSN 0974-7907 (Online); ISSN 0974-7893 (Print)

Publisher
Wildlife Information Liaison Development Society
www.wild.zooreach.org

Host
Zoo Outreach Organisation
www.zooreach.org

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Cover: Green Sea Turtle *Chelonia mydas* watercolour by Elakshi Mahika Molur.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 January 2024 | 16(1): 24451–24462

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

https://doi.org/10.11609/jott.8164.16.1.24451-24462

#8164 | Received 28 August 2022 | Final received 30 September 2023 | Finally accepted 18 December 2023

OPEN ACCESS

ARTICLE

Use of remote sensing and GIS in assessing the impact of *Prosopis juliflora* proliferation on land use, land cover and diversity of native flora at Point Calimere Wildlife Sanctuary, India

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Abstract: It is crucial to accurately quantify land use and land cover (LULC) within a protected area to understand the implications of habitat changes on biodiversity. Today's remote sensing and GIS technologies greatly facilitate analysis of LULC, especially with regards to tracing changes over space and time. This study uses remote sensing and GIS to examine the impact of climate, herbivore, and anthropogenic pressures including invasive Mesquite *Prosopis juliflora* on native plant communities at Point Calimere Wildlife Sanctuary. Classification of satellite images revealed that dry evergreen, mudflat, and water bodies had transformed into open scrub from 1995 to 2018 and the shift in LULC is detected with optimal accuracy (85%). Changes in LULC are largely attributable to a rise in open scrub caused by the growth in *P. juliflora* from 3 to 6 km^2 since 1995. GLM-based regression to examine the influence of climate, herbivores, and anthropogenic pressure including *P. juliflora* on native flora show native tree density, shrub density, shrub diversity, herb, and grass cover decreasing with *P. juliflora* cover or density. These findings imply that as the *P. juliflora* spreads the native plant diversity and density at Point Calimere Wildlife Sanctuary will continue to decline. *P. juliflora* is being eradicated in phases through management efforts, however, here we recommend a coordinated effort to curb further expansion in order to reverse ecological decline.

Keywords: Alien invasive species, diminishing grasslands, LULC accuracy and changes, NDVI, reduced native plant communities, mesquite impact.

Editor: C.P. Singh, Space Applications Centre, ISRO, Ahmedabad, India.

Date of publication: 26 January 2024 (online & print)

Citation: Gupta, S., S. Arandhara, S. Sathishkumar & N. Baskaran (2024). Use of remote sensing and GIS in assessing the impact of *Prosopis juliflora* proliferation on land use, land cover and diversity of native flora at Point Calimere Wildlife Sanctuary, India. *Journal of Threatened Taxa* 16(1): 24451–24462. https://doi.org/10.11609/jott.8164.16.1.24451–24462

Funding: The project was funded by the Science and Engineering Research Board [SERB], Department of Science and Technology, New Delhi, Government of India, [Grant File. No. EMR/2016/001536].

Competing interests: The authors declare no competing interests.

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Author contributions: SG—data collection, analyses, and draft preparation. SA—data collection, analyses, and draft preparation. SS—data collection and draft preparation. NB—conceptualizing, supervising and final draft preparation.

Acknowledgements: We would like to acknowledge the Department of Science and Technology, Government of India, for funding [Grant File. No.EMR/2016/001536] this study under the SERB Extramural Research Category. We express our sincere thanks to the Tamil Nadu Forest Department, especially its former Chief Wildlife Warden, Mr. P.C. Thyagi, I.F.S., Mr. S.K. Srivatsava, I.F.S., and the Wildlife Wardens Point Calimere, Nagapattinam, for granting permission [Ref. No. WL(A)/21321/2017, Permit No44/2017] to conduct the study and support it. We are also thankful to the management and the Principal of A.V.C. College for their constant support of this project.

Introduction

To meet global conservation goals, protected areas must preserve native features. Human-induced land use, including the introduction of alien invasive is triggering significant changes in tropical forests, leading to a drastic decline in wildlife and the local extinction of native species (Felker 2003). It's important to periodically assess a protected area's environmental preservation and identify barriers to success. Alien species invasions can change ecosystem functions and community structure among other negative effects (Vitousek 1990; Myers & Bazely 2003; Simberloff et al. 2013). Understanding the factors that control invasions is essential for describing the spread of invasive species and predicting their spread into new areas based on land-use patterns, vegetation, soil, and animal interactions (Wiens 1989; Richardson & Bond 1991; Hulme 2003; Rouget et al. 2004). Many exotic plant introductions were deliberate for habitat improvement, ornamental purposes, wood or fiber production, soil conservation, livestock forage production, or other crop uses (Harrod 2001). Invasive exotics are hard to control due to their aggressive expansion. The management of their growth, including an adaptation of alien species to non-native ecological niches is poorly understood (Dellinger et al. 2016).

Prosopis juliflora (Mesquite) is a Central and South American shrub. According to the global invasive database (http://www.iucngisd.org/gisd), it is one of the most invasive tropic species. Many countries introduced it to provide local communities with fodder and wood (Gallaher & Merlin 2010). Subsequently, unprecedented natural seed dispersal by livestock, wildlife, and water led to its spread (Mwangi & Swallow 2008; Mworia et al. 2011; Muturi et al. 2013). It now dominates many plant communities and is considered a weed. It is highly aggressive and coppices so well that it crowds out native vegetation (Tiwari 1999; Al-Rawai 2004). Invasion factors include land use change, deforestation, and climate change (Pasiecznik et al. 2001).

This fast-growing leguminous species was introduced in 1940–1960 at Point Calimere Wildlife Sanctuary. It has since invaded many habitats, becoming dominant at the sanctuary (Ali 2005; Arasumani et al. 2019; Krishna et al. 2019; Baskaran et al. 2020; Murugan et al. 2020). This has had a negative impact on the sanctuary and will continue to have an adverse effect on the native flora and fauna by reducing open grasslands and creating physical barriers that prevent animals, especially large herbivores, from moving about freely (Ali 2005; Baskaran et al. 2016; Murugan et al. 2020).

Research on the effects of exotic species on LULC suggests that *P. juliflora* is expanding its territory into Kenya, displacing native plant life in the process (Muturi et al. 2013). According to one study, the amount of coastal grassland habitats has decreased as the amount of land dominated by *P. juliflora* has increased at Point Calimere (Ali 2005). A recent experimental study in the same area suggests the removal of some of the *P. juliflora* to increase native ground cover and diversity indices, especially for grasses. This is because the invasive species alters ecosystem processes by influencing the dynamics of soil organic carbon and nutrients (Murugan et al. 2020).

There is a significant information gap concerning the impact of *P. juliflora* on the temporal change in LULC and native floral composition. By utilising field surveys, remotely sensed satellite imagery, and GIS-based applications, our goals were to: (i) estimate the transition in LULC and (ii) assess the ecological impact of the invasive on the native flora at Point Calimere Wildlife Sanctuary.

MATERIALS AND METHODS

Study area

Point Calimere is a Wildlife Sanctuary (PCWS) (spread over 26.5 km^2) off the coast of Tamil Nadu, India at lat.—10.300^{0}N & long.—79.850^{0}E (Figure 1). The Great Vedaranyam Swamp is included, and it is bounded to the north-east by the Bay of Bengal and to the south-west by Palk Strait. Because of rampant poaching and a lack of legal protection, the sanctuary was established in 1967 to house Blackbuck *Antilope cervicapra*. In 2002, it was designated a Ramsar Site (Ramsar Site No. 1210). The Greater Flamingo and other long-distance migratory water birds make it well-known. The sanctuary is home to the largest population of southern India's endemic Blackbuck. At present, 198 different species of medicinal plants have been identified in the sanctuary's grassland, mudflats, backwaters, and sand dunes (Ramasubramaniyan 2012). Soil and water salinization, the loss of wetland habitat, the spread of the invasive species, i.e., *P. juliflora*, the presence of cattle, and a lack of fresh water are the most pressing issues in Point Calimere (Ali 2005).

Geospatial data acquisition

The administrative boundary in vector polygon was obtained from the forest department. Archived satellite imageries were downloaded from USGS (United States

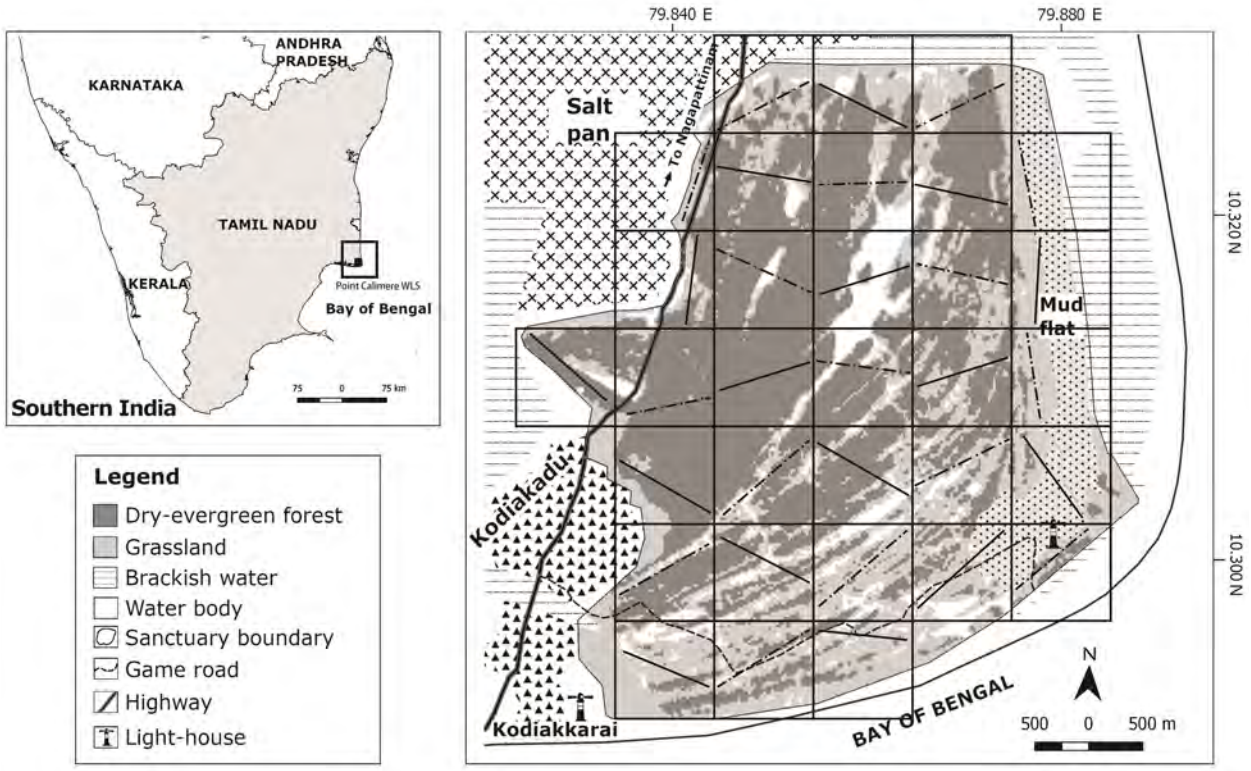

Figure 1. Map showing the study area - Point Calimere Wildlife Sanctuary, India.

Geological Survey) site, at a spatial resolution of 30 m for the years 1995 (5-TM/8 January) and 2018 (2 OLI-TIRS/8 July) (given in S-Table 1). While temporally comparable imageries prevent seasonal effects in LULC changes over several years (Im & Jensen 2005), quality images meeting this criterion were unavailable. Thus, quality images, especially those with low clouds, were used closer to the required dates. Each image was projected to WGS 84 and UTM-Zone 35 North. For the georectification process, 25 Ground Control Points (GCPs) was used along with the landsat image, tie points were established between the two images. Later, layer-stacking was done to combine the three landsat TM and landsat 8 bands (4, 3, 2, and 5, 4, 3). ArcMap 10 and ENVI 5 programs were used for geospatial processing.

Ground-truthing

The study area map was overlaid with a grid consisting of 1 km^2 cells, resulting in a total of 39 grid cells. In each grid cell, two plots of 30 x 30 m were placed to sample for tree species composition. From the 78 vegetation plots and also from nearby areas 1,280 ground-truthing points (GTP) were obtained. At every GTP that corresponds to a specific land-cover type, we recorded the geo-coordinate using a global positioning system (GPS) device**.** From these GTPs, five major LULC elements were identified: (i) tropical dry-evergreen, (ii) open-scrub (with and without *P. juliflora*), (iii) grassland, (iv) mudflat, and (v) water body.

Temperature and humidity

Temperature and humidity data are collected from each grid cell physically using HTC HD-303 digital thermometer cum hygrometer.

Image classification and accuracy assessment

LULC elements were classified in ENVI 5.0 using a supervised classification based on a maximum likelihood algorithm. These were integrated into a matrix table showing four different types of accuracy results (given in S-Table 2,3). Accuracy assessment requires a sufficient number of samples per map class and comparison with actual ground conditions. Standard LULC map accuracy are between 85% and 90% (Lins & Kleckner 1996). Overall, classification accuracy was 85% for 1995 and 92% for 2018 (S-Table 3).

Change detection

After classification, the two images were compared using change-detection analysis. The matrix table of

transition change class was obtained using a change-detection statistical tool in ENVI (Peiman 2011).

NDVI analysis

The NDVI imagery in this case was obtained by using a landsat image, which is a multiband dataset. The normalised difference vegetation index (NDVI) was calculated as per the following equation:

NDVI = (ρNIR – ρRED) / (ρNIR + ρRED)

where, ρNIR is the reflectance of near-infrared band, and ρRED is the reflectance of red band. For landsat 4-5 TM, the NIR band is 4 and for RED, it is 3, but for landsat-8 OLI it is band 5, and band 4, respectively.

Following the derivation of the NDVI image as a single band raster, a threshold of pixel values were applied in order to segment the data in various classes using the quantile reclassification option in ARC GIS.

As NDVI depicts vigour of the vegetation, two additional elements, viz., grasslands and *P. juliflora* were considered. For *P. juliflora,* a total of 100 GTPs (ground truthing points) were also collected systematically in plots with the presence of *P. juliflora*. After NDVI processing, four different NDVI elements were identified using the GTPs as threshold: (i) tropical dry-evergreen (0.300 to 0.700), (ii) open-scrub without *P. juliflora* (0.238 to 0.300), (iii) grasslands (0.090 to 0.146), and (iv) *P. juliflora* area (0.146 to 0.238). Water bodies and mudflats, both of which lack vegetation, were categorised as 'non-vegetation'. NDVI images from 1995 and 2018 were compared using change-detection analysis as

Table 1A. Native vegetation attributes (dependent variables) used in the study.

Variables	Sampling unit	Description
Tree		
Tree density/km^2	Two 30×30 m plots/ grid cell	At each grid cell diagonally opposite side, two plots of mentioned size were laid and counted all trees with >20 cm GBH. Density was calculated following number of tree/unit area
Tree diversity	As above	Data collected from the above description following Shannon diversity index
Shrub		
Shrub density /km^2	Four 5×5 m plots/ grid cell	In each grid cell, four plots of the mentioned size were laid diagonally opposite side in each of two tree plots and counted all the shrubs species. Density was calculated following number of shrub/unit area
Shrub diversity	As above	Data collected from the above description following Shannon diversity index
Grass and herb		
Herb cover	Eight 1×1 m plots/ grid cells	In each grid cell, eight plots of the mentioned size were laid diagonally opposite side in each of four shrub plots. From each plot % cover of herb was arrived as percentage of area of the plot covered by herb visually.
Grass cover	As above	Same as above

Table 1B. Independent variables used in the study.

Variables	Sampling unit	Description
Temperature and humidity		
Temperature (Celsius)	05 locations /grid-cells	Measured at 05 locations per grid cell with one each at four corners and one at the middle of two tree plots digital thermometer-cum-hygrometer device in degree Celsius.
Humidity (%)	As above	As above description and measured using digital thermometer-cum-hygrometer in %
***P. juliflora* pressure**		
P. juliflora cover %	Two 30×30 m plots/ grid-cell	Estimated from the two tree plots in each grid cell by multiplying the crown length × crown width of each *P. juliflora* and arriving at mean % cover of *P. juliflora* /unit area.
P. juliflora density/ km^2.	As above	Estimated from the two tree plots in each grid cell by counting the number of *P. juliflora* and arriving at number of *P. juliflora*/unit area.
Anthropogenic pressure		
Number of people	Per grid-cell	Measured counting number of people observed per grid cell during the survey time.
Distance to human settlements (m)	One/grid-cell	Measured from the centre of the gird cell to the nearest human settlement using GIS-ArcMap 10 program.
Herbivore pressure		
Spotted Deer density/km^2	One 1-km line transect /grid-cell	In each grid cell, animal surveys were conducted for three walks employing the line-transect distance sampling method (Burnham et al. 1980, Buckland et al. 2001).
Blackbuck density /km^2		
Feral horse density / km^2		

separate thresholds were found based on GTPs. The GIS methodology flow chart is given in S-Figure 1.

Vegetation survey

Vegetation attributes: (i) tree density/km^2, (ii) tree diversity, (iii) shrub density/km^2, (iv) shrub diversity, (v) herb cover, and (vi) grass cover, were sampled by laying plots of different sizes at 1 km^2 grid cells. Density and diversity were calculated in software PAST Version 3.23 for each grid cell (the dependent variables are described in Table 1A.

Evaluation of the temperature & humidity effect, anthropogenic pressure, herbivore density, and *Prosopis* pressure on native flora

To assess the effect of temperature, humidity, anthropogenic pressure, and *P. juliflora* pressure on native flora, sampling was done using different plot sizes for the tree, shrub, herb and grass as described in (Table 1B) for each grid cell. The measure of covariates including *P. juliflora* species was recorded first followed by the measure of the entire indigenous vegetation in the plots. We assessed two covariates (i) temperature (Celsius), (ii) humidity (%); two covariates from *P. juliflora* pressure [(iii) *P. juliflora* cover %, (iv) *P. juliflora* density/km^2]; two from anthropogenic pressure [(v) number of people (visual count), (vi) distance to human settlements (m)], and three belonging to herbivore density [(vii) spotted deer density/km^2, (viii) Blackbuck density/km^2, and (ix) feral-horse density/km^2].

Statistical analysis

We used the R-program (Version 3.3.1) for statistical analyses. First, a Shapiro-Wilk test was conducted to test the homogeneity of variance and normality of the dependent factors (Shapiro & Wilk 1965). Normality was not obtained for the six dependent factors related to the native tree, shrub, herb, and grass. Following this, the non-normal variables were transformed using log, arsine, negative exponential, and square root transformations. Normality was not achieved using any of the transformations, thus we used non-parametric tests for further analysis for the dependent variables, viz., tree density, tree diversity, shrub density, shrub diversity, herb cover, and grass cover. Normality test results are reported in S-Table 4.

Difference in vegetation attributes between the levels of temperature and humidity, anthropogenic pressure, herbivore density, and *Prosopis* pressure

Mann-Whitney U-test was used to examine the difference in vegetation attributes (dependent factor) between the levels of covariates (independent factor) by splitting them into two categories, for example, low level with *P. juliflora* cover <25%, and high level with *P. juliflora* cover >25%.

Influence of temperature and humidity, anthropogenic pressure, herbivore density, and *Prosopis* on native vegetation

To evaluate the influence of covariates on native flora, six dependent factors related to the native tree, shrub, herb, and grass and nine covariates belonging to temperature and humidity, anthropogenic pressure, herbivore and *P. juliflora* parameters were subjected to regression analysis following generalised linear model (GLM) (McCullagh & Nelder 1989; Dobson 1990) in the *R-program* (R Core team 2019). Since the covariates were continuous variables, they were assumed to be Poisson error distribution and logarithmic functions (McCullagh & Nelder 1989). In other analyses, an F-test was used since the deviance was under-dispersed and covariates were evaluated separately up to a polynomial of the third order (Hastie & Pregibon 1993).

RESULTS

Land-use and Land-cover in 1995 & 2018

The land use and land cover (LULC) components assessed within the study region in 1995 and 2018 demonstrate the presence of four primary elements: tropical dry-evergreen, open-scrub, mudflat, and water bodies (Figure 2). In 1995, the most dominant among these was the tropical dry-evergreen (36.8%) category, succeeded by open-scrub (28.5%), mudflat (21.6%), and water bodies (13.1%) (Table 2). Conversely, by 2018, the open-scrub (44.4%) element had become the most prevalent, followed by tropical dry-evergreen (33.6%), mudflat (13.5%), and water bodies (10.5%) (Table 2).

Table 2. Area and percentage of different land cover classes of 2018 classified image at Point Calimere Wildlife Sanctuary.

	Class	1995		2018	
		Area (km^2)	Area (%)	Area (km^2)	Area (%)
1	Dry-evergreen	9.74	36.77	8.91	33.64
2	Open-scrub	7.55	28.52	11.23	44.40
3	Mudflat	5.73	21.65	3.57	13.47
4	Water	3.46	13.06	2.78	10.50

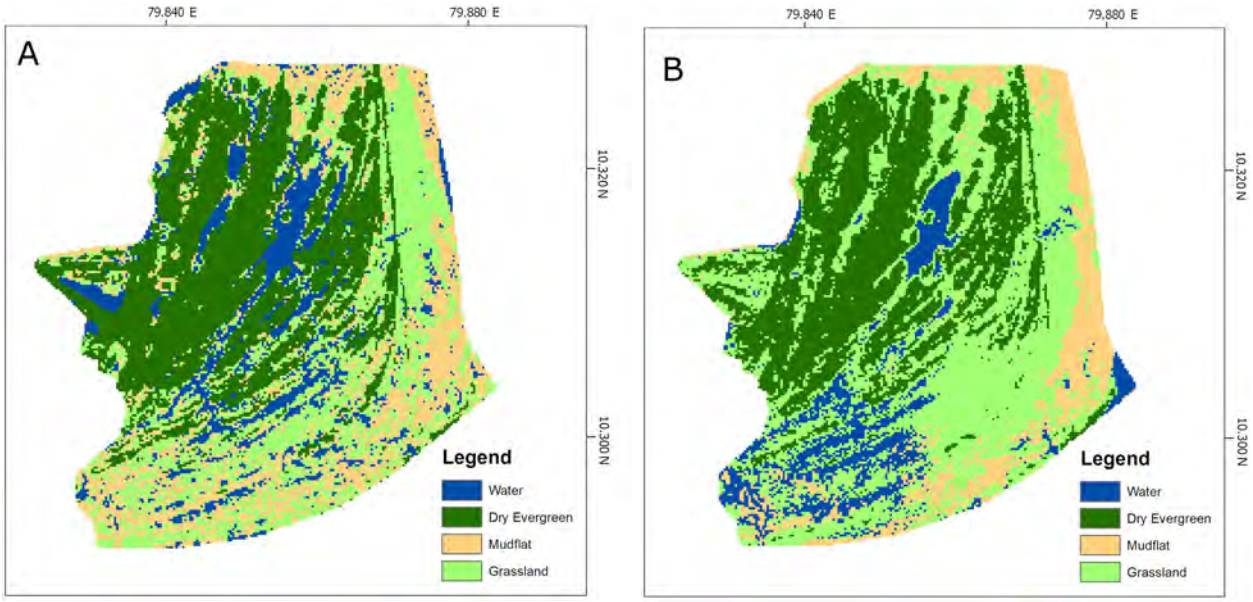

Figure 2. Map showing the land use and land cover of Point Calimere Wildlife Sanctuary during 1995 (A) and during 2018 (B).

Land-use and land-cover (LULC) changes

The image processed through the post-classification change detection technique is given in Figure 3 and statistical summaries on the spatial distribution of different land-cover transitions and unchanged areas are tabulated in S-Table 5. The results showed that 6.5 km^2 area changed from dry evergreen (2.3 km^2), mudflat (2.5 km^2), and water (1.7 km^2) to open scrub between 1995 and 2018.

Invasion of *Prosopis*

Normalised Difference Vegetation Index for *P. juliflora* abundance map (Figure 4) illustrates changes in *P. juliflora* coverage between 1995 (Figure 4A) and 2018 (Figure 4B). Over the past 23 years, *P. juliflora* has expanded its range, most noticeably into open scrub. The elements also show that the area covered by *P. juliflora* in 1995 was 3.03 km^2 and has since doubled to 6.16 km^2; meanwhile, the area covered by open-scrub has shrunk from 6.79 km^2 to 4.06 km^2 over the same time period (Table 3).

Difference in vegetation attributes in relation to covariate level

Among temperature and humidity, no significant difference was seen in vegetation attributes, except for tree density, which was higher in higher humidity areas than that at a lower level of humidity (U = 768, p <0.05). In relation to the levels of *P. juliflora* cover, the following vegetation attributes differed significantly revealing lower mean vegetation attributes at higher levels of *P. juliflora* cover than that of at lower level of *P. juliflora*; tree density, shrub density, herb density, and grass cover (p <0.05). Similarly, at higher levels of *P. juliflora* density, tree diversity, shrub density, shrub diversity, and herb cover were significantly lower (p <0.05) compared to plots with low level of *P. juliflora* density. In relation to herbivore density, no significant difference was seen in any vegetation attributes, except for shrub diversity, which was significantly lower at a higher level of Blackbuck density (p <0.05). Herb cover was significantly lower at higher population levels (p <0.05), while shrub density, herb cover, and grass cover (p <0.03) were higher away from human settlements (Table 4).

Influence of covariates on native flora

In models of GLM-based regression analysis, the influence of temperature and humidity, *P. juliflora*, herbivore density, and anthropogenic attributes on native vegetation revealed that tree density reduced significantly only with *P. juliflora* cover (pseudo-R^2 = 0.21), but no variables turned significant in the case of tree diversity (Table 5). Shrub density decreased significantly with *P. juliflora* cover, and density (pseudo-R^2 = 0.25) and shrub diversity with *P. juliflora* density (pseudo-R^2 = 0.19). The herb and grass cover decreased significantly with *P. juliflora* cover, but increased with distance to human settlements (herb; pseudo-R^2 = 0.43 and grass pseudo-R^2 = 0.37).

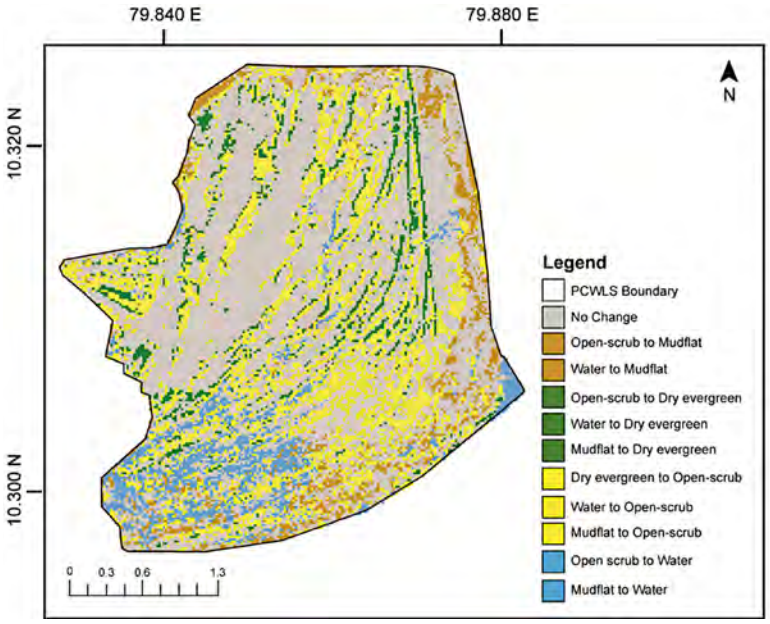

Figure 3. Map showing the change detection in LULC from 1995 to 2018 at Point Calimere Wildlife Sanctuary.

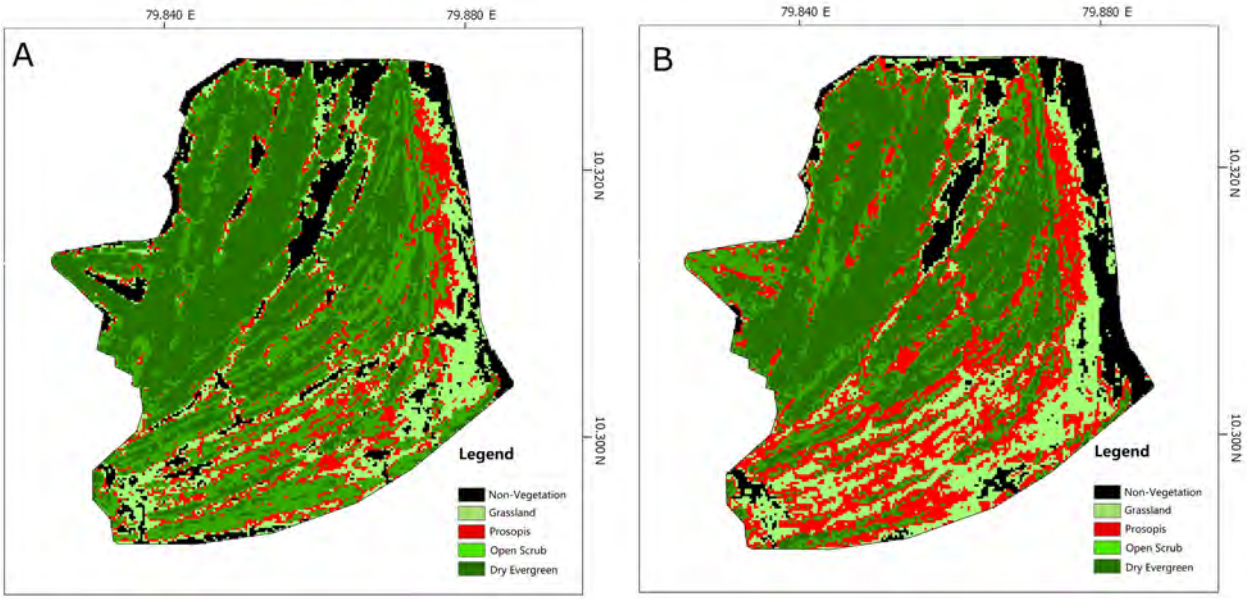

Figure 4. Map showing the changes in the abundance of *Prosopis juliflora* from 1995 (A) to (B) 2018 at Point Calimere Wildlife Sanctuary.

Table 3. Range and area of different classes of NDVI arrived for 1995 and 2018 period at Point Calimere Wildlife Sanctuary.

	Class	1995		2018	
		NDVI Range	Area (km^2)	NDVI Range	Area (km^2)
1	Grasslands	> 0.000 to 0.100	3.69	> 0.000 to 0.100	4.49
2	Open-scrub	> 0.200 to 0.400	6.79	> 0.200 to 0.300	4.06
3	*P. juliflora*	> 0.100 to 0.200	3.03	> 0.100 to 0.300	6.16
4	Dry-evergreen	> 0.400	9.89	> 0.300 to 0.500	9.18
5	Non vegetation	< 0.000	3.10	< 0.000	2.61

DISCUSSION

Land-use and land-cover change

Since 1995, the study area has seen a significant shift in the extent of various LULC elements. The loss of dry-evergreen, mudflat, and water areas, as measured by satellite imagery and a change area matrix, has resulted in an open-scrub expansion of 6.5 km^2. Further, NDVI analysis has revealed that the extent of *P. juliflora* increased from 3.03 km^2 in 1995 to 6.16 km^2 in 2018. The LULC classification shows an increasing trend in open-scrub, while the *P. juliflora* abundance (NDVI) map shows a decreasing trend in open-scrub with *P. juliflora* proliferation. This suggests that *P. juliflora* proliferated significantly in the study area's LULC elements especially in open scrub. *P. juliflora* is well-known for its ability to thrive in open areas rather than occupied ones. Compared to dry-evergreen, mudflat and water areas, open-scrub, which also includes grasslands, has a greater empty niche that allows the invasive to exhibit effective succession. This is supported by the propagule pressure hypothesis, which states that *P. juliflora* grows rapidly because of its ruderal characteristics (Williamson 1996). During times of seasonal resource stress, ungulates may rely heavily on fruits from browse species like *P. juliflora*. There is, however, a hidden cost in the proliferation of invasive species in open habitats such as grasslands, where territorial males and harems defecate in the grasslands, causing open grasslands to become open scrub (Ranjitsinh 1986; Jhala 1997; Jadeja et al. 2013).

Table 4. Dependent factors level recorded in relation to the level of each covariate.

Covariates	Level	Dependent factor					
		Tree density /km^2	Tree diversity	Shrub density/ km^2	Shrub diversity	Herb cover %	Grass cover %
Temperature (Celsius)	Low (<30)	69.4 ± 6.31	1.1 ± 0.11	4185 ± 572.0	1.3 ± 0.07	7.6 ± 0.89	12.9± 1.07
	High (>30)	51.7 ± 9.16	0.9 ± 0.15	3455 ± 463.5	1.2 ± 0.11	6.3 ± 1.09	12.7± 1.78
	U (p)	532 (0.070)	501 (0.340)	877 (0.600)	459 (0.170)	505 (0.670)	546 (0.890)
Humidity (%)	Low (<40)	52.0 ± 6.41	1.1 ± 0.11	3738 ± 518.9	1.3 ± 0.08	7.0 ± 0.89	13.4 ± 1.19
	High (>40)	75.5 ± 9.19	1.1 ± 0.15	4360 ± 735.5	1.3 ± 0.10	7.6 ± 1.17	11.8 ± 1.39
	U (p)	768 (**0.050**)	766 (0.560)	423 (0.900)	510 (0.770)	467 (0.500)	578 (0.700)
P. juliflora cover %	Low (<20)	74.9 ± 9.28	1.0 ± 0.11	4615 ± 612.0	1.4 ± 0.07	9.2 ± 0.84	14.4 ± 1.04
	High (>20)	58.6 ± 6.23	1.2 ± 0.14	2670 ± 207.4	1.1 ± 0.11	3.3 ± 0.72	9.6 ± 1.64
	U (p)	733 (**0.040**)	792 (0.350)	531 (**0.020**)	760 (0.200)	472 (**0.010**)	663 (**0.030**)
P. juliflora density /km^2	Low (<1400)	72.4 ± 6.21	1.2 ± 0.11	4253 ± 585.1	1.4 ± 0.07	9.0 ± 0.83	13.9 ± 1.04
	High (>1400)	43.6 ± 8.76	0.7 ± 0.13	3261 ± 249.9	1.1 ± 0.11	3.0 ± 0.89	10.3 ± 1.75
	U (p)	709 (0.690)	529 (**0.010**)	796 (**0.040**)	614 (**0.050**)	401 (**0.000**)	641 (0.090)
Spotted Deer density /km^2.	Low (<1.5)	64.0 ± 6.67	1.0 ± 0.11	3868 ± 456.8	1.3 ± 0.07	7.3 ± 0.81	12.5 ± 1.12
	High (>1.5)	64.2 ± 8.42	1.2 ± 0.16	4172 ± 910.6	1.3 ± 0.12	7.0 ± 1.36	13.7 ± 1.57
	U (p)	865 (0.090)	806 (0.500)	877 (0.920)	877 (0.950)	835 (0.670)	745 (0.230)
Blackbuck density /km^2.	Low (<2)	78.0 ± 10.17	1.2 ± 0.17	4123 ± 571.2	1.5 ± 0.11	7.8 ± 1.18	14.4 ± 1.59
	High (>2)	58.1 ± 5.99	1.0 ± 0.10	3600 ± 476.7	1.2 ± 0.07	7.0 ± 0.87	12.2 ± 1.10
	U (p)	643 (0.080)	743 (0.340)	760 (0.430)	760 (**0.050**)	750 (0.340)	775 (0.480)
Feral horse density /km^2	Low (>1.5)	76.7 ± 10.87	1.2 ± 0.18	3885 ± 589.8	1.5 ± 0.12	7.4 ± 1.31	13.6 ± 1.56
	High (<1.5)	60.2 ± 5.96	1.0 ± 0.10	3991 ± 524.9	1.2 ± 0.07	7.2 ± 0.83	12.6 ± 1.09
	U (p)	567 (0.130)	634 (0.380)	537 (0.740)	537 (0.070)	699 (0.800)	718 (0.100)
People (count)	Low (<2)	60.5 ± 7.61	1.1 ± 0.13	4269 ± 0.1	1.4 ± 0.08	8.8 ± 0.94	14.3 ± 1.24
	High (>2)	66.4 ± 6.98	1.0 ± 0.13	3605 ± 0.1	1.2 ± 0.09	5.4 ± 1.00	11.1 ± 1.31
	U (p)	498 (0.070)	677 (0.800)	478 (0.700)	600 (0.900)	655 (**0.050**)	723 (0.800)
Distance to human settlements (m)	Low (<100)	65.5 ± 6.30	1.1 ± 0.11	3488 ± 387.8	1.1 ± 0.11	4.3 ± 0.83	12.1 ± 1.13
	High (>100)	61.3 ± 9.58	1.0 ± 0.15	5003 ± 993.3	1.3 ± 0.09	8.6 ± 1.29	14.3 ± 12.50
	U (p)	744 (0.560)	533 (0.340)	553 (**0.003**)	533 (0.340)	477 (**0.030**)	456 (**0.030**)

Table 5. GLM regression model to determine predictors of vegetation attributes at Point Calimere Wildlife Sanctuary.

Dependent factor	Covariate	β±SE	z	p	Adj R^2
Tree density	Intercept	4.561 ± 0.0454	100.50	0.00	0.21
	P. juliflora cover	-0.246 ± 0.0277	-9.12	0.00	
Shrub density	Intercept	8.834 ± 0.0048	1833.00	0.000	0.25
	P. juliflora cover	-0.067 ± 0.0003	-230.30	0.010	
	P. juliflora density	-0.001 ± 0.0007	-120.74	0.000	
Shrub diversity	Intercept	2.309 ± 0.0146	256.47	0.001	0.19
	P. juliflora density	-0.196 ± 0.0431	5.60	-0.013	
Herb cover	Intercept	2.629 ± 0.1006	26.13	0.000	0.43
	P. juliflora cover	-0.036 ± 0.0052	-6.81	0.000	
	Distance to human settlements	0.185 ± 0.0778	2.37	0.018	
Grass cover	Intercept	3.038 ± 0.0756	40.18	0.000	0.37
	P. juliflora cover	-0.031 ± 0.0039	-7.81	0.000	
	Distance to human settlements	0.001 ± 0.0002	2.80	0.005	

Impact of *P. juliflora* parameters on the native flora

The GLM-based regression in this study shows that *P. juliflora* has a negative impact on the density of native tree, shrub, and herb and grass species at Point Calimere (Ali 2005). This is because the ruderal characteristics of *P. juliflora* allow it to spread over time. To put it another way, the amount of open space with sunlight, which is essential for the regeneration of native species such as trees and shrubs, is decreasing. Ecological studies have shown that invasive plants have a negative effect on native species by decreasing species richness, diversity, and displacing indigenous species. (e.g., Smith et al. 1999; Brooks & Pyke 2001; Kedzie-Webb et al. 2001; Lesica & Miles 2001; Prieur-Richard et al. 2002; Badano & Pugnaire 2004). *P. juliflora* in Ethiopia created an impenetrable bush that restricted the native herbivores and livestock from grazing in the area, as well as displacing the native trees (Kebede et al. 2009; Rot et al. 2023). Similarly, *P. juliflora* invasion in the riverine forest habitat of Kenya showed reduced herbaceous cover and diversity (Muturi et al. 2013).

An experimental study at Point Calimere (Murugan et al. 2020) demonstrated the detrimental effects of *P. juliflora*, including herb and grass species' diversity, on local vegetation. Invasive plant species disrupt soil organic matter due to changes in the quality and quantity of litter inputs (Ehrenfeld 2010; Kaur et al. 2012). According to this research, the subsequent removal of *P. juliflora* facilitated the recolonization of local vegetation in terms of species composition and ground vegetation cover, as compared to an unremoved site, including (i) decline in the accumulation of soil organic matter C, total Nitrogen due to enhanced microbial respiration and Nitrogen mineralisation rates, (ii) loss of plant canopy suppressed microbial biomass and enzyme activities indicating decline in soil quality while enhanced mineralisation of soil organic matter, (iii) higher metabolic quotient at *P. juliflora* removed site indicate that microbial C pools declined at a faster rate than soil organic matter C, resulting in a drop in microbial biomass C/soil organic matter C- ratio due to stress caused by plant removal and presence of allelopathic phenolic compounds released by invasive plant species roots and litter. Further, the authors have pointed that although the magnitude of invasive removal on local plant diversity and few ecosystems were examined, they speculate uncertainty as to how long these observed results may persist. Thus, suggesting long term and periodic monitoring experiments that evaluate the effects of invasive species removal on the environmental conditions.

Impact of anthropogenic pressure on the native flora

This study found that grass and herb cover decreased noticeably as distance increased from human settlements, indicating a negative effect on grass and herb cover. It is not uncommon for cattle from nearby human settlements to wander into the forest in search of grazing. Because of this, cattle are more likely to graze and trample areas near human settlements as opposed to more remote areas. Therefore, grass and herb cover increase as one moves further away from anthropogenic populated areas (Baskaran 1998; Baskaran et al. 2012).

CONCLUSION

From 1995 to 2018, findings show a transition from dry evergreen, mudflat, and water bodies to open scrub at Point Calimere Wildlife Sanctuary. The dramatic increase in *P. juliflora* from 3.03 km^2 to 6.16 km^2 since 1995, as revealed by this study, is a major cause of LULC shifts and thus the primary cause of the expansion of open-scrub. The detrimental effects of *P. juliflora* on native tree, shrub, herb, and grass species were revealed through a comparison of the effects of temperature and humidity, human activity, herbivores, and *P. juliflora*. The study found that the native flora at Point Calimere Sanctuary was reduced due to the proliferation of *P. juliflora*. Therefore, effective control of invasive species is necessary to save native species. To restore native ecological processes, the study recommends a concerted effort to slow the spread of *P. juliflora* at the same time that it is being eradicated. Other vegetation indices, such as SAVI (Soil-adjusted vegetation index) and similar indices, could address differences due to vegetation and soil fraction in future research. In addition to LANDSAT TM and LANDSAT 8 OLI data, Sentinel data can also be utilised to better comprehend spatial and temporal changes.

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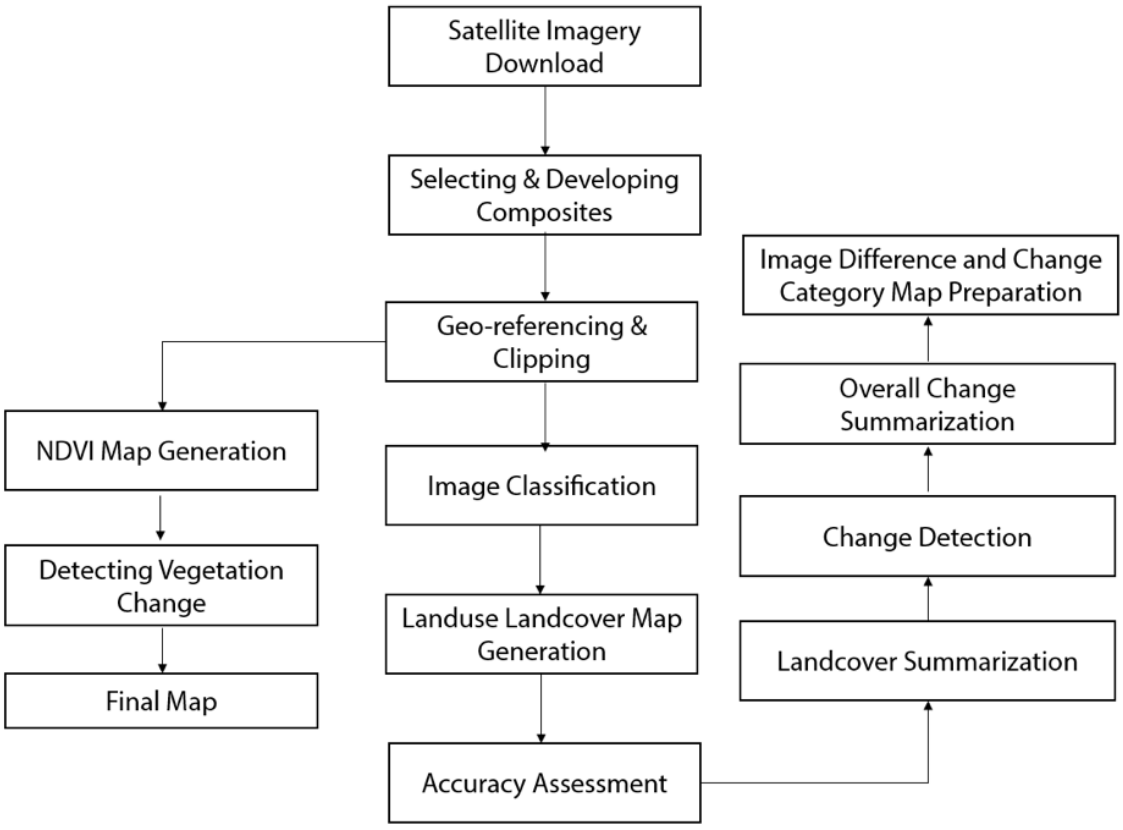

S-Figure 1. GIS methodology flowchart.

S-Table 1. Image acquisition details.

Details	Landsat-TM	Landsat-8
Data download source	USGS https://earthexplorer.usgs.gov	USGS https://earthexplorer.usgs.gov
Data catalouge	WRS path/row: 142/053	WRS path/row: 142/053
Sensor	SAM	OLI
Spatial coverage	170 km north-south by 183 km east-west	170 km north-south by 183 km east-west
Date of acquisition	08-01-1995	02-07-2018
Spatial resolution	30 m	30 m
Bands associated	B4, B3, and B2	B5, B4, and B3

S-Table 2. Confusion matrix and accuracy measures for the classification of land cover classes 2018.

	Actual (%)						User Accuracy (%)
		Water	Dry evergreen	Mudflat	Grassland	Total	
Classified	-	1	0	0	0	1	
	Water	89	0	0	5	94	98
	Dry-evergreen	0	97	0	0	97	100
	Mudflat	5	0	94	8	107	91
	Grassland	5	3	6	87	101	79
	Total	100	100	100	100	400	
	Producer Accuracy (%)	89	100	94	87		

S-Table 3. Accuracy statistics for the classification of various LULC of Point Calimere Wildlife Sanctuary.

Class Name	Accuracy (%)			
	Producer	User	Kappa	Over-all
1995				
Dry-evergreen	100	100	97	85
Open-scrub	99	79	71	
Mudflat	78	91	71	
Water	73	98	85	
2018				
Dry-evergreen	100	100	96	
Open-scrub	87	79	82	92
Mudflat	94	91	92	
Water	89	98	93	

S-Table 4. Normality test using Shapiro-Wilk Statistic and significance value.

Dependent factor	Shapiro-Wilk statistic (p)
Tree density	5.97 (0.037)
Tree diversity	7.20 (0.011)
Shrub density	8.82 (0.003)
Herb cover	12.18 (0.007)
Grass cover	10.15 (0.032)

S-Table 5. Change area matrix of Point Calimere: 1995–2018 (Area in km2).

	2018 km²			
1995 km²	Open-scrub	Dry-evergreen	Mudflat	Water
Open-scrub	-	0.9	**1.1**	0.9
Dry Evergreen	**2.3**	-	0.0	0.2
Mudflat	**2.5**	0.4	-	0.8
Water	**1.7**	0.3	0.5	-

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 January 2024 | 16(1): 24463–24468
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.8591.16.1.24463-24468
#8591 | Received 14 June 2023 | Final received 21 August 2023 | Finally accepted 14 December 2023
OPEN ACCESS
COMMUNICATION

Two *Ceratosporella* (Fungi: Ascomycota) species from oak leaf litter in Almora, Uttarakhand, India

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Abstract: Two species of *Ceratosporella* collected on leaf litter of Mohru Oak *Quercus floribunda* in Uttarakhand, India, are described herein and compared with closely allied species. They are *Ceratosporella deviata* and *Ceratosporella cheiroidea*. Among them, *C. cheiroidea* is newly recorded from India. Morphological descriptions, illustrations, and comments are provided for the aforementioned species.

Keywords: Anamorphic fungi, biodiversity, Binser forest, cellotape technique, hyphomycetes, Quercus, saprobic, taxonomy.

Editor: Gunjan Biswas, Vidyasagar University, West Bengal, India.

Date of publication: 26 January 2024 (online & print)

Citation: Dubey, M.K., R.S. Upadhyay & R.C. Gupta (2024). Two *Ceratosporella* (Fungi: Ascomycota) species from oak leaf litter in Almora, Uttarakhand, India. *Journal of Threatened Taxa* 16(1): 24463–24468. https://doi.org/10.11609/jott.8591.16.1.24463–24468

Funding: Self-funded.

Competing interests: The authors declare no competing interests.

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Author contributions: The study was conceived and designed by RCG. RCG and MKD performed all worked on the project in the field. MKD performed analyses and led the writing. RSU and RCG supervised the research; also reviewed the manuscript's final version.

Acknowledgements: We are grateful to the Head, Department of Botany, Kumaun University, S.S.J. Campus, Almora for providing laboratory and library facilities. We also express our gratitude to the reviewers for their valuable insights and contributions.

INTRODUCTION

The dematiaceous hyphomycete genus *Ceratosporella* Höhn. was established by Höhnel (1923), with *C. bicornis* (Morgan) Höhn. as the type species, and subsequently revised by Hughes (1951). *Ceratosporella* is characterized by mononematous, straight, erect, smooth, septate, pigmented (mid to dark brown) and unbranched conidiophores. Conidiogenous cells are percurrently extending, monoblastic, integrated, terminal and produce acrogenous, cheiroid, bifurcate or stauriform, smooth or verrucose, septate, brown to dark brown, solitary conidia with schizolytic secession (Monteiro & Gusmão 2014; Hernández-Restrepo et al. 2017). Besides these traits, the arms extend from a single basal cell of the conidium and branch into rows of cells (1–16), that separate this genus from other morphologically similar anamorphic genera including *Pentaster* Koukol, *Actinocladium* Ehrenberg, and *Tripospori*um Rope (Manoharachary et al. 2010; Koukol & Říhová 2013).

Ceratosporella has been reported from temperate and tropical regions worldwide and it is associated with numerous types of plant substrates such as bark, leaves, stems or branches, and the petioles of many plant hosts in both freshwater and terretrial ecosystems (Ellis 1971; Wu & Zhuang 2005). Most species included in this genus are saprobic in nature, often found growing on decaying plants debris of a wide range of hosts in contrast to the generic type, *C. bicornis*, which is a plant pathogenic fungus on *Zea mays* L. (Hughes 1971; Matsushima 1993; Castañeda-Ruiz et al. 1996; Seephueak et al. 2010). Some species are also known to interact with trees in the families Euphorbiaceae, Betulaceae and Fagaceae such as *Carpinus betulus* L., *Castanea sativa* Mill. and *Hevea brasiliensis* Muell. Arg. In this sense, *Ceratosporella disticha* Kuthub. was isolated from leaf litter of the Palm tree *Arenga westerhautii* Griff in Malaysia (Kuthubutheen & Nawawi 1991).

The Kumaon or Kumaun Himalaya region and its associated forests are considered an important reservoir of Indian biodiversity; nevertheless, the mycobiota of its ecosystems is poorly documented and still remains obscure, predominantly the dematiaceous hyphomycetes that grows on dead and decaying residues of plants. During field work carried out in the subtropical forest area of Almora District, Uttarakhand, India, we found two interesting microfungi associated with decaying Mohru Oak *Quercus floribunda* leaf litter material sharing features of *Ceratosporella*. These two species, namely *C. deviata* and *C. cheiroidea*, have unique conidia that differ from other taxa in *Ceratosporella* and are reported and described herein.

MATERIAL AND METHODS

Isolate and morphology

Leaf litter of Mohru Oak *Quercus floribunda* Lindl. ex Camus were collected during a mycological field work in Binser forest, Almora, Uttarakhand, India in the June of 2017. The collected samples were preserved in separate zip-locked plastic bags and transported to the laboratory. Once there, they were incubated in moist chambers consisting of sterile Petri dishes at room temperature (about 25°C) and periodically examined within two weeks for the presence of microfungi using a dissecting microscope. The samples were prepared for microscopic examination using a newly developed cellotape technique (Gupta 2016). Microscopic features and fungal structures such as septation, conidiogenous cells, developmental stages, branching pattern, conidial size and shape were measured, photographed and studied by employing standard mycological protocols and relevant literature to enable species identification. The permanent slides and examined specimens were deposited in the fungarium of the Department of Botany, Kumaun University, Almora, India (HKUM).

RESULTS

Taxonomy

Ceratosporella deviata Subram., Proc. Indian Acad. Sci. Sect. B. 46: 327, 1957. Image 1A–C

Synonym: *Tripospori*um *deviatum* (Subram.) R.F. Castañeda, Mycotaxon 60: 278, 1996.

Colonies on natural substrate effuse, brown or dark blackish brown, velvety. Mycelium partly superficial and partly immersed in the substratum, composed of irregular branches, smooth, septate, subhyaline to pale or dark brown, 1.5–3.0 µm wide hyphae. Conidiophores simple, erect, straight or slightly curved, smooth, cylindrical, brown or pale brown toward the apex, dark brown toward the base, up to 150 µm long, 4–6 µm wide, often extending percurrently, with up to 10 septa, dark brown basal cell; conidiogenous cells monoblastic, integrated, terminal, smooth, pale brown, cylindrical and truncated at the apex. Conidial secession schizolytic. Conidia acrogenous, smooth, pale to mid brown, with 2–4 (usually 3) divergent, subulate, septate arms, often constricted at septa, the apical (central) arm 30–55 ×

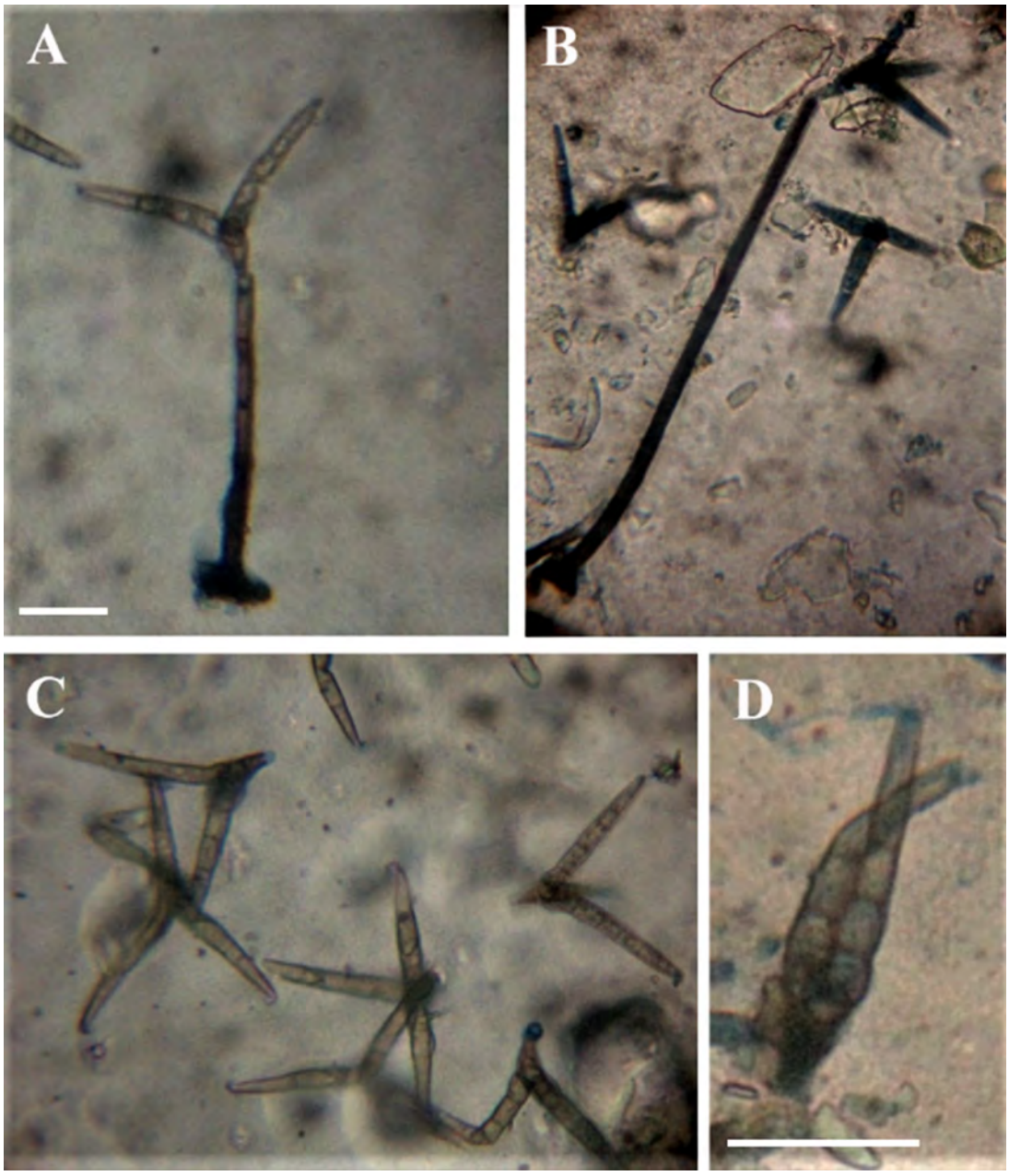

Image 1. A–C—Conidia and conidiophores of *Ceratosporella deviata* | D—Conidium of *Ceratosporella cheiroidea*. Bars A–C = 20 µm | D = 40 µm. © Ramesh Chandra Gupta.

5–7 µm, lateral arms 15–45 × 4–7 µm, arising from a turbinate or pyriform basal cell, 8–14 µm long, 5–8 µm wide at the broadest part, 3–5 µm at the base attached directly to the conidiophores.

Specimen examined: HKU(M) 2623, 10.vi.2012, India, Uttarakhand, Almora, Binser forest, on dead leaf bases of *Q. floribunda* (Fagaceae), coll. R.C. Gupta.

Note: The collection adequately fits the original diagnosis of Subramanian (1957) for describing *Ceratosporella deviata* on dead leaf bases of *Raphiostyles sapida* from Chennai (formerly Madras), India. This species is distint from other representatives of the genus by its two–four (mostly three) divergent conidial arms. This fungus has a close resemblance with species such as *C. stipitata* and *C. bicornis*. However, conidia in *C. stipitata* are smaller and consistently two-armed whereas in *C. bicornis* the two conidial arms diverge more or less 180°C (Monteiro & Gusmão 2014). Castañeda-Ruiz et al. (1996) proposed a new combination *Triposporium deviatum* for this species based on the presence of stauroconidia

and its strong resemblance with species of *Triposporium* Corda, particularly *T. elegans* Corda (Ellis 1971).

Ceratosporella cheiroidea R.C. Sinclair, Morgan-Jones & Eicker, in Sinclair, Eicker & Morgan-Jones, Mycotaxon 30: 352, 1987. Image 1D

Colonies on natural substrate effuse, light brown to dark brown, velvety. Mycelium partly superficial, mostly immersed in the substratum, composed of septate, branched, pale brown to brown, smooth hyphae. Conidiophores mononematous, macronematous, simple, erect, smooth, thick walled, cylindrical, straight or slightly flexuous, 2–10 septate, 45–110 × 4–6 µm, mostly dark brown with a 4–8 µm wide bulbose base. Conidiogenous cells monoblastic, integrated, terminal, smooth, brown to pale brown, usually cylindrical with two–three successive percurrent extensions, truncated at the apex. Conidial maturation synchronous with conidial ontogeny: conidial secession schizolytic. Conidia solitary, acrogenous, cheiroid, smooth, composed of a 2-celled stalk-like base and usually with two or rarely three cylindrical arms, flexuous, 1–6 septate, usually of unequal sizes, pale brown, 20–55 × 5–7.5 µm, tapering towards the distal cell with primary arms usually longer than secondary arms; basal stalk obconic, versicolor and truncate at base.

Specimen examined: HKU(M) 2640, 11.vi.2017, India, Uttarakhand, Almora, Binser forest, on leaf litter of Mohru oak *Q. floribunda*, coll. R.C. Gupta.

Note: The most striking feature of this isolate is the presence of conidia with 2–3 arms, conidial development pattern and versicolor basal cell. These characteristics were easily observed in the isolated specimens, agreeing with the original description (Sinclair et al. 1987). According to Monteiro & Gusmão (2014), only 12 representatives hitherto described under *Ceratosporella* possess cheiroid conidia- *C. basibicellularia*, *C. basicontinua*, *C. caliculata*, *C. compacta*, *C. cheiroidea*, *C. disticha*, *C. flagellifera*, *C. fertilis*, *C. novae-zelandiae*, *C. hernandezii*, *C. ponapensis*, and *C. stipitata. C. cheiroidea* conidia possess 2–3 arms (20–55 µm long in length), with a pattern of conidial development closely similar to the above mentioned representatives of *Ceratosporella*; but the number of arms, septa, size, and pigmented basal cell are the certain features that clearly distinguish this fungus from other mentioned representatives (Sinclair et al. 1987; Monteiro & Gusmão 2014). Synoptic characteristics for all these mentioned *Ceratosporella* species were reviewed and provided by Monteiro & Gusmão (2014).

DISCUSSION

During a survey of microfungi aimed to shed light on the microfungi inhabiting leaf litter of Binser forest in Uttarakhand (India), two dematiaceous hyphomycetous fungi belonging to the genus *Ceratosporella* were found. On critical study and comparison with other known representatives of the genus, *Ceratosporella deviata* and *Ceratosporella cheiroidea* were found to be newly recorded species for Uttarakhand and India, respectively. The taxonomic diagnosis of these recorded species is provided herein. Apart from this, the ecology of the recorded species is also described with reference to their substratum and habitat preferences. Our previous surveys also reflect that this region harbors a huge diversity of unknown mycobiota that could be discovered through proper mycological surveys (Dubey et al. 2019b, 2020a,b, 2022a,b, 2023); thus, the protection of the Binser forest is mandatory and of the utmost importance. In recent years, several mycological explorations have been conducted throughout India aimed for the discovery of its largely unknown mycobiota (Dubey et al. 2019b, 2020a,b, 2022a,b). Furthermore, as part of these surveys, several novel fungal species occurring on dead and decaying leaves or other plant parts have been described recently in India (Verma et al. 2021; Singh et al. 2022).

Over the years, 18 taxa have been included and described under the genus *Ceratosporella*, namely, *C. basicontinua* (Matsushima, 1993), *C. basibicellularia* (Matsushima, 1993), *C. bicornis* (Höhnel, 1923), *C. cheiroidea* (Sinclair et al., 1987), *C. caliculata* (Lustrati, 1980), *C. disticha* (Kuthubutheen & Nawawi, 1991), *C. compacta* (Castañeda-Ruiz et al., 1996), *C. flagellifera* (Matsushima, 1993), *C. fertilis* (Castañeda-Ruiz, 1985), *C. ponapensis* (Matsushima, 1981), *C. novae-zelandiae* (Hughes, 1971), and *C. stipitata* (Hughes, 1952). However, taxonomic confusion has arisen for some of the taxa due to their similarity and comparison amongst similar genera. Based on the above fact, *Ceratosporella* has been generically delimited and five taxa specifically, *C. deviata* and *C. lambdaseptata*, *C. goidanichii*, *C. longiramosa* and *C. pulneyensis* were excluded and assigned to other similar genera. *Ceratosporella elegans* is a synonym of *C. bicornis*. To date, only 12 species are retained in the genus *Ceratosporella*, with the criteria used for species identification and delimitation being primarily based morphological features such as conidial size, shape, septation, depelopmental pattern, ornamentation, pigmentation and the absence or presence of appendages (Castañeda-Ruiz et al. 1996; Monteiro &

Gusmão, 2014). Castañeda-Ruiz et al. (1996) provided the key to species of *Ceratosporella*. However, Monteiro & Gusmão (2014) recently revised the key and reviewed the synoptic characteristics for all the accepted species. In this sense, the distinguishing characteristics of all the accepted species were compared with closely resembling species for taxonomic clarity. Similar characteristics are also used for distinguishing other known species in many closely related saprobic dematiaceous hyphomycetes genera, like *Cercosporella,* where little is known about teleomorph relationships and molecular data are sparse (Seifert et al. 2011; Heredia et al. 2014; Xia et al. 2014; Hernández-Restrepo et al. 2017). Even in genera where molecular data are available, morphology alone is often conclusive (Almeida et al. 2014). Therefore, the phylogenetic placement of the representatives in this genus remained highly uncertain until new insights based on molecular data are provided for these fungi. In this regard, ecological and taxonomical observations in this genus are, therefore, largely based on morphology.

CONCLUSION

In the present study, two *Ceratosporella* species were investigated based on their critical morphological characters. These two species possess unique conidia that differ from other species in *Ceratosporella*, and therefore, *Ceratosporella deviata* is described as a new record for Uttarakhand whereas *Ceratosporella cheiroidea* is reported for the first time from India. Overall, this study contributes to the knowledge of the fungal diversity present in Uttarakhand, especially in the oak forest-covered regions, demonstrating the importance to explore other new habitats of the Himalayan region during mycological surveys.

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Journal of Threatened Taxa | www.threatenedtaxa.org | 26 January 2024 | 16(1): 24469–24484
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.8622.16.1.24469-24484
#8622 | Received 02 July 2023 | Final received 13 November 2023 | Finally accepted 20 December 2023
OPEN ACCESS
COMMUNICATION

The genus *Holigarna* Buch.-Ham. ex Roxb. (Anacardiaceae) in the central Western Ghats, Karnataka, India

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Abstract: The article deals with the taxonomy of the genus *Holigarna* found in the Western Ghats of Karnataka. Five species of *Holigarna* have been reported from the Western Ghats of Karnataka. The study includes—field surveys, herbarium examinations, and literature references provided the information on endemism, correct names, a short description, flowering & fruiting period, distribution, and illustrations & photographs of all the five species of the genus *Holigarna*. This information will be helpful in the identification of *Holigarna* species in the field.

Keywords: Field survey, herbarium examinations, *Holigarna arnottiana*, *H. beddomei*, *H. ferruginea*, *H. grahamii*, *H. nigra*, morphology, taxonomy.

Editor: W. Arisdason, Botanical Survey of India, Coimbatore, India.

Date of publication: 26 January 2024 (online & print)

Citation: Manjunath, K.M., H.S. Shashwathi, H.M.R. Jain & Y.L. Krishnamurthy (2024). The genus *Holigarna* Buch.-Ham. ex Roxb. (Anacardiaceae) in the central Western Ghats, Karnataka, India. *Journal of Threatened Taxa* 16(1): 24469–24484. https://doi.org/10.11609/jott.8622.16.1.24469–24484

Funding: None.

Competing interests: The authors declare no competing interests.

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Author contributions: KMM conceptualized the idea, data collection, and drafting of the manuscript. HSS contributed to data collection and analyses. HMR helped in the field survey and analyses. YLK contributed to data analyses and approved the final manuscript.

Acknowledgements: The authors thankfully acknowledge the Research supervisor Dr. Y. L. Krishnamurthy Department of Applied Botany Kuvempu University, Karnataka India. The authors would like to acknowledge Kuvempu University, Karnataka, India for the facilities provided. The authors are also grateful to the Karnataka Forest Department for their support during the sample collection. As would like to acknowledge the reviewers and the editor for the critical comments and suggestions for transforming the manuscript into the present form.

INTRODUCTION

The Anacardiaceae family encompasses approximately 950 species spread across 82 genera worldwide (Mabberley 2017). In India, this family is represented by 67 species, two subspecies, and two varieties, alongside four cultivated species within 23 genera (Chandra & Mukherjee 2000; Pramanick et al. 2020). Due to the extensive diversity and complexity of identifying species, the taxonomy of Anacardiaceae is not well understood. *Holigarna*, a polygamous evergreen genus, characterized by tall trees with acrid juice has seven species (*H. arnottiana* Hook.f., *H. beddomei* Hook.f., *H. ferruginea* Marchand, *H. grahamii* (Wight) Kurz, *H. kurzii* King, *H. longifolia* Buch.-Ham. ex Roxb., and *H. nigra* Bourd.) in India. Of these, *H. kurzii* and *H. longifolia* are the only ones not endemic to the country (Chandra & Mukherjee 2000). Five species (*H. arnottiana*, *H. beddomei*, *H. ferruginea*, *H. grahamii*, and *H. nigra*) are reported from the central Western Ghats of Karnataka (Gamble 1918; Saldanha 1984; Chandra & Mukherjee 2000).

In Karnataka, these *Holigarna* species are primarily found in evergreen and semi-evergreen forests, with only a few in moist deciduous forests. The polygamous nature of *Holigarna* poses challenges in collecting and identifying species, notably due to insufficient information on flowering and fruiting seasons and the limited availability of detailed morphological characters in the literature. Consequently, the present study aims to comprehensively document the taxonomy and morphological features of the *Holigarna* genus in the central Western Ghats, Karnataka.

MATERIALS AND METHODS

Study area

The study was conducted in Uttara Kannada, Shivamogga, Chikkamagaluru, Hassan, and Kodagu districts (Figure 1), known for their rich variety of plant and animal species. Field surveys took place from 2019 to 2022, covering moist deciduous, semi-evergreen, and evergreen forests across the central Western Ghats. The surveys included all altitudinal ranges to investigate the genus *Holigarna.*

This was supported by an extensive literature review and an examination of herbarium specimens deposited at the herbarium JCB Centre for Ecological Sciences, Indian Institute of Science, Bengaluru. The identity of collected specimens of *Holigarna* species was determined by referring to regional Floras (Gamble 1918; Saldanha 1996) and also cross-referenced with the images of type specimens available online at the Kew Herbarium Catalogue (http://apps.kew.org/herbcat/navigator.do). Leaves of five species of *Holigarna* have been dried, mounted on the herbarium sheets, and deposited in the herbarium of the Department of Applied Botany at Kuvempu University, Karnataka.

RESULTS AND DISCUSSION

Structural account of genus *Holigarna*.

In certain parts of the central Western Ghats, 10 sampling sites were explored to study the distribution and morphology of *Holigarna* species. The study identified five different species—*H. arnottiana* Wall. ex Hook.f., *H. beddomei* ex Hook.f., *H. ferruginea* Marchand, *H. grahamii* (Wight) Kurz, and *H. nigra* Bourd.—across these sites. Among them, *H. arnottiana*, *H. grahamii*, and *H. ferruginea* are widespread, while *H. nigra* and *H. beddomei* are less common in the central Western Ghats. The research highlighted that *H. arnottiana* and *H. grahamii* dominate in Shivamogga, Chikkamagaluru, Hassan, Kodagu, and Uttara Kannada districts, followed by *H. ferruginea*. Of the seven *Holigarna* species in India, five are found in the Western Ghats of Karnataka (Image 1). Leaf herbarium specimens were prepared and deposited at the Department of Applied Botany, Kuvempu University, for future reference (Table 1, Image 2).

Color and texture of bark

The bark in *Holigarna* species is usually greenish-grey to brown, and the inner bark is white and occasionally light pink. The stems and twigs produce a white or cream-coloured exudate which turns black after drying. The bark is rough in *H. arnottiana* and *H. grahamii*, whereas *H. beddomei, H. ferruginea* and *H.nigra* have smooth bark (Image 3).

Taxonomy of the genus *Holigarna*

Lofty trees, polygamous. Leaves are simple and alternate, usually in clusters near the branch apex, entire; petioles with spur-like deciduous or persistent appendages near leaf bases. Inflorescences panicles, axillary and terminal. Flowers both bisexual and male, bracteate, perigynous. Calyx cupular, 5-lobed; lobes imbricate. Petals 5, valvate, villous on the inner surface. Stamens 5. Disk cupular, 5-lobed. Carpels 3–5, syncarpous; ovary inferior, 1-loculed; ovule 1; styles

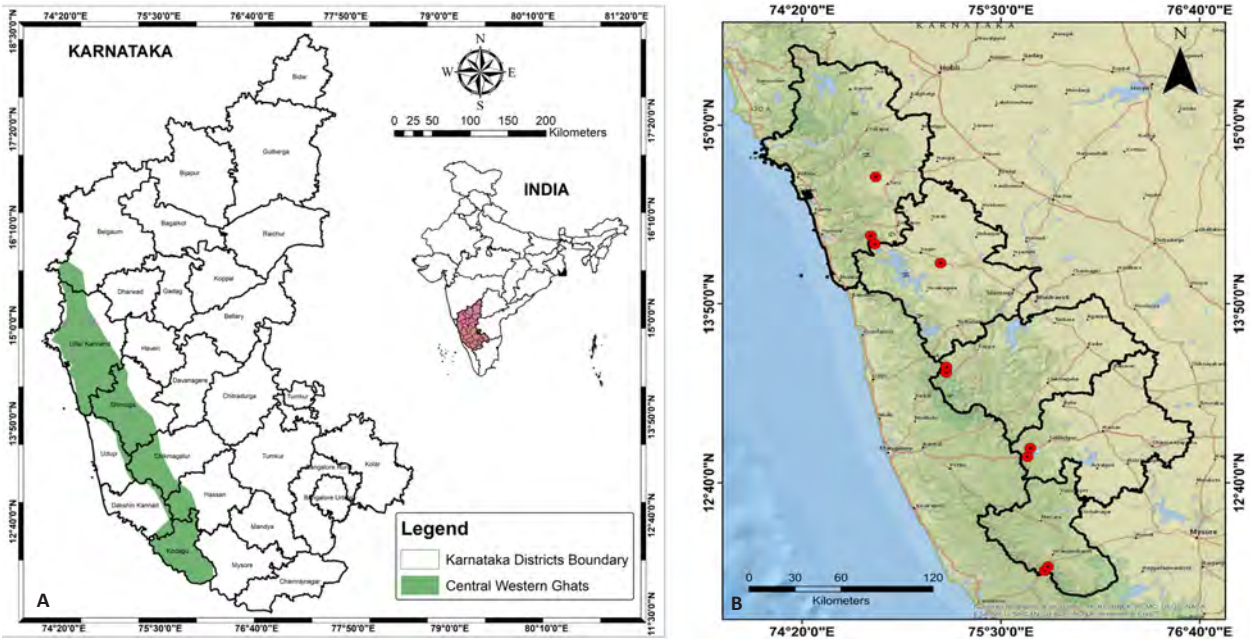

Figure 1. The GIS Map showing sampling locations of *Holigarna* species in the central Western Ghats: A—Outline map of Karnataka showing the central Western Ghats (in green) | B—The study sites of *Holigarna* species in central Western Ghats, Karnataka.

Table 1. Five species of *Holigarna* were collected from Karnataka with collection ID and herbarium accession numbers.

Name of the species	Collection ID	Herbarium accession no.
Holigarna arnottiana Wall. ex Hook.f.	HAKU-01	KUAB478
Holigarna beddomei Hook.f.	HBKU-05	KUAB482
Holigarna ferruginea Marchand	HFKU-02	KUAB479
Holigarna grahamii (Wight) Kurz	HGKU-03	KUAB480
Holigarna nigra Bourd.	HNKU-04	KUAB481

terminal, 3–5; stigma clavate. Drupes wholly or partly enclosed within obconic and turbinate hypocarp, resinous, acrid.

Habitat and Distribution: Moist deciduous, semi-evergreen, and evergreen forests of the Western Ghats (Shivamogga, Chikkamagaluru, Uttara Kannada, Hassan, and Kodagu districts)

Vernacular names: English: Junglemarking Nut, Black Varnish Tree, Kannada: Sanna Holegara, Holigeru, Tamil: Kattu-cheru, Karuncheru, Malayalam: Cheru, Naicheru.

Flowering: November–December; Fruiting: January–June.

Some important diagnostic characteristics features of documented *Holigarna* species were tabulated in Table 2.

Morphology of Flowers and Fruits

The basic inflorescence type is a panicle (Image 4), sometimes racemes. Flowers are small, polygamous, pentamerous, and perigynous, with a cup-shaped accrescent calyx and five valvate petals, inserted on the edges of the disk. Stamens 5, inserted on the edges of the disk, densely villous inside the disk along the calyx tube. Ovary inferior, 1-celled; ovule 1, subapical; styles 3, divergent; stigma capitate. Female flowers show self-incompatibility (Figure 2). Fruits of resinous, pungent, compressed ovoid drupes, partially or entirely hypocarpic (Image 5).

Taxonomic treatment of genus *Holigarna*

1. *Holigarna arnottiana* Wall. ex Hook.f.

Fl. Brit. India 2: 36. 1876; T. Cooke, Fl. Bombay 1: 279. 1902; Gamble, Fl. Madras: 268. 1918; C.J. Saldanha, Fl. Karnataka 2: 204. 1996; Sasidh., Biodivers. Doc. Kerala 6: Fl. Pl.: 111. 2004; K.G. Bhat, Fl. South Kanara: 514. 2014. *H. longifolia* Wight & Arn., Prodr. Fl. Ind. Orient.: 169. 1834; Bedd., Fl. Sylv. S. India: t. 107. 1871.

A large tree with black caustic juice; branches glabrous. Leaves obovate to oblanceolate, acute at apex, glabrous beneath, c. 23 × 9 cm; lateral veins 14–20 pairs; petioles up to 1.5 cm long with a pair of spurs. Panicles with golden brown pubescence, 12–18 cm long. Flowers are yellowish-green, pentamerous, perigynous, and densely villous inside the disk. Corolla green; anthers red. Drupes are

Image 1. The field photographs of different *Holigarna* species: A—*H. arnottiana* | B—*H. beddomei* | C—*H. ferruginea* | D—*H. grahamii* | E—*H. nigra* | F—Phyllotaxy | G—Close-up of the lower portion of leaves showing the spurs on the petioles.

Image 2. Herbarium specimens (leaves) of different *Holigarna* species: A—*arnottiana* (KUAB478) | B—*beddomei* (KUAB482) | C—*ferruginea* (KUAB479) | D—*grahamii* (KUAB480) | F—*nigra* (KUAB481).

Image 3. Bark of different *Holigarna* species: A—*H. arnottiana* | B—*H. beddomei* | C—*H. ferruginea* | D—*H. grahamii* | E—*H. nigra*.

obliquely ovoid, c. 2.5 cm long, light brownish, completely enclosed in the hypocarp, and black when ripe.

Habitat and Distribution: Endemic to the Western Ghats. Frequent in the semi-evergreen forests (Shivamogga, Chikkamagaluru, Uttara Kannada, Hassan, and Kodagu districts).

Vernacular names: English: Jungle Marking Nut, Black Varnish Tree; Kannada: Sanna Holegara, Holigeru; Malayalam: Cheru, Naicheru; Tamil: Kattu-cheru, Karuncheru.

Image 4. Polygamous nature of flowers in *Holigarna* of the central Western Ghats: A & B—Panicle of male flowers | C—Male flower and stamens arrangement | D—Panicle of Female flower | E—Female flower | F—Pistil | G—Staminode of the female plant.

Table 2. Important diagnostic characteristics and features of the genus *Holigarna*.

Characters	*Holigarna arnottiana*	*Holigarna ferruginea*	*Holigarna nigra*	*Holigarna grahamii*	*Holigarna beddomei*
Habit	Medium-sized, multiple branching	Large-sized, multiple branching	Medium-sized, multiple branching	Large-sized, simple branching	Large-sized, simple branching
Leaf shape	Obovate to Oblanceolate	Obovate	Spathulate	Obovate to Oblanceolate	Oblanceolate, immediately widened just above the middle
Leaf tip	Acute	Acuminate	Obtuse	Acute	Acuminate
Leaf base	Cuneate or Attenuate	Cuneate	Cuneate	Cuneate	Cuneate
Lateral Nerves	14–20 pairs	10–14 pairs	6–10 pairs	22–30 pairs	20–30 pairs
Spurs	Single pair, deciduous	Single pair, deciduous	Single pair, deciduous	Two pairs, of stout	Single pair, slender, hirsute
Panicle	12–18 cm long, with golden-brown pubescence	16–20 cm long, with dark brown pubescence	8–10 cm long, dark purple-brown-tomentose	20–35 cm long, with brown pubescence	20–35 cm long, with golden-brown pubescence
Flower	Yellowish-green	White	Greenish-white	White	White

Photographs: Image 6; Illustration: Figure 3.

Flowering: November–December; Fruiting: January–May.

2. *Holigarna beddomei* Hook.f.

Fl. Brit. India 2: 38. 1876; Gamble, Fl. Madras: 269. 1918; Sasidh., Biodivers. Doc. Kerala 6: Fl. Pl.: 111. 2004.

Large tree with acrid juice. Leaves simple, alternate, clustered at the tip of branches, oblanceolate,

Image 5. Fruits of different species of *Holigarna*: A—*H. grahamii* | B—*H. arnottiana* | C—*H. ferruginea* | D—*H. beddomei* | E—*H. nigra*.

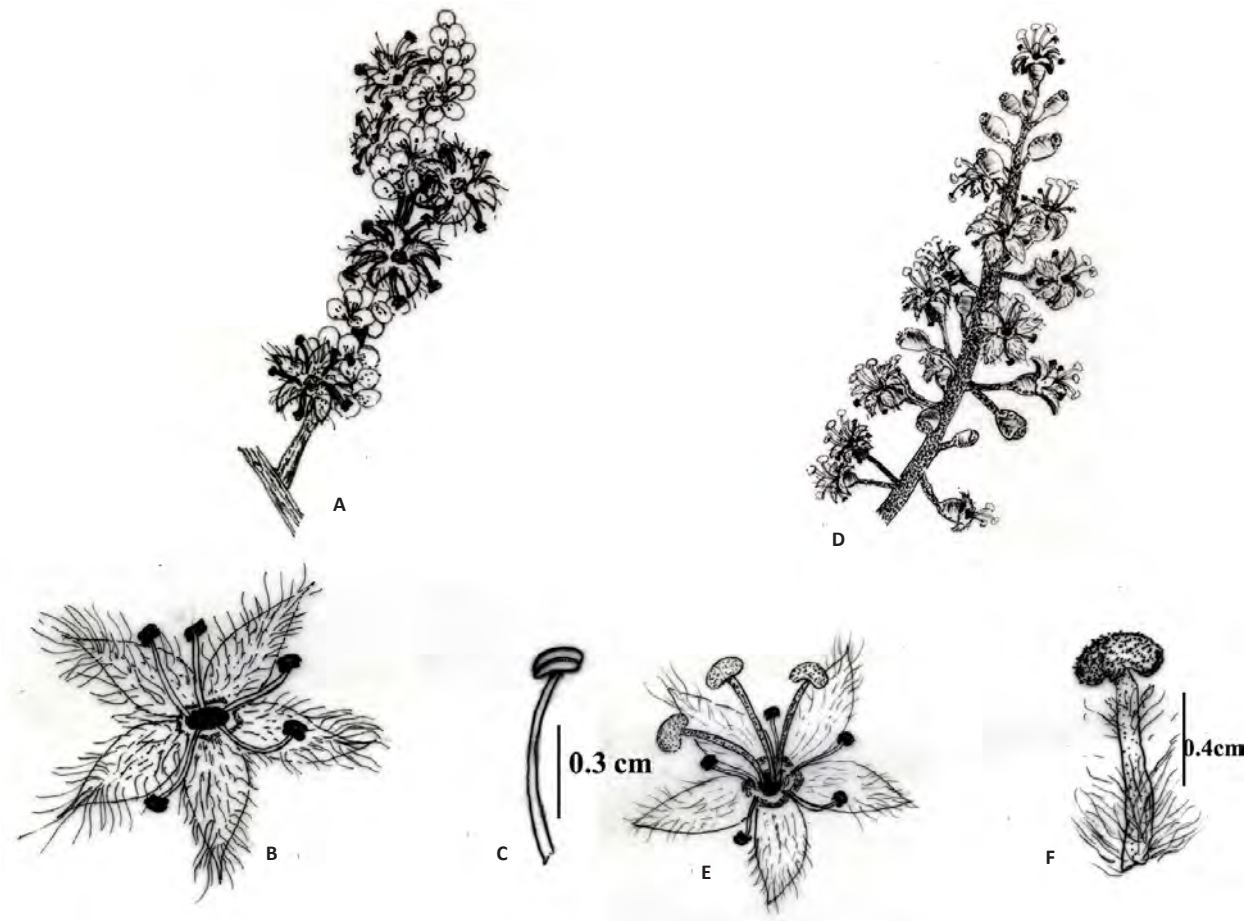

Figure 2. Illustrations of the male and female flowers in *Holigarna*: A—Panicle of the male flowers | B—Male flower | C—Stamen | D—Panicle of the female flowers | E—Female flower | F—Stigma.

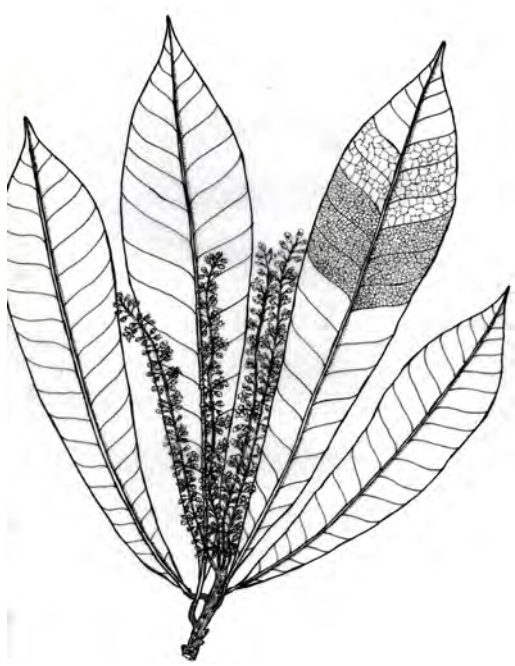

Figure 3. *Holigarna arnottiana* Wall. ex Hook.f.

immediately widened just above the middle, apex acuminate, base cuneate, margins entire, ciliate pubescent, up to 35 × 18 cm, pubescent beneath; petioles 1–2 cm long, villous, with a pair of slender, hirsute, and prominent spurs; midvein ciliate on the upper surface; lateral veins 20–30 pairs, parallel, prominent. Flowers polygamous, pentamerous. Petals 5, united at their bases, villous inside, white; a disk lines the tube of the calyx. Stamens 5, inserted outside the disk; anthers oblong-cordiform, versatile. Ovary inferior, 1-celled; styles 3, divergent; stigma capitate. Drupes are obliquely ovoid and 2–3 cm long.

Distribution: Endemic to the Western Ghats. Frequent in evergreen forests (Chikkamagaluru, Uttara Kannada, and Kodagu districts).

Vernacular Names: Kannada: Chere; Tamil: Pal vadinjan, Pal vidinyan.

Photographs: Image 7; Illustration: Figure 4.

Flowering: February–March; Fruiting: April–June.

Image 6. *Holigarna arnottiana*: A & B—Habit | C—Male inflorescence | D—Female inflorescence | E—Male flower with stamens | F—Female flower with staminodes and pistil showing self-incompatibility | G—Fruits.

Image 7. ***Holigarna beddomei*****: A & B—habit | C—Male inflorescence | D—Female inflorescence | E—Pistils | G—Fruits.**

3. Holigarna ferruginea Marchand

Rev. Anacardiac.: 171. 1869; Bedd., Fl. Sylv. S. India: t. 107. 1871; Hook.f., Fl. Brit. India 2: 36. 1876; Gamble, Fl. Madras: 268. 1918; C.J. Saldanha, Fl. Karnataka 2: 205. 1996; Sasidh., Biodivers. Doc. Kerala 6: Fl. Pl.: 111. 2004; K.G. Bhat, Fl. South Kanara: 514. 2014.

A medium-sized tree with black caustic juice; branches glabrous. Leaves up to 18 × 9 cm, obovate, subacute at apex, glabrous beneath; lateral veins 10–14 pairs; petioles *c.* 1.5 cm long, with a pair of deciduous

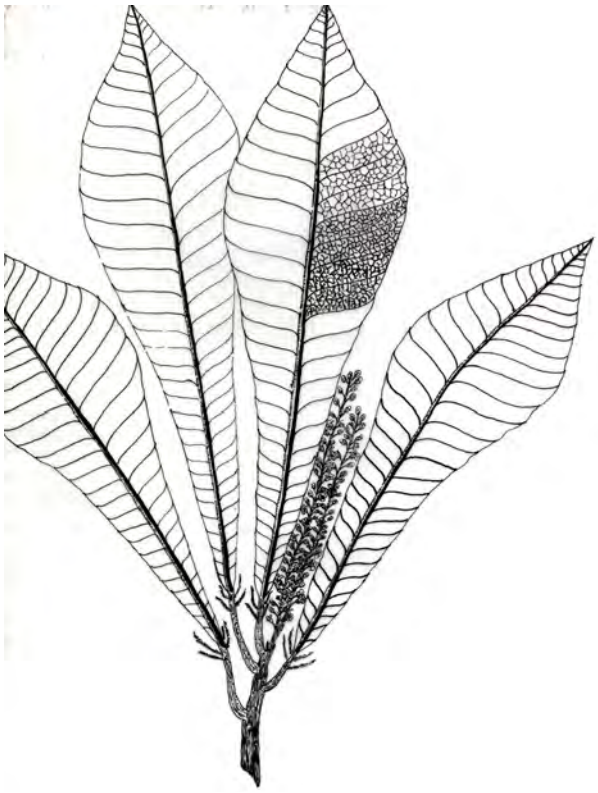

Figure 4. *Holigarna beddomei* Hook.f.

spurs. Panicles are 16–20 cm long, with dark brown pubescence. Flowers whitish. Calyx ferruginous-tomentose outside. Petals 5, cohering at the base and with the edges of the disk, are thickly villous inside. Stamens 5. Ovary inferior, 1-celled; styles 3, divergent; stigma capitates. Drupes ellipsoid, dark brown, turning black when ripe.

Distribution: Endemic to the Western Ghats. Frequently in the semi-evergreen forests (Hassan, Kodagu, Shivamogga, and Uttara Kannada districts).

Vernacular Names: Kannada: Chara; Tamil: Charei.

Photographs: Image 8; Illustration: Figure 5.

Flowering: January–February; Fruiting: March–May.

4. *Holigarna grahamii* (Wight) Kurz

Hook.f., Fl. Brit. India 2: 36. 1876; T. Cooke, Fl. Bombay 1: 282. 1902; Gamble, Fl. Madras: 268. 1918; C.J. Saldanha, Fl. Karnataka 2: 205. 1996; Sasidh., Biodivers. Doc. Kerala 6: Fl. Pl.: 112. 2004; K.G. Bhat, Fl. South Kanara: 514. 2014. *Semecarpus grahamii* Wight, Icon. Pl. Ind. Orient. 1(12): t. 235. 1839; Bedd., Fl. Sylv. S. India: t. 107. 1871.

A big tree with tomentose juvenile branches. Leaves simple, alternate, clustered at the tips of branchlets, estipulate, obovate to oblanceolate, base cuneate, apex acute; lateral veins 22–30 pairs, parallel, prominent; intercostae reticulate, prominent; petioles stout, 2–4 cm long, with 2 pairs of typical persistent spurs, brown-tomentose. Panicles 20–35 cm long, brown-pubescent. Petals 5, white, placed outside the disk and adhering to base and margins, villous inside. Ovary inferior, 1-celled; styles often divergent; stigma capitate. Drupes ovoid, 2–3 cm long, yellowish or reddish-purple.

Distribution: Endemic to the Western Ghats. Frequent in the moist deciduous and evergreen forests of Western Ghats (Shivamogga, Chikkamagaluru, Dakshina Kannada, Hassan, Kodagu, Udupi, and Uttara Kannada districts).

Vernacular Names: Kannada: Doddele Holagara; Malayalam: Anacheru, Valia cheru; Marathi: Balwuli, Bipte.

Photographs: Image 9; Illustration: Figure 6.

Flowering: November–December; Fruiting: January–March.

5. *Holigarna nigra* Bourd.

Indian Forester 30: 95. 1904; Gamble, Fl. Madras: 268. 1918; C.J. Saldanha, Fl. Karnataka 2: 205. 1996; Sasidh., Biodivers. Doc. Kerala 6: Fl. Pl.: 112. 2004.

A large tree with black caustic exudate; branches glabrous. Leaves simple, alternate, spathulate, base cuneate, margins entire, apex obtuse, sometimes retuse, glabrous; lateral veins 6–10 pairs, parallel, prominent, intercostae reticulate; petioles 1.5–2.5 cm long, with pair of deciduous spurs. Inflorescences racemose panicles, 8–10 cm long, terminal and axillary, dark purple-brown tomentose. Flowers are polygamous and white. Calyx is cupular and villous. Petals 5. Stamens 5; filaments white. Ovary inferior, 1-celled; styles 3; stigma capitates. Drupes obovoid, 1–2 cm long.

Distribution: Endemic to the Western Ghats. Frequent in the evergreen forests (Uttara Kannada and Kodagu districts).

Vernacular Names: Kannada: Cheru geru; Malayalam: Cheru.

Photographs: Image 10; Illustration: Figure 7.

Flowering: February–March; Fruiting: April–June.

CONCLUSION

The present study reports the distribution of five species of *Holigarna* in the central Western Ghats, Karnataka along with distinguished morphological features of every species with illustrations, photographs, significant key characters, and flowering and fruiting season, which will be helpful in the identification of *Holigarna* species in the field.

Image 8. *Holigarna ferruginea*: A—Habit | B—A flowering-twig | C—Male inflorescence | D—Female inflorescence | E—Female flower with staminodes and pistils, showing self-incompatibility | G—Fruits.

Image 9. *Holigarna grahamii*: A & B—Habit | C—Male inflorescence | D—Female inflorescence | E—Female flower with stamens and pistils showing self-incompatibility | G—Fruits.

Image 10. ***Holigarna nigra***: **A—Habit | B—A twig | C—Female flowers with stamens and pistils showing self-incompatibility | D—Female inflorescence | E—Fruits.**

Figure 5. *Holigarna ferruginea* Marchand.

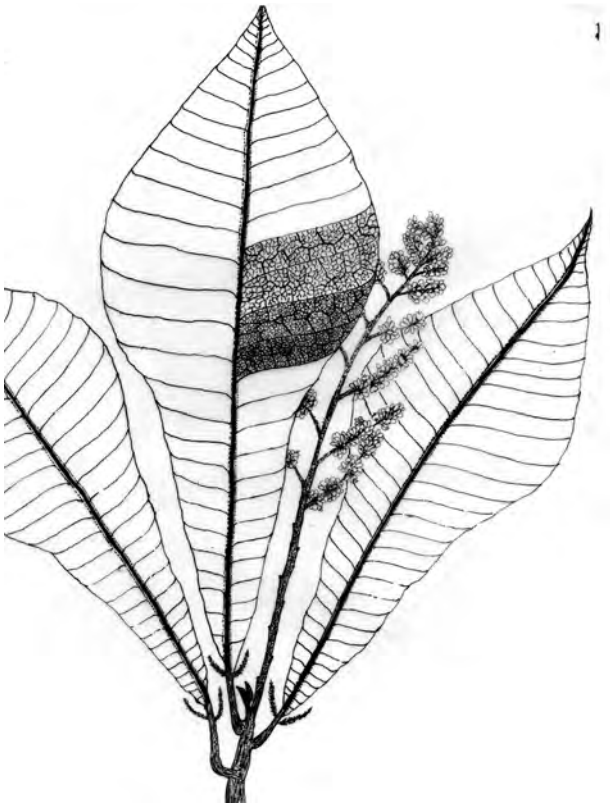

Figure 6. *Holigarna grahamii* (Wight) Kurz.

Figure 7. *Holigarna nigra* Bourd.

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Journal of Threatened Taxa | www.threatenedtaxa.org | 26 January 2024 | 16(1): 24485–24495
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.8829.16.1.24485-24495
#8829 | Received 16 November 2023 | Final received 31 December 2023 | Finally accepted 12 January 2024
OPEN ACCESS
COMMUNICATION

Report of *Bathycoelia indica* Dallas, 1851 (Hemiptera: Heteroptera: Pentatomidae) as a pest of pomegranate *Punica granatum* L. cultivated in Maharashtra State

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Abstract: A pentatomid bug *Bathycoelia indica* Dallas, 1851 is reported as a pest of pomegranate plantation in Maharashtra (India). Brief re-description of the species, including that of male and female genitalia, eggs, some nymphal stages and live adults, with many digital illustrations, is provided.

Keywords: Bathycoeliini, DNA Barcode, eggs, genetic divergence, male and female genitalia, nymphs, pest, stink bug.

Editor: Petr Kment, National Museum, Cirkusova, Czech Republic. **Date of publication:** 26 January 2024 (online & print)

Citation: Kudnar, P.S., G.G. Gowande & H.V. Ghate (2024). Report of *Bathycoelia indica* Dallas, 1851 (Hemiptera: Heteroptera: Pentatomidae) as a pest of pomegranate *Punica granatum* L. cultivated in Maharashtra State. *Journal of Threatened Taxa* 16(1): 24485–24495. https://doi.org/10.11609/jott.8829.16.1.24485–24495

Funding: Self-funded.

Competing interests: The authors declare no competing interests.

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Author contributions: PSK did field work and worked on lab population. GGG did molecular analysis. HVG dissected the specimens and prepared images. All contributed to writing and checked the text.

Acknowledgements: P. Kudnar and H.V. Ghate are indebted to the authorities of Modern College for facilities and encouragement. P. Kudnar acknowledges help received from Dattu Kudnar and Vikas Dhulgand during fieldwork. We thank Dr. Miss Shruti Paripatyadar for preparing photoplates. We are also pleased to thank the reviewers for improving the manuscript.

INTRODUCTION

There was a plantation of pomegranate *Punica granatum* L. over an area of about 3 acres in Shindodi (District Ahmednagar), Maharashtra, India, until January 2023. The trees in this plantation were seven years old; the plants were about 3 m tall (Image 1A).

On 6 August 2022, one of us (PSK) noticed a few nymphs of a pentatomid bug feeding on fruits and tender shoots (Image 1C,F). Within a few days, on 15 August, there were many adult bugs affecting practically every plant (Image 1B), some pairs were mating. A couple of fifth instar nymphs were observed, along with adults, on 5 September. Total number of bugs on the farm reached several hundred specimens within 15 days. The trees started showing effects of this infestation by bugs, such as: curling and yellowing of young leaves and puncture marks that led to black spotting of all affected fruits (Image 1D). By mid-September approximately 70–80 % of trees showed stunted and spotted fruits, no control measures were applied, no pesticides were sprayed. Eventually, the entire produce of the farm lost its value as all pomegranates were damaged by bugs. The plantation was cut down in February 2023 for other cultivation.

This pentatomid bug was subsequently identified using keys in Salini & Viraktamath (2015) as *Bathycoelia indica* Dallas, 1851. Additionally, species confirmation was also made by sequencing ~550 nucleotide bases of the mitochondrial barcoding region [cytochrome c oxidase subunit gene (COI)], which was aligned with other related species of the family Pentatomidae and subjected to phylogenetic analyses.

Brief morphology of the bug and comments on the structure of the male and the female genitalia, eggs, and nymphs are provided here.

MATERIALS AND METHODS

Field observations were carried out every 15 days from August to October 2022. Heavy rains disturbed the population of bugs. So, a few bugs were collected in August 2022 for laboratory rearing to observe mating and subsequent life history. Five males and five females, which are easily identifiable because of external morphology, were kept in large 5 l plastic jar and provided with fresh tender stems and small fruits of pomegranate.

Dissections of male and female genitalia were done as per established methods. Briefly, the male was treated with warm 10% KOH for five minutes and the pygophore was pulled out with fine forceps. The dissected male was then washed with 5% acetic acid and then 70% alcohol and absolute alcohol before mounting on card. The pygophore was further boiled in 10% KOH for 8–10 min. Parameres were removed with fine forceps and the pygophore was carefully opened from dorsal side to free the phallus from attachment. The phallus was then treated with 10% lactic acid for 15 minutes and then carefully everted with forceps. For female genitalia the abdomen was boiled in 10% KOH for 10 minutes and washed with water. The female genitalia, including spermatheca, were stained with dilute methylene blue for contrast. Terms used broadly follow Morariu (2012), Salini (2015), and Schuh & Weirauch (2020).

In the field, photographs were taken on mobile camera Moto G Plus which is equipped with 16-megapixel camera, while in the laboratory photographs were taken on Leica stereozoom microscope MZ-6 with attached Canon Powershot S50. Multiple photos taken under microscope were stacked using Combine ZM freeware. The images were processed in Photoshop CS5.

Total genomic DNA was extracted from two legs of a single specimen which was further subjected to COI amplification and sequencing following the protocols as mentioned in Tembe et al. (2014); the work was outsourced this time to Barcode Biosciences, Bangalore, who provided sequence data.

Sequence alignment

The reverse and the forward sequences were aligned in MEGA v.6 (Tamura et al. 2013) and a consensus sequence was generated with the help of chromatograms visualized in Chromas v.2.6.5 (Technelysium Pty. Ltd. 2018). Sequences of related species from the family Pentatomidae available on GenBank® (Benson et al. 2017) were downloaded, including a sequence of *Bathyoelia indica* (HQ236463) and were aligned with the newly generated sequence using MUSCLE incorporated in MEGA v.6. Low quality ends were trimmed and the resultant 467 base pair (bp) long alignment was used for molecular phylogenetic analyses. Other sequences included in the alignment are listed in the Table 1.

Genetic divergence (p-distance)

The p-distances were calculated for the mitochondrial COI in MEGA v.6. The substitution type was set as nucleotide, the model was kept as *p*-distance and the substitutions included were d: transitions + transversions. Uniform rates were kept for analysis. Missing data were partially deleted and the site cut-off was set as 95%. All three codon position sites were

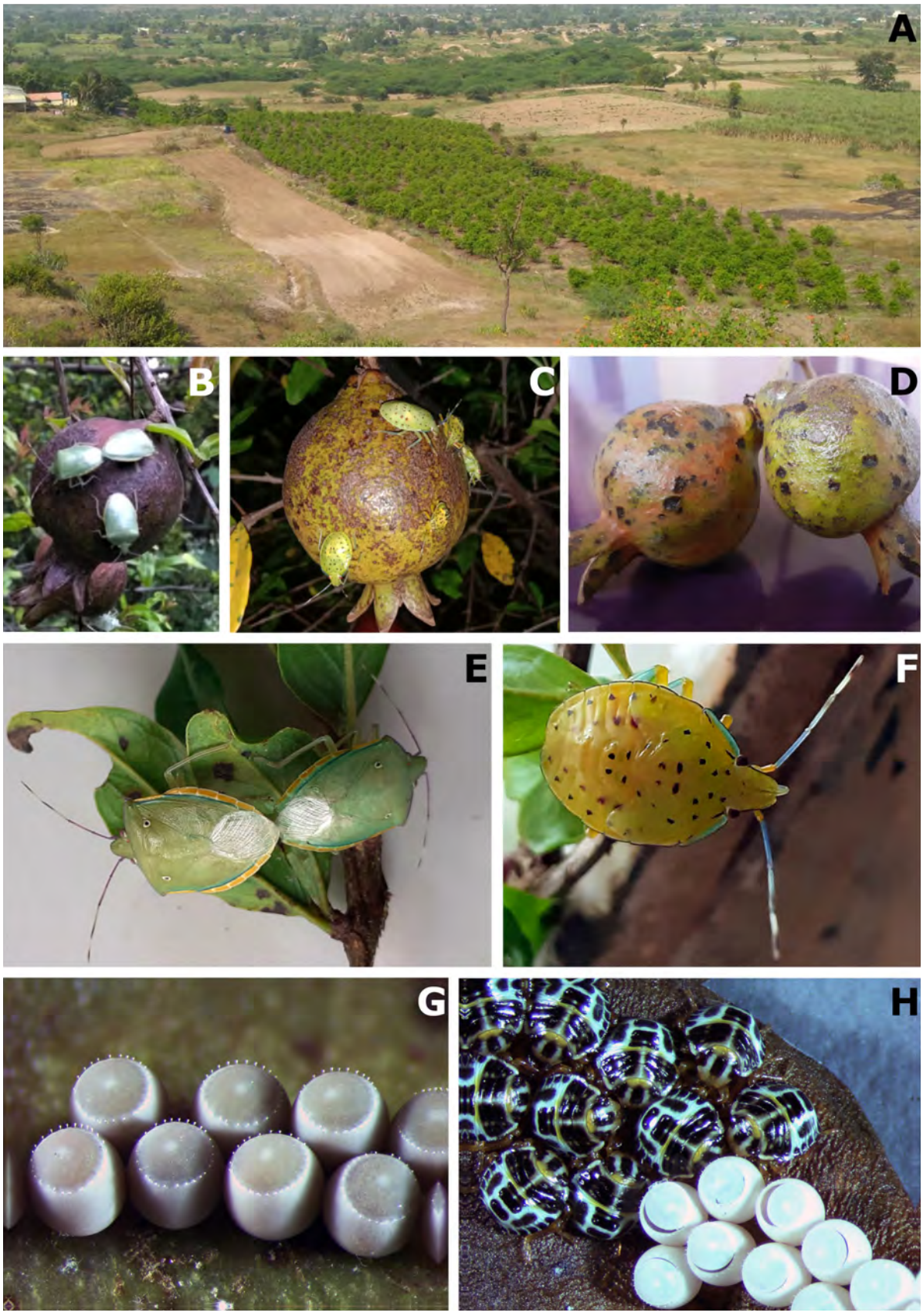

Image 1. A—Pomegranate farm | B–H *Bathycoelia indica* eggs, nymphs and adults: B— mating pair on fruit | C—nymphs on fruit | D—fruits showing black spots | E—mating pair | F—fifth instar nymph | G—eggs | H—hatched eggs with nymphs. © 1A—P.S. Kudnar | 1B–H—H.V. Ghate.

Table 1. A list of sequences used in the molecular phylogenetic analyses along with their accession numbers.

Accession Number	Species	Family
MW983247	*Dysdercus fasciatus*	Pyrrhocoridae
MG838358	*Dysdercus evanescens*	Pyrrhocoridae
MG838360	*Dysdercus koenigii*	Pyrrhocoridae
HQ236463	*Bathycoelia indica*	Pentatomidae
PP177471 This study	*Bathycoelia indica*	Pentatomidae
OM263631	*Bathycoelia distincta*	Pentatomidae
MT253050	*Piezodorus punticeps*	Pentatomidae
MG838405	*Piezodorus hybneri*	Pentatomidae
MW535996	*Nezara viridula*	Pentatomidae
KY835350	*Nezara viridula*	Pentatomidae
MG838340	*Catacanthus incarnatus*	Pentatomidae
HQ236459	*Catacanthus incarnates*	Pentatomidae
KX051838	*Catacanthus viridicatus*	Pentatomidae

selected (the p-distances are mentioned in Table 2).

Molecular phylogenetic analyses

Maximum Likelihood (ML) method of phylogenetic analyses was implemented. Maximum Likelihood analysis was performed using the web implementation of IQ-tree (Nguyen et al. 2015) web server (Trifinopoulos et al. 2016) under the HKY+F+R2 for position 1, TN+F+G4 for position 2 and HKY+F+I for position 3 models of sequence evolution, which were determined using ModelFinder (Kalyaanamoorthy et al. 2017) on the IQ-tree web platform. Branch support was tested using 1000 non-parametric rapid ultrafast bootstrap pseudo-replicates (Hoang et al. 2018). Members of the genus *Dysdercus* Guérin-Méneville, 1831 (Pyrrhocoridae) were used to root the alignment.

RESULTS

Classification (as per website: Pentatomoidea web page, Rider 2024):

Heteroptera, Pentatomoidea, Pentatomidae, Pentatominae, Bathycoeliini

Bathycoelia Amyot & Serville, 1843

= *Jurtina* Stål, 1868 (syn. by Bergroth 1913)

Bathycoelia indica Dallas, 1851

Material examined for morphology and dissection: three males and three females of *Bathycoelia indica* collected by P.S. Kudnar from Shindodi, near Sangamner (19.3748N and 74.3797E), District Ahmednagar, Maharashtra State, India, 15 August 2022. Specimens are deposited in Modern College. Two males are numbered MASCZ Het 153 and 154. One female is numbered MASCZ 155.

Table 2. p-distances between the sequences used in the molecular phylogenetic analyses

	Sequence	1	2	3	4	5	6	7	8	9	10	11	12
1	HQ236463.1_*Bathycoelia_indica*												
2	PP177471 this study *Bathycoelia_indica*	0.00%											
3	OM263631.1_*Bathycoelia_distincta*	5.14%	5.14%										
4	MT253050.1_*Piezodorus_punctipes*	10.71%	10.71%	10.71%									
5	MG838405.1_*Piezodorus_hybneri*	14.35%	14.35%	14.13%	12.21%								
6	MW535996.1_*Nezara_viridula*	14.99%	14.99%	13.49%	14.13%	14.35%							
7	KY835350.1_*Nezara_viridula*	13.49%	13.49%	12.21%	12.42%	13.92%	6.42%						
8	MG838340.1_*Catacanthus_incarnatus*	17.77%	17.77%	17.56%	14.99%	18.63%	13.70%	13.70%					
9	KX051838.1_*Catacanthus_viridicatus*	19.06%	19.06%	17.56%	15.85%	19.06%	16.49%	16.06%	13.28%				
10	HQ236459.1_*Catacanthus_incarnatus*	17.77%	17.77%	17.56%	14.99%	18.20%	13.70%	13.70%	0.43%	13.28%			
11	MG838358.1_*Dysdercus_evanescens*	15.63%	15.63%	14.56%	14.13%	17.34%	16.92%	16.27%	15.63%	16.92%	16.06%		
12	MW983247.1_*Dysdercus_fasciatus*	16.06%	16.06%	13.92%	15.20%	17.99%	17.99%	16.49%	17.56%	18.20%	17.56%	8.78%	
13	MG838360.1_*Dysdercus_koenigii*	16.70%	16.70%	14.78%	14.13%	18.20%	16.49%	16.27%	15.20%	16.92%	15.63%	4.93%	7.71%

Brief comments on bionomics

The males and females kept under laboratory condition were found feeding and surviving well under lab conditions and were also observed mating (28 & 30 August 2022). Mating lasted for several hours. In nature as well as in lab the bugs were observed mating in typical end-to-end position (Image 1B,E). In field, mating was observed on shoots, above and under the leaves and even on fruits. Both, nymphs and adults were found feeding on tender shoots and fruits under natural conditions and the feeding marks on fruits turned black after two or three days.

In laboratory one female laid 12 eggs on 5 September 2022, these eggs were arranged in two rows but actual egg laying behaviour was not observed. These eggs hatched on 8 September (Image 1 G,H); on 13 September, second instar nymphs were observed; subsequent instars did not survive. In natural condition also nymphs were washed away by rains, so no details on other nymphal instars are available. The two other egg clutches observed in field showed 14 and 16 eggs (i.e., an average of 14 eggs / female). Since late fourth and fifth instar nymphs were observed in field during early August, the September generation was likely to be a second generation.

Each egg is barrel shaped, pale green, about 1.4 mm in height, somewhat broader in the middle than at both ends. Each egg showed about 25 tiny micropyles around "the lid or cap" at cephalic end; proximal end of egg is glued to leaf surface. Hatching was 100% successful. First instar nymphs resembled rounded buttons, about 2.5 mm long, with a pattern of black blotches or spots. These nymphs remained together for two days around the empty egg shells and moulted; the second instar nymphs were initially about 4.5 mm long but measured about 6 mm after two days of feeding.

Due to some unknown factor (probably the fruits brought from other farm and supplied as food were sprayed with pesticide), all the adults and nymphal stages of the bug in laboratory-maintained population did not survive and the observations on egg-laying behaviour and nymphal development under lab conditions also remained incomplete. A few fifth instar nymphs were again observed in field 20 days after the heavy rains which had wiped out most of the nymphs and adults. These fifth instar nymph showed many black spots on a green or yellowish green body (see Image 1F) with well-developed wing pads reaching third abdominal segment. The dorsal abdominal glands were prominent in this stage.

Brief redescription of adults

Male

Overall colour green, lateral margins of head and pronotum violaceous or magenta. Eyes red. Antennomeres 1, 2 and proximal half of antennomere 3 violaceous. Basal angles of scutellum with black spots which are surrounded by cream coloured, slightly elevated callose rim. Posterolateral angles of abdominal segments with minute black spine. All legs green, tibiae and tarsi paler than femora (Image 2A). Ventral side pale green.

Head triangular but truncate at apex. Mandibular plates and clypeus of equal length. Mandibular plates transversely rugulose dorsally. Ocelli closer to eye than to each other. Bucculae well developed (Image 2E). Labium very long, reaching posterior margin of sixth abdominal ventrite and fitting in shallow, median, longitudinal, abdominal groove (Image 2D). Antennae long, first antennomere just reaching apex of head. Ventrally head finely punctured and finely rugulose.

Pronotum trapezoidal, finely and superficially punctured, finely rugulose in anterior half, pronotal calli indistinct; pronotal anterior margin concave behind head, anterolateral margin straight, posterior margin straight. Pronotal anterior angles obtuse, width at anterior angles only slightly shorter than width of head including eyes (Image 2B). Scutellum triangular, slightly convex or tumescent in basal half, slightly longer than broad, passing middle of abdomen, rugulose punctate, distinctly narrowed in distal one third of its length, its basal angles depressed.

Pro-, meso- and metasterna finely and sparsely punctured, discal area medially smooth and shallowly sulcate. Metathoracic scent gland peritreme transverse, evaporatorium very small. Legs mostly smooth, only distal half of tibia with short setae.

Hemelytra long, extending beyond tip of abdomen in both sexes; corium finely punctured and dull, broadest in middle; membrane translucent, with multiple veins. Connexivum narrowly exposed.

Abdomen ventromedially sulcate, third ventrite anteriorly with minute median tubercle. Segmental sutures curved; spiracles closer to anterior border than lateral border of segment. Pygophore not visible externally in dorsal as well as ventral view.

Detached pygophore rhomboidal in shape, narrow at base but wide at apex, with deeply emarginate dorsal and ventral rims producing prominent caudo-lateral angles; dorsal rim smooth but ventral rim with long setae along its entire length. Small knob-like, black and sclerotized dorsal sclerites visible on either side in dorsal

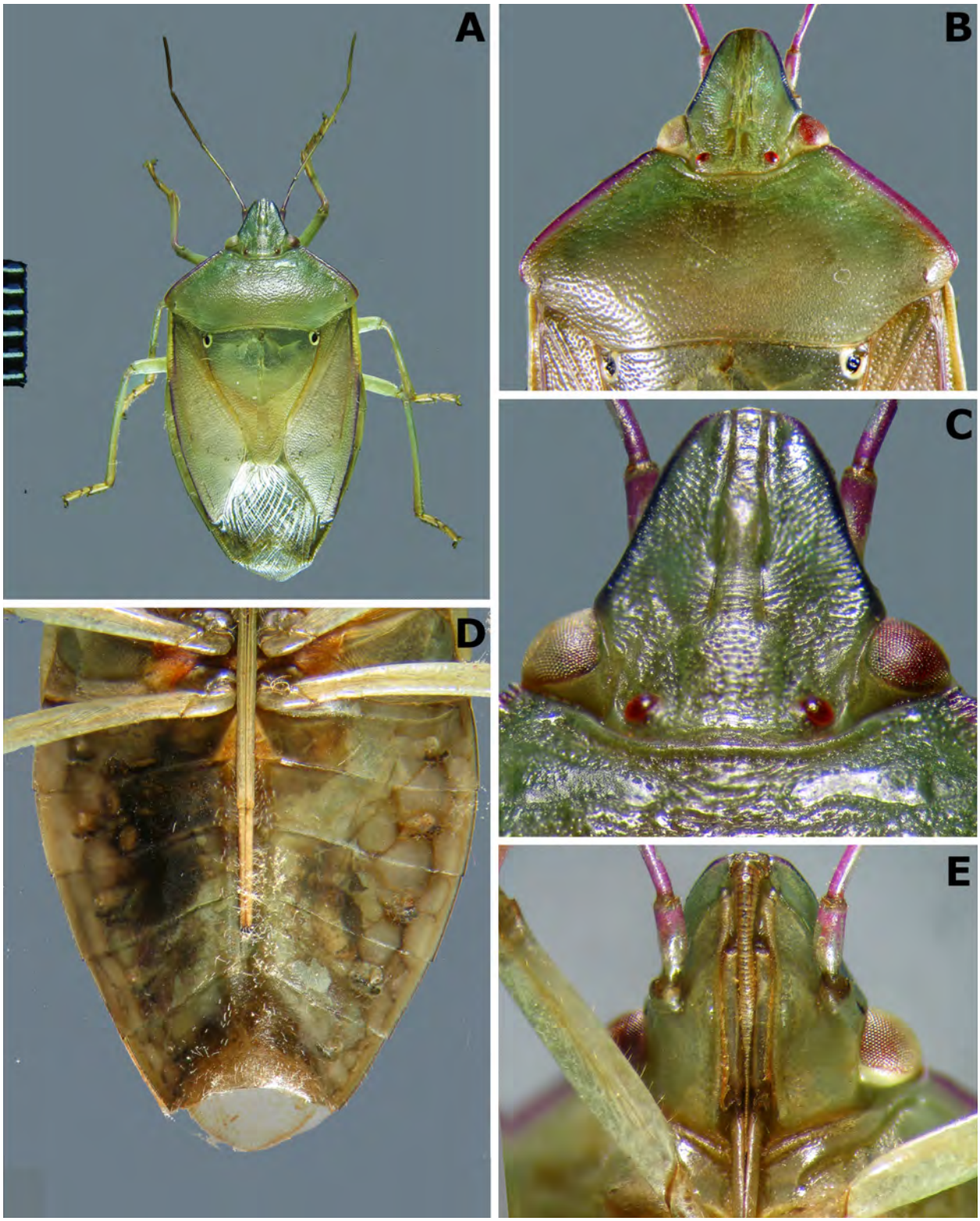

Image 2. *Bathycoelia indica* structure: A—dorsal habitus, scale 5 mm | B—head and pronotum | C—head in dorsal view | D—abdomen in ventral view | E—head in ventral view. © H.V. Ghate.

view. In dorsal view proctiger and moderately large, projecting parameres, with black, sclerotized distal margin of crown, are visible (Image 3A). In ventral view caudo-lateral angles and median portion of emargination

show some black spots (Image 3B). Parameres of characteristic shape, as shown in Image 3C, with a T-like crown, stem and a short basal apodeme, with few but long setae on crown and median part. Phallus with short but well-developed articulating apparatus; phallotheca partly sclerotized, more or less cylindrical, without any processes; a pair of membranous conjunctival processes with three lobes at apex are present, most apical part of some of these lobes are black (Image 3E,F); processes of aedeagus short, sclerotized, encircling median aedeagus, as seen in Image 3D.

Female

Female is very similar to male but is slightly larger than male. The female terminalia are shown here in ventral view (Image 4A). The female genitalia include two pairs of valvifers (= gonocoxites) and two pairs of associated valvulae (= gonapophyses); valvifer VIII (labelled vf 8) and valvifer IX (labelled vf9); valvifer VIII is larger, triangular, visible externally and covered with sparse but long setae while valvifer IX is small and covered with setae; valvulae are very small and not seen externally; laterotergites (= paratergites) VIII and IX are also seen posterior to valvifers (labelled 8 lt and 9 lt). Spermatheca is large with elongate balloon-like and membranous proximal dilation (MD) and small distal pumping region of peculiar shape, with proximal (PF) and distal flange (DF); with proximal (PSD) and distal spermathecal ducts (DSD) with the connection of PSD to genital chamber. Spermathecal bulb (SB) is small with a long lateral appendage (Image 4B,C).

Molecular analysis

The ML analysis (see Image 5) placed the newly generated sequence of *Bathycoelia indica* as sister to the other sequence of the species available on GenBank® (HQ236463), with very strong ultrafast bootstrap support (97), and no intraspecific divergence (p-distance 0%) for the 467 bp COI sequences. *Bathycoelia distincta* was recovered as sister to its congener *B. indica*, with strong ultrafast bootstrap support of 93. The interspecific genetic divergence (p-distance) between the two species stood at 5.1%. All the representatives of the family Pentatomidae included in this study were observed to be monophyletic, with a very strong ultrafast bootstrap support (100). Molecular phylogenetic analysis confirms the specimens included in this study as *Bathycoelia indica*.

Measurements (in mm. Males (n = 2, separated by /). Total length 18.0 /17.5; head length 2.9 / 2.9; head width at eye 3.4 / 3.3; interocular distance 2.0 / 2.0; labium segment I 2.7 / 2.8, segment II 3.25 / 3.0, segment III 4.5 / 4.5, segment IV 2.5 /2.25; antennomere one 1.0 / 1.0, two 1.6 / 1.8, three 2.5 / 2.8, four 4 2.7 / 3.2, five 2.5/ 2.7; pronotal median length 3.25 / 3.25, pronotal width at humerus 9.0 / 9.0; scutellum width at base 5.5 / 5.70, scutellum median length 6.2 / 6.3; fore leg coxa 0.5 / 0.5, femur 4.0 / 4.0, tibia 3.25 / 3.5, tarsus 2.0/2.0; middle leg coxa 0.6 / 0.6, femur 4.6 / 4.7, tibia 4.0/4.0, tarsus 2.0 / 2.0; hind leg coxa 0.7 / 0.7, femur 5.5 / 5.5, tibia 5.0 / 5.0 ; tarsus 2.75 / 2.75.

Females (n = 2, separated by /).Total length 19.0 / 19.0; head length 3.4 / 3.2; head width at eye 3.75 / 3.70; interocular distance 2.25 / 2.20; labium segment I 2.75 / 2.8, segment II 3.0 / 3.0, segment III 5.0 / 5.1, segment IV 3.0 /2.9; antennomere one 1.2 / 1.0, two 1.75 / 1.75, three 2.0 / 2.5, four 2.75 / 2.8, five 2.75/ 2.75; pronotal median length 4.0 / 4.0, pronotal width at humerus 9.5 / 9.4; scutellum width at base 7.5 / 7.4, scutellum median length 4.0 / 4.0; fore leg coxa 0.5 / 0.5, femur 4.0 / 4.1, tibia 3.75 / 3.7, tarsus 2.0 / 1.9; mid leg coxa 0.6 / 0.5, femur 5.5 / 5.4, tibia 4.25 / 4.25, tarsus 2.1 / 2.2; hind leg coxa 0.7 / 0.6, femur 6.25 / 6.20, tibia 5.75 / 5.75 ; tarsus 2.8 / 2.9.

DISCUSSION

Some species of the genus *Bathycoelia,* especially species *Bathycoelia thalassina* (Herrich-Schaffer, 1844), are known as a serious pest on Cocoa plant *Theobroma cacao,* L., (Malvaceae) in tropical Africa, causing considerable damage to cocoa beans (e.g., Lodos 1967; Linnavuori 1982; Nwana 1983). The other species, namely *Bathycoelia distincta* Distant, 1878 is known to affect and severely damage Macadamia *Macadamia integrifolia* Maiden & Betche and *Macadamia tetraphylla* L. Johnson, (Proteaceae) plantations in South Africa (Schoeman 2018). *Bathycoelia indica* has been recorded from pomegranate (Balikai et al. 2011 and additional references cited there) but not regarded as a serious pest in any recent publications (e.g., Elango et al. 2021). However, our observations indicate that this species has a potential of becoming serious pest of pomegranate if control measures are not taken. These bugs seriously damage pomegranate fruits by puncturing that leads to formation of black necrotic spot at the place of puncture; the fruits are also smaller on bug affected plants. At present *B. indica* is the only species under this genus in India.

The egg morphology and even nymphs are remarkably similar to those of *Bathycoelia thalassina*, a species that

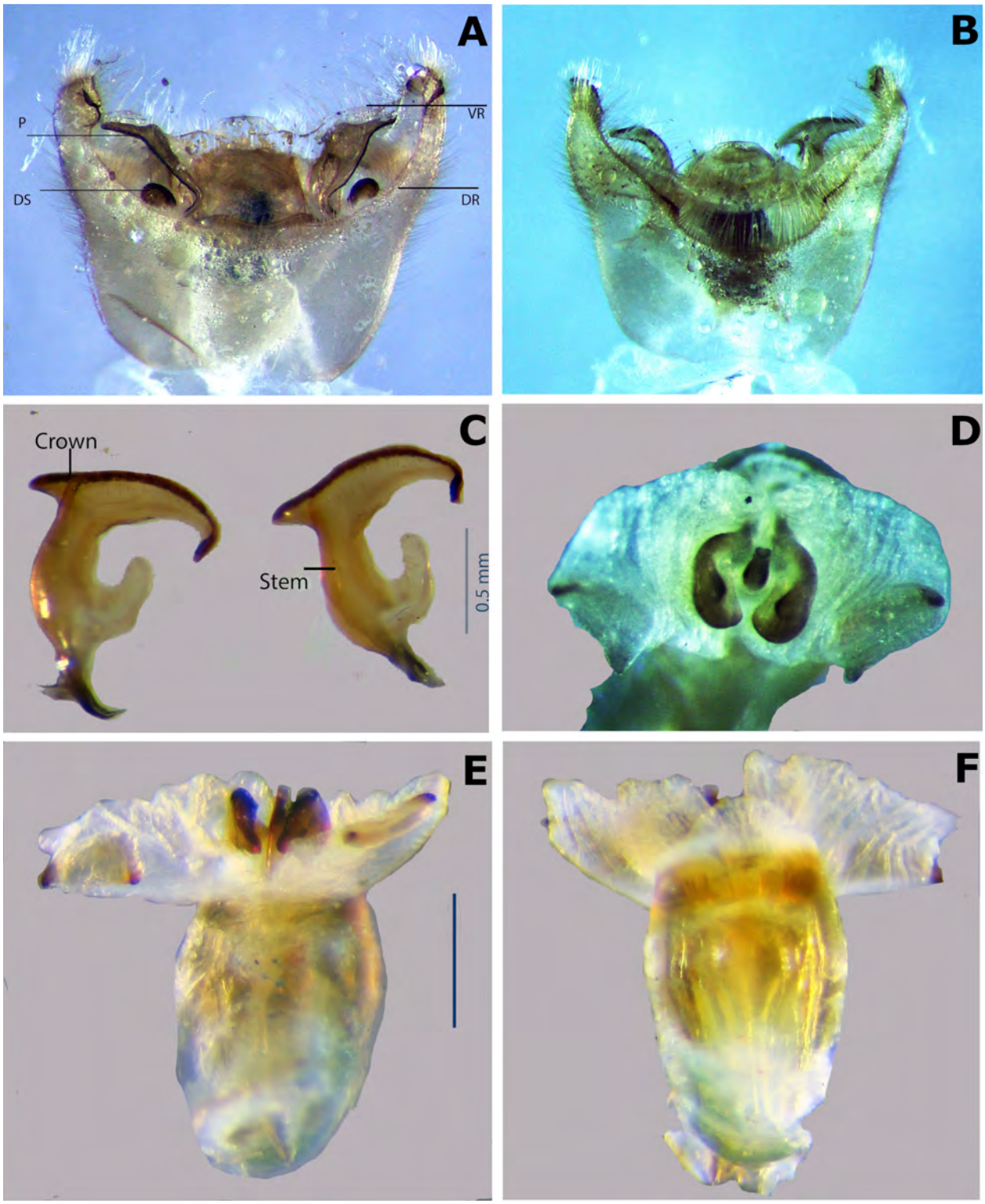

Image 3. ***Bathycoelia indica*** **male genitalia: A & B—pygophore dorsal and ventral view respectively | C—parameres | D—phallus posterior view | E & F—phallus dorsal and ventral view respectively, scale bar 1mm. Abbreviations: DR—dorsal rim | DS—dorsal sclerite | VR—ventral rim | P—parameres. © H.V. Ghate.**

damages cocoa pods, studied by Lodos (1966); the eggs however have about 25 micropyles in *B. indica* while in *B. thalassina* there are about 110 micropyles. According to Lodos (1966) the tissue around the site of puncture

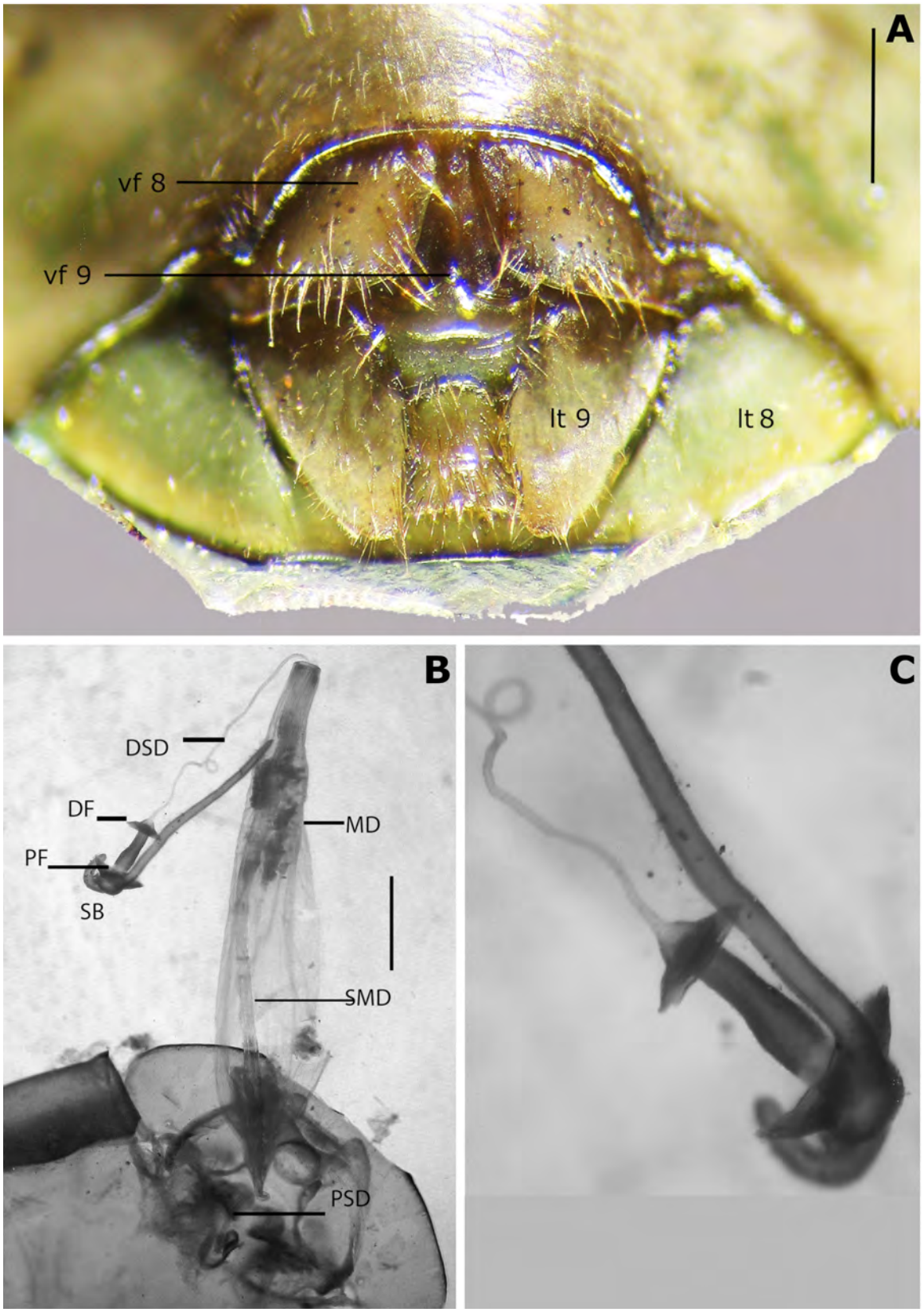

Image 4. *Bathycoelia indica* female genitalia: A—terminalia in ventral view, scale bar 1 mm vf8 and vf9 are valvifers; lt8 and lt9 are laterotergites| B—dissected view of female genitalia, scale 1 mm | C—spermatheca details. Abbreviations: DF—distal flange | DSD—distal spermathecal tube | MD—median dilation | PF—proximal flange | PSD—proximal spermathecal duct | SB—spermathecal bulb | SMD—sclerotized median dilation. © H.V. Ghate.

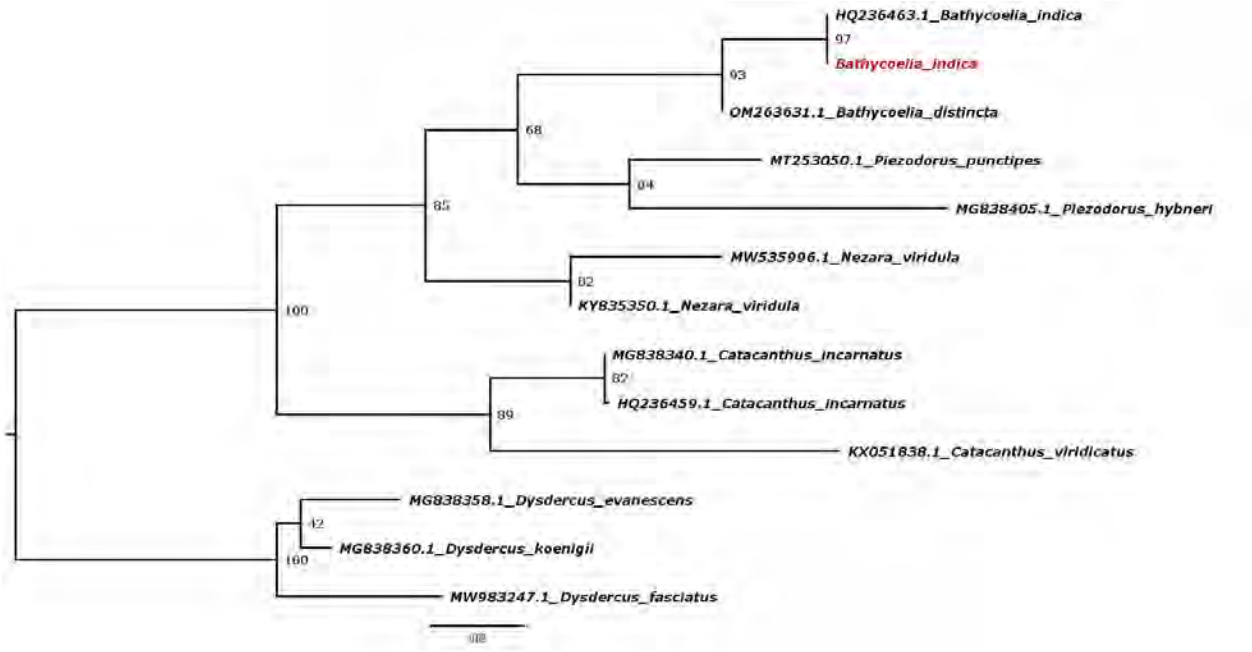

Image 5. Maximum likelihood tree based on COI gene.

in pods dies due to injected fluid and turns yellow to brown to black. This is similar to black spots observed on pomegranate fruits punctured by *B. indica*.

Here we have given photographic documentation of *B. indica* and also the damage caused by it. In addition, we have provided brief information on morphology, including that of male / female genitalia. Earlier Ahmad (1996) gave some diagrams of *B. indica* and Linnavuori (1982) discussed about male genitalia of several *Bathycoelia* species from western Africa, with many figures, and found male genitalia to be relatively similar in species studied. Detailed morphology of *B. indica* has been previously described by Salini (2015, Unpublished PhD Thesis), who also reviewed previous work on this genus.

Fan & Liu (2009) studied *Bathycoelia sinica* Zheng & Liu, 1987 and provided details of male genitalia which are also comparable with our images. Another species in which comparable structure of male genitalia can be observed is *Bathycoelia chlorospila* Walker, 1867 collected from New Guinea (Gross 1978), however, based on figures provided in these papers, their pygophore and parameres are distinctly different from *B. indica*. Gross (1978) also gives detailed diagnosis of the genus *Bathycoelia*, comments on its distribution and also suggests that it is closely related to '*Pentatoma*' group. Tsai & Rédei (2014), who revised the genus *Amblycara* Bergroth, 1891 from the Oriental and Austro-Pacific areas, found close relationship between *Bathycoelia* and *Amblycara* and suggested that both these genera could belong to the tribe Pentatomini; an isolated position in a separate tribe Bathycoeliini is unnecessary for *Bathycoelia*, but more studies on related genera are required. Some of these aspects and general characters of the tribe Bathycoeliini, including pest status of some species, are also discussed by Rider et al. (2018).

We have also sequenced COI gene and shown that the sequence is similar to Pune population that was sequenced earlier (Tembe et al. 2014). It is also apparent that the African species *Bathycoelia distincta* is genetically very close to Indian species. Pal et al. (2022) studied in detail the genetic diversity of *B. distincta* affecting macadamia in three different areas from South Africa and found very low pairwise mean genetic distance among different populations. Based on comparison of COI sequences it appears that *Piezodorus* and *Nezara* are closely related to *Bathycoelia*. Unfortunately, there are no sequences of *Amblycara*, a genus which is suggested close to *Bathycoelia*, as stated above.

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Journal of Threatened Taxa | www.threatenedtaxa.org | 26 January 2024 | 16(1): 24496–24502
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.8349.16.1.24496-24502
#8349 | Received 22 December 2022 | Final received 08 October 2023 | Finally accepted 13 December 2023
OPEN ACCESS
COMMUNICATION

First documentation of diversity of the Heteroptera of Cotton University Campus, Kamrup (Metropolitan), Assam, India

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Abstract: Cotton University, a developing university in Guwahati city of Kamrup district from Assam is undergoing a lot of developmental changes leading to a change in land use pattern which will have an impact on insect distribution. Heteroptera studies being severely lacking from this region needs attention for their documentation. A survey conducted on the campus from July 2018 to July 2019 every week between 0700–0900 h on all types of vegetation documented a total of 163 bugs of 20 different species under 10 families of Heteroptera. Pentatomidae was found to be the most dominant family with eight recorded species. Wild vegetation supported more diverse bug forms than the other garden plants. This survey is the first record of these insects from the Cotton University campus and such data forms an important database of available bugs from this region in the wake of the developmental changes the university is going through. Any change in their distribution, if found in the future, will reflect the impact of anthropogenic activities on their existence and distribution. Studies of this kind may be minuscule in level, but it forms an important record of their presence before we lose them to time.

Keywords: Abundance, anthropogenic activities, evenness, host-switching behaviour, insect distribution, insect inventory, nature, pentatomidae, polyphagous, species richness, vegetation.

Editor: M.E. Hassan, Zoological Survey of India, Patna, India.

Date of publication: 26 January 2024 (online & print)

Citation: Saikia, S. & A.S. Naorem (2024). First documentation of diversity of the Heteroptera of Cotton University Campus, Kamrup (Metropolitan), Assam, India. *Journal of Threatened Taxa* 16(1): 24496–24502. https://doi.org/10.11609/jott.8349.16.1.24496–24502

Funding: Department of Biotechnology, India. Project No. BT/IN/Indo-US/Foldscope/39/2015.

Competing interests: The authors declare no competing interests.

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Author contributions: Concept & Supervision-ASN; Data collection and survey—SS; Data analysis—ASN & SS; Manuscript writing—SS; Manuscript editing and reviewing—ASN.

Acknowledgements: We are thankful to the Department of Biotechnology, India for all the financial support under the project BT/IN/Indo-US/Foldscope/39/2015. We are grateful to the Cotton University authorities for all the institutional support and facilities. We are also thankful to Dr. H.V. Ghate, Department of Zoology, Modern College of Arts, Science and Commerce, Pune, Maharashtra for identification of few bugs and to the esteemed anonymous reviewers for their critical reviews and suggestions. We thank Sadhika Naorem with graphic designing and redefining.

INTRODUCTION

Northeastern region of India is one of the biodiversity hotspots. Assam with tropical monsoon rainfall type region with a mix of hot and humid climate serves as one of the best places for insect population to flourish. However, literature report on Heteroptera diversity from this region is almost negligible. Most of the literature reports about Heteroptera diversity are from northern India or southern India and a few are from western India (Azim 2011; Salini & Viraktamath 2015). Heteroptera is the largest suborder under the order Hemiptera comprising more than 40,000 reported species and possibly 25,000 species are still to be identified (Schaefer & Panizzi 2000). This group of insects are economically very important as they include pests, predators, and vectors of plant pathogens (Mitchell 2004; Kaur et al. 2012; Halder et al. 2020).

Heteropterans are not just insect pests but some of them are important predators of insect pests and they are an important component of our ecosystem. Unfortunately, literature reports on the terrestrial heteropteran studies are lacking from this region despite its faunistic richness. Due to increasing anthropogenic activities related to the developmental work and urbanisation, existence of many organisms, invertebrates, in particular, have become critical, many of them even get extinct over time without having been noticed for their existence. Heteroptera is one such neglected insect group whose records are sparse and limited. Therefore, this work was undertaken to build a biodiversity inventory of heteropteran fauna of Cotton University campus (α diversity) which is a developing university and many new constructions are under way, so an attempt was made to record the available Heteroptera diversity of the campus before much tampering with the natural ecosystem of the campus is done. Study of such insect diversity and their documentation is important to understand the systematics, ecological role, and significance of the insects in an ecosystem. Change in land use pattern, habitat fragmentation, etc., result in distributional variation in insect fauna (Kruess & Tscharntke 2000). So, the objective of this study was to record all the available heteropteran diversity of Cotton University campus before more habitat destruction/fragmentation occurs.

MATERIAL AND METHODS

Study area

Cotton University campus (26.1868 N & 91.7476 E) is situated in the heart of the city Kamrup (M)**,** Assam on the south bank of the mighty Brahmaputra River covering an area of 12.04-acre land (Figure 1). The weather of this location during summer is very hot and humid with heavy rainfall but relatively cooler during winter. The temperature during our study period ranged 10.3–34.4 °C. University campus has the residential area of staff, hostels and cafeteria apart from the main university building. There is a mixed vegetation of wild plants, trees, some herbaceous plants, and vegetable garden but the vegetation distribution is patchy.

Collection

A survey of Heteroptera diversity of the Cotton University campus was carried out from July 2018 to July 2019. For insect collection, random sampling method was used as the vegetation distribution was patchy and not a continuous kind and there is also no specific sampling method for Heteroptera (Fauvel 1999). Insects were collected directly by hand or sweep net and transferred directly into plastic containers. Time of collection was 0700–0900 h as insects are generally active during this time period. The host plants from where the insects were collected were also recorded.

Identification

After collection, insects were observed under stereozoom microscope (Magnus, 2X to 4X) and then they were identified on the basis of morphological characters, using suitable keys (Distant 1902) and book (Rider et al. 2018). Photographs were taken with mobile camera (Samsung M 51, 64 MP camera) and processed in Adobe Photoshop (Version 24.0.1, 2022).

Preservation

Large and hard bodied insects were pinned and dried for 15 days. Dry preserved bugs were kept in wooden boxes provisioned with naphthalene balls to prevent any insect attack. For wet preservation, insects were kept in 70% ethanol along with few drops of glycerine (Mouhoubi et al. 2019). All the dried and wet preserved insects were labelled properly.

Statistical Analysis

Measurement of Diversity

Heteroptera diversity of the Cotton University was calculated using Shannon-Wiener diversity index (H)

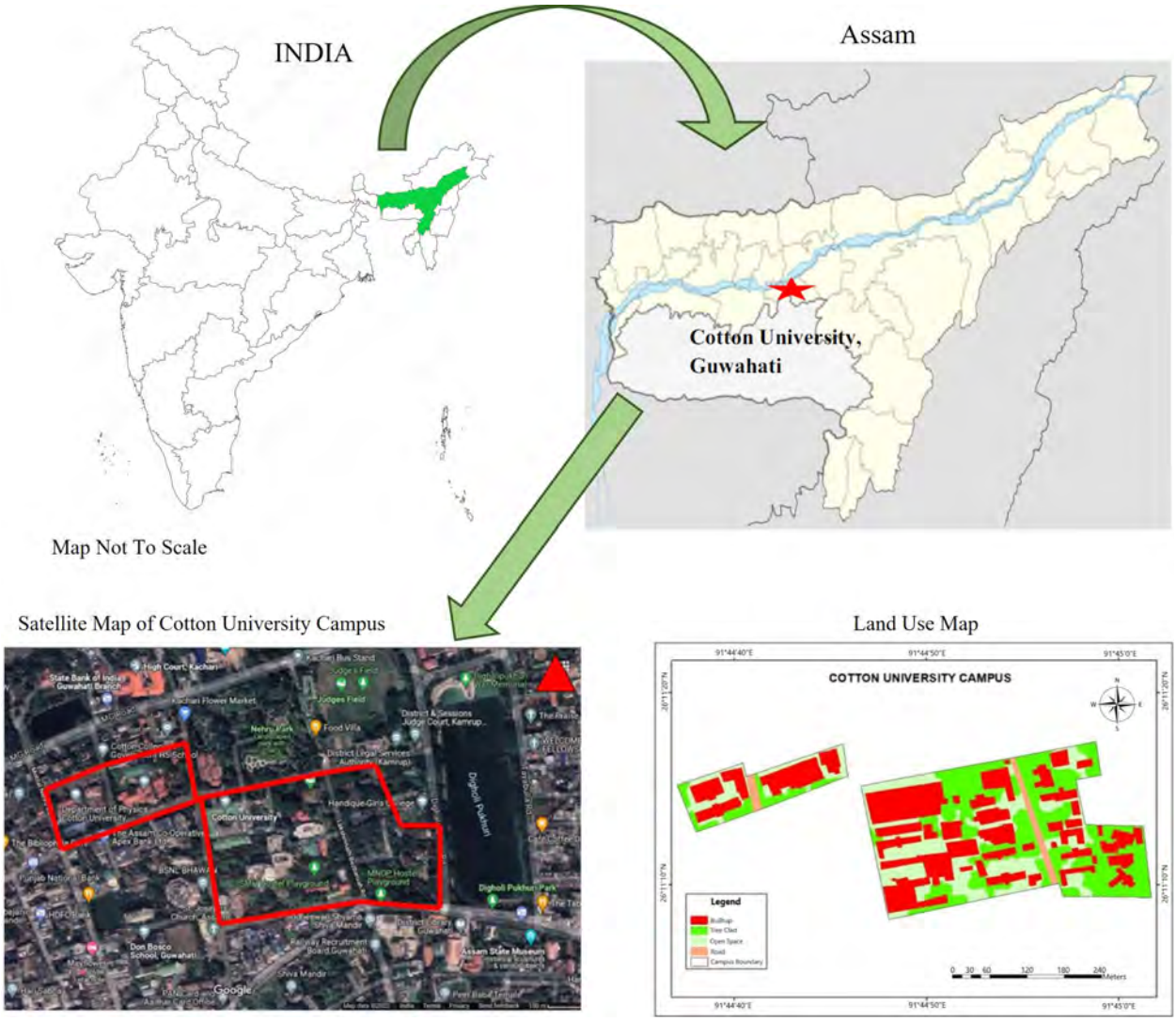

Figure 1. Map of Cotton University Campus (Yumnam & Dey 2022).

(Shannon & Wiener 1949), Simpson's index (D) (Simpson 1949), Margalef's species richness (Margalef 1958), and Pielou's species evenness (Pielou 1966). Dominance status of various species were described on the basis of relative abundance following Engelmann's scale (Engelmann 1973).

RESULTS

During the collection period, July 2018 to July 2019, a total of 163 Heteroptera samples were recorded with 20 species under 10 families (Table 1, Images 1–20). Pentatomidae family was the most diverse in species (40%) in the university campus and three families, viz., Coreidae, Alydidae, and Plataspidae represented nearly 10% each of the Heteroptera diversity and the remaining families represented only 5% of the diversity (Table 1, Figure 2). Bugs like *Carbula scutellata, Megacopta cribraria*, and *Cochlochila bullita* were abundant as compared to other bugs which were either subdominant or recedent.

Bugs were observed and collected from both wild plants as well as some garden plants. Though the plants like *Ocimum sanctum* and *Lablab pururеus* were observed to harbour large number of individuals of a particular bug species but the bug diversity was more on either wild vegetation or on *Acalypha indica,* a herbaceous wild plant under the family Euphorbiaceae or on *Solanum* plant (Figure 3).

Both the Shannon-Wiener index (H) (0.90781) and Simpson index (D) (0.205635) clearly indicated good

Table 1. List of heteropteran insects from Cotton University Campus along with their host plant from where they were collected.

	Family	Name of the insect	Plant/ place of collection	Number of individuals	Relative abundance (%)	Dominance status
1.	Pentatomidae	*Carbula scutellata* Distant, 1887	*Acalypha indica*	27	16.56	Dominant
		Plautia crossota Dallas, 1851	-do-	6	3.68	Subdominant
		Halyomorpha picus Fabricius, 1794	*Solanum melongena*	5	3.07	Recedent
		Tolumnia latipes Dallas, 1851	*Acalypha indica*	2	1.23	Recedent
		Eocanthecona furcellata Wolff, 1811	*Solanum melongena*	1	0.61	Subrecedent
		Piezodorus hybnerii Gmelin, 1789	-do-	1	0.61	Subrecedent
		Eysarcoris guttiger Thunberg, 1783	*Acalypha indica*	9	5.52	Subdominant
		Acrozangis antica Vollenhoven, 1868	Found dead	1	0.61	Subrecedent
2.	Coreidae	*Cletus* sp. Stål, 1860	Wild vegetation	2	1.23	Recedent
		Acanthocoris scabrator Fabricius, 1803	-do-	3	1.84	Recedent
3.	Alydidae	*Riptortus pedestris* Fabricius, 1775	-do-	4	2.45	Recedent
		Leptocorisa acuta Stål, 1825	-do-	4	2.45	Recedent
4.	Plataspidae	*Megacopta cribraria* Fabricius, 1789	*Lablab purpureus*	65	39.88	Eudominant
		Brachyplatys subaeneus Westwood, 1837	-do-	4	2.45	Recedent
5.	Urostylidae	*Urolabida histrionica* Westwood, 1837	*Ficus elastica*	1	0.61	Subrecedent
6.	Lygaeidae	*Graptostethus servus* Fabricius, 1787	Wild vegetation	5	3.07	Recedent
7.	Largidae	*Physopelta* sp. Amyot & Serville, 1843	Found dead	1	0.61	Subrecedent
8.	Scutelleridae	*Chrysocoris stollii* Wolff, 1801	*Solanum lycopersicum*	1	0.61	Subrecedent
9.	Dinidoridae	*Coridius nepalensis* Westwood, 1837	*Solanum melongena*	1	0.61	Subrecedent
10.	Tingidae	*Cochlochila bullita* Stål, 1873	*Ocimum sanctum*	20	12.27	Dominant

RA <1 = Subrecedent; RA = 1.1–3.1 = Recedent; RA = 3.2–10 = Subdominant; RA = 10.1–31.6 = Dominant; RA >31.7 = Eudominant. (Jana et al. 2009; Engelmann 1973).

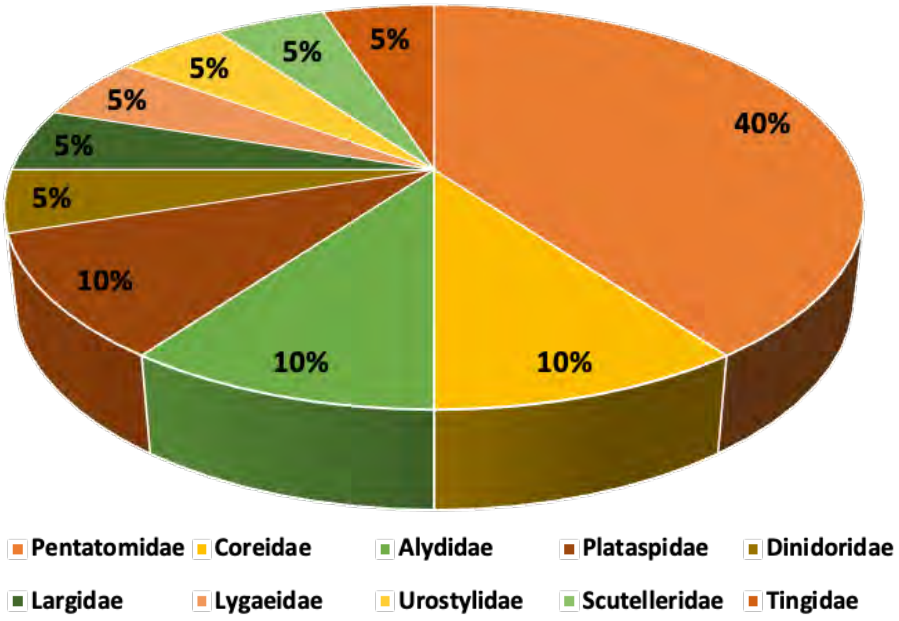

Figure 2. Percentage of bugs according to their number of species collected from a particular Heteroptera family from Cotton University Campus.

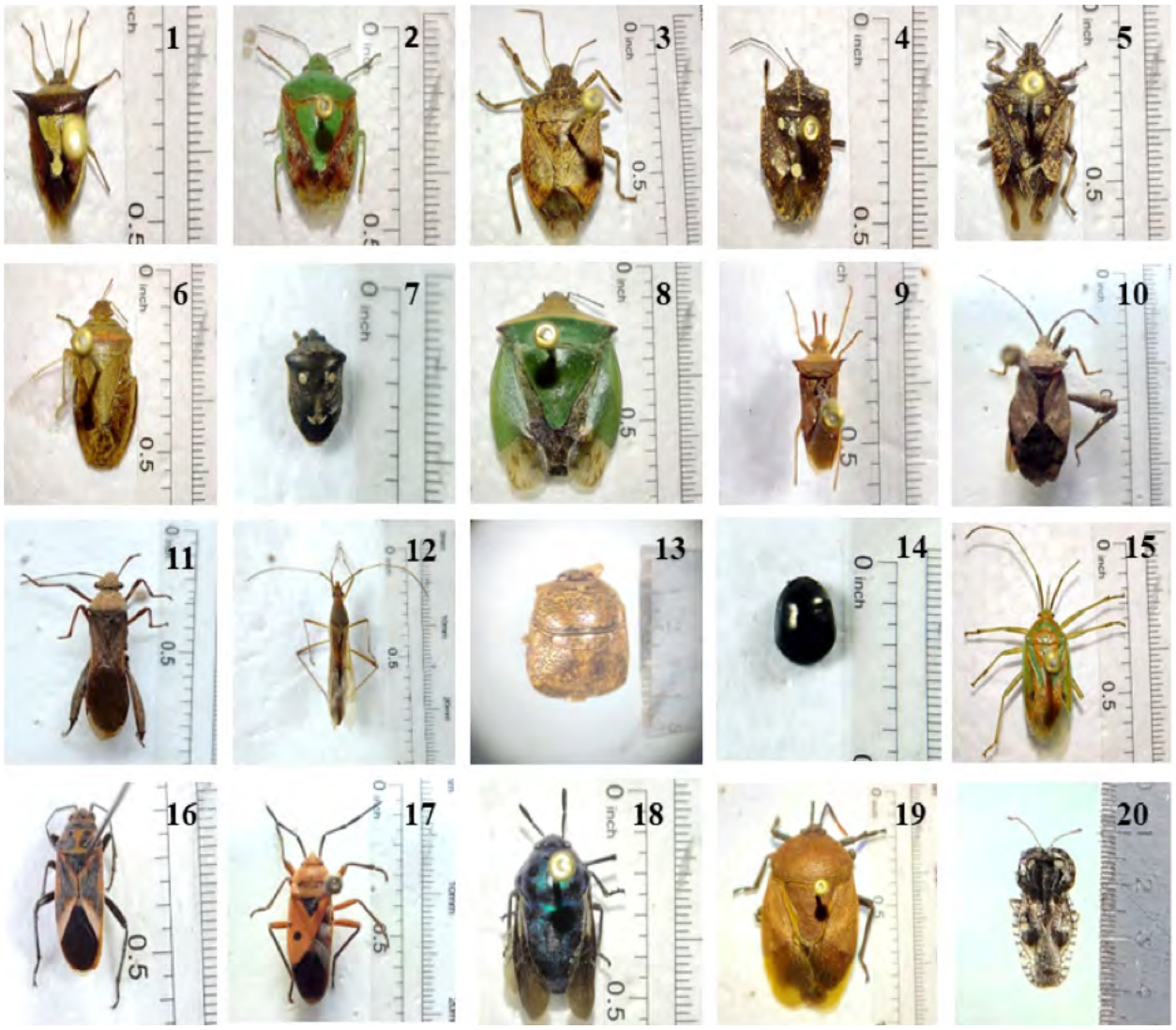

Image 1–20. Heteroptera Diversity of Cotton University Campus.
1—*Carbula scutellata* Distant, 1887 | 2—*Plautia crossota* Dallas, 1851 | 3—*Halyomorpha picus* Fabricius, 1794 | 4—*Tolumnia latipes* Dallas, 1851 | 5—*Eocanthecona furcellata* Wolff, 1811 | 6—*Piezodorus hybnerii* Gmelin, 1789 | 7—*Eysarcoris guttiger* Thunberg, 1783 | 8—*Acrozangis antica* Vollenhoven, 1868 | 9—*Cletus* sp. Stål, 1860 | 10—*Acanthocoris scabrator* Fabricius, 1803 | 11—*Riptortus pedestris* Fabricius, 1775 | 12—*Leptocorisa acuta* Stål, 1825 | 13—*Megacopta cribraria* Fabricius, 1789 | 14—*Brachyplatys subaeneus* Westwood, 1837 | 15—*Urolabida histrionica* Westwood, 1837 | 16—*Graptostethus servus* Fabricius, 1787 | 17—*Physopelta* sp. Amyot & Serville, 1843 | 18—*Chrysocoris stollii* Wolff, 1801 | 19—*Coridius nepalensis* Westwood, 1837 | 20—*Cochlochila bullita* Stål, 1873 . © Santana Saikia.

amount of Heteroptera diversity in the university campus. Margalef's richness was 8.58878 and Pielou's evenness index (0.697762) indicated moderate evenness in the distribution of the species.

DISCUSSION

Heteroptera are one of the most successful insects that almost occupy all the diverse array of habitat owing to their diverse feeding habits (Schuh & Slater 1995). In the present study, Heteroptera bugs were sampled from different kinds of plants some wild and some home-grown garden vegetables. Availability of bugs on these diverse plants could be associated with their polyphagous nature (Panizzi & Grazia 2015) and host switching behaviour to sustain their population. Amongst the 10 different families of Heteroptera recorded from the university campus, Pentatomidae family exhibited most diverse species as compared to others that could be due to their choice of wider range of host plants and ability to thrive well on both cultivated and non-cultivated plants (Panizzi 1997). Presence of large number of Pentatomid bugs may also be because

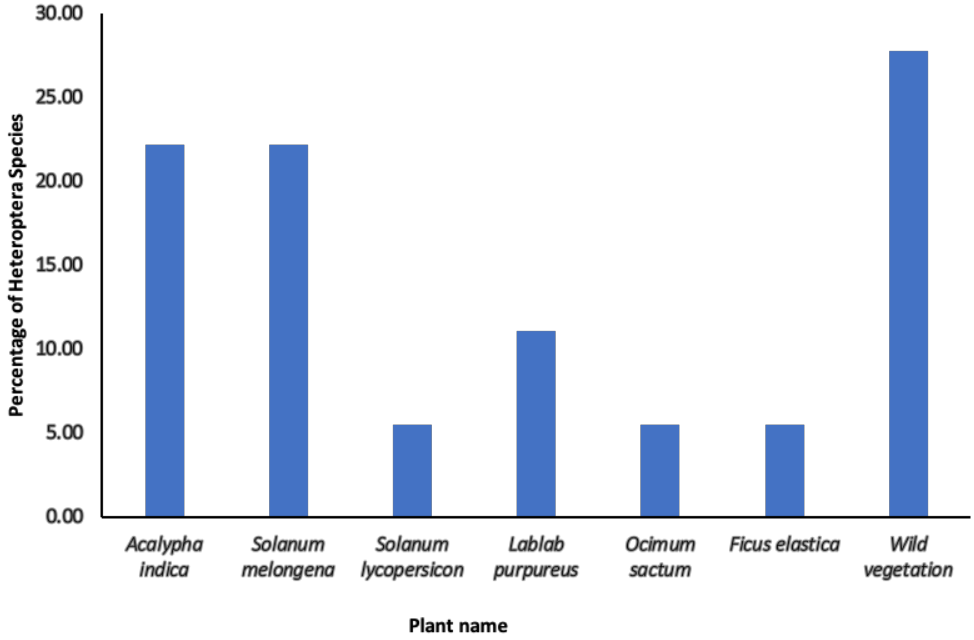

Figure 3. Percentage of different bug species collected from different plants from Cotton University Campus.

of the availability of their suitable host plants/alternate host plants/insect hosts in the university campus. The suborder Heteroptera has 91 different families recorded worldwide (Henry 2017) and among all, Miridae is the most diverse family, followed by Reduviidae, Pentatomidae, Lygaeidae (Schaefer 2013). But deviation from such findings in the present study where we did not find even a single species of Miridae and Reduviidae could be related to the absence of their host/hosts. Pentatomidae was the most diverse family in terms of eight recorded species followed by Coreidae, Alydidae, Plataspidae and so on. Abundance of *M. cribraria* and *C. bullita* in the present study as compared to other bugs was due to the availability of their primary host plant (Zhang et al. 2012; Kumar 2014) in the campus.

Despite the patchy distribution of vegetation in the campus, the diversity indices indicated good diversity in the university campus and the moderate evenness indicated by the Pielou's evenness index was due to the predominance of one species over the other in the region.

CONCLUSION

Insects contribute a lot to the ecosystem services like, source of food, biocontrol agent, and medicine. Their diversity and distributional knowledge therefore, would be of use to mankind in many ways. Study on distribution status of Heteroptera is often neglected primarily due to two reasons; firstly, they are not as attractive as butterflies and secondly their invisible feeding damage to the food crops often goes unnoticed and hence their economic importance is not realised. Moreover, many of them are important as predator of agricultural pests and as vectors of plant pathogen, therefore knowledge of such heteropteran bugs will be helpful in designing pest management strategies. Besides this any studies pertaining to biodiversity like taxonomic identification or report of new species helps in enriching the knowledge of faunal diversity of that region and documenting the insect inventory. The present study was carried out in a small university campus for just one year and it revealed a good amount of Heteroptera diversity. Studies like this forms a base for further research on different aspects of Heteroptera and will lead us to better understanding of diverse group of insects existing in this region. This university, under development is experiencing a lot of changes in terms of land use as well as land cover, thereby having a direct influence on faunal distribution, especially insects. So, any change in the bug diversity in future will be an indication of the impact of anthropogenic activities on their existence and distribution.

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Journal of Threatened Taxa | www.threatenedtaxa.org | 26 January 2024 | 16(1): 24503–24528

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

https://doi.org/10.11609/jott.8636.16.1.24503-24528

#8636 | Received 19 July 2023 | Final received 31 October 2023 | Finally accepted 01 December 2023

OPEN ACCESS

COMMUNICATION

Checklist of hawkmoths (Lepidoptera: Bombycoidea: Sphingidae) in the Central Highlands of Vietnam

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Abstract: Study on hawkmoths (Sphingidae family) in the Central Highlands of Vietnam (Kon Tum, Gia Lai, Dak Lak, Dak Nong, and Lam Dong provinces) was carried out during the years 2016–2022. Light traps and butterfly nets were used to collect specimens of the Sphingidae family in the night and day times. An update checklist of Sphingidae was based on collected specimens in the studied area and combine the review data. Totally, 113 Sphingidae species from the Central Highlands of Vietnam are recorded. Among them, 78 species are recorded from collected specimens and 35 species without collected specimens are compiled from the literatures. Addition, 14 species are herein added to the known list, including one very rare species, *Eurypteryx geoffreyi* Cadiou & Kitching, 1990, and two endemic species, *Griseosphinx marchandi* Cadiou, 1996 and *Callambulyx schintlmeisteri* Brechlin, 1997.

Keywords: Endemic species, *Eurypteryx*, *Griseosphinx*, light trap, national park, rare species, review, specimens, updated list.

Tóm tắt: Nghiên cứu loài Ngài chim (họ Sphingidae) ở Tây Nguyên Việt Nam (tỉnh Kon Tum, Gia Lai, Đắk Lắk, Đắk Nông và Lâm Đồng) được thực hiện trong giai đoạn 2016 - 2022. Bẫy đèn và vợt bướm được sử dụng để thu thập mẫu vật các loài Ngài chim cả ban đêm và ban ngày. Danh sách loài cập nhật về họ Sphingidae được xây dựng dựa trên các mẫu vật thu thập trong khu vực nghiên cứu và kết hợp dữ liệu tổng hợp từ các nghiên cứu trước. Tổng cộng có 113 loài Sphingidae ở Tây Nguyên Việt Nam đã được ghi nhận. Trong đó có 78 loài ghi nhận từ các mẫu vật thu thập được và 35 loài không thu thập mẫu vật, được tổng hợp từ tài liệu. Ngoài ra, có 14 loài bổ sung thêm vào danh sách, bao gồm một loài rất hiếm, Eurypteryx geoffreyi Cadiou & Kitching, 1990, và hai loài đặc hữu, Griseosphinx marchandi Cadiou, 1996 và Callambulyx schintlmeisteri Brechlin, 1997.

Editor: Jatishwor Singh Irungbam, Ceske Budejovice, Czech Republic. **Date of publication:** 26 January 2024 (online & print)

Citation: Le, T.Q. & L.V. Vu (2024). Checklist of hawkmoths (Lepidoptera: Bombycoidea: Sphingidae) in the Central Highlands of Vietnam. *Journal of Threatened Taxa* 16(1): 24503–24528. https://doi.org/10.11609/jott.8636.16.1.24503–24528

Funding: The Master, PhD Scholarship Programme of Vingroup Innovation Foundation (VINIF), code [VINIF. 2022. TS134]; the VIETBIO project and the grant (NCVCC33.01/24-25) from the Vietnam Academy of Science and Technology.

Competing interests: The authors declare no competing interests.

Author details: T.Q. Le: a PhD student on Sphingidae fauna in Vietnam at the Graduate University of Science and Technology, Vietnam Academy of Science and Technology. L.V. Vu: associate professor at the Graduate University of Science and Technology, Vietnam Academy of Science and Technology, and a Deputy General Director of the Vietnam National Museum of Nature, supervisor of the first author.

Author contributions: T.Q. Le conceived the concept of the work, conducted the fieldwork, and wrote the manuscript. L.V. Vu collected some specimens, revised and edited the work, and prepared the Map of Vietnam showing the location of Central Highlands.

Acknowledgements: [Le Quynh Trang] was funded by the Master, PhD Scholarship Programme of Vingroup Innovation Foundation (VINIF), code [VINIF.2022. TS134]. Thanks to the VIETBIO project [Innovative approaches to biodiversity discovery and characterisation in Vietnam] for supporting us in conducting field surveys. Thanks to the grant (NCVCC33.01/24-25) from the Vietnam Academy of Science and Technology.

INTRODUCTION

The family Sphingidae, commonly known as hawkmoths, consists of more than 1,700 species of small to huge moths (wingspans ranging 25–200 mm) that are found worldwide except for Antarctica (Kitching et al. 2018). Zolotuhin & Ryabov (2012) reported 174 hawkmoth species from Vietnam, of which 91 were recorded from the Central Highlands. The Central Highlands includes five provinces, Kon Tum, Gia Lai, Dak Lak, Dak Nong, and Lam Dong (Figure 1), and is topographically dominated by the Annamese Mountains (Truong Son Ranges). The World Wide Fund for Nature has highlighted the rainforests on the northern and southern Truong Son Ranges as global ecoregions that have unique species, communities, and geographical conditions, with globally outstanding biodiversity (Olson et al. 2001)

The moths of the Central Highlands region have not been extensively studied, with very few publications mentioning Sphingidae. Hoang et al. (2011) reported 259 species of Lepidoptera belonging to 27 families, including 22 species and subspecies of Sphingidae, from a survey along the Ho Chi Minh trail through four provinces in the Central Highlands (Kon Tum, Gia Lai, Dak Lak, and Dak Nong). In this paper, the available data on the geographic distributions and taxonomy of the Sphingidae from the Central Highlands of Vietnam was reviewed. Field surveys were undertaken to add to these data and combine the review data with the field data to provide an updated checklist.

MATERIALS AND METHODS

The study area

The Central Highlands extend from the northern borders of Quang Nam province to the southern borders of Gia Lai province. The climate is monsoon tropical with a warm winter, a rainy summer, and a very high annual level of precipitation (3,500–4,500 mm). Two main vegetation types are found: evergreen forest at low and medium altitudes and evergreen mountain forest (1,000–2,500 m) on silicate soils. Surveys were undertaken in the National Parks (NP), Nature Reserves (NR), and forests in four provinces of the Central Highlands region (Kon Tum, Gia Lai, Dak Nong, and Lam Dong provinces) during the years 2016–2022. The region covered by this study comprises Tu Mo Rong district in 2018, Kon Plong district in 2016 and 2019, Dak Glei district in 2019 (Kon Tum province), Kon Ka Kinh NP in 2019, and Kon Chu Rang NR in 2016 and 2019 (Gia Lai province), Nam Nung NR in 2017 and 2020 (Dak Nong province), Bidoup-Nui Ba NP in 2020 and 2022, and the Di Linh Plateau in 2020 (Lam Dong province).

Methods

Specimens were collected using light traps consisting of two 250-watt mercury-vapour lamps powered by a small generator. The light sources were placed in front of a 200 x 300 cm white linen sheet and, if required, protected from the rain by an umbrella. Beck & Linsenmair (2005) showed that the abundance of specimens at light influenced by moonlight and moonless nights produced the highest specimen counts, so to avoid the negative effect of the moon, our collecting was carried out from a week before the new moon until a week after. The traps were run from about half an hour after the sunset to half an hour before the sunrise, totaling an average sampling time of about ten hours per night. In addition, some species are active during the daytime, so were collected using a butterfly net. Specimens were also collected along trails in the study areas where their host plants were flowering for one hour after sunrise and one hour before sunset. Specimens were killed by ammonia or ethyl acetate and then dried and preserved in the Vietnam National Museum of Nature, Vietnam Academy of Science and Technology.

Taxonomic study

Identifications were undertaken using the taxonomic literature: Rothschild & Jordan (1903), Bell & Scott (1937), Kitching & Spitzer (1995), Inoue et al. (1997), Kitching & Cadiou (2000), Zolotuhin & Ryabov (2012), and the Sphingidae Taxonomic Inventory website (Kitching 2023). Higher classification and nomenclature follow Kitching et al. (2018). For species whose external morphology is indistinct, genitalia dissection was undertaken, following Clarke (1941) and Robinson (1976).

The recorded global distributions of Sphingidae were referred from literatures (Walker 1856; Holloway 1987; Haruta 1993, 1994; Lodl 1993; Smetacek 1994, 2008; Kitching & Spitzer 1995; Inoue et al. 1997; Kishida 1998; Mandal & Ghosh 1999; Kitching & Cadiou 2000; Pittaway & Kitching 2000; Kendrick 2002; Chandra & Rajan 2004; Brechlin 2009; Chandra et al. 2014, 2019; Kendrick & Young 2014; Pathania et al. 2014; Rafi et al. 2014; Ivshin & Krutov 2018; Kitching et al. 2018; Sanyal et al. 2018; Irungbam & Irungbam 2019; Iyer & Kitching 2019; Melichar et al. 2018; Kishida & Yano 2020; Irungbam & Fric 2021; Singh et al. 2021; Gielis et al. 2022; Norbu et al. 2022; Kitching 2023).

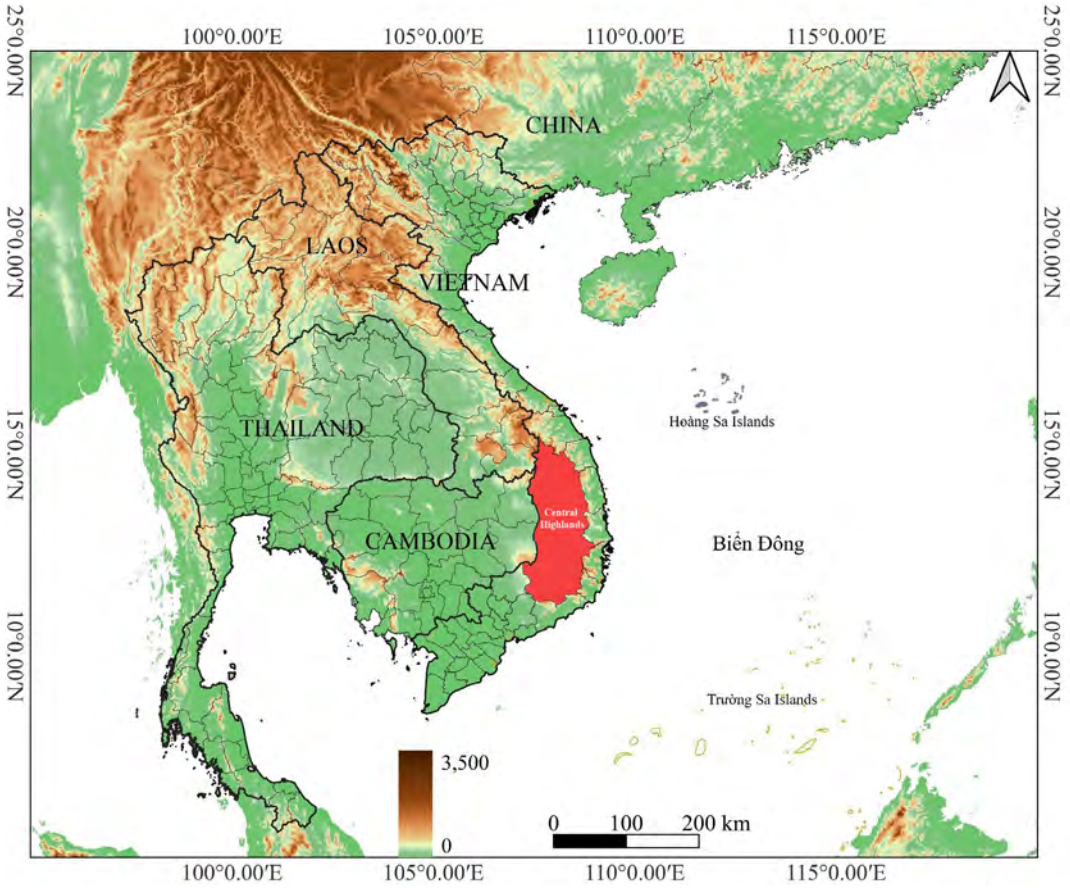

Figure 1. Map of Vietnam showing the location of Central Highlands (red area).

RESULTS

Around 113 species belonging to three subfamilies, comprising 11 Sphinginae, 36 Smerinthinae, and 66 Macroglossinae. We added 14 species to those reported by previous studies, including a very rare species, *Eurypteryx geoffreyi* Cadiou & Kitching, 1990, and two endemic species, *Griseosphinx marchandi* Cadiou, 1996 and *Callambulyx schintlmeisteri* Brechlin, 1997. They are indicated in the following list by an asterisk.

Subfamily Sphinginae Latreille, 1802

Genus *Acherontia* [Laspeyres], 1809

1. *Acherontia lachesis* (Fabricius, 1798) (Image 1.1)

Sphinx lachesis Fabricius, 1798, *Supplementum Entomologiae Systematicae:* 434. Type locality: "India orientali".

Materials: 1 male, 1 female, xii.2020, v.2022, Lam Dong province, Bidoup-Nui Ba NP, 20.333°N, 105.583°E, 400 m, coll. Q.T. Le.

Distribution: Eastern Pakistan, Sri Lanka, India, Nepal, Bhutan, Myanmar, China, Hong Kong, southern Japan, Thailand, Laos, Vietnam, Malaysia, Philippines, and Indonesia to Papua New Guinea.

Local distribution: Lao Cai, Cao Bang, Lang Son, Vinh Phuc, Quang Ninh, Ninh Binh, Nghe An, Thua Thien Hue, and the Central Highlands (Kon Tum, Gia Lai, Lam Dong, Dak Nong).

2. *Acherontia styx* (Westwood, 1847) (Image 1.2)

Sphinx styx Westwood, 1847, *The Cabinet of Oriental Entomology*: 88, pl. 42, fig. 3. Type locality: "East Indies".

Materials: 1 male, xii.2020, v.2022, Lam Dong province, Bidoup-Nui Ba NP, 20.333°N, 105.583°E, 400 m, coll. Q.T. Le.

Distribution: Iraq, Saudi Arabia to Iran, Pakistan, India, Nepal, Bhutan, Bangladesh, Myanmar, China, Thailand, Vietnam, and Philippines.

Local distribution: Lao Cai, Vinh Phuc, Thua Thien Hue, and the Central Highlands (Lam Dong).

Genus *Agrius* Hübner, [1819]

3. *Agrius convolvuli* (Linnaeus, 1758) (Image 1.3)

Sphinx convolvuli Linnaeus, 1758, *Systema Naturae*

(Ed. 10), 1: 490. Type locality: not stated [Europe].

Materials: 1 male, xii.2020, v.2022, Lam Dong province, Bidoup-Nui Ba NP, 20.333°N, 105.583°E, 400 m, coll. Q.T. Le.

Distribution: Africa, southern Europe Sri Lanka, Pakistan, India, Bhutan, Myanmar, China, Hong Kong, Vietnam, Malaysia, Indonesia, Australia, and the Pacific.

Local distribution: Lai Chau, Lao Cai, Vinh Phuc, Lang Son, Quang Ninh, Hoa Binh, Ninh Binh, Nghe An, Thua Thien Hue, Quang Tri, and the Central Highlands (Lam Dong, Dak Nong).

Genus *Megacorma* Rothschild & Jordan, 1903

4. *Megacorma obliqua* (Walker, 1856) (Image 1.4)

Macrosila obliqua Walker, 1856, *List of the Specimens of Lepidopterous Insects in the Collection of the British Museum,* 8: 208. Type locality: Ceylon [Sri Lanka].

Materials: 2 males, v.2020, Dak Nong province, Krong No District, Nam Nung NR, 12.016°N, 107.716°E, 920 m, coll. Q.T. Le.

Distribution: Sri Lanka, India, Myanmar, Thailand, Vietnam, Malaysia, Philippines, Indonesia, New Guinea, and Solomon Islands.

Local distribution: Lao Cai, Lang Son, Vinh Phuc, Ninh Binh, Nghe An, Thua Thien Hue, and the Central Highlands (Kon Tum, Gia Lai, Lam Dong, Dak Nong).

Genus *Hyloicus* Hübner, [1819]

5. *Hyloicus centrovietnama* (Brechlin, 2015)

Sphinx centrovietnama Brechlin, 2015, *Entomo-Satsphingia,* 8(1): 16–19. Type locality: Kon Tum, Plato Tay Nguyen, Mt. Ngoc Linh [Vietnam].

Materials examined: None

Remarks: This species was previously as recorded as *Sphinx caligineus* (Butler, 1877) by Hoang et al. (2011).

Distribution: China, Thailand, Vietnam, and Laos.

Local distribution: the Central Highlands.

Genus *Meganoton* Boisduval, [1875]

6. *Meganoton nyctiphanes* (Walker, 1856) (Image 1.6)

Macrosila nyctiphanes Walker, 1856, *List of the Specimens of Lepidopterous Insects in the Collection of the British Museum,* 8: 209. Type locality: Silhet [Bangladesh].

Materials: 2 male, 1 female, v.2020, Dak Nong province, Krong No District, Nam Nung NR, 12.016°N, 107.716°E, 920 m, coll. Q.T. Le.

Distribution: Sri Lanka, India, Myanmar, Thailand, Vietnam, Andamans, Malaysia, Philippines, and Sumatra.

Local distribution: Lao Cai, Thua Thien Hue, Quang Nam, Quang Binh, the Central Highlands (Lam Dong, Dak Nong), and Dong Nai.

Genus *Cerberonoton* Zolotuhin & Ryabov, 2012

7. *Cerberonoton rubescens* (Butler, 1876) (Image 1.7)

Diludia rubescens Butler, 1876, *Proceedings of the Zoological Society of London,* 1875: 623. Type locality: [North India].

Materials: 1 male, v.2019, Kon Tum province, Dak Glei District, 15.067°N, 107.733°E, 1,053 m, coll. V.L Vu.

Distribution: India, Thailand, and Vietnam

Local distribution: Lao Cai, Yen Bai, Lang Son, Quang Ninh, Vinh Phuc, Ninh Binh, Nghe An, Quang Binh, Thua Thien Hue, Quang Nam, the Central Highlands (Kon Tum, Gia Lai), and Dong Nai.

Genus *Notonagemia* Zolotuhin & Ryabov, 2012

8. *Notonagemia analis* (Felder, C. & Felder, R., 1874) (Image 1.8)

Sphinx analis Felder, C. & Felder, R., 1874, *Lepidoptera. Heft IV. Atlas der Heterocera Sphingidae-Noctuidae*, pl.78, fig. 4. Type locality: Shanghai [China].

Materials: 1 male, v.2019, Kon Tum province, Konplong District, Village Mang Canh, 14.667°N, 108.267°E, 1,226 m, coll. Q.T. Le.

Distribution: China, Taiwan, Thailand, Vietnam, Malaysia, Singapore, and Indonesia.

Local distribution: Lao Cai, Vinh Phuc, Nghe An, Quang Tri, Thua Thien Hue, Khanh Hoa, the Central Highlands (Kon Tum, Gia Lai, Dak Nong), and Dong Nai.

Genus *Psilogramma* Rothschild & Jordan, 1903

9. *Psilogramma increta* (Walker, 1865) (Image 1.9)

Anceryx increta Walker, 1865, *List of the Specimens of Lepidopterous Insects in the Collection of the British Museum,* 31: 36. Type locality: Shanghai [China].

Materials: 1 male, v.2022, Lam Dong province, Bidoup-Nui Ba NP, 20.333°N, 105.583°E, 400 m, coll. Q.T. Le.

Distribution: Northern Pakistan, throughout India, Nepal, Bhutan, Myanmar, eastern China to Korea, Hong Kong, Taiwan, Japan, Thailand, Laos, and Vietnam.

Local distribution: Cao Bang, Lang Son, Vinh Phuc, Thai Nguyen, Ninh Binh, Nghe An, Quang Binh, Quang Tri, Thua Thien Hue, Quang Nam, the Central Highlands (Lam Dong), and Dong Nai.

10. *Psilogramma discistriga* (Walker, 1856) (Image 1.10)

Macrosila discistriga Walker, 1856, *List of the Specimens of Lepidopterous Insects in the Collection of the British Museum,* 8: 209 Type locality: Silhet [Bangladesh].

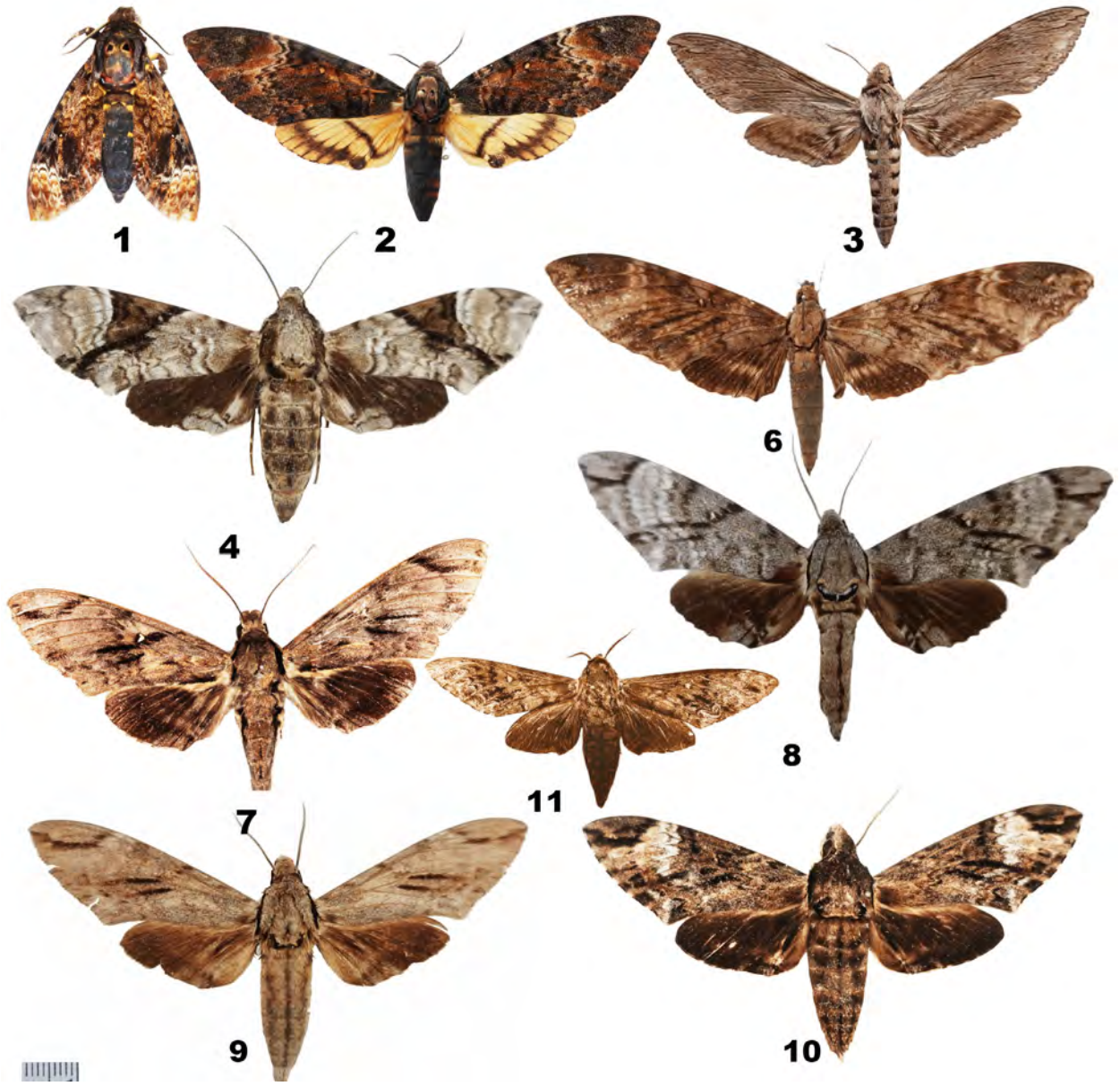

Image 1. Species pictures of the subfamily Sphinginae Latreille, 1802.
1—*Acherontia lachesis* (Fabricius, 1798) | 2—*Acherontia styx* (Westwood, 1847) | 3—*Agrius convolvuli* (Linnaeus, 1758) | 4—*Megacorma obliqua* (Walker, 1856) | 6- *Meganoton nyctiphanes* (Walker, 1856)| 7—*Cerberonoton rubescens* (Butler, 1876) | 8—*Notonagemia analis* (Felder C. & Felder R., 1874) | 9—*Psilogramma increta* (Walker, 1865) | 10—*Psilogramma discistriga* (Butler, 1875) | 11—*Dolbina inexacta* (Walker, 1856). © T.Q. Le.

Materials: 1 male, x.2017, Dak Nong province, Krong No District, Nam Nung NR, 12.016°N, 107.716°E, 920 m, coll. Q.T. Le.

Distribution: throughout India, Sri Lanka, China, Thailand, Vietnam, Sundaland, Philippines, and Australia.

Local distribution: Cao Bang, Lao Cai, Vinh Phuc, Ninh Binh, Nghe An, Quang Binh, Thua Thien Hue, Quang Nam, the Central Highlands (Gia Lai, Lam Dong, Dak Nong), and Dong Nai.

Genus *Dolbina* Staudinger, 1887

11. *Dolbina inexacta* (Walker, 1856) (Image 1.11)

Macrosila inexacta Walker, 1856, *List of the Specimens of Lepidopterous Insects in the Collection of the British Museum,* 8: 208. Type locality: [N. India].

Materials: 1 male, v.2022, Lam Dong province, Bidoup-Nui Ba NP, 20.333°N, 105.583°E, 400 m, coll. Q.T. Le.

Distribution: Pakistan, throughout India, Nepal, Bhutan, Myanmar, southern China, Taiwan, Thailand,

and Vietnam.

Local distribution: Cao Bang, Lao Cai, Ninh Binh, Bac Giang, Nghe An, Quang Tri, Thua Thien Hue, Da Nang, and the Central Highlands (Lam Dong).

Subfamily Smerinthinae Grote & Robinson, 1865

Genus *Ambulyx* Westwood, 1847

12. *Ambulyx canescens* (Walker, 1865)* (Image 2.12)

Basiana canescens Walker, 1865, *List of the Specimens of Lepidopterous Insects in the Collection of the British Museum,* 31: 38. Type locality: Cambodia.

Materials: 1 male, v.2020, Dak Nong province, Krong No District, Nam Nung NR, 12.016°N, 107.716°E, 920 m, coll. Q.T. Le.

Distribution: China, Thailand, Vietnam, Cambodia, Malaysia, Philippines, and Singapore.

Local distribution: Quang Nam, and the Central Highlands (Dak Nong).

13. *Ambulyx liturata* Butler, 1875 (Image 2.13)

Ambulyx liturata Butler, 1875, *Proceedings of the Zoological Society of London,* 1875: 251. Type locality: Locality not stated.

Materials: 1 male, x.2020, Lam Dong province, Di Linh, 11.516°N, 108.083°E, coll. Q.T. Le.

Distribution: Northeastern India, Nepal, Bhutan, Myanmar, southern China, Hong Kong, Thailand, Vietnam, Laos, and Cambodia.

Local distribution: Lao Cai, Vinh Phuc, Lang Son, Quang Ninh, Thua Thien Hue, Quang Nam, Khanh Hoa, and the Central Highlands (Kon Tum, Lam Dong, Dak Nong).

14. *Ambulyx moorei* Moore, 1858 (Image 2.14)

Ambulyx moorei Moore, 1858, in Horsfield & Moore, *A catalogue of the Lepidopterous Insects in the Museum of the Hon. East-India Company,* 1: 266. Type locality: [Indonesia,] Java [Jawa].

Materials: 1 male, v.2019, Gia Lai province, Kon Ka Kinh NP, 14.215°N, 108.283°E, 901m, coll. Q.T. Le.

Distribution: India, China, Thailand, Vietnam, Malaysia, Philippines, and Singapore.

Local distribution: Lao Cai, Vinh Phuc, Hoa Binh, Son La, Ninh Binh, Quang Ninh, Thanh Hoa, Nghe An, Thua Thien Hue, Quang Nam, and the Central Highlands (Kon Tum, Gia Lai, Lam Dong, Dak Nong), and Dong Nai.

15. *Ambulyx ochracea* Butler, 1885 (Image 2.15)

Ambulyx ochracea Butler, 1885, *Cistula Entomologica,* 3: 113. Type locality: Nikko [Japan].

Materials: 1 male, v.2019, Gia Lai province, Kon Ka Kinh NP, 14.215°N, 108.283°E, 901m, coll. Q.T. Le.

Distribution: Northeastern India, Nepal, Bhutan, China, Taiwan, Hong Kong, Japan, Korea, Thailand, Vietnam, Laos, and Cambodia.

Local distribution: Lao Cai, Son La, Lang Son, Vinh Phuc, Thua Thien Hue, Quang Nam, the Central Highlands (Kon Tum, Gia Lai, Lam Dong), and Dong Nai.

16. *Ambulyx pryeri* Distant, 1887 (Image 2.16)

Ambulyx pryeri Distant, 1887, *Annals and Magazine of Natural History,* 20: 271. Type locality: North Borneo [Malaysia].

Materials: 1 female, v.2020, Dak Nong province, Krong No District, Nam Nung NR, 12.016°N, 107.716°E, 920 m, coll. Q.T. Le.

Distribution: Malaysia, Philippines, Indonesia, Singapore, Thailand, and Vietnam.

Local distribution: Vinh Phuc, Thua Thien Hue, Quang Nam, and the Central Highlands (Dak Nong).

17. *Ambulyx schauffelbergeri* Bremer & Grey, 1853* (Image 2.17)

Ambulix [sic] schauffelbergeri Bremer & Grey, 1853, in Motschulsky (ed.), Études Entomologiques, 1: 62. Type locality: Pekin [China, Beijing].

Materials: 1 male, v.2019, Kon Tum province, Dak Glei District, 15.067°N, 107.733°E, 1,053m, coll. V.L Vu.

Distribution: China, Japan, Korea, and Vietnam.

Local distribution: Nghe An and the Central Highlands (Kon Tum, Dak Nong).

18. *Ambulyx sericeipennis* Butler, 1875 (Image 2.18)

Ambulyx sericeipennis Butler, 1875, *Proceedings of the Zoological Society of London,* 1875: 252. Type locality: Northwestern Himalaya [India, Uttarakhand,] Masuri [Mussoorie].

Materials: 1 male, v.2016, Gia Lai province, K'Bang District, Kon Chu Rang NR, 14.471°N, 108.574°E, 1,097 m, coll. Q.T. Le.

Distribution: Northern Pakistan, Nepal, Bhutan, northern India, Myanmar, China, Taiwan, Thailand, Vietnam, Laos, Cambodia, Indonesia (Java), and Philippines.

Local distribution: Lao Cai, Lang Son, Vinh Phuc, Quang Ninh, Nghe An, Quang Tri, Thua Thien Hue, Khanh Hoa, and the Central Highlands (Kon Tum, Gia Lai, Lam Dong).

19. *Ambulyx substrigilis* Westwood, 1847 (Image 2.19)

Sphinx substrigilis Westwood, 1847, *The Cabinet of Oriental Entomology*: [61], pl. 30, fig. 2. Type locality:

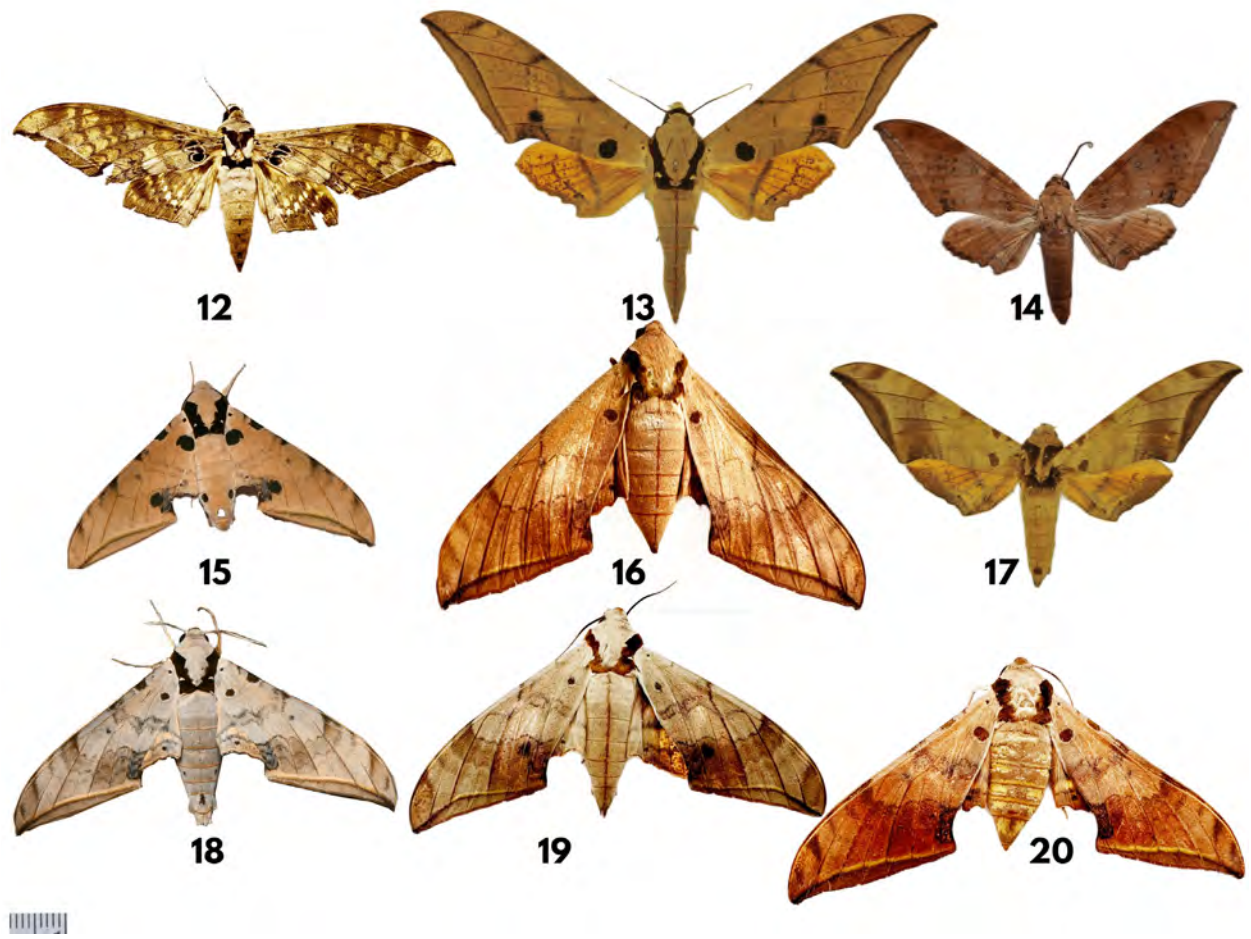

Image 2. Species pictures of the genus *Ambulyx* of the subfamily Smerinthinae Grote & Robinson, 1865.
12—*Ambulyx canescens* (Walker, 1865)* | 13—*Ambulyx liturata* Butler, 1875 | 14—*Ambulyx moorei* Moore, 1858 | 15—*Ambulyx ochracea* Butler, 1885 | 16—*Ambulyx pryeri* Distant, 1887 | 17—*Ambulyx schauffelbergeri* Bremer & Grey, 1853* | 18—*Ambulyx sericeipennis* Butler, 1875 | 19—*Ambulyx substrigilis* Westwood, 1847 | 20—*Ambulyx tobii* (Inoue, 1976)*. © T.Q. Le.

Sylhet [Bangladesh].

Materials: 1 male, v.2020, Dak Nong province, Krong No District, Nam Nung NR, 12.016°N, 107.716°E, 920 m, coll. Q.T. Le.

Distribution: Sri Lanka, northern and southern India, Nepal, Bhutan, Bangladesh, Thailand, Vietnam, Malaysia, Philippines, and Indonesia.

Local distribution: Lai Chau, Lao Cai, Lang Son, Vinh Phuc, Ninh Binh, Quang Binh, Quang Tri, Thua Thien Hue, Quang Nam, and the Central Highlands (Dak Nong), and Dong Nai.

20. *Ambulyx tobii* (Inoue, 1976) * (Image 2.20)

Oxyambulyx sericeipennis tobii Inoue, 1976, *Bulletin. Faculty of Domestic Sciences of Otsuma Women's University,* 12: 173. Type locality: Japan, "Nakatsugawa, Sumoto City, Awajishima" <<Shimane, Ichibata>>.

Type locality: [♂] Japan: Nakatsugawa, Awajishima, Sumoto City.

Materials: 1 male, v.2019, Gia Lai province, Kon Ka Kinh NP, 14.215°N, 108.283°E, 901 m, coll. Q.T. Le.

Distribution: China, Taiwan, Japan, Korea, and Vietnam.

Local distribution: Vinh Phuc, Thua Thien Hue, and the Central Highlands (Gia Lai, Dak Nong).

Genus *Amplypterus* Hübner, [1819]

21. *Amplypterus mansoni* (Clark, 1924) (Image 3.21)

Compsogene mansoni Clark, 1924, *Proceedings of the New England Zoological Club,* 9: 17. Type locality: Sikkim [Northeastern India].

Materials: 2 females, v.2016, Gia Lai province, K'Bang District, Kon Chu Rang NR, 14.471°N, 108.574°E, 1097 m, coll. Q.T. Le.

Distribution: Northeastern India, Nepal, Bhutan, Thailand, Vietnam, Malaysia, and Singapore.

Local distribution: Lao Cai, Thua Thien Hue, and the Central Highlands (Kon Tum, Gia Lai, Lam Dong).

22. *Amplypterus panopus* (Cramer, 1779) (Image 3.22)

Sphinx panopus Cramer, 1779, *Uitlandsche Kapellen,* 3: 50, pl. 224, figs A, B. Type locality: Java [Indonesia].

Materials: 2 females, v.2020, Dak Nong province, Krong No District, Nam Nung NR, 12.016°N, 107.716°E, 920 m, , coll. Q.T. Le.

Distribution: Northern, western, & northeastern India, Nepal, Bhutan, Myanmar, China, Thailand, Vietnam, Cambodia, Laos, Sundaland, and Philippines.

Local distribution: Lao Cai, Lang Son, Vinh Phuc, Hanoi, and the Central Highlands (Dak Nong).

Genus *Anambulyx* Rothschild & Jordan, 1903

23. *Anambulyx elwesi* (Druce, 1882)

Ambulyx elwesi Druce, 1882, *Entomologist's Monthly Magazine,* 19: 17. Type locality: Darjiling [India].

Materials examined: None

Remarks: This species was recorded previously by Zolotuhin & Ryabov (2012).

Distribution: northern Pakistan, northern and northeastern India, Nepal, Bhutan, Myanmar, southwestern China, northern Thailand, and Vietnam.

Local distribution: Lao Cai, Lang Son, Vinh Phuc, Thua Thien Hue, and the Central Highlands (Gia Lai, Lam Dong).

Genus *Barbourion* Clark, 1934

24. *Barbourion lemaii* (Le Moult, 1933) (Image 3.24)

Callambulyx lemaii Le Moult, 1933, *Novitates Entomologicae,* 3: 19, pl.1, fig. 7. Type locality: Chapa [Tonkin] (Sa Pa: Vietnam).

Materials: 1 male, v.2016, Kon Tum province, Konplong District, Village Mang Canh, 14.667°N, 108.267°E, 1,226 m, coll. Q.T. Le.

Distribution: Myanmar, China, Thailand, Vietnam, and Laos.

Local distribution: Lao Cai, Vinh Phuc, Thua Thien Hue, and the Central Highlands (Kon Tum, Gia Lai, Lam Dong).

Genus *Callambulyx* Rothschild & Jordan, 1903

25. *Callambulyx diehli* Brechlin & Kitching, 2012 (Image 3.25)

Callambulyx diehli Brechlin & Kitching, 2012, *Entomo-Satsphingia,* 5: 56. Type locality: Sumatra [Indonesia].

Materials: 1 male, v.2022, Lam Dong province, Bidoup-Nui Ba NP, 20.333°N, 105.583°E, 700 m, coll. Q.T. Le.

Distribution: Myanmar, China, Thailand, Vietnam, Laos, and Indonesia (Sumatra).

Local distribution: Lang Son, Vinh Phuc, Nghe An, and the Central Highlands (Lam Dong).

26. *Callambulyx rubricosa* (Walker, 1856) (Image 3.26)

Ambulyx rubricosa Walker, 1856, *List of the Specimens of Lepidopterous Insects in the Collection of the British Museum,* 8: 122. Type locality: "Hindostan".

Materials: 2 males, v.2019, Gia Lai province, Kon Ka Kinh NP, 14.215°N, 108.283°E, 901 m, coll. Q.T. Le.

Distribution: Northeastern India, Nepal, Bhutan, Myanmar, China, Thailand, Vietnam, Laos, and Cambodia.

Local distribution: Lang Son, Cao Bang, Vinh Phuc, Ninh Binh, Nghe An, Quang Binh, Quang Tri, Thua Thien Hue, Quang Nam, Khanh Hoa, and the Central Highlands (Kon Tum, Gia Lai, Lam Dong), Dong Nai.

27. *Callambulyx schintlmeisteri* Brechlin, 1997 (Image 3.27)

Callambulyx schintlmeisteri Brechlin, 1997, *Nachrichten des Entomologischen Vereins Apollo (N.F.),* 17(4): 368. Type locality: Thua Thien-Hue, Bach-Ma National Park [Vietnam]

Materials: 1 male, xii.2020, Lam Dong province, Bidoup-Nui Ba NP, 20.333°N, 105.583°E, 700 m, coll. Q.T. Le.

Distribution: Vietnam

Local distribution: Ninh Binh, Nghe An, Thua Thien Hue, and the Central Highlands (Lam Dong, Dak Nong).

Genus *Craspedortha* Mell, 1922

28. *Craspedortha porphyria* (Butler, 1876) (Image 3.28)

Daphnusa porphyria Butler, 1876, *Transactions of the Zoological Society of London,* 9: 640. Type locality: Darjeeling [India].

Materials: 1 male, x.2020, Lam Dong province, Di Linh, 11.516°N, 108.083°E, coll. Q.T. Le

Distribution: India, Nepal, China, Thailand, Vietnam, and Laos.

Local distribution: Lao Cai, Bac Giang, Ninh Binh, Nghe AnQuang Binh, Thua Thien Hue, Quang Nam, the Central Highlands (Lam Dong), and Dong Nai.

Genus *Opistoclanis* Jordan, 1929

29. *Opistoclanis hawkeri* (Joicey & Talbot, 1921)

Clanis hawkeri Joicey & Talbot, 1921, *Entomologist,* 54: 106. Type locality: French Indo-China (probably Laos).

Materials examined: None

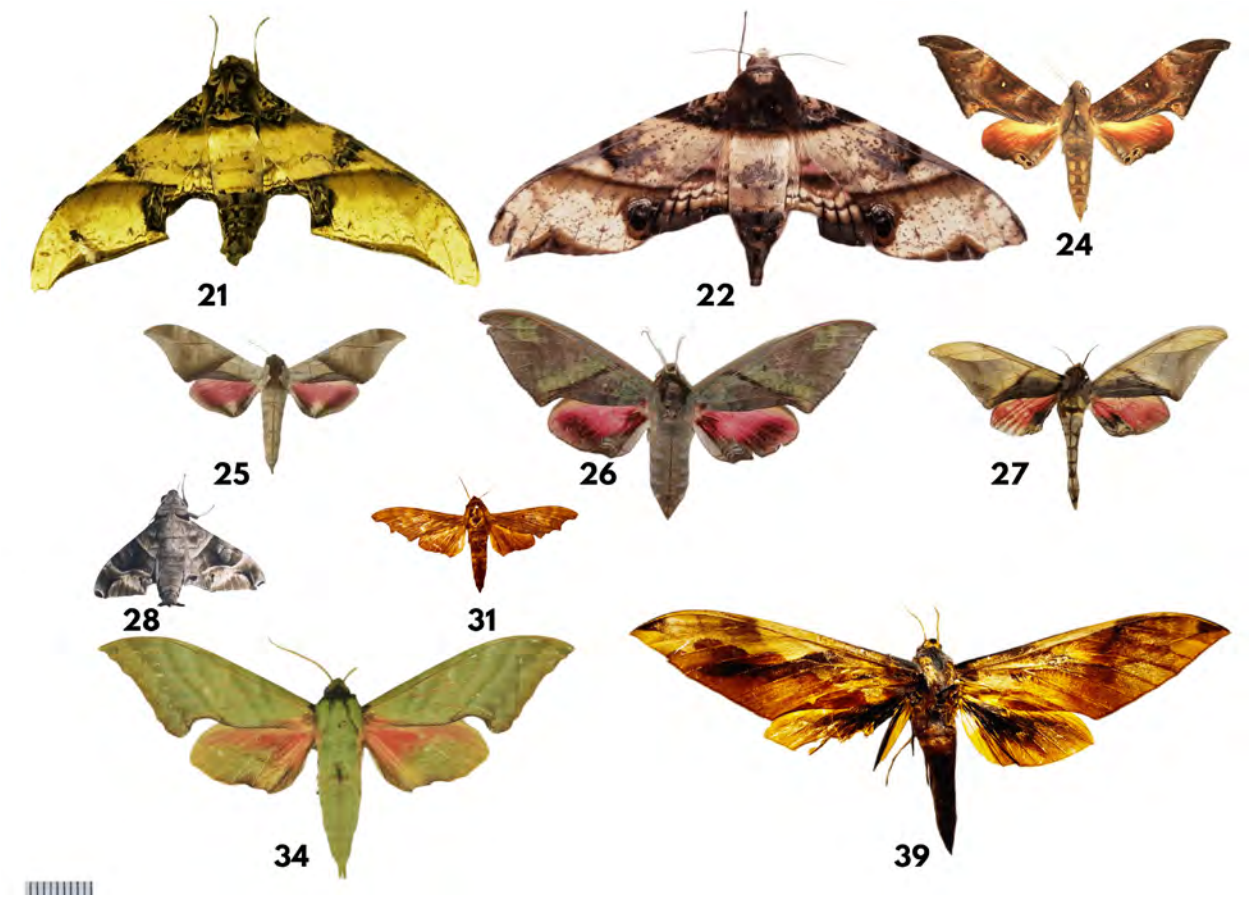

Image 3. Species pictures of the genera *Amplypterus, Barbourion, Callambulyx, Craspedortha, Cypa, Rhodoprasina*, and *Clanis* of the subfamily Smerinthinae Grote & Robinson, 1865.
21—*Amplypterus mansoni* (Clark, 1924) | 22—*Amplypterus panopus* (Cramer, 1779) | 24—*Barbourion lemaii* (Le Moult, 1933) | 25—*Callambulyx diehli* Brechlin & Kitching, 2012 | 26—*Callambulyx rubricosa* (Walker, 1856) | 27—*Callambulyx schintlmeisteri* Brechlin, 1997 | 28—*Craspedortha porphyria* (Butler, 1876) | 31—*Cypa decolor* (Walker, 1856)* | 34—*Rhodoprasina callantha centrovietnama* Brechlin, 2015 | 39—*Clanis schwartzi* Cadiou, 1993. © T.Q. Le.

Remarks: This species was recorded previously by Hoang et al. (2011).

Distribution: Thailand, Laos, China, and Vietnam.

Local distribution: Lang Son, Quang Ninh, Quang Binh, Quang Tri, and the Central Highlands.

Genus *Parum* Rothschild & Jordan, 1903

30. *Parum colligata* (Walker, 1856)

Daphnusa colligata Walker, 1856, *List of the Specimens of Lepidopterous Insects in the Collection of the British Museum,* 8: 238. Type locality: [Nothern China].

Materials examined: None

Remarks: This species was recorded previously by Hoang et al. (2011).

Distribution: India, Myanmar, China, Japan, Taiwan, Korea, Thailand, Vietnam, Laos, and Phillipines.

Local distribution: Lao Cai, Yen Bai, Cao Bang, Lang Son, Thai Nguyen, Vinh Phuc, Quang Ninh, Ninh Binh, Nghe An, Quang Binh, Quang Nam, the Central Highlands, and Dong Nai.

Genus *Cypa* Walker, 1865

31. *Cypa decolor* (Walker, 1856)* (Image 3.31)

Smerinthus decolor Walker, 1856, *List of the Specimens of Lepidopterous Insects in the Collection of the British Museum,* 8: 255. Type locality: Hindostan [India].

Materials examined: 1 male, v.2019, Gia Lai province, Kon Ka Kinh NP, 14.215°N, 108.283°E, 901 m, coll. Q.T. Le.

Distribution: India, Myanmar, China, Thailand, Vietnam, Laos, Cambodia, Malaysia, Philippines, New Guinea, and Singapore.

Local distribution: Quang Binh, Thua Thien Hue, the Central Highlands (Gia Lai, Dak Nong), and Binh Phuoc.

32. *Cypa enodis* Jordan, 1931

Cypa enodis Jordan, 1931, *Novitates Zoologicae,* 36: 240. Type locality: Assam [India].

Materials examined: None

Remarks: This species was recorded previously by Zolotuhin & Ryabov (2012).

Distribution: Nepal, Myanamar, China, Thailand, Vietnam, and Laos.

Local distribution: Lai Chau, Lao Cai, Lang Son, Thua Thien Hue, and the Central Highlands (Gia Lai).

33. *Cypa latericia* Inoue, 1991

Cypa latericia Inoue, 1991, *Tinea*, 13: 132. Type locality: Phu-Hin Rongkla [Thailand].

Materials examined: None

Remarks: This species was recorded previously by Zolotuhin & Ryabov (2012).

Distribution: Myanmar, Thailand, and Vietnam.

Local distribution: Thua Thien Hue and the Central Highlands.

Genus *Rhodoprasina* Rothschild & Jordan, 1903

34. *Rhodoprasina callantha centrovietnama* Brechlin, 2015 (Image 3.34)

Rhodoprasina callantha centrovietnama Brechlin, 2015, *Entomo-Satsphingia,* 8: 27. Type locality: Quang Ngai [Vietnam].

Materials examined: 1 male, v.2016, Gia Lai province, K'Bang District, Kon Chu Rang NR, 14.471°N, 108.574°E, 1,097 m, coll. Q.T. Le.

Distribution: Thailand, Vietnam and Laos.

Local distribution: Lai Chau, Lao Cai, and the Central Highlands (Kon Tum, Gia Lai).

Genus *Smerinthulus* Huwe, 1895

35. *Smerinthulus perversa bachmaensis* Brechlin, 2016

Smerinthulus perversa bachmaensis Brechlin, 2016, *Entomo-Satsphingia,* 9: 88. Type locality: Thua Thien-Hue, Bach Ma Mts. [Vietnam].

Materials examined: None

Remarks: This species was recorded previously by Zolotuhin & Ryabov (2012).

Distribution: Vietnam

Local distribution: the Central Highlands

36. *Smerinthulus baokimae* Brechlin, 2015

Smerinthulus baokimae Brechlin, 2015, *Entomo-Satsphingia,* 8: 5. Type locality: Da Nang, Ba Na Hills. [Vietnam].

Materials examined: None

Remarks: This species was recorded previously by Zolotuhin & Ryabov (2012).

Distribution: Vietnam and Laos

Local distribution: Lao Cai and the Central Highlands.

Genus *Smerinthus* Latreille, [1802]

37. *Smerinthus szechuanus* (Clark, 1938)

Anambulyx szechuanus Clark, 1938, *Proceedings of the New England Zoological Club*, 17: 43. Type locality: Sichuan [China].

Materials examined: None

Remarks: This species was recorded previously by Zolotuhin & Ryabov (2012).

Distribution: China and Vietnam

Local distribution: Lai Chau, Lao Cai, Cao Bang, and the Central Highlands.

Genus *Clanis* Hübner, [1819]

38. *Clanis bilineata* (Walker, 1866)

Basiana bilineata Walker, 1866, *List of the Specimens of Lepidopterous Insects in the Collection of the British Museum,* 35: 1857. Type locality: Darjeeling [India].

Materials examined: None

Remarks: This species was recorded previously by Hoang et al. (2011).

Distribution: India, Nepal, China, Thailand, and Vietnam.

Local distribution: Lao Cai, Lang Son, Quang Ninh, Ninh Binh, Nghe An, Quang Binh, Quang Tri, Thua Thien Hue, Quang Nam, the Central Highlands, and Dong Nai.

39. *Clanis schwartzi* Cadiou, 1993 (Image 3.39)

Clanis schwartzi Cadiou, 1993, *Lambillionea,* 93: 445. Type locality: Ban Kheun [Laos].

Materials examined: 1 male, v.2016, Gia Lai province, K'Bang District, Kon Chu Rang NR, 14.471°N, 108.574°E, 1,097 m, coll. Q.T. Le.

Distribution: China, Thailand, Vietnam, and Laos.

Local distribution: Lao Cai, Vinh Phuc, Quang Ninh, Nghe An, Thua Thien Hue, Quang Nam, and the Central Highlands (Gia Lai).

40. *Clanis undulosa gigantea* Rothschild, 1894

Clanis gigantea Rothschild, 1894, *Novitates Zoologicae,* 1: 96. Type locality: Assam [N India].

Materials examined: None

Remarks: This species was recorded previouslyby Zolotuhin & Ryabov (2012).

Distribution: Northeastern India, Nepal, Bhutan, China, Thailand, Vietnam, and Malaysia.

Local distribution: Lai Chau, Lao Cai, Hoa Binh, Thua Thien Hue, and the Central Highlands.

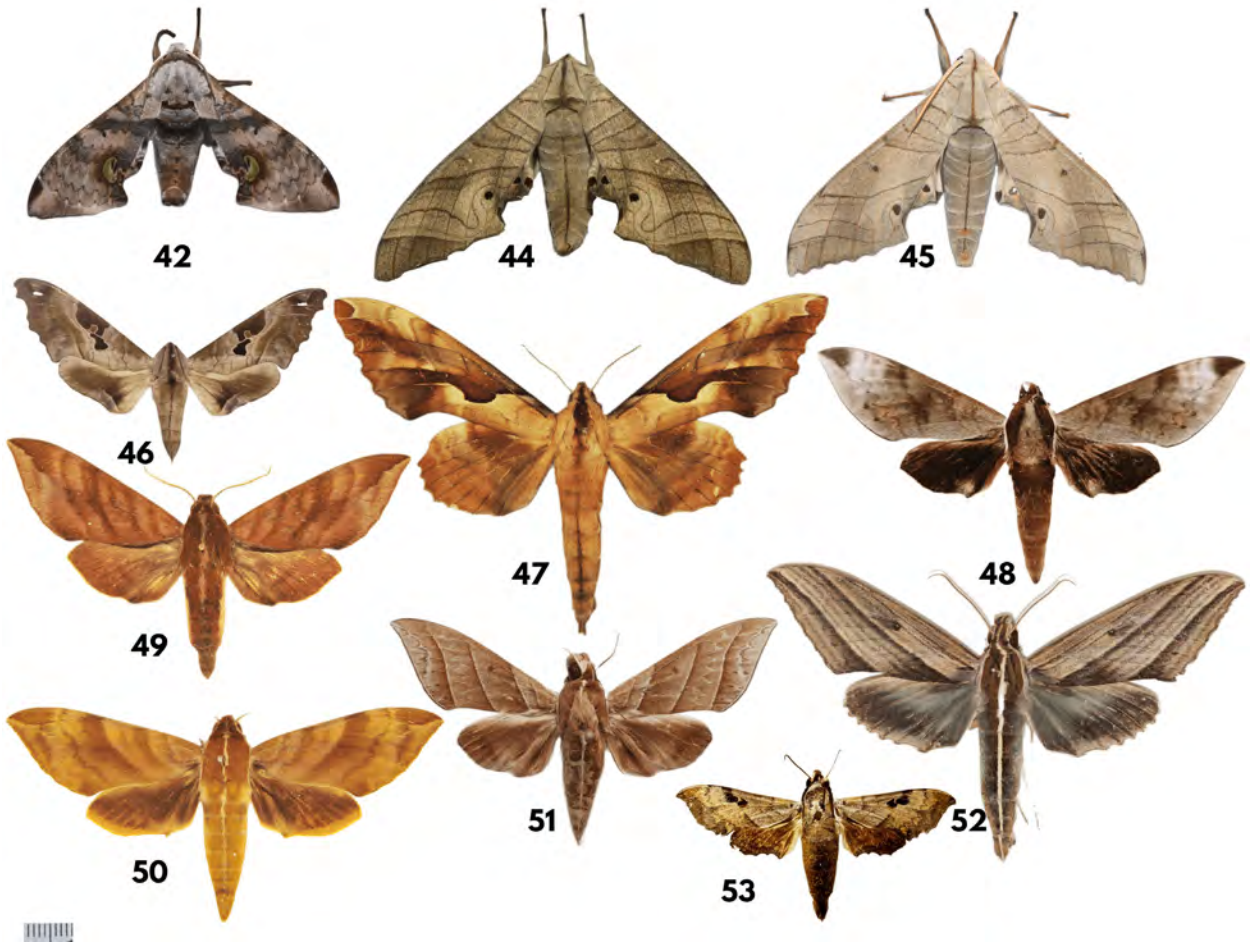

Image 4. Species pictures of the genera *Daphnusa*, *Marumba*, *Morwennius*, and *Phyllosphingia* of the subfamily Smerinthinae Grote & Robinson, 1865; genera *Acosmerycoides*, *Ampelophaga*, *Elibia*, and *Enpinanga* of the subfamily Macroglossinae Harris, 1839
42—*Daphnusa sinocontinentalis* Brechlin, 2009 | 44—*Marumba dyras* (Walker, 1856) | 45—*Marumba sperchius* (Ménétriés, 1857) | 46—*Morwennius decoratus* (Moore, 1872) | 47—*Phyllosphingia dissimilis berdievi* Zolotuhin & Ryabov, 2012 | 48—*Acosmerycoides harterti* (Rothschild, 1895) | 49—*Ampelophaga khasiana* Rothschild, 1895 | 50—*Ampelophaga rubiginosa* Bremer & Grey, 1852* | 51—*Elibia dolichoides* (Felder, C. & Felder, R., 1874) | 52—*Elibia dolichus* (Westwood, 1847) | 53—*Enpinanga assamensis* (Walker, 1856)*. © T.Q. Le.

Genus *Leucophlebia* Westwood, 1847

41. *Leucophlebia lineata* Westwood, 1847

Leucophlebia lineata Westwood, 1847, *The Cabinet of Oriental Entomology*: [46], pl. 22, fig.2. Type locality: Assam [India].

Materials examined: None

Remarks: This species was recorded previously by both Hoang et al. (2011) and Zolotuhin & Ryabov (2012).

Distribution: Sri Lanka, India, Nepal, China, Taiwan, Thailand, Vietnam, Malaysia, Philippines, and Indonesia.

Local distribution: Lao Cai, Vinh Phuc, Hanoi, Quang Tri, the Central Highlands, and Dong Nai.

Genus *Daphnusa* Walker, 1856

42. *Daphnusa sinocontinentalis* Brechlin, 2009 (Image 4.42)

Daphnusa sinocontinentalis Brechlin, 2009, *Entomo-Satsphingia,* 2: 12. Type locality: Chiang Mai, Doi Inthanon NP. [Thailand].

Materials examined: 1 male, v.2019, Gia Lai province, Kon Ka Kinh NP, 14.215°N, 108.283°E, 901 m, coll. Q.T. Le.

Distribution: India, Myanmar, China, Thailand, Vietnam, Laos, and Cambodia.

Local distribution: Vinh Phuc, Quang Ninh, Bac Giang, Ninh Binh, Thanh Hoa, Nghe An, Quang Binh, Quang Tri, Thua Thien Hue, Quang Nam, the Central Highlands (Gia Lai, Dak Nong), Dong Nai.

Genus *Marumba* Moore, 1882

43. *Marumba cristata* (Butler, 1875)

Triptogon cristata Butler, 1875, *Proceedings of the Zoological Society of London,* 1875: 253. Type locality: Darling [India].

Materials examined: 1 male, v.2020, Dak Nong

province, Krong No District, Nam Nung NR, 12.016°N, 107.716°E, 920 m, coll. Q.T. Le.

Distribution: India, Nepal, Bhutan, China, Thailand, Vietnam, Laos, Indonesia and Singapore.

Local distribution: Lai Chau, Lao Cai, Lang Son, Vinh Phuc, Nghe An, and the Central Highlands (Dak Nong).

44. *Marumba dyras* (Walker, 1856) (Image 4.44)

Smerinthus dyras Walker, 1856, *List of the Specimens of Lepidopterous Insects in the Collection of the British Museum,* 8: 250. Type locality: Ceylon [Sri Lanka].

Materials examined: 1 male, v.2020, Dak Nong province, Krong No District, Nam Nung NR, 12.016°N, 107.716°E, 920 m, coll. Q.T. Le.

Distribution: Sri Lanka, northwestern India, Nepal, Bhutan, Andaman & Nicobar Islands, Myanmar, China, Taiwan, Thailand, Vietnam, Cambodia, Laos, Malaysia, Indonesia, and Philippines.

Local distribution: Tuyen Quang, Lang Son, Quang Ninh, Ninh Binh, Nghe An, Quang Tri, Thua Thien Hue, the Central Highlands (Gia Lai, Lam Dong, Dak Nong), and Dong Nai.

45. *Marumba sperchius* (Ménétriés, 1857) (Image 4.45)

Smerinthus sperchius Ménétriés, 1857, *Classis Insectorum Ordo Lepidopterorum,* 2: 137, pl. 13, fig. 5. Type locality: [Japan].

Materials examined: 1 male, v.2020, Dak Nong province, Krong No District, Nam Nung NR, 12.016°N, 107.716°E, 920 m, coll. Q.T. Le.

Distribution: Northern Pakistan, northern India, Nepal, Bhutan, Russian Far East, China, Taiwan, Korea, Japan, Thailand, Vietnam, Laos, and Indonesia (Sumatra).

Local distribution: Hoa Binh, Lai Chau, Lao Cai, Vinh Phuc, Lang Son, Thua Thien Hue, and the Central Highlands (Gia Lai, Lam Dong, Dak Nong).

Genus *Morwennius* Cassidy, Allen & Harman, 2002

46. *Morwennius decoratus* (Moore, 1872) (Image 4.46)

Smerinthus decoratus Moore, 1872, *Proceedings of the Zoological Society of London,* 1872: 568. Type locality: Sikkim [India].

Materials examined: 1 male, v.2020, Dak Nong province, Krong No District, Nam Nung NR, 12.016°N, 107.716°E, 920 m, coll. Q.T. Le.

Distribution: India, China, Laos, Thailand, Vietnam, and Indonesia (Sumatra).

Local distribution: Ninh Binh, and the Central Highlands (Dak Nong).

Genus *Phyllosphingia* Swinhoe, 1897

47. *Phyllosphingia dissimilis berdievi* Zolotuhin & Ryabov, 2012 (Image 4.47)

Phyllosphingia dissimilis berdievi Zolotuhin & Ryabov, 2012, *The hawkmoths of Vietnam*, 2012: 201. Type locality: Kon Tum, Kon Plong [Vietnam].

Materials examined: 1 male, v.2022, Lam Dong province, Bidoup-Nui Ba NP, 20.333°N, 105.583°E, 1,700 m, coll. Q.T. Le.

Distribution: Myanmar, China, Thailand, Vietnam, and Laos.

Local distribution: Lai Chau, Lao Cai, Nghe An, Ha Tinh, Quang Binh, and the Central Highlands (Lam Dong)

Subfamily Macroglossinae Harris, 1839

Genus *Acosmerycoides* Mell, 1922

48. *Acosmerycoides harterti* (Rothschild, 1895) (Image 4.48)

Ampelophaga harterti Rothschild, 1895, *Deutsche Entomologische Zeitschrift, Iris,* 7: 299. Type locality: Assam [India].

Materials examined: 1 male, v.2016, Kon Tum province, Konplong District, Village Mang Canh, 14.667°N, 108.267°E, 1,226 m, coll. Q.T. Le.

Distribution: India, Bhutan, Myanmar, China, Taiwan, Thailand, Vietnam, Laos and Malaysia.

Local distribution: Lang Son, Vinh Phuc, Ninh Binh, Nghe An, Quang Binh, Quang Tri, Thua Thien Hue, Quang Nam, Khanh Hoa, the Central Highlands (Kon Tum, Gia Lai, Dak Nong), and Dong Nai.

Genus *Ampelophaga* Bremer & Grey, 1853

49. *Ampelophaga khasiana* Rothschild, 1895 (Image 4.49)

Ampelophaga khasiana Rothschild, 1895, *Novitates Zoologicae*, 2: 482. Type locality: Assam [India].

Materials examined: 1 male, v.2019, Kon Tum province, Dak Glei District, 15.067°N, 107.733°E, 1,053 m, coll. V.L Vu.

Distribution: India, Nepal, Bhutan, Myanmar, China and Vietnam.

Local distribution: Lai Chau, Lao Cai, Lang Son, Cao Bang, Quang Tri, Khanh Hoa, and the Central Highlands (Kon Tum).

50. *Ampelophaga rubiginosa* Bremer & Grey, 1852* (Image 4.50)

Ampelophaga rubiginosa Bremer & Grey, 1853, in Motschulsky (ed.), *Études Entomologiques*, 1: 61. Type locality: [North China].

Materials examined: 1 male, v.2022, Lam Dong

province, Bidoup-Nui Ba NP, 20.333°N, 105.583°E, 1,700 m, coll. Q.T. Le.

Distribution: Afghanistan, Pakistan, India, Nepal, Bhutan, Myanmar, Peninsula, the Russian Far East, China, Hong Kong, Japan, Korea, Thailand, Laos, Malaysia, and Indonesia (northern Sumatra).

Local distribution: Lai Chau, Lao Cai, Vinh Phuc, Thua Thien Hue, and the Central Highlands (Lam Dong, Gia Lai).

Genus *Elibia* Walker, 1856

51. *Elibia dolichoides* (Felder, C. & Felder, R., 1874) (Image 4.51)

Philampelus dolichoides Felder, C. & Felder, R., 1874, *Lepidoptera. Heft IV. Atlas der Heterocera Sphingidae-Noctuidae*, pl. 76, fig. 8. Type locality: Sikkim [India].

Materials examined: None

Remarks: This species was recorded previously by Zolotuhin & Ryabov (2012).

Distribution: Northeastern India, Nepal, Bhutan, Thailand, Vietnam, Malaysia, and Laos.

Local distribution: Cao Bang, Vinh Phuc, Bac Giang, Ninh Binh, Nghe An, Thua Thien Hue, Quang Nam, and the Central Highlands.

52. *Elibia dolichus* (Westwood, 1847) (Image 4.52)

Sphinx dolichus Westwood, 1847, *The Cabinet of Oriental Entomology*: [61], pl. 30, fig. 1. Type locality: Silhet [Bangladesh].

Materials examined: 1 male, v.2016, Gia Lai province, K'Bang District, Kon Chu Rang NR, 14.471°N, 108.574°E, 1,097 m, coll. Q.T. Le.

Distribution: India, Nepal, Bangladesh, China, Thailand, Vietnam, Malaysia, Philippines and Indonesia (Sumatra, Borneo, Java).

Local distribution: Quang Ninh, Nghe An, Quang Binh, Quang Tri, the Central Highlands (Lam Dong, Gia Lai), and Dong Nai.

Genus *Enpinanga* Rothschild & Jordan, 1903

53. *Enpinanga assamensis* (Walker, 1856)* (Image 4.53)

Panacra assamensis Walker, 1856, *List of the Specimens of Lepidopterous Insects in the Collection of the British Museum,* 8: 160. Type locality: Silhet [Bangladesh].

Materials examined: 1 male, v.2019, Gia Lai province, K'Bang District, Kon Chu Rang NR, 14.471°N, 108.574°E, 1,097 m, coll. Q.T. Le.

Distribution: India, Sri Lanka, Bangladesh, southern China, Hong Kong, Thailand, Vietnam, Laos, Cambodia, and Malaysia.

Local distribution: Vinh Phuc, Bac Giang, Quang Ninh, Nghe An, and the Central Highlands (Gia Lai, Lam Dong).

54. *Enpinanga borneensis* (Butler, 1879)

Angonyx borneensis Butler, 1879, *Transactions of the Zoological Society of London,* 12: 261. Type locality: [Borneo].

Materials examined: None

Remarks: This species was recorded previously by Zolotuhin & Ryabov (2012).

Distribution: Thailand, Vietnam, Malaysia, and Indonesia (Sumatra, Borneo, Java).

Local distribution: the Central Highlands.

Genus *Acosmeryx* Boisduval, [1875]

55. *Acosmeryx anceus subdentata* Rothschild & Jordan, 1903 (Image 5.55)

Acosmeryx anceus subdentata Rothschild & Jordan, 1903, *Novitates Zoologicae,* 9: 528. Type locality: [India, Cherrapunji, Bhutan, Indonesia].

Materials examined: 2 males, vi.2019, Kon Tum province, Konplong District, Village Mang Canh, 14.667°N, 108.267°E, 1,133 m, coll. Q.T. Le.

Distribution: India, Nepal, Bhutan, China, Thailand, Vietnam, Malaysia, Philippines, and Indonesia.

Local distribution: Lai Chau, Lao Cai, Lang Son, Quang Ninh, Vinh Phuc, Ninh Binh, Nghe An, Quang Binh, Quang Tri, Thua Thien Hue, Quang Nam, the Central Highlands (Kon Tum, Gia Lai, Lam Dong, Dak Nong), and Dong Nai.

56. *Acosmeryx castanea* Rothschild & Jordan, 1903

Acosmeryx castanea Rothschild & Jordan, 1903, *Novitates Zoologicae,* 9: 527. Type locality: Yokohama [Japan].

Materials examined: None

Remarks: This species was recorded previously by Zolotuhin & Ryabov (2012).

Distribution: China, Taiwan, Japan, Korea, and Vietnam.

Local distribution: Ninh Binh, Quang Nam, and the Central Highlands (Kon Tum).

57. *Acosmeryx naga* (Moore, [1858]) (Image 5.57)

Philampelus naga Moore, 1858 in Horsfield & Moore, A *Catalogue of the Lepidopterous Insects in the Museum of the Hon. East-India Company,* 1: 271. Type locality: Darjeeling [India, Darling].

Materials examined: 1 male, v.2020, Dak Nong province, Krong No District, Nam Nung NR, 12.016°N, 107.716°E, 920 m, coll. Q.T. Le.

Distribution: India, Nepal, Bhutan, Russian Far East,

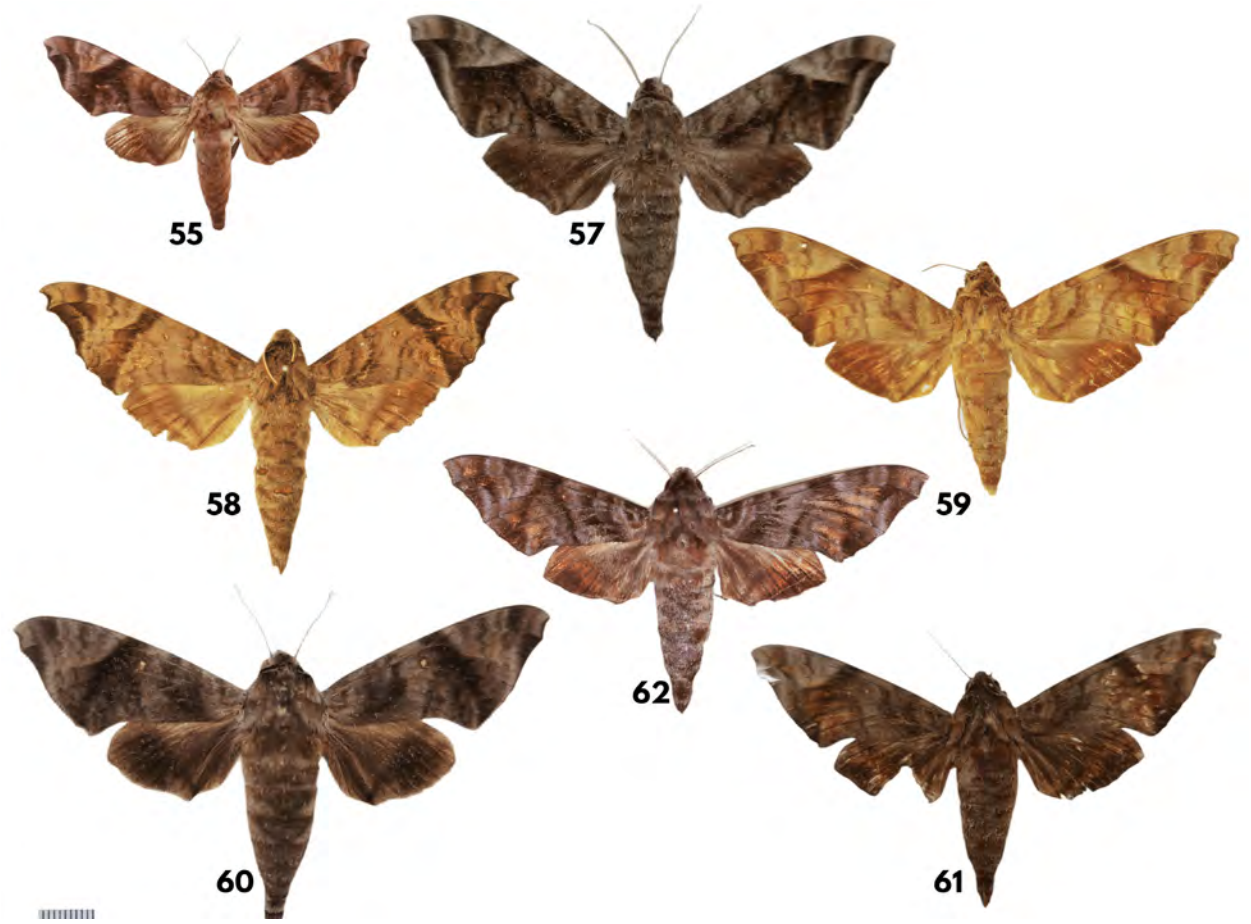

Image 5. Species pictures of the genus *Acosmeryx* of the subfamily Macroglossinae Harris, 1839.
55—*Acosmeryx anceus subdentata* Rothschild & Jordan, 1903 | 57—*Acosmeryx naga* (Moore, [1858]) | 58—*Acosmeryx omissa* Rothschild & Jordan, 1903* | 59—*Acosmeryx pseudomissa* Mell, 1922 | 60—*Acosmeryx pseudonaga* Butler, 1881 | 61—*Acosmeryx shervillii* Boisduval, 1875 | 62—*Acosmeryx sericeus* (Walker, 1856). © T.Q. Le.

China, Taiwan, Japan, Korea, Thailand, Vietnam, and Malaysia.

Local distribution: Lai Chau, Lao Cai, Cao Bang, Lang Son, Vinh Phuc, Nghe An, Thua Thien Hue, Khanh Hoa, and the Central Highlands (Kon Tum, Gia Lai, Dak Nong).

58. *Acosmeryx omissa* Rothschild & Jordan, 1903* (Image 5.58)

Acosmeryx omissa Rothschild & Jordan, 1903, *Novitates Zoologicae,* 9: 530. Type locality: [Bhutan].

Materials examined: 1 male, v.2019, Kon Tum province, Dak Glei District, 15.067°N, 107.733°E, 1,053 m, coll. V.L Vu.

Distribution: Northeastern India, Nepal, Bhutan, northern Thailand, and Vietnam.

Local distribution: Lao Cai, Ninh Binh, Nghe An, Quang Binh, and the Central Highlands (Kon Tum, Dak Nong).

59. *Acosmeryx pseudomissa* Mell, 1922 (Image 5.59)

Acosmeryx pseudomissa Mell, 1922, *Beiträge zur Fauna sinica. Biologie und Systematik der südchinesischen Sphingiden*, 1922: 230. Type locality: Kuangtung [China].

Materials examined: 1 male, v.2019, Kon Tum province, Dak Glei District, 15.067°N, 107.733°E, 1,053 m, coll. V.L Vu.

Distribution: China, Thailand, Vietnam, and Laos.

Local distribution: Vinh Phuc, Ninh Binh, Nghe An, Quang Nam, and the Central Highlands (Kon Tum, Gia Lai, Dak Nong).

60. *Acosmeryx pseudonaga* Butler, 1881 (Image 5.60)

Acosmeryx pseudonaga Butler, 1881, *Illustrations of Typical Specimens of Lepidoptera Heterocera in the Collection of the British Museum,* 5: 2. Type locality: [Bhutan].

Materials examined: 1 male, v.2022, Lam Dong province, Bidoup-Nui Ba NP, 20.333°N N, 105.583°E,

1,700 m, coll. Q.T. Le.

Distribution: Western and northeastern India, Bhutan, China, Thailand, Vietnam, Laos, Malaysia, and Indonesia.

Local distribution: Lao Cai, Tuyen Quang, Vinh Phuc, Quang Ninh, Ninh Binh, Thanh Hoa, Nghe An, Quang Binh, Quang Tri, Thua Thien Hue, Quang Nam, the Central Highlands (Kon Tum, Gia Lai, Lam Dong, Dak Nong), and Dong Nai.

61. *Acosmeryx shervillii* Boisduval, 1875 (Image 5.61)

Acosmeryx shervillii Boisduval, 1875, *Histoire Naturelle des Insectes. Species général des Lépidoptères Hétérocères,* 1: 217. Type locality: [India].

Materials examined: 1 male, v.2022, Lam Dong province, Bidoup-Nui Ba NP, 20.333°N, 105.583°E, 1,700 m, coll. Q.T. Le.

Distribution: Northern India, Sri Lanka, Nepal, Bhutan, southern China, Hong Kong, Thailand, Vietnam, Malaysia, and Indonesia (Sumatra, Borneo, Java).

Local distribution: Hoa Binh, Tuyen Quang, Cao Bang, Lang Son, Quang Ninh, Vinh Phuc, Ninh Binh, Thanh Hoa, Quang Binh, Quang Tri, Thua Thien Thien Hue, Quang Nam, the Central Highlands (Lam Dong, Gia Lai, Dak Nong), and Dong Nai.

62. *Acosmeryx sericeus* (Walker, 1856) (Image 5.62)

Philampelus sericeus Walker, 1856, *List of the pecimens of Lepidopterous Insects in the Collection of the British Museum,* 8: 181. Type locality: Silhet [Bangladesh].

Materials examined: 1 male, x.2020, Lam Dong province, Di Linh, 11.516°N, 108.083°E, coll. Q.T. Le.

Distribution: Northeastern India, Nepal, Bangladesh, southern China, Thailand, Vietnam, and Malaysia.

Local distribution: Lao Cai, Tuyen Quang, Lang Son, Vinh Phuc, Ninh Binh, Nghe An, Quang Binh, Quang Tri, Thua Thien Hue, Quang Nam, Khanh Hoa, the Central Highlands (Kon Tum, Gia Lai, Lam Dong, Dak Nong), and Dong Nai.

Genus *Dahira* Moore, 1888

63. *Dahira obliquifascia siamensis* Melichar & Haxaire, 2021 (Image 6.63)

Dahira obliquifascia siamensis Melichar & Haxaire, 2021, *The European Entomologists*, 13 (3+4): 124. Type locality: [Laos].

Materials examined: 1 male, v.2016, Kon Tum province, Konplong District, Village Mang Canh, 14.667°N, 108.267°E, 1,226 m, coll. Q.T. Le.

Distribution: Myanmar, China, Thailand, Vietnam, and Laos.

Local distribution: Khanh Hoa and the Central Highlands (Kon Tum, Gia Lai).

64. *Dahira orlovi* (Zolotuhin & Ryabov, 2012)

Dahira pinratanai orlovi Zolotuhin & Ryabov, 2012, *The hawkmoths of Vietnam*, 2012: 202. Type locality: Gia Lai Pr., K'Bang Dist., Kon Ka Kinh NP [Vietnam].

Materials examined: None

Remarks: This species was recorded previously by Zolotuhin & Ryabov (2012) as *Dahira pinratanai orlovi*. The subspecies *orlovi* was raised to species *orlovi* (Haxaire et al., 2021).

Distribution: Vietnam.

Local distribution: the Central Highlands (Gia Lai)

Genus *Angonyx* Boisduval, [1875]

65. *Angonyx testacea* (Walker, 1856) (Image 6.65)

Perigonia testacea Walker, 1856, *List of the Specimens of Lepidopterous Insects in the Collection of the British Museum,* 8: 102. Type locality: "Unknown".

Materials examined: 1 male, x.2020, Lam Dong province, Di Linh, 11.516°N, 108.083°E, coll. Q.T. Le.

Distribution: India, Nepal, Myanmar, China, Taiwan, Thailand, Vietnam, Malaysia, Philippines, and Indonesia (Sumatra, Borneo, Java).

Local distribution: Lai Chau, Lao Cai, Lang Son, Bac Giang, Quang Ninh, Vinh Phuc, Ninh Binh, Nghe An, Quang Binh, Quang Tri, Thua Thien Hue, Quang Nam, and the Central Highlands (Kon Tum, Gia Lai, Lam Dong, Dak Nong).

Genus *Daphnis* Hübner, [1819]

66. *Daphnis hypothous crameri* Eitschberger & Melichar, 2010 (Image 6.66)

Daphnis hypothous crameri Eitschberger & Melichar, 2010, *The European Entomologist*, 2: 67. Type locality: Chiang Rai, Wiang Pa Pao [Thailand].

Materials examined: 2 males, v.2019, Kon Tum province, Konplong District, Village Mang Canh, 14.667°N, 108.267°E, 1,226 m, coll. Q.T. Le.

Distribution: India, Sri Lanka, Nepal, Bhutan, Myanmar, southern China, Taiwan, Hong Kong, Thailand, Vietnam, Malaysia, Philippines, western Indonesia, and the Western Palearctic region.

Local distribution: Lai Chau, Lao Cai, Yen Bai, Cao Bang, Lang Son, Thai Nguyen, Vinh Phuc, Hanoi, Ninh Binh, Nghe An, Thua Thien Hue, Quang Nam, Khanh Hoa, the Central Highlands (Kon Tum, Gia Lai, Lam Dong, Dak Nong), and Dong Nai.

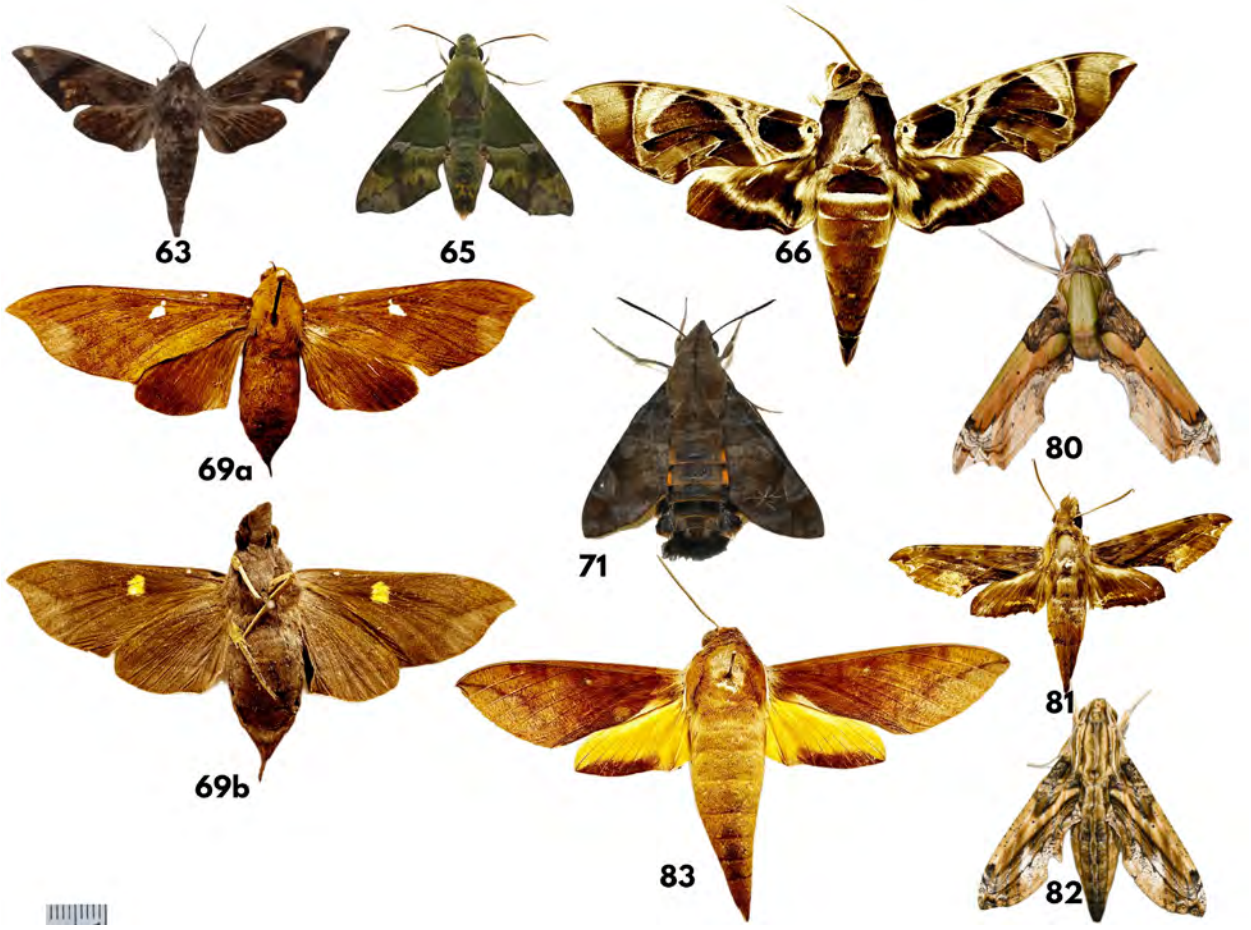

Image 6. Species pictures of the Genera *Dahira, Angonyx, Daphnis, Eurypteryx, Macroglossum, Eupanacra,* and *Gnathothlibus* of the Subfamily Macroglossinae Harris, 1839.
63—*Dahira obliquifascia siamensis* Melichar & Haxaire, 2021 | 65—*Angonyx testacea* (Walker, 1856) | 66—*Daphnis hypothous crameri* Eitschberger & Melichar, 2010 | 69—*Eurypteryx geoffreyi* Cadiou & Kitching, 1990* (a/dosal side | b/ventral side) | 71—*Macroglossum belis* (Linnaeus, 1758) | 80—*Eupanacra busiris* (Walker, 1856) | 81—*Eupanacra sinuata* (Rothschild & Jordan, 1903) | 82—*Eupanacra variolosa* (Walker, 1856) | 83—*Gnathothlibus erotus* (Cramer, 1777). © T.Q. Le.

67. *Daphnis nerii* (Linnaeus, 1758)

Sphinx nerii Linnaeus, 1758, *Systema Naturae* (Edn 10), 1: 490. Type locality: "Unknown".

Materials examined: None

Remarks: This species was recorded previously by Hoang et al. (2011).

Distribution: Africa, Europe, Arbia, Afghanistan, Pakistan, India, Nepal, Myanmar, Japan, Thailand, Vietnam, Laos, and Indonesia (Sumatra).

Local distribution: Hanoi, Thua Thien Hue, the Central Highlands, and Ho Chi Minh City.

68. *Daphnis placida placida* (Walker, 1856)

Darapsa placida Walker, 1856, *List of the Specimens of Lepidopterous Insects in the Collection of the British Museum,* 8: 186. Type locality: Samatra [Indonesia, Sumatra].

Materials examined: None

Remarks: This species was recorded previously by Zolotuhin & Ryabov (2012).

Distribution: India (Andaman & Nicobar Islands), southern China, Thailand, Vietnam, Philippines, Indonesia (Sumatra, Java, Bali, Flores, Timor), northern Australia, Vanuatu, New Caledonia, and Loyalty Islands and Malaysia.

Local distribution: the Central Highlands (Kon Tum)

Genus *Eurypteryx* Felder, C. & Felder, R., 1874

69. *Eurypteryx geoffreyi* Cadiou & Kitching, 1990* (Image 6.69)

Eurypteryx geoffreyi Cadiou & Kitching, 1990, *Lambillionea*, 90 (4): 15. Type locality: Nakhon Nayok, Khao Yai NP. [Thailand].

Materials examined: 1 female, v.2020, Lam Dong

province, Bidoup-Nui Ba NP, 20.333°N, 105.583°E, 1,700 m, coll. Q.T. Le.

Distribution: Thailand and Vietnam

Local distribution: Lao Cai and the Central Highlands (Lam Dong).

Genus *Macroglossum* Scopoli, 1777

70. *Macroglossum affictitia* (Butler, 1875)

Macroglossum affictitia Butler, 1875, *Proceedings of the Zoological Society of London*, 1875: 240, pl. 36, fig. 7. Type locality: Canara [India, Karnataka].

Materials examined: None

Remarks: This species was recorded previously by Zolotuhin & Ryabov (2012).

Distribution: India, Myanmar, Thailand, and Vietnam.

Local distribution: the Central Highlands of Vietnam (Lam Dong)

71. *Macroglossum belis* (Linnaeus, 1758) (Image 6.71)

Sphinx belis Linnaeus, 1758, *Systema Naturae* (Edn 10), 1: 493. Type locality: "In calidis regionibus".

Materials examined: 1 female, v.2020, Dak Nong province, Krong No District, Nam Nung NR, 12,016°N, 107,716°E, 920 m, coll. Q.T. Le.

Distribution: India, Sri Lanka, Myanmar, Thailand, Vietnam, and Cambodia.

Local distribution: Lao Cai, Vinh Phuc, Ninh Binh, Da Nang, and the Central Highlands (Dak Nong).

72 *Macroglossum corythus* (Walker, 1856)

Macroglossum corythus Walker, 1856, *List of the Specimens of Lepidopterous Insects in the Collectio of the British Museum,* 8: 92. Type locality: Ceylon [Sri Lanka].

Materials examined: None

Remarks: This species was recorded previously by Zolotuhin & Ryabov (2012).

Distribution: Western and northeastern India, Nepal, Bhutan, Bangladesh, Andaman Islands, eastern & southern China, Taiwan, Hong Kong, Japan, Thailand, Vietnam, Malaysia, Philippines, Indonesia, Wallacea, and Sundaland.

Local distribution: Lao Cai, Yen Bai, Lang Son, Bac Giang, Hai Phong, Vinh Phuc, Ninh Binh, Nghe An, Thua Thien Hue, Da Nang, and the Central Highlands.

73. *Macroglossum divergens heliophila* Boisduval, ([1875])

Macroglossa heliophila Boisduval, 1875, *Histoire Naturelle des Insectes. Species général des Lépidoptères Hétérocères,* 1: 354. Type locality: [Indonesia].

Materials examined: None

Remarks: This species was recorded previously as *Macroglossum heliophila* Boisduval, ([1875]) by Zolotuhin & Ryabov (2012).

Distribution: Northeastern India, Sri Lanka, China, Taiwan, Japan, Thailand, Vietnam, Philippines, and New Guinea.

Local distribution: Ninh Binh, Nghe An, Thua Thien Hue, and the Central Highlands (Gia Lai).

74. *Macroglossum fritzei* Rothschild & Jordan, 1903

Macroglossum fritzei Rothschild & Jordan, 1903, *Novitates Zoologicae,* 9: 654. Type locality: Loo Choo Islands [Ryūkyū Islands: Japan].

Materials examined: None

Remarks: This species was recorded previously by Zolotuhin & Ryabov (2012).

Distribution: China, Japan, Thailand, Vietnam, and Borneo.

Local distribution: Quang Ninh, Vinh Phuc, Nghe An, Da Nang, and the Central Highlands (Gia Lai, Lam Dong).

75. *Macroglossum gyrans* Walker, 1856

Macroglossum gyrans Walker, 1856, *List of the Specimens of Lepidopterous Insects in the Collection of the British Museum,* 8: 91. Type locality: [Northern India].

Materials examined: None

Remarks: This species was recorded previously by Hoang et al. (2011).

Distribution: India, Sri Lanka, Nepal, Myanmar, Thailand, Vietnam, Malaysia, and Indonesia (Sumatra, Borneo, Java) to Timor.

Local distribution: the Central Highlands (Gia Lai).

76. *Macroglossum mitchellii imperator* Butler, 1875

Macroglossum mitchellii imperator Butler, 1875, *Proceedings of the Zoological Society of London*, 1875: 243. Type locality: Ceylon [Sri Lanka].

Materials examined: None

Remarks: This species was recorded previously by Zolotuhin & Ryabov (2012).

Distribution: India, China, Taiwan, Thailand, Vietnam, Malaysia, and Sumatra.

Local distribution: Lai Chau, Lao Cai, Lang Son, Vinh Phuc, Ninh Binh, Nghe An, and the Central Highlands (Gia Lai, Lam Dong).

77. *Macroglossum neotroglodytus* Kitching & Cadiou, 2000

Macroglossum neotroglodytus Kitching & Cadiou, 2000, *Hawkmoths of the World*: 206. Type locality: Assam

[India].

Materials examined: None

Remarks: This species was recorded previously by Zolotuhin & Ryabov (2012).

Distribution: Southern & northeastern India, Sri Lanka, Nepal, Bhutan, southern China, Taiwan, Thailand, Vietnam, Malaysia, Philippines, and Indonesia.

Local distribution: Son La, Ha Giang, Vinh Phuc, Nghe An, and the Central Highlands (Kon Tum).

78. *Macroglossum pyrrhosticta* Butler, 1875

Macroglossum pyrrhosticta Butler, 1875, *Proceedings of the Zoological Society of London*, 1875: 242. Type locality: Shanghai [China].

Materials examined: None

Remarks: This species was recorded previously by Hoang et al. (2011).

Distribution: Eastern India, Sri Lanka, Nepal, Bhutan, the southern Russian Far East, China, Taiwan, Hong Kong, South Korea, North Korea, Japan, Thailand, Vietnam, Malaysia, Philippines, Indonesia, and Sundaland.

Local distribution: Lao Cai, Vinh Phuc, Ninh Binh, Nghe An, and the Central Highlands (Gia Lai).

Genus *Nephele* Hübner, [1819]

79. *Nephele hespera* (Fabricius, 1775)

Sphinx hespera Fabricius, 1775, *Systema Naturae:* 546. Type locality: "India orientali".

Materials examined: None

Remarks: This species was recorded previously by Zolotuhin & Ryabov (2012).

Distribution: Afghanistan, Pakistan, Sri Lanka, throughout India, Nepal, Bhutan, the Andaman Islands, Myanmar, southern China, Hong Kong, Thailand, Vietnam, Laos, Malaysia, Sumatra, and Java.

Local distribution: Yen Bai, Vinh Phuc, and the Central Highlands (Kon Tum).

Genus *Eupanacra* Cadiou & Holloway, 1989

80. *Eupanacra busiris* (Walker, 1856) (Image 6.80)

Panacra busiris Walker, 1856, *List of the Specimens of Lepidopterous Insects in the Collection of the British Museum,* 8: 158. Type locality: Silhet [Bangladesh].

Materials examined: 1 male, v.2020, Dak Nong province, Krong No District, Nam Nung NR, 12.016°N, 107.716°E, 920 m, coll. Q.T. Le.

Distribution: North & northeastern India, Nepal, Myanmar, China, Thailand, Vietnam, Laos, Malaysia, and Indonesia.

Local distribution: Cao Bang, Vinh Phuc, Ninh Binh, Nghe An, Thua Thien Hue, the Central Highlands (Lam Dong, Dak Nong), and Dong Nai.

81. *Eupanacra sinuata* (Rothschild & Jordan, 1903) (Image 6.81)

Panacra sinuata Rothschild & Jordan, 1903, *Novitates Zoologicae,* 9: 537. Type locality: [N India].

Materials examined: 1 male, v.2020, Dak Nong province, Krong No District, Nam Nung NR, 12.016°N, 107.716°E, 920 m, coll. Q.T. Le.

Distribution: India (Arunachal Pradesh, Himachal Pradesh, Assam, Sikkim, Manipur, Meghalaya, Uttarakhand, West Bengal), Nepal, China, northern Thailand, Vietnam Laos, and Malaysia.

Local distribution: Lai Chau, Lao Cai, Hoa Binh, Vinh Phuc, Quang Binh, Thua Thien Hue, Khanh Hoa, and the Central Highlands (Kon Tum, Lam Dong, Dak Nong).

82. *Eupanacra variolosa* (Walker, 1856) (Image 6.82)

Panacra variolosa Walker, 1856, *List of the Specimens of Lepidopterous Insects in the Collection of the British Museum,* 8: 156. Type locality: Silhet [Bangladesh].

Materials examined: 1 male, v.2020, Dak Nong province, Krong No District, Nam Nung NR, 12.016°N, 107.716°E, 920 m, coll. Q.T. Le.

Distribution: Northeastern India, Bhutan; Bangladesh; southwestern China, Thailand, Vietnam; Laos, Malaysia (Peninsular, Sarawak), and Indonesia.

Local distribution: Bac Giang, Vinh Phuc, Nghe An, Quang Tri, Thua Thien Hue, Khanh Hoa, the Central Highlands (Lam Dong, Dak Nong), and Dong Nai.

Genus *Gnathothlibus* Wallengren, 1858

83. *Gnathothlibus erotus* (Cramer, 1777) (Image 6.83)

Sphinx erotus Cramer, 1777, *Uitlandsche Kapellen,* 2: 12, pl. 104, fig. B. Type locality: No locality given.

Materials examined: 1 male, v.2016, Kon Tum province, Konplong District, Village Mang Canh, 14.667°N, 108.267°E, 1,226 m, coll. Q.T. Le.

Distribution: India (Punjab, Himachal Pradesh), the Andaman Islands), Indo-Australian tropics and eastwards into Polynesia as far as Pitcairn and Henderson Island.

Local distribution: Khanh Hoa, the Central Highlands (Kon Tum), and Dong Nai.

Genus *Cechenena* Rothschild & Jordan, 1903

84. *Cechenena aegrota* (Butler, 1875) (Image 7.84)

Pergesa aegrota Butler, 1875, *Proceedings of the Zoological Society of London*, 1875: 246. Type locality: Silhet [Bangladesh].

Materials examined: 2 males, 2 females, v.2016, Gia Lai province, K'Bang District, Kon Chu Rang NR, 14.471°N,

108.574°E, 1,097 m, coll. Q.T. Le.

Distribution: Northeastern India, Nepal, Bhutan, Bangladesh, southern China, Hong Kong, Thailand, Vietnam, and Laos.

Local distribution: Lang Son, Vinh Phuc, Ninh Binh, Nghe An, Thua Thien Hue, Quang Nam, and the Central Highlands (Gia Lai, Lam Dong).

85. *Cechenena helops* (Walker, 1856) (Image7.85)

Philampelus helops Walker, 1856, *List of the Specimens of Lepidopterous Insects in the Collection of the British Museum,* 8: 180. Type locality: "Port Natal".

Materials examined: 2 males, 2 females, v.2022, Lam Dong province, Bidoup-Nui Ba NP, 20.333°N, 105.583°E, 1,700 m, coll. Q.T. Le.

Distribution: Northeastern India, Nepal, Bhutan, southwestern China, Thailand, Vietnam, Malaysia, Philippines, and Indonesia.

Local distribution: Lao Cai, Lang Son, Thai Nguyen, Vinh Phuc, Ninh Binh, Thanh Hoa, Nghe An, Quang Binh, Quang Tri, Thua Thien Hue, Quang Nam, Khanh Hoa, the Central Highlands (Kon Tum, Gia Lai, Lam Dong), and Dong Nai.

Genus *Cechetra* Zolotuhin & Ryabov, 2012

86. *Cechetra lineosa* (Walker, 1856) (Image 7.86)

Chaerocampa lineosa Walker, 1856, *List of the Specimens of Lepidopterous Insects in the Collection of the British Museum,* 8: 144. Type locality: Silhet [Bangladesh].

Materials examined: 2 males, 1 female, v.2022, the Central Higlands of Vietnam, Lam Dong province, Bidoup-Nui Ba NP, 20.333°N, 105.583°E, 1,700 m, coll. Q.T. Le.

Distribution: Northern India, Nepal, Bhutan, Bangladesh, Myanmar, southern China, Taiwan, Thailand, Vietnam, Malaysia, and Indonesia.

Local distribution: Lai Chau, Lao Cai, Lang Son, Vinh Phuc, Ninh Binh, Nghe An, Thua Thien Hue, and the Central Highlands.

87. *Cechetra minor* (Butler, 1875) (Image 7.87)

Chaerocampa minor Butler, 1875, *Proceedings of the Zoological Society of London,* 1875: 249. Type locality: Massuri [India].

Materials examined: 1 male, v.2016, Kon Tum province, Konplong District, Village Mang Canh, 14.667°N, 108.267°E, 1,226 m, coll. Q.T. Le.

Distribution: India, Nepal, Bhutan, China, Taiwan, and Japan, Thailand, and Vietnam.

Local distribution: Lao Cai, Lang Son, Vinh Phuc, Ninh Binh, Nghe An, Thua Thien Hue, Quang Nam, and the Central Highlands (Kon Tum, Gia Lai).

88. *Cechetra subangustata continentalis* Ivshin & Krutov, 2018 (Image 7.88)

Cechetra subangustata continentalis Ivshin & Krutov, 2018, *Zootaxa,* 4450(1): 13. Type locality: Nan, Doi Phu Kha NP. [Thailand].

Materials examined: 1 male, v.2020, Dak Nong province, Krong No District, Nam Nung NR, 12.016°N, 107.716°E, 920 m, coll. Q.T. Le.

Distribution: India (Arunachal Pradesh), Nepal, Bhutan, southwestern China, Taiwan, Thailand, Vietnam, Malaysia, and Indonesia.

Local distribution: Lai Chau, Lao Cai, Cao Bang, Lang Son, Nghe An, Quang Tri, Thua Thien Hue, and the Central Highlands (Gia Lai, Lam Dong, Dak Nong).

Genus *Griseosphinx* Cadiou & Kitching, 1990

89. *Griseosphinx marchandi* Cadiou, 1996* (Image 7.89)

Griseosphinx marchandi Cadiou, 1996, *Entomologia Africana*: 20. Type locality: Tonkin [Vietnam].

Materials examined: 1 male, v.2020, Dak Nong province, Krong No District, Nam Nung NR, 12.016°N, 107.716°E, 920 m, coll. Q.T. Le.

Distribution: Vietnam

Local distribution: Cao Bang, Bac Kan, Thai Nguyen, Ninh Binh, Quang Binh, and the Central Highlands (Dak Nong).

Genus *Hippotion* Hübner, 1819 [1816]

90. *Hippotion boerhaviae* (Fabricius, 1775) (Image 7.90)

Sphinx boerhaviae Fabricius, 1775, *Systema Naturae*: 542. Type locality: Locality not stated.

Materials examined: 2 males, v.2020, Dak Nong province, Krong No District, Nam Nung NR, 12.016°N, 107.716°E, 920 m, coll. Q.T. Le.

Distribution: Northeastern Pakistan, India, Sri Lanka, Nepal, Bhutan, southeastern China, Thailand, Vietnam, Philippines, Indonesia, New Guinea, eastern Australia, The Solomon Islands, and New Caledonia.

Local distribution: Lao Cai, Yen Bai, Lang Son, Vinh Phuc, Nghe An, Quang Binh, Quang Tri, Thua Thien Huethe Central Highlands (Dak Nong, Lam Dong), and Dong Nai.

91. *Hippotion celerio* (Linnaeus, 1758)* (Image 7.91)

Sphinx celerio Linnaeus, 1758, *Systema Naturae* (Edn 10), 1: Type locality: Unknown.

Materials examined: 1 male, v.2020, Dak Nong province, Krong No District, Nam Nung NR, 12.016°N,

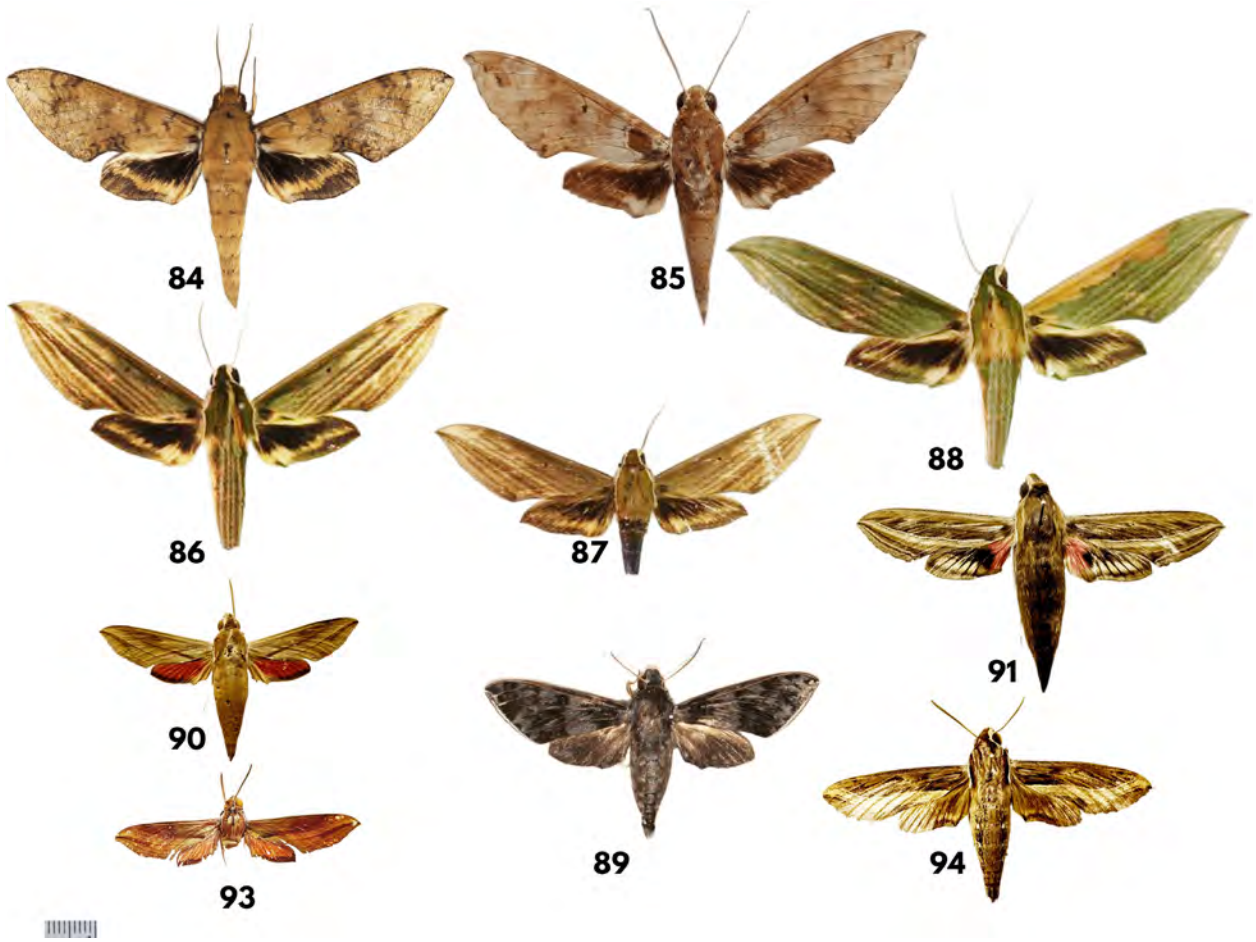

Image 7. Species pictures of the genera *Cechenena*, *Cechetra*, *Griseosphinx*, and *Hippotion* of the subfamily Macroglossinae Harris, 1839. 84—*Cechenena aegrota* (Butler, 1875) | 85—*Cechenena helops* (Walker, 1856) | 86—*Cechetra lineosa* (Walker, 1856) | 87—*Cechetra minor* (Butler, 1875) | 88—*Cechetra subangustata continentalis* Ivshin & Krutov, 2018 | 89—*Griseosphinx marchandi* Cadiou, 1996* | 90—*Hippotion boerhaviae* (Fabricius, 1775) | 91—*Hippotion celerio* (Linnaeus, 1758)* | 93—*Hippotion rosetta* (Swinhoe, 1892) | 94—*Hippotion velox* (Fabricius, 1793)*. © T.Q. Le.

107.716°E, 920 m, coll. Q.T. Le.

Distribution: Africa, southern Europe, Arabian Peninsula, Pakistan, India, Nepal, Bhutan, southern China, Hong Kong, and southern Japan, Vietnam, and Australia.

Local distribution: Lao Cai, Vinh Phuc, Hanoi, Thua Thien Hue, and the Central Highlands (Dak Nong).

92. *Hippotion rafflesii* (Moore, 1858)

Deilephila rafflesii Moore, 1858, in Horsfield & Moore, *A Catalogue of the Lepidopterous Insects in the Museum of the Hon. East-India Company,* 1: 276. Type locality: Java [Indonesia].

Materials examined: None

Remarks: This species was recorded previously by Zolotuhin & Ryabov (2012).

Distribution: Southern and eastern India, Sri Lanka, Nepal, Bhutan, Myanmar, southern China, Thailand, Vietnam, Malaysia, Philippines, and Indonesia.

Local distribution: Lao Cai, Hanoi, and the Central Highlands (Kon Tum).

93. *Hippotion rosetta* (Swinhoe, 1892) (Image 7.93)

Choerocampa rosetta Swinhoe, 1892, *Catalogue of Eastern Lepidoptera Heterocera in the Oxford University Museum,* 1: 16. Type locality: Ceram [Indonesia].

Materials examined: None

Remarks: This species was recorded previously by Zolotuhin & Ryabov (2012).

Distribution: Southern Pakistan, India, Sri Lanka, Bhutan, China, Taiwan, Hong Kong, southern Japan, Thailand, Vietnam, Philippines, Maldives Islands, Andaman Islands, The Solomon Islands, and New Guinea.

Local distribution: Lao Cai, Lang Son, Vinh Phuc, Ninh

Binh, Nghe An, Quang Binh, Thua Thien Hue, the Central Highlands (Lam Dong, Kon Tum), and Dong Nai.

94. *Hippotion velox* (Fabricius, 1793)* (Image 7.94)

Sphinx velox Fabricius, 1793, *Systema Naturae,* 3(1): 378. Type locality: "India orientali".

Materials examined: 1 males, x.2020, Lam Dong province, Di Linh, 11.516°N, 108.083°E, coll. Q.T. Le.

Distribution: India, China, Taiwan, Thailand, Vietnam, Malaysia, Philippines, Indonesia, and Singapore.

Local distribution: Lao Cai, Quang Binh, and the Central Highlands (Lam Dong).

Genus *Pergesa* Walker, 1856

95. *Pergesa acteus* (Cramer, 1779) (Image 8.95)

Sphinx acteus Cramer, 1779, *Uitlandsche Kapellen,* 3: 93, pl.248, fig. A. Type locality: [Java].

Materials examined: 1 male, v.2016, Kon Tum province, Konplong District, Village Mang Canh, 14.667°N, 108.267°E, 1,226 m, coll. Q.T. Le.

Distribution: India, Sri Lanka, Nepal, Bhutan, Myanmar, China, Taiwan, Hong Kong, Japan, Thailand, Vietnam, Malaysia, Philippines, Indonesia, Sundaland, and Moluccas.

Local distribution: Lai Chau, Lao Cai, Cao Bang, Lang Son, Quang Ninh, Vinh Phuc, Ninh Binh, Nghe An, Thua Thien Hue, the Central Highlands (Kon Tum, Gia Lai, Dak Nong), and Dong Nai.

Genus *Rhagastis* Rothschild & Jordan, 1903

96. *Rhagastis acuta* (Walker, 1856)* (Image 8.96)

Zonilia acuta Walker, 1856, *List of the Specimens of Lepidopterous Insects in the Collection of the British Museum,* 8: 195. Type locality: Hindostan [India].

Materials examined: 1 male, v.2019, Gia Lai province, Kon Ka Kinh NP, 14.215°N, 108.283°E, 901 m, coll. Q.T. Le.

Distribution: India, Nepal, Bhutan, eastern Bangladesh, Myanmar, China (Guizhou, Yunnan, Hainan), Thailand, Vietnam, Laos, Cambodia, Malaysia, Philippines (Palawan) and Indonesia (Sumatra, Java).

Local distribution: Nghe An, Quang Binh, Quang Nam, and the Central Highlands (Gia Lai)

97. *Rhagastis albomarginatus* (Rothschild, 1894)

Metopsilus albomarginatus Rothschild, 1894, *Novitates Zoologicae,* 1: 78. Type locality: Assam [India].

Materials examined: None

Remarks: This species was recorded previously by Zolotuhin & Ryabov (2012).

Distribution: India, Nepal, Bhutan, Myanmar, China, Hong Kong, Vietnam, Sumatra, Java, Borneo.

Local distribution: Lai Chau, Lao Cai, Lang Son, Bac Giang, Vinh Phuc, Ninh Binh, Nghe An, Quang Binh, Quang Tri, Thua Thien Hue, Quang Nam, and the Central Highlands.

98. *Rhagastis castor aurifera* (Butler, 1875) (Image 8.98)

Pergesa castor aurifera Butler, 1875, *Proceedings of the Zoological Society of London*, 1875: 7. Type locality: "Sikhim".

Materials examined: 1 male, v.2016, Kon Tum province, Konplong District, Village Mang Canh, 14.667°N, 108.267°E, 1,226 m, coll. Q.T. Le.

Distribution: Northeastern India, Nepal, Bhutan, southern China, Thailand, and Vietnam.

Local distribution: Lao Cai, Cao Bang, Lang Son, Vinh Phuc, Quang Ninh, Ninh Binh, Nghe An, Quang Binh, Quang Tri, Thua Thien Hue, and the Central Highlands (Kon Tum, Gia Lai, Dak Nong).

99. *Rhagastis confusa* Rothschild & Jordan, 1903

Rhagastis confusa Rothschild & Jordan, 1903, *Novitates Zoologicae,* 9: 795. Type locality: [North India].

Materials examined: None

Remarks: This species was recorded previously by Zolotuhin & Ryabov (2012).

Distribution: Northern Pakistan, India, Nepal, Bhutan; southwestern China, Thailand, and northern Vietnam.

Local distribution: Lao Cai, Ninh Binh, and the Central Highlands (Gia Lai).

100. *Rhagastis olivacea* (Moore, 1872)

Pergesa olivacea Moore, 1872, *Proceedings of the Zoological Society of London,* 1872: 567. Type locality: "Simla".

Materials examined: None

Remarks: This species was recorded previously by Zolotuhin & Ryabov (2012).

Distribution: Northeastern Pakistan, northern India, Nepal, Bhutan, Myanmar, southern China, northern Thailand, Vietnam, and Laos.

Local distribution: Lai Chau, Lao Cai, Vinh Phuc, and the Central Highlands (Kon Tum).

101. *Rhagastis rubetra* Rothschild & Jordan, 1907

Rhagastis rubetra Rothschild & Jordan, 1907, *Novitates Zoologicae,* 14: 95. Type locality: "Nias".

Materials examined: None

Remarks: This species was recorded previously by Zolotuhin & Ryabov (2012).

Distribution: Thailand, Vietnam, Malaysia, Philippines, and Indonesia.

Local distribution: Lao Cai, Cao Bang, Lang Son, Quang Ninh, Nghe An, Quang Binh, Khanh Hoa, and the Central Highlands (Gia Lai, Lam Dong).

Genus *Theretra* Hübner, [1819]

102. *Theretra alecto* (Linnaeus, 1758)

Sphinx alecto Linnaeus, 1758, *Systema Naturae* (Edn 10), 1: 492. Type locality: [India].

Materials examined: None

Remarks: This species was recorded previously by Zolotuhin & Ryabov (2012).

Distribution: Greece, Bulgaria, Turkey, Iran, Turkmenistan, Uzbekistan, Kyrgyzstan, Afghanistan, Iraq, Lebanon, Israel, and Egypt, Pakistan, India, Sri Lanka, Nepal, Bhutan, China, Taiwan, Hong Kong, Japan, Vietnam, Philippines, Indonesia.

Local distribution: Lai Chau, Lao Cai, Lang Son, Vinh Phuc, Ninh Binh, and the Central Highlands (Lam Dong).

103. *Theretra boisduvalii* (Bugnion, 1839) (Image 8.103)

Sphinx boisduvalii Bugnion, 1839, *Annales de la Société Entomologique de France,* 1839: 13. Type locality: Île de Candie [Greece].

Materials examined: 1 male, v.2022, Lam Dong province, Bidoup-Nui Ba NP, 20.333°N, 105.583°E, 1,700 m, coll. Q.T. Le.

Distribution: Greece, India, Sri Lanka, Taiwan, Thailand, Vietnam, Laos and Indonesia.

Local distribution: Lao Cai, Vinh Phuc, Ninh Binh, Nghe An, Quang Tri, Thua Thien Hue, Quang Nam, the Central Highlands (Kon Tum, Gia Lai, Lam Dong, Dak Nong), and Dong Nai.

104. *Theretra clotho* (Drury, 1773) (Image 8.104)

Sphinx clotho Drury, 1773, *Illustrations of Natural History. Wherein are exhibited upwards of two hundred and forty figures of exotic insects,* 2: Index [91], pl.28: 1. Type locality: Madras [India].

Materials examined: 1male, 1 female, x.2017, Dak Nong province, Krong No District, Nam Nung NR, 12.016°N, 107.716°E, 920 m, coll. Q.T. Le.

Distribution: Northern Pakistan, India, Sri Lanka, Nepal, Bhutan, Myanmar, China, Hong Kong, Taiwan, South Korea, Japan, Vietnam, Laos, Indonesia, Philippines, and Sundaland.

Local distribution: Lao Cai, Vinh Phuc, Quang Ninh, Ninh Binh, Quang Tri, Thua Thien Hue, Quang Nam, Khanh Hoa, the Central Highlands (Kon Tum, Gia Lai, Dak Nong), and Dong Nai.

105. *Theretra lucasii* (Walker, 1856) (Image 8.105)

Chaerocampa lucasii Walker, 1856, *List of the Specimens of Lepidopterous Insects in the Collection of the British Museum,* 8: 141. Type locality: Silhet [Bangladesh]

Materials examined: 1 male, v.2019, Gia Lai province, Kon Ka Kinh NP, 14.215°N, 108.283°E, 901 m, coll. Q.T. Le.

Distribution: India, Sri Lanka, Nepal, Bangladesh, Myanmar, China, Hong Kong Taiwan, Thailand, Vietnam, Laos, Cambodia, , Philippines, and Indonesia, Sumatra, Borneo, Java, the Lesser Sunda Islands.

Local distribution: Lang Son, Quang Ninh, Ninh Binh, Nghe An, Quang Binh, Quang Tri, Thua Thien Hue, Quang Nam, the Central Highlands (Gia Lai), and Dong Nai.

106. *Theretra lycetus* (Cramer, 1775) (Image 8.106)

Sphinx lycetus Cramer, 1775, *Uitlandsche Kapellen,* 1: 96. Type locality: Bengal [India], Coromandel, Ceylon [Sri Lanka].

Materials examined: 1 male, v.2020, Dak Nong province, Krong No District, Nam Nung NR, 12.016°N, 107.716°E, 920 m, coll. Q.T. Le.

Distribution: India, Sri Lanka, Nepal, Myanmar, Thailand, Vietnam, Laos, Malaysia, and Indonesia.

Local distribution: Lao Cai, Yen Bai, Vinh Phuc, Quang Binh, and the Central Highlands (Dak Nong).

107. *Theretra nessus* (Drury, 1773) (Image 8.107)

Sphinx nessus Drury, 1773, *Illustrations of Natural History. Wherein are exhibited upwards of two hundred and forty figures of exotic insects,* 2: index [91], pl. 76, fig. 1. Type locality: Madras [India].

Materials examined: 1 male, v.2020, Dak Nong province, Krong No District, Nam Nung NR, 12.016°N, 107.716°E, 920 m, coll. Q.T. Le.

Distribution: India, Sri Lanka, Nepal, Bhutan, Myanmar, southern China, Taiwan, South Korea, Japan, Thailand, Vietnam, Malaysia, Singapore, Indonesia, Sundaland, Philippines, and Australia.

Local distribution: Lai Chau, Lao Cai, Lang Son, Vinh Phuc, Ninh Binh, Hai Phong, Nghe An, Quang Tri, Thua Thien Hue, Quang Nam, Khanh Hoa, the Central Highlands (Kon Tum, Gia Lai, Lam Dong, Dak Nong), and Dong Nai.

108. *Theretra oldenlandiae* (Fabricius, 1775)* (Image 8.108)

Sphinx oldenlandiae Fabricius, 1775, *Systema Naturae*: 542. Type locality: "Indiae Oldenlandiis".

Materials examined: 1 male, xii.2020, Lam Dong province, Bidoup-Nui Ba NP, 20.333°N, 105.583°E, 1,700

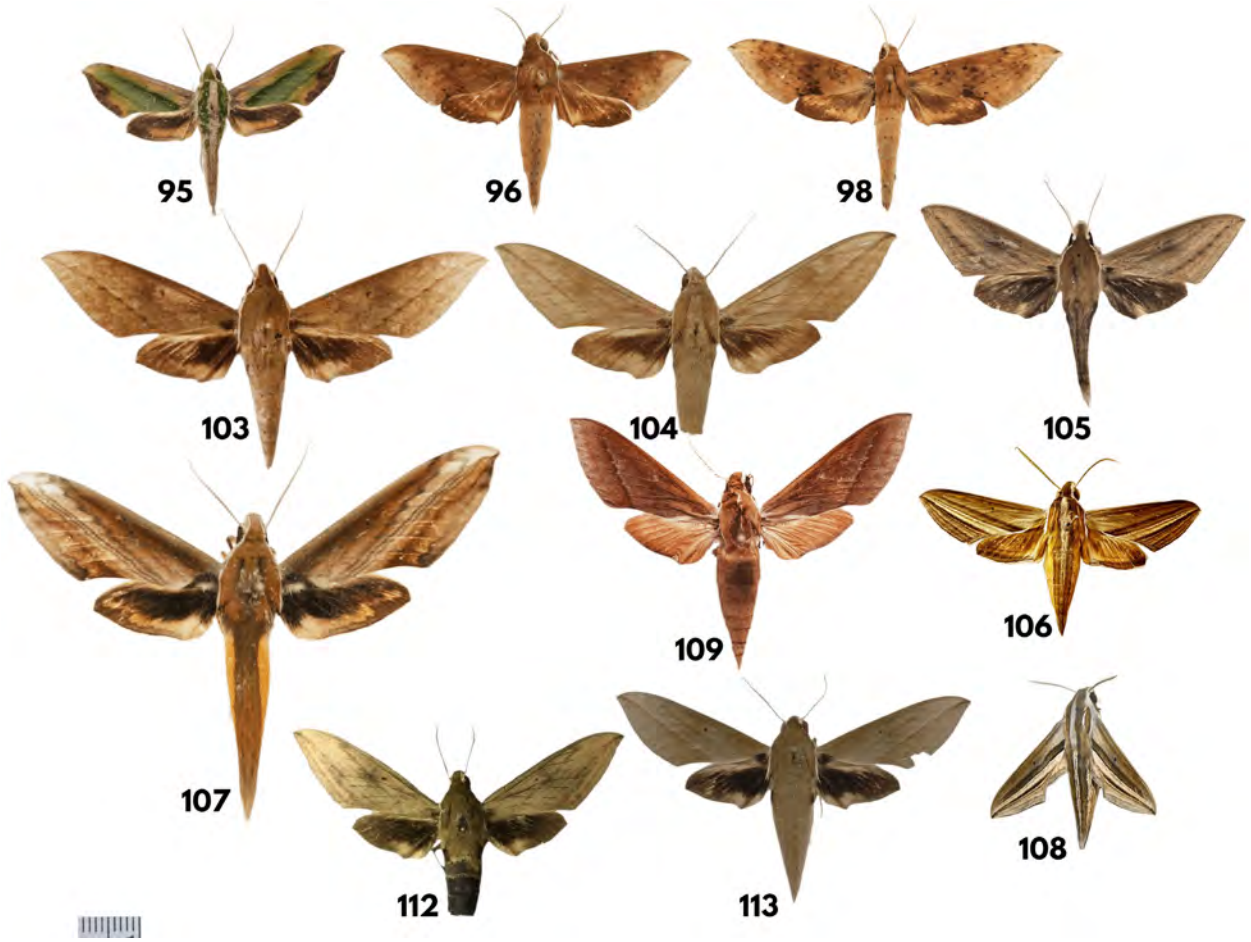

Image 8. Species pictures of the genera *Hippotion, Pergesa,* and *Rhagastis* of the subfamily Macroglossinae Harris, 1839.
95—*Pergesa acteus* (Cramer, 1779) | 96—*Rhagastis acuta* (Walker, 1856)* | 98—*Rhagastis castor aurifera* (Butler, 1875) | 103—*Theretra boisduvalii* (Bugnion, 1839) | 104—*Theretra clotho* (Drury, 1773) | 105—*Theretra lucasii* (Walker, 1856) | 106—*Theretra lycetus* (Cramer, 1775) | 107—*Theretra nessus* (Drury, 1773) | 108—*Theretra oldenlandiae* (Fabricius, 1775)* | 109—*Theretra pallicosta* (Walker, 1856) | 112—*Theretra sumatrensis* (Joicey & Kaye, 1917)* | 113—*Theretra tibetiana* Vaglia & Haxaire, 2010. © T.Q. Le.

m, coll. Q.T. Le.

Distribution: Northern Afghanistan, northern Pakistan, India, Sri Lanka, Nepal, Bhutan, Myanmar, China, Taiwan, Hong Kong, South Korea, Japan, Vietnam, Laos, Malaysia, The Solomon Islands, New Guinea, and Philippines.

Local distribution: Lai Chau, Lao Cai, Vinh Phuc, Ninh Binh, Nghe An, Thua Thien Hue, and the Central Highlands (Gia Lai, Lam Dong).

109. *Theretra pallicosta* (Walker, 1856) (Image 8.109)

Chaerocampa pallicosta Walker, 1856, *List of the Specimens of Lepidopterous Insects in the Collection of the British Museum,* 8: 145. Type locality: Silhet [Bangladesh], Hong Kong [China].

Materials examined: 1 male, v.2019, Gia Lai province, Kon Ka Kinh NP, 14.215°N, 108.283°E, 901 m, coll. Q.T. Le.

Distribution: India, Sri Lanka, Nepal, Bangladesh, Myanmar, China, Hong Kong, Thailand, Vietnam, Malaysia, and Indonesia.

Local distribution: Lao Cai, Lang Son, Vinh Phuc, Quang Ninh, Ninh Binh, Nghe An, Thua Thien Hue, and the Central Highlands (Gia Lai, Lam Dong).

110. *Theretra silhetensis* (Walker, 1856)

Chaerocampa silhetensis Walker, 1856, *List of the Specimens of Lepidopterous Insects in the Collection of the British Museum,* 8: 143. Type locality: Ceylon [Sri Lanka], [North India], Silhet [Bangladesh].

Materials examined: None

Remarks: This species was recorded previously by Hoang et al. (2011).

Distribution: India, Sri Lanka, Nepal, Bhutan, Bangladesh, Myanmar, the Andaman Islands, China, Taiwan, Japan, Thailand, Vietnam, Malaysia, and Indonesia.

Local distribution: Lao Cai, Cao Bang, Lang Son, Vinh Phuc, Bac Giang, Quang Binh, Thua Thien Hue, the Central Highlands (Kon Tum), and Dong Nai.

111. *Theretra suffusa* (Walker, 1856)

Chaerocampa suffusa Walker, 1856, *List of the Specimens of Lepidopterous Insects in the Collection of the British Museum,* 8: 146. Type locality: [Hong Kong].

Materials examined: None

Remarks: This species was recorded previously by Zolotuhin & Ryabov (2012).

Distribution: India, Sri Lanka, Nepal, southern China, Taiwan, southern Japan (Ryukyu Archipelago), Thailand, Vietnam, Cambodia, Laos, Malaysia, Singapore, Indonesia (Sumatra, Java, Kalimantan, Sulawesi), and Palawan.

Local distribution: Lang Son, Vinh Phuc, Ninh Binh, Quang Binh, Quang Tri, and the Central Highlands (Kon Tum).

112. *Theretra sumatrensis* (Joicey & Kaye, 1917) * (Image 8.112)

Cechenena sumatrensis Joicey & Kaye, 1917, *Annals and Magazine of Natural History,* 20: 307. Type locality: Sumatra Langkat.

Materials examined: 1 male, v.2022, Lam Dong province, Bidoup-Nui Ba NP, 20.333°N, 105.583°E, 1,700 m, coll. Q.T. Le.

Distribution: Northeastern India, Bhutan, central Myanmar, southwestern China, northern Thailand, Vietnam, Laos, and Malaysia.

Local distribution: Lai Chau, Lao Cai, Lang Son, Vinh Phuc, Ninh Binh, Nghe An, Thua Thien Hue, Quang Nam, and the Central Highlands (Lam Dong).

113. *Theretra tibetiana* Vaglia & Haxaire, 2010 (Image 8.113)

Theretra tibetiana Vaglia & Haxaire, 2010, *The European Entomologist*, 3(1): 60. Type locality: Tibet [China].

Materials examined: 1 male, v.2020, Dak Nong province, Krong No District, Nam Nung NR, 12.016°N, 107.716°E, 920 m, coll. Q.T. Le.

Distribution: Northeastern India, Bhutan, China, Thailand, and Vietnam.

Local distribution: Lao Cai, Lang Son, Nghe An, Thua Thien Hue, Quang Nam, the Central Highlands (Kon Tum, Dak Nong), and Dong Nai.

DISCUSSION

Hoang et al. (2011) reported 23 species of hawkmoth in the Central Highlands of Vietnam, including one unidentified species, *Smerinthulus* sp.1. Therefore, this species is not listed in the Result.

The genus *Eurypteryx* Felder & Felder, 1874 (Sphingidae: Macroglossinae) is limited to the Oriental and Australian regions (Jiang & Wang 2020) and currently comprises two species in Vietnam, *Eurypteryx geoffreyi* Cadiou & Kitching, 1990 and *Eurypteryx bhaga* (Moore, 1866) (Zolotuhin & Ryabov 2012). Both species are rare in Vietnam. Zolotuhin & Ryabov (2012) reported that the only male of *Eurypteryx geoffreyi* was collected at an elevation of about 1,600 m in the disturbed humid primary forest on Fansipan mountain in northwestern Vietnam. In our surveys, we collected a female specimen of the species at an elevation of about 1,450 m in an evergreen broad-leaf forest while feeding on flowers of a low tree at Giang Ly ranger station in Bidoup-Nui Ba National Park, Lam Dong province. Its distribution is broader than previous records suggest, not limited to the north-west but also occurring in the Central Highlands and maybe has an even wider distribution.

Contrasted with prior studies, our updated list includes 16 species documented in both the 2011 and 2012 lists. The total of 78 species closely aligns with Zolotuhin & Ryabov's (2012) report, with 12 species matching Hoang et al.'s (2011) list. The key highlight is the addition of 14 new species to the Sphingidae checklist for the Central Highlands of Vietnam.

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Journal of Threatened Taxa | www.threatenedtaxa.org | 26 January 2024 | 16(1): 24529–24534

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

https://doi.org/10.11609/jott.8684.16.1.24529-24534

#8684 | Received 12 August 2023 | Final received 31 December 2023 | Finally accepted 06 January 2024

OPEN ACCESS

COMMUNICATION

Observations on the courtship behaviour of Deocata Pipefish *Microphis deocata* (Hamilton, 1822) (Actinopterygii: Syngnathiformes: Syngnathidae) in an aquarium

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Abstract: The Deocata Pipefish *Microphis deocata,* is the sole freshwater syngnathid found in the Himalayan range. This species is categorised as 'Near Threatened' by the IUCN Red List and is also listed as a Schedule I species under the Wildlife Protection Act of 1972. This species is highly sought after in the ornamental fish trade due to its attractive colouration and uniqueness. The courtship behaviour of *M. deocata* consists of three distinct phases (initial courtship, spawning, and swaying) characterized by substantial behavioural alterations. *M. deocata* is a species where the action of females is more visible for commencing courting and strengthening at later phases. The females exhibit skin fold ornamentation to signal their readiness to spawn mature eggs. The first courtship phase is characterised by female quivering along with head pointing by both sexes and often tail entangling. As a sign of embracing the male often overlies upon the female. In the second phase, the female transfers her eggs onto the male incubating ventral surface with an upside-down body posture. During the final phase, the male forms his body into a contracting wave and lastly settles down in the bottom of the tank.

Keywords: Conservation, captive breeding, male pregnancy, sex-role reversal, spawning.

Editor: Ingrid Ahnesjö, Uppsala University, Uppsala, Sweden. **Date of publication:** 26 January 2024 (online & print)

Citation: Saikia, A., J.K. Nath & D. Sarma (2024). Observations on the courtship behaviour of Deocata Pipefish *Microphis deocata* (Hamilton, 1822) (Actinopterygii: Syngnathiformes: Syngnathidae) in an aquarium. *Journal of Threatened Taxa* 16(1): 24529–24534. https://doi.org/10.11609/jott.8684.16.1.24529-24534

Funding: This study was funded by the ICAR-National Bureau of Fish Genetic Resources (ICAR-NBFGR), Lucknow (Project code: G./NE/2015).

Competing interests: The authors declare no competing interests.

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Author contributions: The experiment was planned and critically examined by AS and DS; the methodologies were carried out by AS and JKN; the manuscript was prepared by AS and JKN; the final editing was done by DS. All authors reviewed and approved the final version of the manuscript.

Acknowledgements: The authors express gratitude to the NFDB, Hyderabad, and the University Grants Commission (UGC), New Delhi, for their technical assistance and support through SAP (DRS-Phase III). Additionally, the local fishermen are acknowledged for their valuable assistance during the fieldwork.

INTRODUCTION

Although the family Syngnathidae largely consists of a marine taxon that includes seahorses, pipefishes, and seadragons, there are a few pipefishes of the genus *Dorichthys* and *Microphis* that inhabit freshwater habitat (Dawson 1979, 1984). These species often exhibit a unique pre-copulation nuptial dance in the water column (Gudger 1905) and paternal care where male investment in offspring typically is in the form of embryo incubation, aeration, protection, and provisioning (Ridley 1978; Wilson et al. 2001; Stölting & Wilson 2007; Kvarnemo et al. 2011). In the Broadnosed Pipefish *Syngnathus typhle*, males possess a brood pouch that enables efficient nursing of offspring (Kvarnemo et al. 2011). In contrast, *Nerophis ophidion* lacks such a brood pouch (Berglund et al. 1986). Predominant competition for mates in females is more pronounced in species where the male potential reproductive rate is lower than that of females (Vincent et al. 1992). Moreover, among species the male shows a variation in the degree of structural and physiological specialization of parental care (Herald 1959; Vincent et al. 1992; Wilson et al. 2001). Within this family the operation of sexual selection (Trivers 1972; Thornhill & Gwynne 1986) can work on either of the sex (Shuker & Kvarnemo 2021), by the process of competition for mating or differential mate choice (Trivers 1972; Shuker & Kvarnemo 2021). If males compete among themselves for females, then the sexual selection pressure will be primarily on males, whereas predominant female competition results in sexually selected traits and ornaments in females (Vincent et al. 1992). However, in the conventional courtship pattern of the animal kingdom, where males are typically more competitive, females may invest a greater portion of their energy towards offspring than males (Trivers 1972; Masonjones 1996).

In this article, we present data on the courtship and spawning of *M. deocata.* Some brief notes on several aspects of syngnathid behaviour are also presented, to allow comparisons with *M. deocata*'s specific reproductive behaviour patterns. As this species is the only threatened freshwater syngnathid from Himalayan range therefore it should be our prime concern to save this species and their natural populations. Its conservation is much more crucial as by protecting this species, the habitat and rest of the fish communities will also get protected (Vincent et al. 2011a). In addition, this species has got a huge market demand in the ornamental fish business because of its uniqueness (Vincent et al. 2011b). Overexploitation and habitat destruction have resulted in a significant loss of wild stocks. Acquiring an understanding of courtship behaviour will improve our knowledge of their reproductive ecologies, and how to protect them in nature, but it can also enable captive propagation, thereby reducing pressure on wild stocks.

METHODS

The present study was approved by the Institutional Animal Ethical Committee of Gauhati University, Assam (Reference ID: IAEC/PER/2019/PP-IAEC/2018-034). *Microphis deocata* occurs mainly in rivers, streams and lakes (Menon 1999) and was found in rivers of northern Bengal and Bihar. Afterwards, reported from the foothills of eastern Himalaya, below Darjeeling (Hora 1921; Menon 1974), Brahmaputra drainage in Assam (Sehgal 1956; Sen & Choudhury 1977; Sen 1980) and Arunachal Pradesh (Sen 2000). The species has been categorized as 'Near Threatened' in the IUCN Red list of Threatened Species due to habitat destruction and overexploitation. The body is elongated and sub-cylindrical with a protruding snout. The sexes are dimorphic. Males are mainly brownish, with a dark lateral stripe on the snout and above the operculum (Dawson 1984). Adult females show distinctive Y-shaped markings on the lower half side of the trunk. During the breeding season, females extend their abdomen from their body axis with vibrant colour pattern whereas males show a continuous distinct white dotted line in its dorsal surface (Image 1) (A. Saikia, pers. obs. 29 August 2020).

About 105 adult individuals (Average total length±S.D: Male—113±3 mm; Female—141±3 mm) were kept for 12 months in three tanks approximately 90 l, depth—365.76 mm with sand and rock bottom, planted with *Vallisneria* sp. and *Hydrilla* sp. sponge and under-gravel filters were provided for the recirculating water. Fishes were kept in the sex ratio of 1:2 (Male: Female). The male produces 7–8 broods over a span of a year, with a brooding period of 25±2 days. The fish were collected as by-catch from local fishermen using scoop nets (mesh size: 1.0–2.0 mm) in January 2020 from the Manas River (Brahmaputra drainage), Assam, India. Thermostats (RS 300 W, 220–240 V) were fitted and maintained at 26°C and the diet consisted of *Artemia nauplii* or copepods/rotifers. The aquaria were illuminated with T5 tubes (24W) maintaining a 14L/10D cycle. More than 200 h of ad libitum observations were made at random intervals, with about 1–2 h of videotape

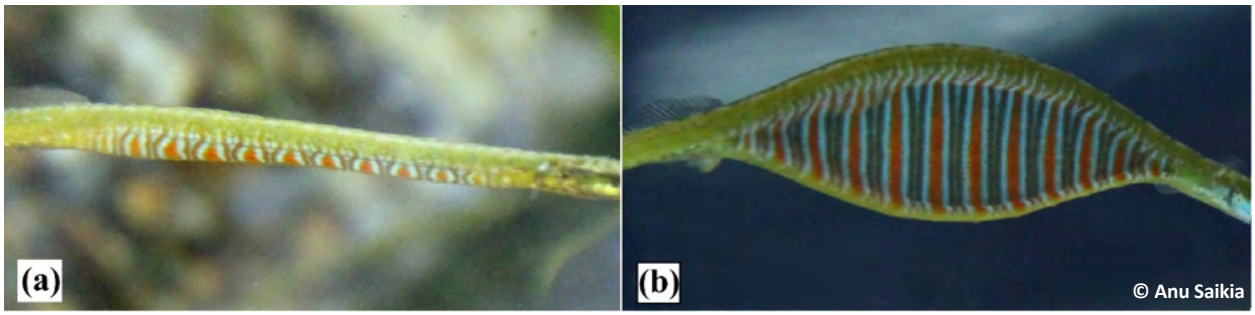

Image 1 . Female amplifiable ornament: a—in isolation | b—interacting with another female (Increasing contrast in the striped pattern).

recordings and the main stages of the courtship rituals were measured and described. In total, we observed eight pairs of courting fish. To give the fish time to get used to the observers, observations were made after a week or two.

RESULTS

Gravid females began to show pre-spawning displays, especially in the morning hours (0430–0600 h), by constantly inflating the ventral skin folds. It consists of a Y-shaped alternate banding pattern (Image 1). The ornament (contrasted bands) is presented throughout the entire courtship process that lasts for 1–2 h. Before the onset of courtship, there is an increase in basal activity of females accompanied by restless parallel movements with other females horizontally. A clearly distinct 1 mm extended ovipositor and contrasted colouration in the trunk region was visible (Image 1). Whereas, in males, the dorsal portion is singly lined with a discontinuous dotted pattern extending from anterior to posterior region, and has a swollen pouch fold. The spawning events of *M. deocata* consisted of three distinct phases marked by prominent behavioural changes and can be summarized as follows:

In the first phase, continuous quivering by females is observed. However, males were seen to dilate the opening of their pouch, inflating the pouch to balloon-like proportions. Both male and female swam side by side and the male often touched the female's belly with his head; the male and female exhibited head-pointing and their tails were often tangled together. The male often overlies upon the female as a sign of embracing the female. After approximately 2 h, the male and female began to swim towards the water's surface. This phase lasts for a long time as males have a low degree of mating propensity or due to interruptions brought about by other females. The interfering females attempted to place their bodies between those of the mating pair (four at a time in one observation). Males that were ready to receive the eggs moved their folds apart and approached the female, manifesting their readiness. (Figure 1a–c)

The mating pair steadily rose in the water column (up to 38 cm) before the actual spawning event. On approaching a male, the female starts to rotate her prehensile tail (4 rotations). Further, the female grasps the tail of the male, swirls it up, and immediately in an upside- down body posture relaxes its abdomen and lay the eggs facing the anterior region of the pouch within 1–2 s of the time period. During egg transfer, the male and female were usually suspended horizontally in the water column. The attempt for the egg-transfer process was usually repeated thrice at each swim towards the surface and it lasted one to three days during which the male was successful to receive the egg (Figure 1d).

The male continued to swim in the water column while bending his body into a contracting wave, while the female started swimming in an orderly directed way right after the egg transfer. The male maintains this posture for 6–8 s then swims back and repeats the movement. Perhaps, this behaviour was responsible for the packing of the eggs in the posterior end of the marsupium. Despite the fact that sperm ejaculation was not clearly visible, fertilization possibly takes place inside the marsupium right after egg transfer (Kvarnemo & Simmons 2004). After this stage, the male progressively sank to the substratum and remained there immobile, occasionally adopting an S-shaped stance, like other pipefish species (Fiedler 1954) (Figure 1e)

DISCUSSION

Before mating, the increase in activity of the female is more pronounced similar to as observed in *Syngnathus*

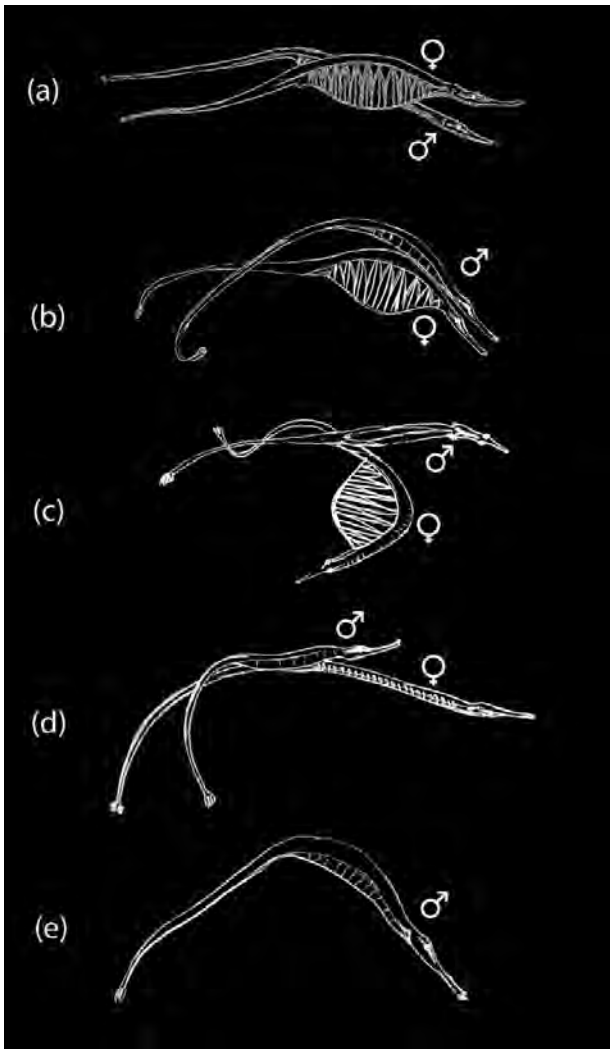

Figure 1. Schematic representation of *Microphis deocata* courtship and spawning sequences: a, b, c—Initial courtship | d—Spawning | e—Swaying. © Jayanta Kumar Nath & Anu Saikia.

abaster (Silva et al. 2006) that usually initiated displays, mainly consisting of vertical swimming movements indicating shallow intertidal habitats also reported in *Corythoichthys intestinalis* (Gronell 1984), *Nerophis ophidion* (L.) (Fiedler 1954). However, it contradicts what is reported for *N. lumbriciformes* where there is a reduction in vertical and swimming movements as they thrive in intertidal zones to avoid strong wave action (Monteiro et al. 2002). In contrast, *M. deocata* shows horizontal parallel movement signifying shallow river and stream habitats, similar as observed in *M. aculeatus* (Christie 2022). Courtship display shown by female of *M. deocata* occurs early in the morning and lasts for about 4.30–6 h. This is in contrast to *S. abster* (Silva et al. 2006) where courtship occurs throughout the day.

Many pipefishes are known to intertwine their bodies like twisted rope during courtship in *C. intestinalis* (Gronell, 1984) and *N. lumbriciformes* (Monteiro, 2002), but the distinct "S" shape curves exhibited here by *M. deocata* are similar to as observed in *M. acul*eatus and other species such as *S. floridae* and *S. abaster* (Breder & Rosen 1966; Gudger 1905; Silva et al. 2006). Male *M. deocata* exhibits a preference for larger-bodied females with greater ornamentation, resembling the characteristics observed in *N. ophidion* (Rosenqvist 1990) and *S. typhle* (Berglund et al. 1997; Berglund & Rosenqvist 2003, 2009). After completion of courtship, the body of the male will be in a bending structure, which indicates that the male has just received the egg. This kind of behavioural adaptation of males strongly signifies that it takes one batch of eggs from a single female at a particular time. During our study, one of the pair pouches was empty before mating but became full after mating. Further investigation is needed on brooding males receiving eggs from one or multiple females.

Afterwards, when the pouch is full, that male will be unavailable for mating with other females in the group. Females are the courting sex and show more intense changes in colour patterns during reproduction than males, as also reported in *N. lumbriciformes*, *N. ophidion* and *S. typhle* (Monteiro 2002; Berglund & Rosenqvist 2003). As in *N. ophidion* (Rosenqvist 1990), *S. typhle* (Berglund & Rosenqvist 2009), *S. abaster* (Silva et al. 2006), and *M. deocata* an overtly interactions among females suggests the female-female competition for mates resulting dominance one over another which occurs mainly through sexual signalling, having a more contrasted colouration in the trunk with more inflation tendency. They can be considered sex role reversed (Vincent et al. 1992) as predominantly females are much more active than males and female-female competition is seen for matings, similar as observed in *M. deocata.*

The incidence of disturbances during the initial stage of the courting ritual appears to be another common occurrence. Females were seen approaching the courting couple and starting to aggressively flicker or just following the pair in a parallel motion, a behaviour that might be seen as a sort of competitiveness (Matsumoto & Yanagisawa 2001). Strangely, the invading female frequently had trouble mating with the courting male. The prolonged courting display, however, appeared to come to a halt as a result of these disruptive females' far greater effectiveness in diverting the other female's attention. Similar observations have been described in *Corythoichthys haematopterus* (Bleeker) (Matsumoto &

Yanagisawa 2001), *Syngnathus schlegeli* Kaup (Watanabe et al. 2000) *N. lumbriciformis* (Monteiro et al. 2002) and *M. deocata*, indicating that the struggle for mates, which differs widely throughout the syngnathid taxa, is highly influenced by female-female interactions (Berglund & Rosenqvist 2003). However, an experiment carried out by Rosenqvist (1990) on *Nerophis ophidion* showed a female-dominance effect in order of the size of the skin fold of females. Similarly, the exhibition of female-dominance cannot be denied in *M. deocata* because the successful deposition of eggs was recorded in all males of the present study despite the maintenance of 1 male: 2 female sex ratio. As females of *M. deocata* exhibit an ornament, i.e., the colourful belly, and distension of the belly amplifies this ornament, there is always a greater tendency of males' choice to select a female having the largest skin fold during courtship and subsequent mating.

In conclusion, the present study provides insights of the breeding behaviour of *M. deocata* in captivity, i.e., in aquarium. Being the only threatened freshwater syngnathid of northeastern India, information shared here will aid in the formulation of effective captive breeding and rearing protocols along with proper identification of broodstock and their basic requirements in captivity. The information shared here aims to assist freshwater pipefish breeders worldwide and restore the population of this threatened species in the wild.

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Journal of Threatened Taxa | www.threatenedtaxa.org | 26 January 2024 | 16(1): 24535–24549

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

https://doi.org/10.11609/jott.8084.16.1.24535-24549

#8084 | Received 01 July 2023 | Final received 01 December 2023 | Finally accepted 22 December 2023

OPEN ACCESS

COMMUNICATION

Freshwater fish diversity and IUCN Red List status of glacial-fed (Bheri) and spring-fed (Babai) rivers in the wake of inter-basin water transfer

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Abstract: Freshwater fish are crucial components of aquatic ecosystems that are affected by a range of anthropogenic activities. Freshwater bodies in Nepal are under different threats affecting biodiversity. Inter-basin water transfer (IBWT) involving damming and diversion of water from one river basin to another is considered a major threat to aquatic biodiversity. Impact assessment of such projects include generation of baseline information on different biotic and abiotic variables. The aim of this study was to generate baseline information on fish diversity from the glacial-fed (Bheri) and the spring-fed (Babai) rivers and their selected tributaries from western Nepal in the wake of the first proposed inter-basin water transfer from the former to the latter. A total of 10 sampling sites, five each from Bheri and Babai River systems, were chosen strategically. Electrofishing was conducted encompassing different seasons in 2018 following the standard method. A total of 32 species with catch per unit effort (CPUE) of 47±24 from Bheri and 42 species with CPUE of 63±52 from Babai River were recorded. Cyprinidae, followed by Nemacheilidae, were the most dominant families in both river systems, and *Barilius vagra* and *Schistura beavani* were the most dominant species in both. Species richness and abundance showed a significant difference between rivers, and differences in fish assemblages reflects differences in ecological regimes. Failure to observe migratory species such as *Anguilla bengalensis* suggests that migratory routes may already have been affected. Of the total 52 species recorded, eight are in the threatened categories of the IUCN Red List and need active conservation measures. The findings provide a reference to assess the impacts of water transfers on fish assemblages in these river systems.

Keywords: Abundance, aquatic ecosystems, Babai River, Bheri River, damming, electrofishing, fish assemblages, threats.

Editor: J.A. Johnson, Wildlife Institute of India, Dehradun, India.

Date of publication: 26 January 2024 (online & print)

Citation: Khatri, K., B.R. Jha, S. Gurung & U.R. Khadka (2024). Freshwater fish diversity and IUCN Red List status of glacial-fed (Bheri) and spring-fed (Babai) rivers in the wake of inter-basin water transfer. *Journal of Threatened Taxa* 16(1): 24535–24549. https://doi.org/10.11609/jott.8084.16.1.24535-24549

Funding: This study was supported by the University Grants Commission of Nepal under Faculty Collaborative Research Grant for F.Y. 2072/73 to Bibhuti Ranjan Jha.

Competing interests: The authors declare no competing interests.

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Author contributions: All authors contributed to the study, conception, and design. Material preparation, data collection and analysis were performed by BRJ, SG, URK, and KK. The first draft of the manuscript was written by KK and all authors rigorously worked and revised the manuscript. All authors have read and approved the final manuscript.

Acknowledgements: We thank the University Grants Commission (UGC) Nepal for funding this research. We also acknowledge the Department of National Park and Wildlife Conservation (DNPWC), Nepal for giving us the permission to sample at Mulghat, Bardiya National Park, staff from Bheri-Babai Diversion Multipurpose Project for their cooperation during the field visits. Finally, we thank the students and technicians for helping this work in field and in labs.

INTRODUCTION

Fish are one of the diverse groups of vertebrates, with an estimated 36,484 species globally including 18,495 freshwater fish (Fricke et al. 2023) and also one of the most frequently investigated aquatic organisms (Tornwall et al. 2015), directly related to human well-being (Öztürk et al. 2021) because of their nutritional, socio-economic, and cultural values (Lynch et al. 2016). An estimated 13,000 (belonging to 2,513 genera) freshwater fish species live in lakes and rivers that cover only around 1% of the earth's surface (Levêque et al. 2007) and are thus one of the major components of global biodiversity (Dudgeon et al. 2006; Sedeño-Díaz & López-López 2013).

Freshwater fisheries provide the main source of protein for 200 million people across Asia, Africa, and South America, as well as jobs and livelihoods for 60 million people (WWF 2021). However, over the past few years, decrease in freshwater fish diversity and their population have been reported from their natural habitats, with one in three species being threatened with extinction (WWF 2021) mainly attributed to a range of anthropogenic activities such as overfishing, pollution, use of destructive fishing methods, climate change, and developmental activities (Saund & Shrestha 2007; ADB 2018; Su et al. 2021).

Asia is the home to about 3,553 freshwater fish species with Cypriniformes and Siluriformes as the most dominant orders (Berra 2007; Levêque et al. 2007; Nelson et al. 2016) with high endemicity (De Silva et al. 2007). The exceptional diversity of fish in this region also supports high diversity of fishes in inland waters, which forms the basis of the livelihood; and extremely important for food security particularly for the rural poor people (Thilsted & Wahab 2014; Gurung 2016). However, the knowledge of fish faunal diversity in many parts of Asia, including Nepal, is still in its progressive phase, where survey works are fragmentary and sporadic, with many species yet to be discovered or to be described (Levêque et al. 2007; Eldho & Sajeevan 2022).

Nepal represents both Indo-Malayan and Palearctic realms (Chaturvedi 2012) and coupled with its rich network of rivers and streams (WECS 2011), the country harbours a rich terrestrial as well aquatic biodiversity (GoN 2014). A recent review reported more than 220 freshwater species in the country (Khatri et al. 2020). However, because of its rich network of rivers and streams, the growing demand for electricity, drinking, and irrigation for increasing population, the damming and diversion of these ecosystems have become common (ADB 2018; WWAP 2009). Recently, Nepal was involved in the implementation of inter basin water transfer (IBWT) schemes (GoN 2019) which involve water transfer from donor basins to receiving basins which provide year-round irrigation, generating reliable electricity and also for other multipurpose benefits (Zhu et al. 2018). Such transfers have also been known to cause a range of upstream-downstream ecological, hydrological, and geomorphological changes (Quan et al. 2016; Zhuang 2016). Therefore, such infrastructural developments and their subsequent environmental consequences are often subject to criticism and discussions (Pittock et al. 2009). However, with a growing population and the country's increasing requirement to produce more food and electricity, damming, and diversion of river waters are on the rise, with many more in the pipeline (Khadka & Khanal 2008; WECS 2011; Gurung & Bharati 2012; Suwal et al. 2020).

Damming, diversion, and inter-basin water transfer affect fish fauna in several ways, including loss of species, decreased abundance, and change in behavior; blockade of migratory routes, and interruption in life cycles (Daga et al. 2020; Tien Bui et al. 2020; Bohada-Murillo et al. 2021). These impacts are attributed to changes in migratory fish habitats, discharge regimes, water temperature and water quality, increased exposure to predation, and loss of riverbank forests (Davies et al. 1992; McAllister et al. 2001). In Nepal, migratory species such as *Tor putitora*, *T. tor*, *Bagarius bagarius*, *Clupisoma gaura*, and *Anguilla bengalensis* have already been reported to be affected through the construction of dams in the country (ADB 2018).

The Bheri Babai Diversion Multipurpose Project (BBDMP) is the first inter-basin water transfer designed to transfer 40 m^3/s water from the glacial-fed Bheri to the spring and rain-fed Babai through a 12-km tunnel for hydropower generation and irrigation. The proposed water transfer aims to generate 46 megawatts (MW) of hydroelectricity and irrigate around 51,000 ha of agricultural land in the southwest districts of Banke and Bardiya (GoN/BBDMP 2018). The mandatory environmental impact assessment (EIA) on BBDMP conducted in 2011 has reported only an inventory on fish fauna from the two rivers with 23 and 20 species from the Bheri and the Babai Rivers respectively (EIA 2011). Moreover, the EIA finding is based on only one time sampling. However, a detailed baseline data on fish diversity, including the seasonal variation in fish assemblages and the International Union for

Conservation of Nature (IUCN) categorization of fish species are still lacking which is crucial for developing effective conservation measures. Therefore, the main objective of this study was to prepare baseline data on fish diversity and to identify IUCN category from the selected stretches of the Bheri and the Babai River in the wake of proposed first inter-basin water transfer in western Nepal. Such baseline information are essential components of impact monitoring and thus forms the basis for development of future management strategies. Furthermore, it could also contribute to update the current IUCN Red List on fishes on local scale.

MATERIALS AND METHODS

Study Area

The study was conducted in the selected stretches of the Bheri and the Babai Rivers and their tributaries in western Nepal. Bheri is a glacial-fed perennial river originating from the Mount Dhaulagiri range (Mishra et al. 2018), whereas the Babai River is a perennial spring as well as rain-fed river with a low flow during dry seasons originating from the Siwalik hills (Sharma 1977). The Bheri River is about 264 km long covering a drainage area of about 13,900 km^2 with an elevational range of 200 to 7,746 m. Based on data from 1975 to 2005 observed from seven climatological stations across the drainage, the average annual precipitation in the drainage was 1,202 mm (Mishra et al. 2018). The average annual discharge of the Bheri River at Samaijighat Hydrological station (Station No. 269.5 located at 500 m), upstream of the proposed water diversion is 331.6 m^3/s with minimum and maximum discharge of 74.5 m^3/s and 2150 m^3/s, respectively (GoN/DoHD 2019). The Babai River is about 400 km long and lies in a subtropical region. It has a drainage area of about 3,250 km^2 with an elevational range of 147 to 2,880 m. The average annual rainfall in the basin is reported to be 1,468 mm, based on data from 1975 to 2005 observed at seven climatological stations (Mishra et al. 2021). The average discharge of the Babai River at Chepang Hydrological station (Station No. 289.95 located at 325 m), near the proposed water release is 34.67 m^3/s with minimum and maximum discharge of 5.1 m^3/s and 477 m^3/s, respectively (GoN/DoHD 2019). Upstream, downstream and three tributaries of both the rivers were strategically chosen for sampling. Thus, 10 sites (five each in the Bheri and Babai River systems; Table 1) were sampled based on strategic occurrence and accessibility (Figure 1). The downstream of water release at Babai River was located at Mulghat at Bardiya National Park- a protected area and the mandatory permit for sampling was procured from the Department of National Parks and Wildlife Conservation, Nepal.

Field Methods

Fish sampling

The sampling was conducted in all major seasons in January (winter), April (spring), June (summer), and November (autumn) in 2018. For fish sampling, electrofishing (Model Honda GXV50) by the wading method was adopted following Jha (2006). Electrofishing is considered a scientific standard method that involves generating an electric field, and the fishes within the field are stunned temporarily. Electrofishing was conducted in two runs of approximately 20 minutes (1200 seconds) each, encompassing approximately 100–500 m (0.1–0.5 km) stretch on each site. The captured fishes were identified up to species level in the field itself following taxonomic literature (Shrestha 1981, 2008), and fishes were photographed. The identified fishes were released back to their natural habitat once the necessary information such as length and weight was collected. Unidentified fish specimens were preserved in 70% ethanol and brought to the Department of Environmental Science and Engineering (DESE), Kathmandu University, for identification following other standard literature (Shrestha 1981; Talwar & Jhingran 1991; Jayaram 2010; Rajbanshi 2012; Fricke et al. 2023) and was further confirmed by fish taxonomists at the Research Laboratory of Fish and Fisheries, Central Department of Zoology, Tribhuvan University. These specimens have been kept for records as voucher specimens at the Central Department of Zoology, Tribhuvan University. Along with fish sampling, selected physico-chemical parameters, viz., temperature, dissolved oxygen (DO), pH, total dissolved solids (TDS), and conductivity were also estimated using portable probes (LUTRON WA-2015). All the samplings were conducted in the morning (0800–1100 h) and afternoon (1300–1600 h).

Data analysis

For fish abundance estimation, the sampled fish species were expressed in catch per unit effort (CPUE) as the number of fishes collected per 10 minutes of electrofishing (Jha 2006). Various species diversity indices such as Shannon index (H') (Spellerberg & Fedor 2003), Simpson's index of diversity (1-D) (Caso & Gil 1988) and Pielou's Evenness (J) (Pielou 1966)

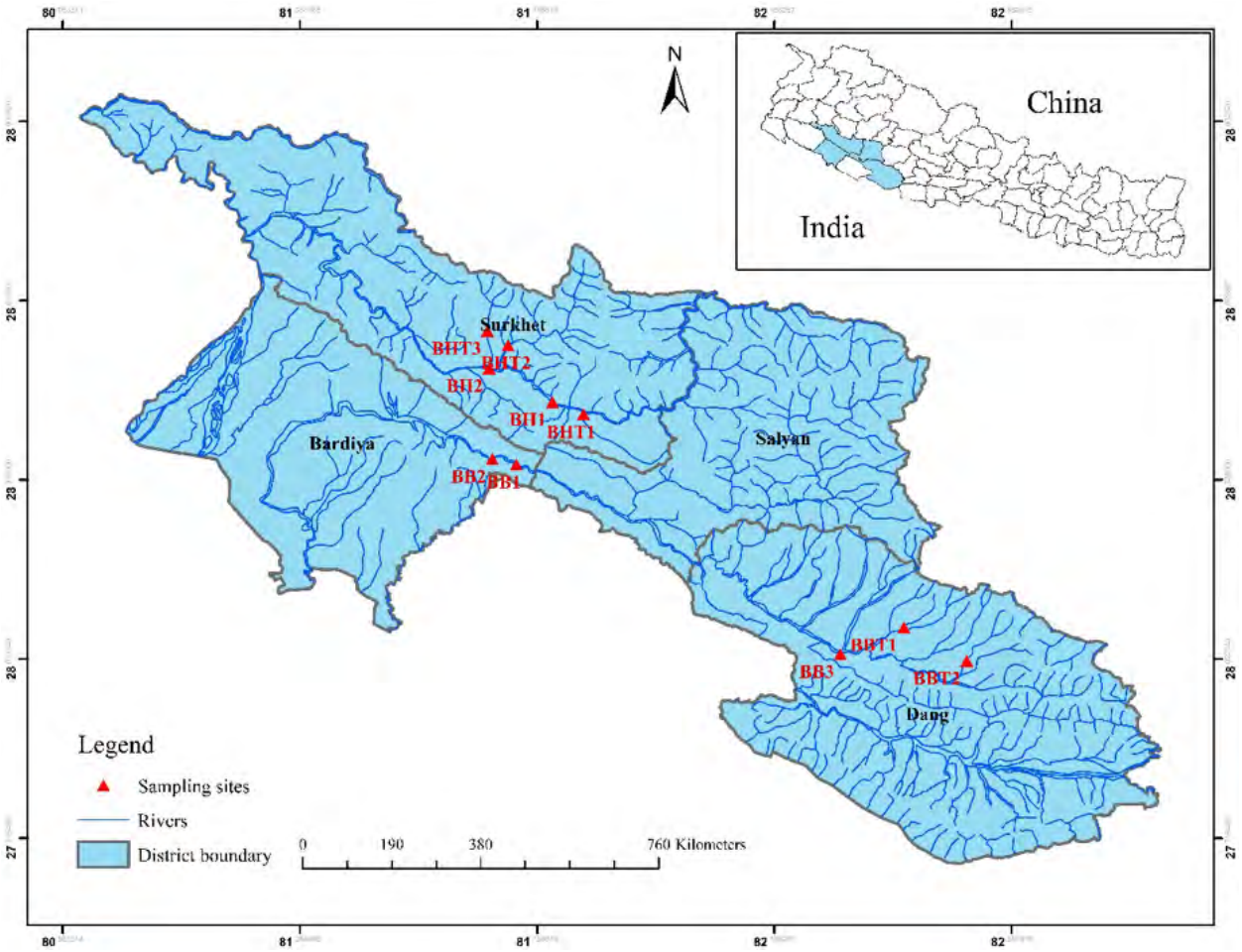

Figure 1. The different sampling sites. Noted legends are sampling sites, major rivers, tributaries and districts boundary.

Table 1. Details of sampling sites with geographical coordinates and elevation.

Site codes	Rivers	Places	Elevation (in m)	Latitude	Longitude	Remarks
BH1	Bheri	Cheepla, Surkhet	436	28.45742°N	081.78235°E	Upstream of water diversion at Bheri
BH2	Bheri	Bhanghari, Surkhet	403	28.51468°N	081.67520°E	Downstream of water diversion at Bheri
BHT1	Goche	Mehelkuna, Surkhet	475	28.43677°N	081.83489°'E	Tributary of Bheri
BHT2	Chingad	Gangate, Surkhet	466	28.55361°N	081.70715°E	Tributary of Bheri
BHT3	Jhupra	Surkhet	497	28.57791°N	081.67207°E	Tributary of Bheri
BB1	Babai	Chepangghat, Surkhet	293	28.35160°N	081.72109°E	Upstream of water release at Babai
B2	Babai	Mulghat, Bardiya	287	28.36127°N	081.68044°E	Downstream of water release at Babai
BB3	Babai	Bel Takura, Dang	561	28.03095°N	082.26972°E	Upstream of Babai
BBT1	Patre	Majhgaun, Dang	594	28.07607°N	082.37733°E	Tributary of Babai
BBT2	Katuwa	Ghorahi, Dang	625	28.01966°N	082.48380°E	Tributary of Babai

were calculated using Past 4 software. Dendrograms were constructed to understand the similarity of fish assemblage structure between the sampling sites. This was done by Hierarchical clustering using group average method with correlation coefficient distance (Jain et al. 1999) using Originpro 2023. Log transformation was done prior to hierarchical clustering to minimize errors. Mann Whitney test was conducted to assess significant

variation between the two river systems in species abundance, whereas Kruskall-Wallis test was performed to assess significant variations in species abundance in different seasons. The threat status categorization of the fish species was conducted following IUCN Red List (2023). Moreover, information from a number of members from fish specialist group working closely with the Department of National Parks and Wildlife Conservation, Nepal and IUCN from the region was also taken in preparing the current IUCN Red List threat status (Shrestha 1995; Jha 2006; Allen et al. 2010).

RESULTS

Fish community structure

A total of 8,735 individuals representing 52 fish species belonging to five orders, 12 families, and 35 genera were recorded from Bheri and Babai River systems. Mann-Whitney test revealed significant variation ($p < 0.05$) in the fish assemblages between the two river systems. A total of 32 species belonging to four orders, eight families, and 20 genera were observed in the Bheri river system, whereas 42 fish species belonging to five orders, 12 families, and 31 genera were observed in the Babai River system. In both the river systems, Cypriniformes and Cyprinidae were the dominant order and family, respectively (Table 2; Figure 2). Order Beloniformes with four families, namely Psilorhynchidae, Cobitidae, Bagridae, and Belonidae, were recorded only in the Babai River system.

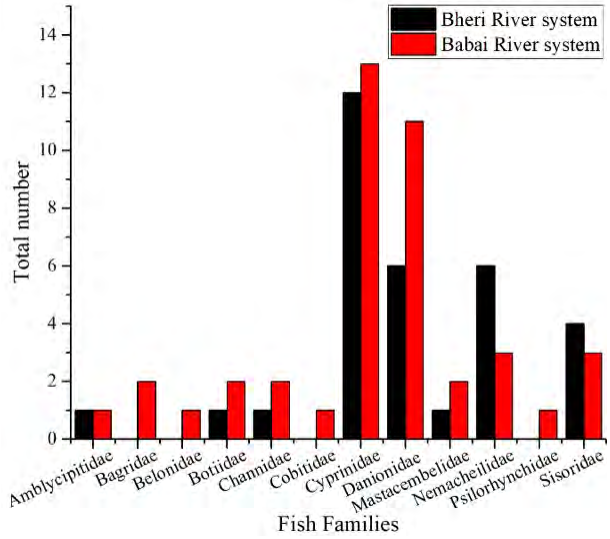

Figure 2. Distribution of fish families recorded in the Bheri and Babai river systems.

In the Bheri river system, order Cypriniformes was represented by four families and 25 species followed by Siluriformes (two families with five species); Perciformes and Synbranchiformes (only one family with one species each). The dominant family, Cyprinidae, contributed 37.5% of the total catch and was represented by 12 species followed by Danionidae and Nemacheilidae (18.8% with six species each), Sisoridae (12.5 % with four species), Amblycipitidae, Botiidae, Channidae, and Mastacembelidae (3.1% with only one species each).

In Babai River system, Cypriniformes was represented by six families and 31 species, followed by, Siluriformes (three families with six species); Synbranchiformes and Perciformes (one family with two species each); and Beloniformes was represented by only one family with one species. The dominant family Cyprinidae contributed 31.0 % of the total catch with 13 species followed by Danionidae (26.2% with 11 species); Nemacheilidae and Sisoridae (7.1% with three species each); Botiidae, Channidae, Mastacembelidae, Sisoridae, and Bagridae (4.8% with two species each); Amblycipitidae, Belonidae, Cobitidae, Erethistidae, and Psilorhynchidae were represented by only one species each (2.4%).

Fish richness, abundance, and diversity

Of the 52 species recorded, 10 species were recorded only from the Bheri system and 20 species were recorded only from the Babai River system; while 22 species were common to both the river systems. Eight species—*Barilius barila*, *Barilius vagra*, *Garra gotyla*, *Puntius sophore*, *Tor putitora*, *Paracanthocobitis botia*, *Schistura beavani*, and *Mastacembelus armatus*—were recorded in all seasons in both river systems. *Cabdio morar*, in the Bheri River and *Systomus sarana*, *Rasbora daniconius*, *Tor tor*, and *Xenentodon cancila* in the Babai River were occasional in occurrence with only a single individual being captured during the present study. The highest number of species was recorded from site BB3 (19 species during autumn) and the lowest number (six species) was recorded from sites BH2 and BBT2 during winter and summer (Figure 4b,d). Ornamental fish species such as *Danio rerio*, *Lepidocephalichthys guntea*, and *Macrognathus pancalus* were observed only from the Babai River system.

In Bheri river system, the fish abundance expressed as CPUE ranged from 7.6 to 96.2 with the average value 46.9 whereas, in the Babai River system it ranged from 11.0 to 242.0 with the average value 63.0 (Table 3) indicating moderate average haul. The most abundant fish species was *Barilius vagra*, followed by *Schistura*

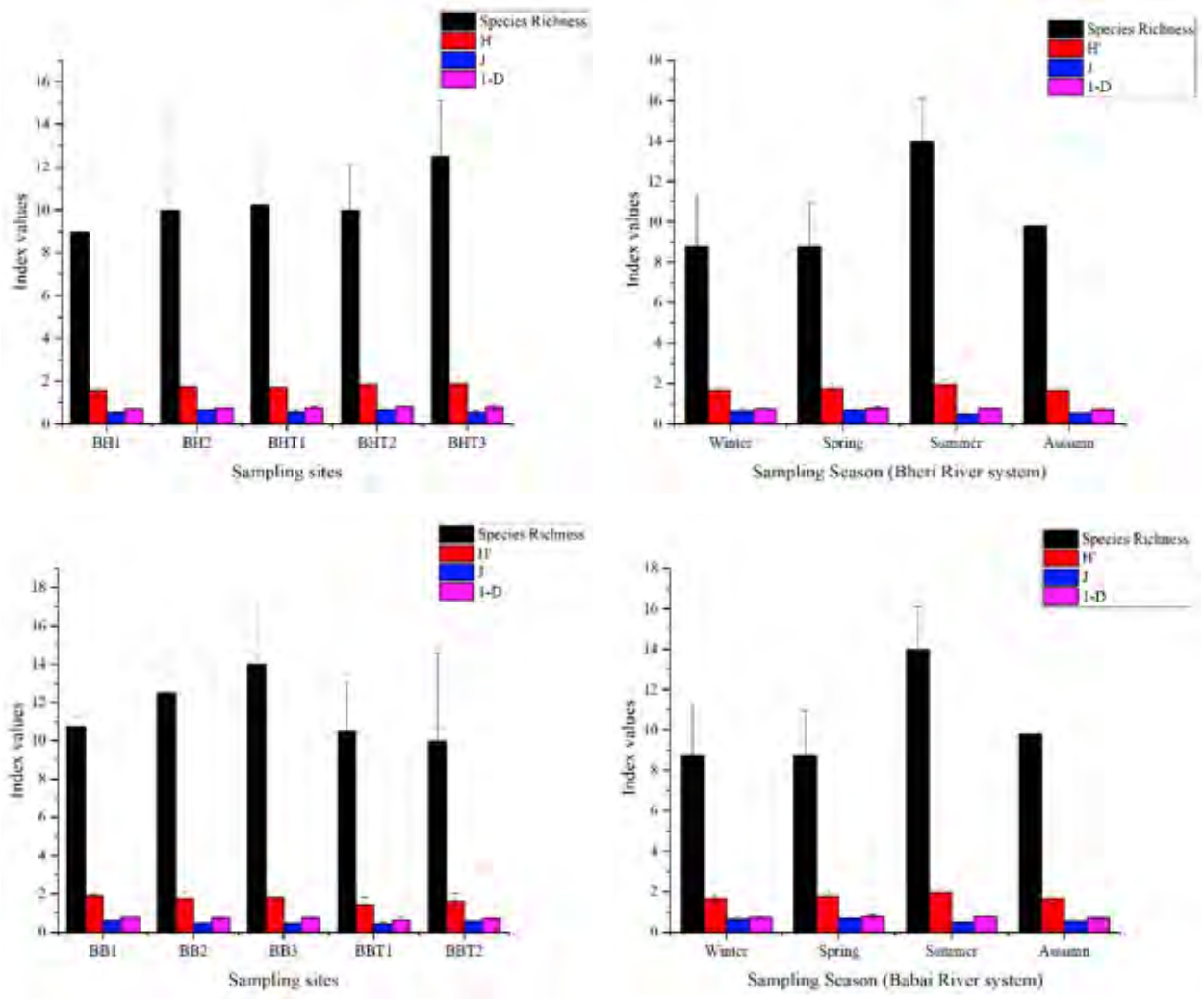

Figure 3. Values of Species Richness, Shannon index (H'), Pielou's evenness (J), and Simpson's index of diversity (1-D) in different sampling sites (3a,c) and seasons (3b,d) in the Bheri and Babai river systems.

beavani in both river systems. The least abundant fish species was *Cabido morar* in Bheri River system (with CPUE of 0.01) whereas, fish species as *Opsarius bendelisis*, *Rasbora daniconius*, *Systomus sarana*, *Tor tor*, and *Xenentodon cancila* (with CPUE of 0.01) were the least abundant in Babai River system.

Seasonal and site-wise ichthyofaunal diversity indices such as Shannon index (H'), Simpson's index of diversity (1-D) and Pielou's Evenness (J) are shown in Figure 3. In Bheri River system, Shannon index (H') ranged from 1.3 to 2.2 with the mean value 1.7± 0.2 while, Simpson's index of diversity (1-D) ranges from 0.6 to 0.8 with mean value 0.7 ±0.1 and Pielou's evenness (J) ranges from 0.5 to 0.9 with mean value 0.7±0.1. Kruskall Wallis test showed significant variation (H = 7.9, P = 0.04) in Pielou's evenness between seasons in the Bheri system. In the Babai River system, Shannon index (H') ranged from 0.9 to 2.0 with the mean value 1.7± 0.3 while, Simpson's index of diversity (1-D) ranged from 0.4 to 0.8 with mean value 0.7±0.1 and Pielou's evenness (J) ranged from 0.4 to 0.8 with mean value 0.7±0.1.

Cluster analysis of species composition revealed that fish assemblages of Bheri and Babai River systems had two distinct clusters based on group average method with correlation coefficient distance (Figure 4). The sites BBT1 and BBT2 had more similar faunal assemblages whereas site BH1 does not show any significant similarity with any other site (Figure 4).

IUCN Red List threat status

The threat status category of the observed fish species based on IUCN Red List have been presented in Table 2. Of the 52 species recorded from this study, 43 fish species has been categorized as 'Least

Table 2. Fish taxa recorded from the Bheri and Babai River systems with threat status.

	Order	Family	Fish species	Bheri River	Babai River	IUCN Red List status
1	Beloniformes	Belonidae	*Xenentodon cancila* (Hamilton, 1822)	×	√	LC
2	Cypriniformes	Botiidae	*Botia almorhae* (Gray, 1831)	√	√	LC
3	Cypriniformes	Botiidae	*Botia dario* (Hamilton, 1822)	×	√	LC
4	Cypriniformes	Cobitidae	*Lepidocephalichthys guntea* (Hamilton, 1822)	×	√	LC
5	Cypriniformes	Cyprinidae	*Bangana dero* (Hamilton, 1822)	√	√	LC
6	Cypriniformes	Cyprinidae	*Chagunius chaunio* (Hamilton, 1822)	×	√	LC
7	Cypriniformes	Cyprinidae	*Tariqilabeo latius* (Hamilton, 1822)	√	√	LC
8	Cypriniformes	Cyprinidae	*Garra annandalei* (Hora, 1921)	√	×	LC
9	Cypriniformes	Cyprinidae	*Garra gotyla* (Gray, 1830)	√	√	LC
10	Cypriniformes	Cyprinidae	*Labeo fimbriatus* (Bloch, 1795)	√	×	LC
11	Cypriniformes	Cyprinidae	*Tariqilabeo macmahoni* (Zugmayer, 1912)	√	×	VU
12	Cypriniformes	Cyprinidae	*Neolissochilus hexagonolepis* (McClelland, 1839)	√	√	NT
13	Cypriniformes	Cyprinidae	*Pethia conchonius* (Hamilton, 1822)	×	√	LC
14	Cypriniformes	Cyprinidae	*Pethia ticto* (Hamilton, 1822)	×	√	LC
15	Cypriniformes	Cyprinidae	*Puntius sophore* (Hamilton, 1822)	√	√	LC
16	Cypriniformes	Cyprinidae	*Puntius terio* (Hamilton, 1822)	√	√	LC
17	Cypriniformes	Cyprinidae	*Schismatorhynchos nukta* (Sykes, 1839)	×	√	EN
18	Cypriniformes	Cyprinidae	*Schizothorax progastus* (McClelland, 1839)	√	×	LC
19	Cypriniformes	Cyprinidae	*Schizothorax richardsonii* (Gray, 1832)	√	×	VU
20	Cypriniformes	Cyprinidae	*Systomus sarana* (Hamilton, 1822)	×	√	LC
21	Cypriniformes	Cyprinidae	*Tor putitora* (Hamilton, 1822)	√	√	EN
22	Cypriniformes	Cyprinidae	*Tor tor* (Hamilton, 1822)	×	√	DD
23	Cypriniformes	Danionidae	*Barilius barila* (Hamilton, 1822)	√	√	LC
24	Cypriniformes	Danionidae	*Opsarius bendelisis* (Hamilton, 1807)	√	√	LC
25	Cypriniformes	Danionidae	*Barilius vagra* (Hamilton, 1822)	√	√	LC
26	Cypriniformes	Danionidae	*Cabdio jaya* (Hamilton, 1822)	√	√	LC
27	Cypriniformes	Danionidae	*Cabdio morar* (Hamilton, 1822)	√	√	LC
28	Cypriniformes	Danionidae	*Danio rerio* (Hamilton, 1822)	×	√	LC
29	Cypriniformes	Danionidae	*Devario devario* (Hamilton, 1822)	×	√	LC
30	Cypriniformes	Danionidae	*Esomus danrica* (Hamilton, 1822)	×	√	LC
31	Cypriniformes	Danionidae	*Laubuka laubuca* (Hamilton, 1822)	×	√	LC
32	Cypriniformes	Danionidae	*Opsarius barna* (Hamilton, 1822)	√	√	LC
33	Cypriniformes	Danionidae	*Rasbora daniconius* (Hamilton, 1822)	×	√	LC
34	Cypriniformes	Nemacheilidae	*Paracanthocobitis botia* (Hamilton, 1822)	√	√	LC
35	Cypriniformes	Nemacheilidae	*Physoschistura elongata* (Sen & Nalbant, 1982)	√	×	VU
36	Cypriniformes	Nemacheilidae	*Schistura beavani* (Günther, 1868)	√	√	LC
37	Cypriniformes	Nemacheilidae	*Schistura prashadi* (Hora, 1921)	√	×	VU
38	Cypriniformes	Nemacheilidae	*Schistura rupecula* (McClelland, 1838)	√	√	LC
39	Cypriniformes	Nemacheilidae	*Schistura savona* (Hamilton, 1822)	√	×	LC
40	Cypriniformes	Psilorhynchidae	*Psilorhynchus pseudecheneis* (Menon & Datta, 1964)	×	√	LC
41	Perciformes	Channidae	*Channa gachua* (Hamilton, 1822)	×	√	LC
42	Perciformes	Channidae	*Channa punctata* (Bloch, 1793)	√	√	LC
43	Siluriformes	Amblycipitidae	*Amblyceps mangois* (Hamilton, 1822)	√	√	LC

	Order	Family	Fish species	Bheri River	Babai River	IUCN Red List status
44	Siluriformes	Bagridae	*Mystus tengara* (Hamilton, 1822)	×	√	LC
45	Siluriformes	Bagridae	*Mystus vittatus* (Bloch, 1794)	×	√	LC
46	Siluriformes	Sisoridae	*Erethistes jerdoni* (Day, 1870)	×	√	LC
47	Siluriformes	Sisoridae	*Glyptothorax kashmirensis* (Hora, 1923)	√	×	CR
48	Siluriformes	Sisoridae	*Glyptothorax telchitta* (Hamilton, 1822)	√	√	LC
49	Siluriformes	Sisoridae	*Glyptothorax trilineatus* (Blyth, 1860)	√	√	LC
50	Siluriformes	Sisoridae	*Pseudecheneis sulcata* (McClelland, 1842)	√	×	LC
51	Synbranchiformes	Mastacembelidae	*Macrognathus pancalus* (Hamilton, 1822)	×	√	LC
52	Synbranchiformes	Mastacembelidae	*Mastacembelus armatus* (Lacepède, 1800)	√	√	LC

Note: IUCN Red list categories of fish taxa observed from the Bheri and Babai River systems following (https://www.iucnredlist.org/).

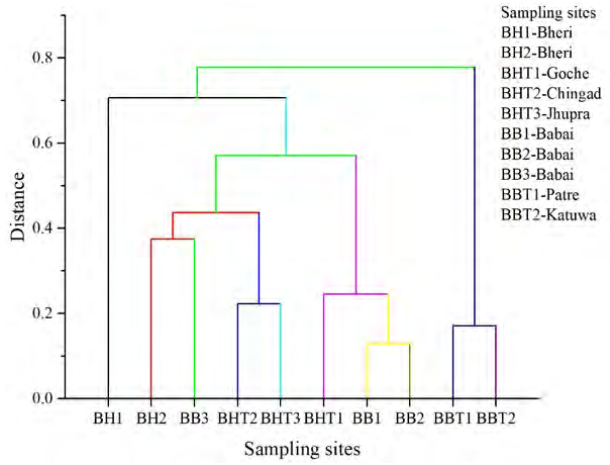

Figure 4. Dendrogram resulting from group average method of fish assemblages from two river systems.

Concerned' and one fish species as 'Data Deficient'. However, two species (*Schismatorhynchos nukta* and *Tor putitora*) have been assigned as 'Endangered', one species (*Neolissochilus hexagonolepis*) as 'Near Threatened', four species (*Tarigilabeo macmahoni*, *Schizothorax richardsonii*, *Physoschistura elongata*, and *Schistura prashadi*) as 'Vulnerable' and one species (*Glyptothorax kashmirensis*) as 'Critically Endangered'.

Physico-chemical parameters

The mean pH, DO, TDS, temperature and conductivity values in the Bheri River system were 8.2 ± 0.5, 9.6 ± 0.9 mgL^{-1}, 159.1 ± 37.0 mgL^{-1}, 21.1 ± 5.2°C, and 295.0 ± 59.7 μScm^{-1}, respectively. In the Babai River system, the mean values of pH, DO, TDS, temperature and conductivity were 8.1 ± 0.4, 8.9 ± 1.6 mgL^{-1}, 198.5 ± 55.3 mgL^{-1},24.5 ± 5.9°C, and 360.7 ± 71.3 μScm^{-1}, respectively. Kruskall Wallis test showed seasonal significant variation in pH, DO and temperature in the Bheri River system ($p < 0.05$); whereas in the Babai River system, significant variation ($p < 0.05$) between seasons was observed only in pH and temperature.

DISCUSSION

Considering more than 220 species reported from Nepalese freshwater ecosystems (Khatri et al. 2020) and presence of 52 (about 23.6%) species in only ten sites indicate a rich fish faunal diversity from the Babai and the Bheri River systems. This is also evident from Pielou's evenness (Figure 3) which ranged from 0.3 (at site BBT1 during winter) to 0.9 (at site BH2 during winter) indicating rich diversity. A previous study by Pandey (2002) reported only 19 species from the Bheri River, whereas the EIA study before the commencement of the dam construction reported 23 species (EIA 2011). Species like *Anguilla bengalensis*, *Labeo angra*, *Bangana dero*, *Psilorhynchus pseudecheneis*, *Bagarius bagarius*, *Clupisoma garua*, *Heteropneustes fossilis*, and *Myersglanis blythii*, reported from Bheri River during EIA (2011) were not observed during our study in Bheri River system. Singh (2002) and G.C & Limbu (2019) reported 39 species and 29 species from the Babai River, respectively, whereas the EIA study conducted in 2011 had reported only 20 fish species from Babai River. Fish species such as *Anguilla bengalensis*, *Amblypharyngodon mola*, *Garra annandalei*, *Bangana dero*, *Labeo dyocheilus*, *Channa striatus*, *Ailia colia*, *Bagarius bagarius*, *Chaca chaca*, and *Wallago attu* reported from Babai River during EIA (2011) were not observed during our study. This difference in the enumeration of the fish species richness could be probably attributed to a range of factors including differences in sampling frequencies, the sampling gears

Table 3. Catch per unit effort values at the Bheri and Babai rivers and their tributaries.

Species	BH1	BH2	BHT1	BHT2	BHT3	Average	BB1	BB2	BB3	BBT1	BBT2	Average	Average total
Xenontodon cancila	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.06	0.00	0.00	**0.01**	0.01
Botia almorhae	0.46	0.00	0.00	0.00	0.00	**0.09**	0.19	0.19	0.00	0.00	0.00	**0.08**	0.08
Botia dario	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.13	0.00	0.00	0.00	**0.03**	0.01
Lepidocephalichthys guntea	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	2.16	25.63	15.88	**8.73**	4.37
Cobdio jaya	0.00	0.00	0.00	0.00	1.25	**0.25**	0.00	0.00	0.00	0.00	0.69	**0.14**	0.19
Bangana dero	0.44	0.56	0.57	0.31	0.00	**0.38**	0.13	1.56	0.13	0.00	0.00	**0.36**	0.37
Barilius barila	1.71	0.38	10.82	1.38	5.75	**4.01**	5.03	8.44	0.19	0.00	0.63	**2.86**	3.43
Opsarius bendelisis	0.00	0.06	0.06	0.00	1.19	**0.26**	0.00	0.00	0.06	0.00	0.00	**0.01**	0.14
Barilius vagra	2.01	1.31	12.09	12.19	16.50	**8.82**	0.69	1.56	4.65	44.13	15.44	**13.29**	11.06
Cabdio morar	0.00	0.06	0.00	0.00	0.00	**0.01**	0.25	0.00	0.00	0.00	0.00	**0.05**	0.03
Chagunius chaunio	0.00	0.00	0.00	0.00	0.00	**0.00**	0.92	0.88	0.00	0.00	0.00	**0.36**	0.18
Tariqilabeo latius	5.29	4.81	0.13	2.25	1.31	**2.76**	0.00	0.19	0.00	0.00	0.00	**0.04**	1.40
Danio rerio	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	1.06	8.00	**1.81**	0.91
Devario devario	0.00	0.00	0.00	0.00	0.00	**0.00**	0.13	0.25	0.00	0.63	0.00	**0.20**	0.10
Esomus danrica	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	1.06	0.00	**0.21**	0.11
Garra annandalei	0.00	0.25	0.00	0.00	0.00	**0.05**	0.00	0.00	0.00	0.00	0.00	**0.00**	0.03
Garra gotyla	1.49	0.56	14.84	3.19	13.50	**6.72**	2.87	11.56	1.49	0.00	0.06	**3.20**	4.96
Labeo fimbriatus	0.00	0.00	0.00	0.00	1.56	**0.31**	0.00	0.00	0.00	0.00	0.00	**0.00**	0.16
Tariqilabeo macmahoni	0.00	0.00	0.00	0.00	0.19	**0.04**	0.00	0.00	0.00	0.00	0.00	**0.00**	0.02
Laubuka laubuca	0.00	0.00	0.00	0.00	0.00	**0.00**	0.19	0.00	0.00	0.00	0.00	**0.04**	0.02
Neolissochilus hexagonolepis	0.00	0.19	0.06	0.13	2.63	**0.60**	0.56	0.00	0.00	0.00	0.00	**0.11**	0.36
Opsarius barna	0.00	0.25	0.00	0.00	0.00	**0.05**	0.06	0.06	0.25	0.00	0.00	**0.08**	0.06
Pethia conchonius	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	1.69	4.69	3.94	**2.06**	1.03
Pethia ticto	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	0.38	**0.08**	0.04
Puntius sophore	0.19	0.06	3.66	2.13	0.69	**1.34**	1.25	0.75	1.25	30.00	5.38	**7.73**	4.53
Puntius terio	0.00	0.00	0.00	0.41	0.00	**0.08**	0.00	0.00	0.00	0.56	2.50	**0.61**	0.35
Rasbora daniconius	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.06	0.00	0.00	0.00	**0.01**	0.01
Schismatorhynchos nukta	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.13	0.00	0.00	**0.03**	0.01
Schizothorax progastus	0.69	0.19	0.00	0.00	0.00	**0.18**	0.00	0.00	0.00	0.00	0.00	**0.00**	0.09
Schizothorax richardsonii	2.96	0.33	0.00	1.75	0.25	**1.06**	0.00	0.00	0.00	0.00	0.00	**0.00**	0.53
Systomus sarana	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.06	0.00	0.00	**0.01**	0.01
Tor putitora	0.06	0.00	3.37	1.00	0.50	**0.99**	1.03	0.81	0.00	0.00	0.00	**0.37**	0.68
Tor tor	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.06	0.00	0.00	0.00	**0.01**	0.01
Paracanthocobitis botia	0.00	1.81	4.99	8.94	3.25	**3.80**	0.06	0.19	11.27	1.94	1.13	**2.92**	3.36
Physoschistura elongata	0.00	1.00	0.00	0.00	0.69	**0.34**	0.00	0.00	0.00	0.00	0.00	**0.00**	0.17
Schistura beavani	2.95	5.00	2.65	6.75	16.94	**6.86**	2.34	8.50	25.38	15.75	0.19	**10.43**	8.64
Schistura prashadi	0.88	0.00	0.00	0.00	0.00	**0.18**	0.00	0.00	0.00	0.00	0.00	**0.00**	0.09
Schistura rupecula	2.65	3.38	0.00	0.00	1.13	**1.43**	0.13	2.63	1.38	0.00	0.25	**0.88**	1.15
Schistura savona	6.74	0.00	0.00	0.00	0.00	**1.35**	0.00	0.00	0.00	0.00	0.00	**0.00**	0.67

Species	BH1	BH2	BHT1	BHT2	BHT3	Average	BB1	BB2	BB3	BBT1	BBT2	Average	Average total
Psilorhynchus pseudecheneis	0.00	0.00	0.00	0.00	0.00	**0.00**	0.19	0.75	0.19	0.00	0.00	**0.23**	0.11
Channa gachua	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.69	4.00	3.63	**1.66**	0.83
Channa punctata	0.00	0.00	0.44	0.00	0.06	**0.10**	0.25	0.00	0.56	1.56	1.38	**0.75**	0.43
Amblyceps mangois	0.00	0.00	0.93	0.00	0.19	**0.22**	0.00	0.00	6.06	0.38	0.38	**1.36**	0.79
Mystus tengara	0.00	0.00	0.00	0.00	0.00	**0.00**	0.13	0.00	0.06	0.25	0.00	**0.09**	0.04
Mystus vittatus	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	1.19	0.00	0.00	**0.24**	0.12
Erethistes jerdoni	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.06	0.13	0.00	0.00	**0.04**	0.02
Glyptothorax kashmirensis	0.00	0.00	0.00	0.00	0.81	**0.16**	0.00	0.00	0.00	0.00	0.00	**0.00**	0.08
Glyptothorax telchitta	0.69	0.88	0.47	6.00	3.31	**2.27**	0.25	0.44	0.00	0.00	0.00	**0.14**	1.20
Glyptothorax trilineatus	0.65	0.50	0.00	0.00	0.00	**0.23**	0.56	0.94	0.00	0.06	0.00	**0.31**	0.27
Pseudecheneis sulcata	0.95	0.56	0.00	0.69	1.00	**0.64**	0.00	0.00	0.00	0.00	0.00	**0.00**	0.32
Marcognathus pancalus	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	1.06	0.00	0.00	**0.21**	0.11
Mastacembelus armatus	0.00	0.58	3.56	1.00	1.75	**1.38**	0.80	1.69	3.19	0.25	0.44	**1.27**	1.33
Total	**30.81**	**22.72**	**58.62**	**48.09**	**74.44**	**46.94**	**17.97**	**41.69**	**63.27**	**131.94**	**60.25**	**63.02**	54.98

used during surveys. Most fish diversity assessments in Nepal are one-time studies and often rely on locals' knowledge and anecdotes (Khatri et al. 2020). Fish assemblages show seasonal variations too, and thus one-time studies often fail to capture the overall assemblages (Jha et al. 2018; Prasad et al. 2020). Moreover, fish species such as *Anguilla bengalensis*, *Clupisoma garua*, *Bagarius yarrelli*, *Labeo pangusia*, *Wallago attu*, and *Ailia colia* which are listed in the IUCN Red List and reported from both river systems (ADB 2018), were not observed in this study. However, these species in Babai River were reported earlier by Shrestha (1999) and EIA (2011) in Bheri River. Species like *Anguilla bengalensis* is a noted catadromous fish (Arai & Chino 2012; Baumgartner & Wibowo 2018) requiring movements from freshwater regimes to oceanic waters for spawning. *Tor putitora* is another migratory species (Pinder et al. 2019) that often takes refuge in upstream river reaches and tributaries. In contrast, species like *Bangana dero*, *Barilius vagra*, *Neolissochilus hexagonolepis*, *Schizothorax progastus*, *S. richardsonii*, *Labeo fimbriatus*, and *Tariqilabeo macmahoni* observed in the Bheri River system are short migratory fishes. Many studies in Nepal and elsewhere have revealed that migratory fish are especially affected when longitudinal connections in rivers are disrupted due to dam construction (Bhatt et al. 2017; ADB 2018; Reid et al. 2019; Barbarossa et al. 2020; Yadav et al. 2020). The Babai Dam Weir cum Bridge at Parewa Odar - located about 40 km downstream of the proposed water release Bardiya National Park, was constructed in 1993 (ADB 2018; GoN/BIP 2001) to supply water for irrigation. The construction and operation of this dam may have disrupted the subsequent migration of these species in upstream reaches of the river.

Our finding regarding Cyprinidae being the most dominant fish family is in accordance with many previous studies from a large number of freshwaters from Nepal (Sharma 2008; Shrestha 2008; Rajbanshi 2012; Khatri et al. 2020). Cyprinidae is considered a rich taxon and is known to contain as many as 1,270 species; and it is one of the most abundant freshwater fish taxa in Asia (Berra 2007; Levêque et al. 2007).

Although several fish species were common to both the river systems, some taxa were exclusively found either in the glacial-fed Bheri River or the rain-fed Babai River system. Taxa like *Schizothorax progastus* and *S. richardsonii* were observed only in Bheri River, whereas taxa like *Xenentodon cancila*, *Danio rerio*, and *Lepidocephalichthys guntea* were observed only in Babai River system. Pathak et al. (2014) and Rajbanshi (2002) have also reported these taxa in glacial-fed and rain-fed rivers of Nepal. *Schizothorax* spp. live typically in cold and fast flowing waters in the Himalayan and sub-Himalayan regions of the Indian subcontinent and are distributed from Afghanistan to Myanmar, including Nepal; central Asia, Kazakhstan and China (Petr & Swar

2002; Sarkar et al. 2012; Khan et al. 2020). In contrast, species like *Barilius* spp., *Puntius* spp., *Tor* spp., *Labeo* spp., *Neolissochilus hexagonolepis*, and *Clarias* spp. are common in cool to warm water regimes (Bhagat 2002; Sharma 2008; Gurung et al. 2016). *Garra gotyla* - a common cyprinid fish has been frequently reported in the lower basin of South Asian rivers (Rayamajhi & Jha 2010), was also observed in both the river systems. *Barilius vagra* is also a common species, particularly in the pools (Singh & Agarwal 2013), and it showed higher abundance in the Babai River.

Ornamental fish species such as *Danio rerio*, *Lepidocephalichthys guntea*, and *Macrognathus pancalus* were observed only in sites BB3, BBT1 and BBT2 characterized by slow and shallow water of the Babai River system. These species are known to be found in a range of habitats such as slow and shallow water of rivers, floodplains, ponds, swamps, ditches, typically in open locations with relatively clear water and abundant vegetation at the margins as well as estuaries (Spence et al. 2006; Suresh et al. 2006; Havird & Page 2010; Gupta 2016). Interestingly, cluster analysis of present study indicated presence of similar fish assemblages in sites BBT1 and BBT2. However, this was expected because these sites were located in the Dang Valley with similar ecological regimes. Similar ecological regimes have been known to support similar biological assemblages too (Granados-Dieseldorff et al. 2012). In contrast, sites BB1 and BB2 from the main Babai River were located in Surkhet Valley and these sites were characterized by higher discharge and rocky substrates. In contrast, sites BH1, BH2, and BHT2 from Bheri River system were characterized by higher discharge, higher depth with a cooler temperature and the dominant substrates in these sites were rock and boulder. These sites form a separate cluster from BBT2 and BBT2.

Fish abundance varied between different seasons in the Bheri and the Babai River systems. The highest fish abundance in the Bheri River system was observed during summer, whereas in the Babai River system, the highest abundance was observed during autumn. Many studies in Nepal (Jha et al. 2007, 2018) and elsewhere (Galib et al. 2016; Park et al. 2020) have reported seasonal variation in fish assemblages in different rivers. Seasons induce change in different environmental regimes of the lotic systems such as discharge, temperature, dissolved oxygen, and availability of food (Dowling & Wiley 1986; Winemiller & Jepsen 1998). The Babai River and its tributaries being rain-fed are characterized by relatively higher temperature (24.5±5.9°C) low flow particularly during winter and spring, whereas during the autumn, the flow and discharge are increased. In contrast, Bheri River being a glacial-fed river is characterized by a low temperature (21.1±5.2°C). Differences in temperature regimes along with differences in flow and food availability during different seasons probably explain the differences in fish abundance in different seasons in the Bheri and the Babai River systems.

Presence of single occurrence of some species like *Cabdio morar*, *Systomus sarana*, *Tor tor*, and *Xenentodon cancila* but their abundant occurrence in earlier studies (Shrestha 1999) suggest that their natural populations are declining mainly attributed to anthropogenically induced stressors (Hossain et al. 2009; Islam & Dutta 2018; Pinder et al. 2019; Barman et al. 2021). Relatively lower CPUE values of 46.9 ± 24.1 and 63.0 ± 51.8 in the Bheri and the Babai River systems respectively also suggests moderate average haul indicating decline in natural fish populations compared to higher CPUE values reported by Jha et al. (2006) in several rivers in Nepal. For instance, CPUE values 71.9, 96.1 and 110.2 were observed in Aandhikhola, Arungkhola, and Karrakhola (Jha et al. 2006).

Tor tor though considered to have a wide distribution (Lal et al. 2013) is being reported to be affected by dams (Sharma 2003). In central India, the species is now restricted in certain pockets of protected areas in Narmada, Tapti, Betwa, and Chambal rivers (Johnson et al. 2012). In this study also, this species was observed only from BB2 which is located inside a protected area—Bardiya National Park.

Although majority of the fish species (43 species out of 52) observed in the study belong to Least Concern category of IUCN Red List, some species belong to Vulnerable and Endangered categories (Table 2) which need active conservation measures. *Tor putitora* (Golden Mahseer) listed as an Endangered species is a large sized migratory fish is an inexpensive but high-quality protein source (WHO 2003; Tacon & Metian 2013; Johnson et al. 2021). This species is also a popular game fish for anglers across India, Pakistan, Bangladesh and Nepal. *Tor tor* (*Tor* mahseer) which was categorized as Data Deficient also needs some attention because studies have showed their decline over the years (Sharma 2003). *Schizothorax richardsonii* Snow Trout categorized as Vulnerable is also one of the highly valued freshwater fish from the Himalayan and trans-Himalayan rivers of India, Bhutan, Nepal, Pakistan, and Afghanistan and constitutes as a principal subsistence food fishery in the different parts of Nepal particularly in the mountainous regions (Peter

& Swar 2002). This study has highlighted the population decline of many species due to various forms of human impacts such as high fishing pressure, loss of habitats resulting from river damming which affect breeding cycle, migration of fish species; natural disasters, pollutions, which requires the need of monitoring and conservation.

CONCLUSION

This study assessed the fish diversity, distribution and selected physico-chemical parameters of Bheri and Babai River systems and in different seasons. A total of 52 species were recorded from the two river systems indicating a rich fish diversity. Moreover, the glacial-fed Bheri River system was found to harbor cold-water taxa, whereas the rain-fed warmer Babai River had warm water taxa only. The difference in the fish community structure and abundance between the two river systems reflects differences in different ecological regimes associated with environmental variables. The average CPUE values in both the river systems reflects a moderate average haul and is indicative of some disturbances in these rivers and their tributaries. Some widely distributed species such as *Barilius vagra, Schistura beavani, Garra gotyla, Puntius sophore, Barilius barila,* and *Paracanthocobitis botia* are abundant corresponding to the previous studies. Observation of some species such as *Opsarius barna, Tor* spp*, Schistura prashadi, Hara jerdoni,* and *Glyptothorax kashmirensis* in small numbers and the fact that out of 52 species observed, eight species belong to IUCN Near Threatened, Vulnerable and Endangered categories indicate the need of an active measure of conservation. Failure to capture long migratory species like *Anguilla bengalensis*, reported in earlier studies, suggest that the migratory route of such species may already have been affected. There is an urgent need for robust surveys on the abundance, distribution and ecological requirements over the natural range of this species. The findings of this research provide baseline information on the fish diversity of the Bheri and Babai River systems. The data obtained could contribute to Fish Specialist Groups to evaluate IUCN Red List, as well as could help in assessing the overall impacts of water transfer in the Bheri and Babai Rivers.

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Journal of Threatened Taxa | www.threatenedtaxa.org | 26 January 2024 | 16(1): 24550–24556
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.8602.16.1.24550-24556
#8602 | Received 19 June 2023 | Final received 15 December 2023 | Finally accepted 08 January 2024
OPEN ACCESS
COMMUNICATION

Population status and habitat use of White-crested Kalij Pheasant *Lophura leucomelanos hamiltoni* (J.E. Gray, 1829) in the Limber Wildlife Sanctuary, Jammu & Kashmir, India

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Abstract: Understanding the population status and habitat use of a species is fundamental for initiating conservation action. The present study was conducted from March 2021 to February 2022 to assess the population status and habitat use of White-crested Kalij Pheasant *Lophura leucomelanos hamiltoni* in the Limber Wildlife Sanctuary. Line transects/trails (n = 7) were established across all the habitat types. A total of 45 direct sightings of the bird were recorded in the study area. The highest abundance was recorded in autumn (2.25 ± 0.53 birds/km) and the lowest in spring (0.22 ± 0.53 birds/km). Flock size ranged from one individual to nine individuals. Of the different habitat types identified, most sightings occurred in coniferous forests with high understory (n = 16). The agricultural terracings (n = 6) and grassy slopes (n = 2) exhibited the fewest sightings. Recognizing and mapping these habitats are fundamental initial measures for conserving the species within the landscape.

Keywords: Abundance, coniferous forests, conservation, encounter rate, habitat preference, line transect, western Himalaya.

Editor: P.O. Nameer, Kerala Agricultural University, Thrissur, India.

Date of publication: 26 January 2024 (online & print)

Citation: Lone, A.N., B.A. Bhat & K. Ahmad (2024). Population status and habitat use of White-crested Kalij Pheasant *Lophura leucomelanos hamiltoni* (J.E. Gray, 1829) in the Limber Wildlife Sanctuary, Jammu & Kashmir, India. *Journal of Threatened Taxa* 16(1): 24550–24556. https://doi.org/10.11609/jott.8602.16.1. 24550–24556

Funding: Thanks to the Council of Scientific and Industrial Research (CSIR) for providing grants under the CSIR-JRF fellowship scheme which made this research work possible.

Competing interests: The authors declare no competing interests.

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Author contributions: ANL: data collection, data analysis and manuscript writing. BAB: helped in study design, data collection and reviewed the manuscript. KA: helped in study design and reviewed the manuscript.

Acknowledgements: Thanks to the CSIR-UGC for providing grants under the CSIR–JRF fellowship scheme. The authors duly acknowledge the Department of Zoology, University of Kashmir for providing laboratory and other facilities. Our sincere thanks go to the Department of Wildlife Protection Jammu & Kashmir for providing the necessary permission for the smooth conduct of this work in the Limber Wildlife Sanctuary.

INTRODUCTION

The Kalij Pheasant belongs to a group of pheasants commonly known as the *Gallopheasants*. Nine morphologically distinct and geographically separate subspecies of Kalij Pheasant have so far been described in the world (Johnsgard 1999). These subspecies are native to southern Asia, distributed from Pakistan in the western Himalaya through India, Nepal, Bhutan, and Burma to western Thailand, and lately introduced into the United States (McGowan & Panchen 1994; BirdLife International 2016). The Kalij Pheasant exhibits conspicuous sexual dimorphism, with males brightly colored and larger in size than females, which are highly cryptic and often blend with the background (Zeng et al. 2016).

In India, four subspecies of Kalij Pheasant are known to occur, which inhabit almost all types of forests with a thick understory of shrubs (Grimmet et al. 2016). The species is primarily found on the western side of the Himalayan mountains (Barnes 1981), generally adapted to sedentary lifestyles and occurring along foothills, woodland roads, forest clearings, and bushy ravines (Bump & Bohl 1971; Ali & Ripley 1983). The subspecies White-crested Kalij Pheasant *Lophura leucomelanos hamiltonii* is found in the western Himalaya (Jammu & Kashmir) and has been reported to occupy a variety of habitat types, including primary forests through scrubs and thickets, agricultural terracings from foothills to 2,400 m elevations, and having direct contact with human habitations (Bisht et al. 2002; Sathyakumar et al. 2010).

Density and abundance are essential in monitoring the population of a species, which in turn is fundamental for devising a proper conservation strategy (Conroy & Noon 1996). Nevertheless, estimating the abundance and densities of pheasants is often cumbersome owing to their shy nature and inhabiting tough habitats (Sathyakumar & Kaul 2007; Miller 2010). Although listed as 'Least Concern', the Kalij Pheasant faces a declining population trend (BirdLife International 2021), and scanty scientific information exists about the population status, behavior, and habitat ecology of the Kalij Pheasant (Andleeb et al. 2012).

Considering the ongoing threats in the form of hunting and habitat degradation and with the recent declaration of the White-crested Kalij Pheasant (hereafter Kalij Pheasant) as the Union Territory (UT) bird of Jammu & Kashmir, the species deserves more conservation priority. No prior information, however, is available about the basic ecology of the species in the UT of Jammu & Kashmir. In this paper, the population status and habitat use of Kalij Pheasant in Limber Wildlife Sanctuary were assessed, for these represent the pioneering steps before any comprehensive management action is undertaken for the survival of a species (McGowan & Gillman 1997).

MATERIAL AND METHODS

Study area

The Limber Wildlife Sanctuary (LWS) (34.153–34.208 ^{0}N & 74.138–74.194 ^{0}E) lies in the district Baramulla of Jammu & Kashmir and is situated on the north bank of river Jhelum, at a distance of 75 km from the capital Srinagar (Image 1). The sanctuary falls within the western Himalayan zone and spans over an area of 26 km^2 (Ahmad et al. 2017). The altitude of the area varies 1,500–2,500 m. The sanctuary represents one of the three protected areas from which the Kazinag National Park has been carved out to conserve one of the largest wild goats in the World, the Pir Panjal markhor *Capra falconeri cashmiriensis* (Bhatnagar et al. 2009).

The LWS represents a prototype of temperate conditions. The landscape of the sanctuary is rough, with moderate to steep slopes and undulating terrain. The vegetation is mainly mixed coniferous chiefly dominated by Blue Pine *Pinus wallichiana* and Deodar *Cedrus deodara* at lower to middle elevations. The streams and brooks are dotted with Walnut *Juglans regia*, Indian horse chestnut *Aesculus indica,* and Cranberry *Viburnum grandiflorum*. The notable fauna of the sanctuary includes Common Leopard *Panthera pardus*, Himalayan Goral *Naemorhedus goral*, Black Bear *Ursus thibetanus*, Yellow-throated Marten *Martes flavigula*, Western Tragopan *Tragopan melanocephalus,* and Cheer Pheasant *Catreus wallichii*. The area witnesses four discrete seasons; spring (March–May), summer (June–August), autumn (September–November), and winter (December–February). The precipitation mainly pours down as rain during summers and as snow during winters. The winters are severe and cold with temperatures plunging as low as -10°C.

Methods

The line transect method, widely used in wildlife ecology for bird sampling, offers fair estimates of population density and abundance, particularly for Galliformes (Azhar 2008). This study, conducted from March 2021 to February 2022 followed Miller's (2010) line approach, which is deemed most appropriate for

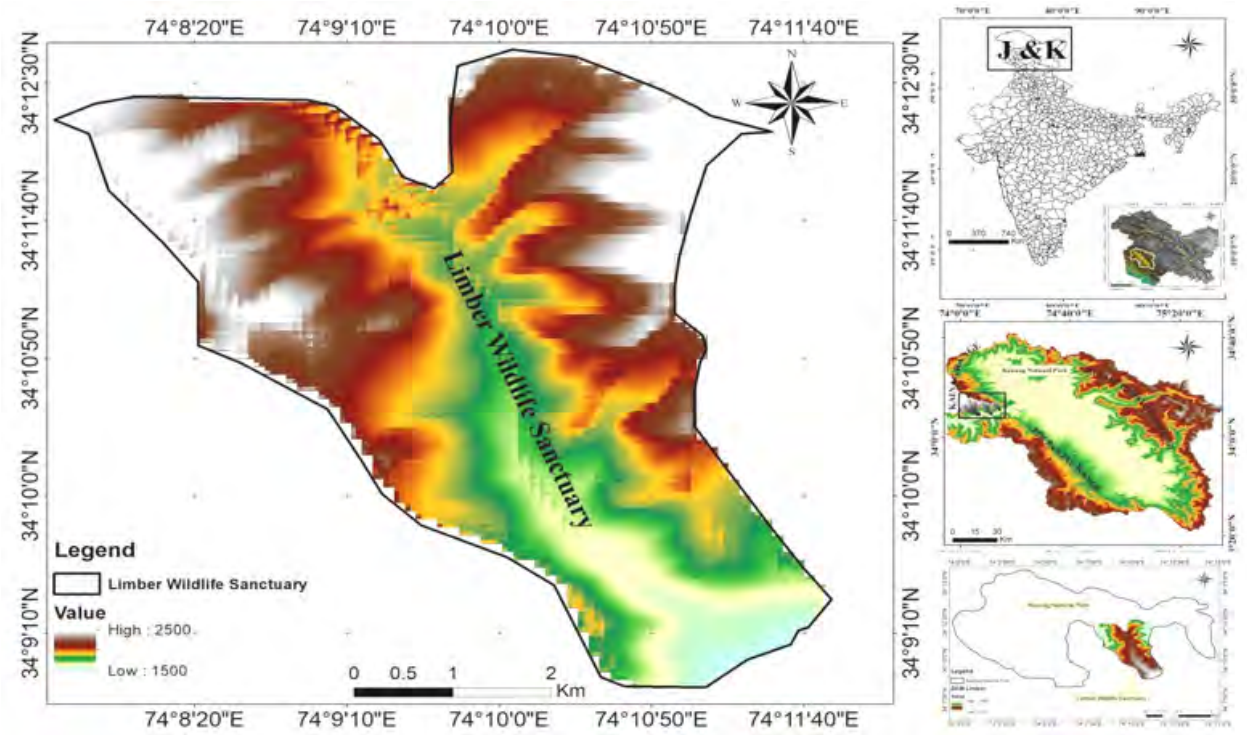

Image 1. Location map of the study area.

the pheasant survey. Seven transects of varying lengths (0.8–2 km), covering a total of 130 km and spanning altitudinal gradients from 1,500 to 2,500 m, were strategically selected across different habitats. Visits occurred seasonally and transects were walked in the early morning (0500–0900 h) and evening (1700–1900 h), aligning with the pheasants' active feeding near roosting sites (Ramesh 2003). Morning data was exclusively used for analysis, assuming animals stayed near their resting sites during this time (Ramesh et al. 1999). To enhance data reliability and minimize bias, two observers walked the same transect. Kalij Pheasant sightings triggered data recording including time, geo-coordinates, flock size, elevation, aspect, and distance from the nearest water source. Field binoculars and cameras were used for observations and photographs respectively. Although fresh droppings were documented, they were excluded from data analysis. Abundance assessment employed the encounter rate (number of birds seen per km) following Caughly's (1975) approach.

Habitat utilization of the Kalij Pheasant was recorded by monitoring the species in different types of habitats. The study area was divided into different habitat types which included coniferous forests with high understory (CFHU), coniferous forests with sparse understory (CFSU), open forests, terraced fields, and grassy slopes. Ensuring that the maximum area was covered in each type of habitat at every direct bird sighting, habitat parameters (elevation, slope, aspect, habitat type, and crown cover) were quantified from 10 m, 5 m, and 1 m plots to study the habitat use of the Kalij Pheasant. The habitat preference was calculated using the Habitat Preference Rating Index (HPRI) of Mishra (1982):

$$\textit{Habitat Rating Index}\ (\text{HRI}) = \frac{\%\ \text{of animals observed in each habitat type } (X)}{\%\ \text{of transect covered in each habitat type } (Y)}$$

RESULTS

In an effort of 130 km of transect walk, during the given study period, a total of 45 direct sightings of the Kalij Pheasant were recorded from the study area. Autumn provided the highest number of sightings (n = 21) and spring the lowest (n = 5). Most of the sightings (65%) were recorded early in the morning before 0700 h and late evening after 1800 h, close to the water sources. One-way ANOVA ($p = 0.01$, $df = 3$, $F = 6.45$) suggested a significant variation in the encounter rates of the species across different seasons (Table 1). The season-wise mean encounter rate was highest during autumn (2.25 ± 0.53 SE) and lowest during spring (0.22 ± 0.08 SE) (Table 2).

The Kalij Pheasant was recorded at different

Table 1. One-way ANOVA for encounter rates across different seasons during 2021–2022.

Source of variation	SS	df	MS	F	P-value	F crit
Between groups	7.9212966	3	2.64043	6.4522708	0.0157443	4.0661805
Within groups	3.273	8	0.7251			
Total	11.1950916	11				

Table 2. Season-wise encounter rate of Kalij Pheasant in Limber Wildlife Sanctuary during the year 2021–2022.

Seasons	Mean Encounter rate (±SE)
Spring	0.22 ± 0.08
Summer	0.31 ± 0.07
Autumn	2.25 ± 0.53
Winter	1.08 ± 0.49

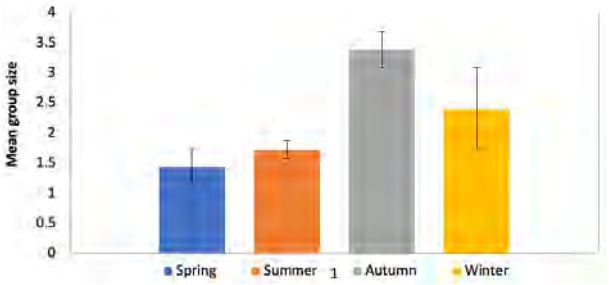

Figure 1. Mean flock size of Kalij Pheasant in different seasons.

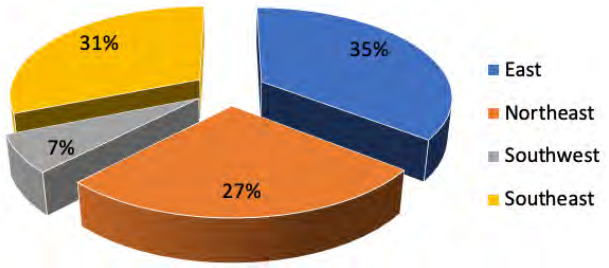

Figure 2. Percentage of sightings in different aspects of the study area.

elevations of the sanctuary with maximum sightings (46.67%) reported between 1,800 to 2,200 m altitude. No direct evidence of the species was reported beyond 2,360 m throughout the whole study period. Four types of flocks; solitary male or female (rare), male and female pair (only at the approach of spring), mixed flocks, and unisex flocks (post summer) were encountered during the study period. Since the Kalij Pheasant exhibit prominent sexual dimorphism, males and females could easily be identified and the flocks always had more males than females and the mean flock size was highest in autumn (3.38 ± 0.30 SE) and lowest in spring (1.44 ± 0.29 SE) (Figure 1).

The Kalij Pheasant was distributed in all the different habitat types, with maximum sightings reported from coniferous forests with high understory (CFHU) (n = 16), followed by coniferous forests with sparse understory (CFSU) (n = 13). Grassy slopes (n = 2) had the lowest number of sightings. Habitat Preference Rating Index (HPRI) revealed that the pheasant utilized CFHU (HPRI = 1.34) and CFSU (HPRI = 1.12) in higher proportion than the open forests and terraced fields (Table 3). Except for shed feathers and fecal droppings, we did not record any direct sightings of the Kalij Pheasant in terraced fields and grassy slopes during the daytime. All the direct sightings (eight in number) observed in these two habitats were reported either in the morning or late evening during autumn and winter. No direct sighting, whatsoever, was witnessed in these two habitats during spring or summer.

This study established that the Kalij Pheasant was mostly concentrated in the east (35%), and southeast (31%) facing aspects (Figure 2). West facing aspect seemed to be avoided by the species. No direct or indirect evidence was reported on the west-facing side during our whole study period. Also, no shift in aspect utilization across the seasons was observed. Since pheasants are extremely shy creatures, Kalij Pheasant was observed occupying dense shrub cover (50–75%) and was encountered at varying degrees of slopes with a majority of individuals (68%) occupying moderate slopes (20–40 °).

DISCUSSION

The present study reported that the abundance of the Kalij Pheasant changed across the seasons; the highest abundance was recorded in autumn (2.25 ± 0.53 birds/km) and the lowest in spring (0.22 ± 0.08 birds/km). The highest number of individuals observed during the autumn season could be attributed to the high visibility due to the disappearance of vegetation

Table 3. Habitat preference rating index (HPRI) of Kalij Pheasant during the period 2021–2022.

Habitat type	Number of Kalij Pheasants observed	*X%	#Y%	HPI^(X/Y)
Coniferous forests with high understory (CFHU)	42	33.6	25	1.34
Coniferous forests with sparse understory (CFSU)	35	28	25	1.12
Open forests	22	17.6	25	0.70
Terraced fields	18	14.4	25	0.58
Grassy slopes	8	6.4	25	0.26
Total	**125**			

*X—Percentage of animals observed in each habitat type | #Y—Percentage of transect traversed in each habitat type | ^HPI—Habitat preference rating index.

and their congregation at lower less dense areas for food and water, as these resources become depleted at upper reaches in autumn (Furqan & Ali 2022). A study conducted by Selvan et al. (2013) recorded a density of 6.7 birds/km^2 for Kalij Pheasant in the eastern Himalaya of Arunachal Pradesh, India. This study is in line with the results of Subedi (2005) who observed a maximum population density of 8.9 birds/km^2 for Nepal Kalij *Lophura leucomelanos leucomelanos* in October and a lowest density of 1.94 birds/km^2 in March. The least number of sightings witnessed during spring is probably because it coincides with the breeding season of the Kalij Pheasant (Ali & Ripley 1983) when they remain in pairs and prefer dense understory of shrubs for breeding and nesting purposes and therefore become difficult to sight.

Except for three solitary bird sightings, all the recordings were in groups, and this is in line with the observation of Sathyakumar et al. (2010) who documented Kalij Pheasant occurring in groups and reported an average group size of 2.1 birds/km^2. Selvan et al. (2013) also observed a nearly similar group size of 2.3 birds/km^2 for Kalij Pheasant in tropical forests of Arunachal Pradesh. Unlike other pheasants (like Himalayan Monal and Western Tragopan) which have a female-biased sex ratio (Sathyakumar 1999), the sex ratio was male-biased for the Kalij Pheasant. The flocks always had more males than females. Lewin & Lewin (1984) have proposed a monogamous behavior for the Kalij Pheasant and observed a sex ratio of 141 males to 100 females (male-biased). The occurrence of more males than females in a group may be due to cooperative breeding exhibited by the Kalij Pheasant (Zeng et al. 2016) or it might be because, unlike males which are quite sneaky and agile, females are less active and become more susceptible to local hunting and predation.

The Kalij Pheasant was recorded from all the five habitat types identified in the study area, though with varying degrees of encounter rates. Coniferous forests with high understory (CFHU) of shrubs had the highest number of sightings (n = 16) followed by coniferous forests with sparse understory (CFSU) (n = 13). The higher percentage of sightings in forests with dense understory reflects the importance of cover in the habitat selection of the Kalij Pheasant. The Kalij Pheasant, being one of the most adaptable pheasant species, occurs in almost all types of forests having thick undergrowth of shrubs (Grimmett et al. 2016). The lowest number of sightings in terraced fields (n = 6) and grassy slopes (n = 2) is because of the virtual absence of cover in these areas and the heavy human interference which was more pronounced in spring and summer seasons when the people are busy with crop cultivation and accompany their cattle and livestock to graze in the grassy habitats. The stealthy nature of pheasants also restricts them to dense habitats to avoid open and human-influenced areas.

Since water plays an essential role in the life cycle of every animal, most of our sightings (80%) were in close proximity to water sources, which is in accord with the findings of Sathyakumar & Kaul (2007) who always found Kalij Pheasant digging and feeding nearby water sources. Furqan & Ali (2022) also noted that the Kalij Pheasant exhibited the greatest activities (54.97%) near water sources within 200 m of range.

Cover plays a consequential role in the selection of habitats by Himalayan pheasants and serves the purpose of protection from predators and vagary weather prevalent at higher altitudes and acts as a safe feeding and breeding abode (Severinghaus 1979; Nelli et al. 2012). While studying density estimates and habitat use of the Kalij Pheasant in Kedarnath Wildlife Sanctuary, Sathyakumar et al. (1992) reported that the Kalij Pheasant usually preferred moderate grass and tree cover but high shrub cover, which has also been observed in our study. The highest number of sightings

was documented from forests having dense shrub cover (50–75 %) and moderate tree cover (25–45 %). A study conducted in the Eastern Himalayas similarly observed Kalij Pheasant occupying low tree cover but high shrub cover (60–90 %) (Selvan et al. 2013).

As the topographic features influence the habitat preference in birds, most of our sightings were observed in the east (35%) and southeast (31%) facing aspects. This might be attributed to the availability of warm sunlight during most of the day hours and sufficient water availability, making these two aspects more suitable environments for survival than others. No direct or indirect records of the Kalij Pheasant were found in the west-facing aspect, probably because of lesser water availability and sparse shrub cover on that side. Norbu et al. (2013) reported similar results for Satyr tragopan *Tragopan satyra* and observed that the pheasant restricted itself towards east and southeast-facing aspects because of the warm environment provided by these aspects.

CONCLUSION

The study, a pioneering effort in the Union Territory of Jammu & Kashmir, has confirmed the presence of a substantial surviving population of Kalij Pheasant in the Limber Wildlife Sanctuary. It offers crucial baseline information on the species, including its abundance, group size, and habitat use. With this foundational data in place, a detailed ecological study is recommended for the sanctuary and its adjacent areas to ensure the species' long-term conservation in the landscape.

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Journal of Threatened Taxa | www.threatenedtaxa.org | 26 January 2024 | 16(1): 24557–24567
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.8639.16.1.24557-24567
#8639 | Received 18 July 2023 | Final received 22 November 2023 | Finally accepted 15 December 2023
OPEN ACCESS
COMMUNICATION

Assessment of diversity, abundance, and seasonal variations of bird species in Bengaluru District, India during COVID-19 lockdown

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Abstract: The study investigates bird population dynamics in Bengaluru, India, post-lockdown, focusing on occurrence, seasonal abundance, species diversity, richness, dominance, and evenness. It covers 55 bird species across 52 genera, grouped into 32 families within 13 orders, with a notable peak in winter. Various indices, including Shannon Wiener, Margalef's, Pielou's, and Simpson's, reveal significant seasonal differences in bird population characteristics. The Rock Pigeon *Columba livia* dominates, while the Black-headed Ibis *Threskiornis melanocephalus* is less prevalent. The study identifies Near Threatened species like Black-headed Ibis and Oriental Darter *Anhinga melanogaster*, along with Least Concern species per the IUCN Red List. Common species include Rock Pigeon, Large-billed Crow *Corvus macrorhynchos*, House Crow *Corvus splendens*, Black Drongo *Dicrurus macrocercus*, Brown Shrike *Lanius cristatus*, Common Myna *Acridotheres tristis*, Jungle Myna *Acridotheres fuscus*, Red-whiskered Bulbul *Pycnonotus jocosus*, and Streak-throated Swallow *Petrochelidon fluvicola*. The study aims to inform improved management and conservation strategies for Bengaluru's diverse bird species.

Keywords: Avian abundance, bird diversity, conservation, lockdown effects, pollution indices, species evenness, species richness, threatened species, water bodies.

ಪ್ರಸ್ತಾವನೆ: ಈ ಅಧ್ಯಯನವು ಭಾರತದ ಬೆಂಗಳೂರಿನಲ್ಲಿನ ಕೋವಿಡ್-೧೯ ಲಾಕ್‌ಡೌನ್ ನಂತರದ ಪಕ್ಷಿಗಳ ಜನಸಂಖ್ಯಾ ಡೈನಾಮಿಕ್ಸ್ ಅನ್ನು ತನಿಖೆ ಮಾಡುತಿದ್ದು, ಮುಖ್ಯವಾಗಿ ಪಕ್ಷಿಗಳ ಸಂಭವಿಸುವಿಕೆ, ಕಾಲೋಚಿತ ಸಮೃದ್ಧಿ, ಜಾತಿಯ ವೈವಿಧ್ಯತೆ, ಶ್ರೀಮಂತಿಕೆ, ಪ್ರಾಬಲ್ಯತೆ ಮತ್ತು ಸಮತೆಯ ಮೇಲೆ ಕೇಂದ್ರೀಕರಿಸುತ್ತದೆ. ಇವುಗಳು ೫೨ ಕುಲಗಳಿಗೆ ಸೇರುವ ೫೫ ಜಾತಿಗಳನ್ನು ಒಳಗೊಂಡಿದ್ದು, ೧೩ ಗಣಗಳು, ೩೨ ಕುಟುಂಬಗಳಾಗಿ ವರ್ಗೀಕರಿಸಲಾಗಿದೆ, ಚಳಿಗಾಲದಲ್ಲಿ ಗಮನಾರ್ಹವಾದ ಉತ್ತುಂಗವನ್ನು ಹೊಂದಿದೆ. ಶಾನನ್ ವೀನರ್, ಮಾರ್ಗಲೆಫ್ಸ್, ಪೈಲೌ ಮತ್ತು ಸಿಂಪ್ಸನ್ ಸೇರಿದಂತೆ ವಿವಿಧ ಸೂಚ್ಯಂಕಗಳು ಪಕ್ಷಿಗಳ ಜನಸಂಖ್ಯೆಯ ಗುಣಲಕ್ಷಣಗಳಲ್ಲಿ ಗಮನಾರ್ಹವಾದ ಕಾಲೋಚಿತ ವ್ಯತ್ಯಾಸಗಳನ್ನು ಬಹಿರಂಗಪಡಿಸುತ್ತಿವೆ. ಗುಡ್ಡದ ಪಾರಿವಾಳ (ಕೊಲಂಬಾ ಲಿವಿಯಾ)ವು ಹೆಚ್ಚು ಪ್ರಾಬಲ್ಯತೆ ಹೊಂದಿದ್ದು, ಬಳಿ ಕೆಂಬರಲು (ಥ್ರೆಸ್ಕಿಯೋರ್ನಿಸ್ ಮೆಲನೊಸೆಫಾಲಸ್) ಕಡಿಮೆ ಪ್ರಚಲಿತದಲ್ಲಿರುವುದು ಕಂಡುಬಂದಿದೆ. ಐಯುಸಿಎನ್ ಕೆಂಪು ಪಟ್ಟಿಯ ಆಧಾರದ ಮೇಲೆ ಬಳಿ ಕೆಂಬರಲು ಮತ್ತು ಹಾವ್ಹಕ್ಕಿ (ಅನ್ಹಿಂಗಾ ಮೆಲನೋಗಾಸ್ಟರ್)ಗಳನ್ನು ಆತಂಕಕ್ಕೆ ಸಮೀಪವಿರುವ ಪಕ್ಷಿಗಳೆಂದು ಹಾಗೂ ಉಳಿದವುಗಳನ್ನು ಕಡಿಮೆ ಕಾಳಜಿಯ ಪಕ್ಷಿಗಳೆಂದು ಅಧ್ಯಯನವು ಗುರುತಿಸುತ್ತದೆ. ಗುಡ್ಡದ ಪಾರಿವಾಳ, ದೊಡ್ಡ ಕೊಕ್ಕಿನ ಕಾಗೆ (ಕಾರ್ವಸ್ ಮ್ಯಾಕ್ರೋರಂಚೋಸ್), ಬೂದು ಕಾಗೆ (ಕಾರ್ವಸ್ ಸ್ಪ್ಲೆಂಡೆನ್ಸ್), ಕಾಜಾಣ (ಡಿಕ್ರುರಸ್ ಮ್ಯಾಕ್ರೋಸೆರ್ಕಸ್), ಕಂದು ಕಳಿಂಗ (ಲ್ಯಾನಿಯಸ್ ಕ್ರಿಸ್ಟಾಟಸ್), ಗೊರವಂಕ (ಅಕ್ರಿಡೋಥೆರ್ಸ್ ಫುಸ್ಕಸ್), ಕೆಮ್ಮೀಸೆ ಪಿಕಳಾರ (ಪಿಕ್ನೋನೋಟಸ್ ಜೋಕೋಸಸ್), ಮತ್ತು ಕವಲುತೋಕೆ (ಪೆಟ್ರೋಚೆಲಿಡಾನ್ ಫ್ಲುವಿಕೋಲಾ)ಗಳನ್ನು ಸಾಮಾನ್ಯವಾಗಿ ಕಂಡುಬರುವ ಪಕ್ಷಿಜಾತಿಗಳೆಂದು ಪರಿಗಣಿಸಲಾಗಿದೆ. ಈ ಅಧ್ಯಯನವು ಬೆಂಗಳೂರಿನ ವೈವಿಧ್ಯಮಯ ಪಕ್ಷಿ ಪ್ರಭೇದಗಳಿಗೆ ಸುಧಾರಿತ ನಿರ್ವಹಣೆ ಮತ್ತು ಸಂರಕ್ಷಣಾ ಕಾರ್ಯತಂತ್ರಗಳನ್ನು ತಿಳಿಸುವ ಗುರಿಯನ್ನು ಹೊಂದಿದೆ.

Editor: H. Byju, Coimbatore, Tamil Nadu, India.

Date of publication: 26 January 2024 (online & print)

Citation: Hemanth, H., R.K.S. Vinanthi & K.A. Paari (2024). Assessment of diversity, abundance, and seasonal variations of bird species in Bengaluru District, India during COVID-19 lockdown. *Journal of Threatened Taxa* 16(1): 24557–24567. https://doi.org/10.11609/jott.8639.16.1.24557–24567

Funding: None.

Competing interests: The authors declare no competing interests.

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Author contributions: HH carried out surveys, photography and identification of birds. RKSV make substantial contributions to acquisition of theoretical data, compilation of data and manuscript preparation. KAP have contributed towards the conception, designing of ideas and critical revision that has helped in the formation of the present research manuscript. All the authors reviewed and approved the final manuscript.

Acknowledgements: The authors wish to acknowledge the support received from the Centre for Research, CHRIST (Deemed to be University) (MRPDSC – 1936).

INTRODUCTION

Bengaluru, the fifth largest city in India, is known as the Garden City owing to its natural vegetation, rich parks, gardens, lakes, and streets lined with large canopied flowering trees (Rajashekara & Venkatesha 2016). Rapid urbanization and massive increase in population density have affected the existence and diversity of wildlife (Ramachandra et al. 2017; Yang et al. 2022). Birds are common inhabitants and are an important component of any ecosystem as they are involved in several trophic levels in the food web (Blair 1999). In the urban ecosystem, the development of huge green spaces contributed to the sustainable conservation of bird species (Campbell et al. 2022; Choudaj et al. 2023). The abundance of bird species and their variety within a specific region can have consequences for both terrestrial and aquatic ecosystems, which are interconnected within the broader food web (Turner 2003). The declining abundance of bird species in specific regions, particularly urban areas, is a cause for concern, especially when considering metrics related to urbanization and pollution (Donaldson et al. 2007).

Factors such as climatic stability and seasonality have a positive influence on avian diversity and are important determinants of avian diversity (Graham et al. 2006). In urban areas, compared to previous years, an increase in the daily mean number and visibility of a new proportion of bird species were witnessed during the COVID-19 pandemic seasons (Basile et al. 2021). The avifaunal diversity reported in Bangladesh during lockdown revealed the relative abundance and detectability of Red-vented Bulbul *Pycnonotus cafer* which was directly related to their breeding season during the seasons from March to August (Shome et al. 2021). The diversity of biological resources depends on climatic, physical conditions, topographic features, altitudinal differences between highland and lowland areas, and the geological history of a region (Parmesan & Yohe 2003). Anthropogenic climate change has a widespread impact on many biological processes and migratory patterns of birds due to the unavailability of primary requirements of food, shelter, roosting, and nesting sites for birds which vary during different seasons (Cockrem 1995). A study by Shome et al. (2021) during the summer and rainy times of Covid pandemic seasons revealed the altered species composition of migratory birds belonging to the family Cuculidae. The restricted human activities and food limitations during the COVID-19 pandemic had an impact on the progressive decline and in the abundance of *Columbia livia* in open feeding hotspots (Soh et al. 2021).

Biotic assemblages are significantly influenced by urbanization factors, leading to restricted turnover rates of bird species and reduced richness of native species due to human settlements (Godefroid 2001). The impact of COVID-19 on bird species, including richness, abundance, and diversity, has been substantial. Recent studies have highlighted the effects of lockdowns on avifauna populations, with observations of nearly 24 bird species' abundance during the spring of 2020 in North America (Schrimpf et al. 2021). Uncommon species like the Black-rumped Flameback *Dinopium benghalense*, not reported in 2019 or the pre-period of 2020, became abundant during the lockdown in Bengaluru. Similarly, the Large-billed Crow was predominantly detected in the post-lockdown period of 2020 in New Delhi (Madhok & Gulati 2022). A study by Estela et al. (2021) on the nocturnal birds of Cali City, Colombia, revealed a decreased species richness of 40–58 % during lockdown restrictions.

The overnight limitations of anthropogenic activities (anthropause) led to the lag between the lockdown and species diversity which exhibited the gradual recovery of species. Though databases such as citizen sciences, iNaturalist, and eBird offer data on population statistics of bird species, scientific evidence concerning the pandemic impact on avifaunal diversity, and seasonal variation detectability is scarce. Therefore, the present article aims to focus on the occurrence, seasonal abundance, species diversity, species richness, species dominance, and species evenness of bird population in different seasons during the pandemic lockdown season. This generated data could be useful for designing high throughput conservation strategies for better management of the avian population.

MATERIALS AND METHODS

Study area and data collection

The research was conducted at Hinnakki Village Lake in the Bengaluru district of Karnataka, India (Figure 1), situated at 12.774N & 77.678E, with an altitude of 889 m (2,918 ft) in the southern part of Karnataka. The average annual rainfall in the region is approximately 1,958.6 mm, with maximum and minimum annual temperatures recorded at 36.7 °C and 13.9 °C, respectively. The dominant vegetation type in the selected study area is tropical deciduous. The study encompassed the lake region and adjacent habitats, including agroforestry, agricultural fields, and anthropogenic regions, as part

Figure 1. The study area, Hinnakki village lake, Bengaluru (extracted from Google maps).

of a systematic examination of the seasonal abundance of birds. Four seasons—winter (December–February), summer (March–May), monsoon (June–August), and retreating monsoon (September–November)—were considered for the study (Girma et al. 2017). The survey employed a point transect method (Newson et al. 2009), with four regions covering 12 spots spaced at least 300 m apart. The study period extended from December 2021 to November 2022, with surveys conducted in the morning (0630–0830 h) and early evening (1630–1830 h) during each site visit. Each spot was visited seasonally 20 times, and bird identification was conducted using CASON 8 x 40 binoculars. Bird frequency was categorized as rare (R), uncommon (UC), common (C), and very common (VC) following the protocol by Kumar & Gupta (1970). Photographs of birds were captured using a Sony DSCHX 400V 20MP camera, and bird identification and checklists were meticulously performed (Ali 2002; Manakadan et al. 2011; Grimmett et al. 2016).

Mathematical formulation for data analysis

Data analysis was carried out using the following equations:

- Shannon Wiener index-The type of diversity used was α- diversity which is the diversity of species within a community or habitat. (Wiener diversity index 1949).
  Diversity index: $H = -\sum Pi \ln Pi$
  where $Pi = S / N$
  S = number of individuals of one species
  N = total number of all individuals in the sample
  ln = logarithm to base e
- Margalef's index was used as a simple measure of species richness (Margalef 1958).
  Margalef's index = $((S - 1))/\ln N$
  S = total number of species
  N = total number of individuals in the sample
  ln = natural logarithm
- Pielou's Evenness Index (e) was used to calculate the evenness of species (Pielou 1966).
  Pielou's Evenness Index = $e = H / \ln S$
  H = Shannon – Wiener diversity index
  S = total number of species in the sample
- Simpson's diversity index (D) was used to calculate the species dominance (Simpson 1949).
  Simpson index = $D = 1 - (\text{sum } n * (n - 1) / N * (N - 1))$
  n = number of individuals of each species
  N = total number of individuals of all species
- Relative abundance

$$\text{Relative abundance} = \frac{\text{Number of checklists in which a bird is recorded}}{\text{Total number of checklists}} \times 100$$

RESULTS AND DISCUSSION

The ecology of birds is intricately tied to rainfall and vegetation, where fluctuations in these environmental factors have direct and indirect effects on avian abundance. Demographic parameters further contribute to the biodiversity shift in birds. In the study area, the total recorded rainfall was 1958.6 mm, with the highest monthly rainfall of 131.6 mm occurring in September.

Summer temperatures ranged from a maximum of 36.7°C to a minimum of 24.2°C in April, while winter temperatures ranged from a maximum of 19.6°C to a minimum of 13.9°C in November. The highest diurnal temperature variation was 17°C in February (max = 33°C, min = 16°C), while the lowest was 1.8°C in December (max = 19.6°C, min = 17.8°C). The harsh environment significantly impacts vital rates in the avian population, with factors such as heat stress and hypothermia affecting survival and population trends. Rainfall, in particular, correlates with breeding success and factors associated with migratory bird assemblages. The study validates a positive correlation between environmental metrics and avian diversity and richness (Saracco et al. 2018).

A total of 55 species of birds belonging to 52 genera belonging to 32 families of 13 orders were recorded during the post-lockdown period in the study area (Imags 1–55; Figure 2). Among the observed bird species, 53 are classified as 'Least Concern,' while two species fall under the category of 'Near Threatened,' namely the Black-headed Ibis and the Oriental Darter (Table 1). The documentation included a total of 18 aquatic birds and 37 terrestrial birds. The Rock Pigeon was identified as the most commonly found species, constituting 6.935% of the observed bird population, owing to its behavioral adaptability to urban settings and resilience to anthropogenic disturbances (Polyavina et al. 2022). The Black-headed Ibis was found to be the most uncommon species (0.012%), which might be due to their preferred habitat and foraging areas such as shallow seasonal or permanent wetlands, marshlands, and water-logged crop fields (Barik et al. 2021). The decrease in marshy vegetation in the current study area due to the alteration of the landscape, which involves the construction of concrete buildings, and roads and also turning paddy fields into dry agricultural lands, affected the avian diversity. The order Passeriformes exhibited the highest relative abundance at 38.18%, attributed to Passerines' predominant diet, which includes insects, nuts, seeds, nectar, berries, and fruits (Bhatti et al. 2017). Most of the passerines were found feeding on Indian Banyan *Ficus bengalensis,* Sacred Fig *Ficus religiosa,* Bur Flower-tree *Neolamarckia cadamba,* Jamaican Berry *Muntingia calabura,* and Bamboo *Dendrocalamus* sp. The family Ardeidae, encompassing herons and egrets, registered the highest relative abundance at 12.7%. The reason for their abundance might be due to the number of water bodies surrounded by a huge number of trees and bushes, which facilitate the nesting of birds. The abundance and richness of Ardeidae species depend on the quality of water bodies, vegetation cover, and the availability of food (Ahlam et al. 2019).

The current observation held during the winter season showed the richness of bird species such as Grey-headed Swamphen *Porphyrio poliocephalus,* Black-winged Stilt *Himantopus himantopus,* Pied Kingfisher *Ceryle rudis,* White-cheeked Barbet *Psilopogon viridis,* and Rosy Starling *Pastor roseus.* In the summer season, Indian Spot-billed Duck *Anas poecilorhyncha,* Indian Golden Oriole *Oriolus kundoo,* and Black-headed Ibis have been found (Figure 3). The significant variation in avifaunal diversity and abundance in different seasons could be due to seasonal migration patterns, habitat changes, and

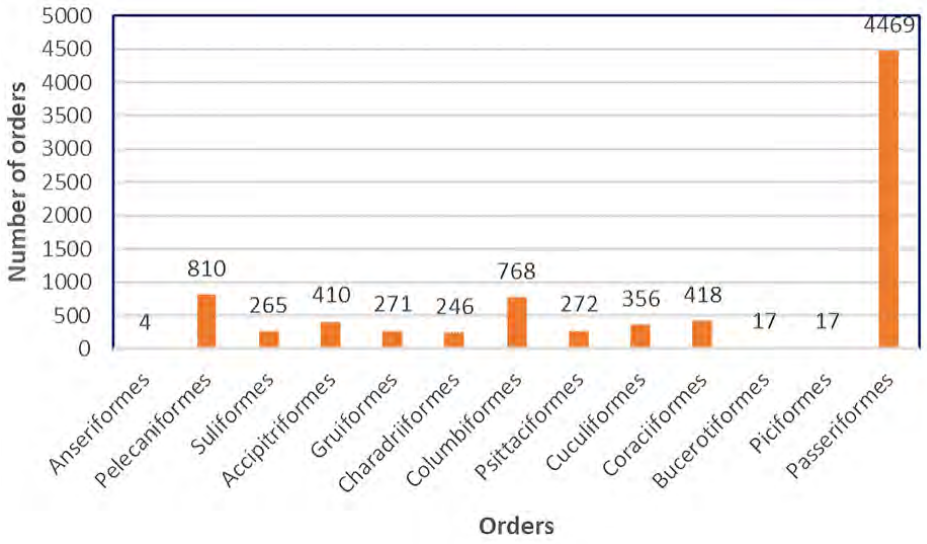

Figure 2. Representation of the bird count belonging to respective orders.

Table 1. Encounter rates, occurrence, conservation status, and the diet type of avian communities reported in the study area.

Scientific name	Common name	Conservation status \ IUCN	Frequency of observation	Winter season	Summer season	Monsoon season	Retreating monsoon season	Total	Relative abundance
Anas poecilorhyncha	Indian Spot-billed Duck	LC	R	0	4	0	0	4	0.048
Threskiornis melanocephalus	Black-headed Ibis	NT	R	0	0	0	1	1	0.012
Egretta garzetta	Little Egret	LC	R	6	12	18	10	46	0.558
Ardea cinerea	Grey Heron	LC	R	5	8	2	2	17	0.206
Ardea purpurea	Purple Heron	LC	R	30	51	38	20	139	1.688
Mesophoyx intermedia	Intermediate Egret	LC	UC	50	77	85	60	272	3.303
Bubulcus ibis	Cattle Egret	LC	R	10	20	22	15	67	0.813
Ardeola grayii	Indian Pond Heron	LC	UC	40	59	75	55	229	2.781
Ardea alba	Great Egret	LC	R	5	10	15	9	39	0.473
Phalacrocorax fuscicollis	Indian Cormorant	LC	UC	80	60	70	50	260	3.158
Anhinga melanogaster	Oriental Darter	NT	R	3	2	0	0	5	0.061
Elanus caeruleus	Black-winged Kite	LC	R	1	2	0	0	3	0.036
Milvus migrans	Black Kite	LC	UC	58	62	51	55	226	2.745
Haliastur indus	Brahminy Kite	LC	UC	47	45	39	43	174	2.113
Accipiter badius	Shikra	LC	R	2	3	1	1	7	0.085
Amaurornis phoenicurus	White-breasted Waterhen	LC	UC	88	44	26	53	211	2.562
Porphyrio poliocephalus	Grey-headed Swamphen	NE	R	10	0	0	0	10	0.121
Fulica atra	Eurasian Coot	LC	R	5	10	20	15	50	0.607
Himantopus himantopus	Black-winged Stilt	LC	R	5	0	0	0	5	0.061
Vanellus indicus	Red-wattled Lapwing	LC	UC	65	50	60	66	241	2.927
Columba livia	Rock Pigeon	LC	VC	148	150	135	138	571	6.935
Spilopelia chinensis	Spotted Dove	LC	UC	50	62	45	40	197	2.393
Psittacula krameri	Rose-ringed Parakeet	LC	UC	50	60	84	78	272	3.303
Centropus sinensis	Greater Coucal	LC	UC	38	48	58	35	179	2.174
Eudynamys scolopacea	Asian Koel	LC	UC	59	45	40	33	177	2.149
Coracias benghalensis	Indian Roller	LC	R	20	5	8	15	48	0.583
Halcyon smyrnensis	White-throated Kingfisher	LC	UC	78	39	45	65	227	2.757
Ceryle rudis	Pied Kingfisher	LC	R	4	0	0	0	4	0.048
Merops philippinus	Blue-tailed Bee-eater	LC	R	35	39	31	34	139	1.688
Ocyceros birostris	Indian Grey Hornbill	LC	R	2	8	0	0	10	0.121
Upupa epops	Hoopoe	LC	R	4	3	0	0	7	0.085
Dinopium benghalense	Black-rumped Flameback	LC	R	2	0	0	0	2	0.024
Psilopogon viridis	White-cheeked Barbet	LC	R	5	0	0	0	5	0.061
Psilopogon haemacephalus	Coppersmith Barbet	LC	R	8	2	0	0	10	0.121
Lanius cristatus	Brown Shrike	LC	C	90	100	60	85	335	4.068
Oriolus kundoo	Indian Golden Oriole	LC	R	0	6	0	0	6	0.072
Dicrurus macrocercus	Black Drongo	LC	VC	180	210	75	50	515	6.255
Corvus splendens	House Crow	LC	C	110	113	60	70	353	4.287

Scientific name	Common name	Conservation status \ IUCN	Frequency of observation	Winter season	Summer season	Monsoon season	Retreating monsoon season	Total	Relative abundance
Corvus macrorhynchos	Large-billed Crow	LC	VC	180	200	90	100	570	6.923
Pycnonotus jocosus	Red-whiskered Bulbul	LC	C	85	78	60	77	300	3.643
Pycnonotus cafer	Red-vented Bulbul	LC	UC	70	50	30	50	200	2.429
Petrochelidon luvicola	Streak-throated Swallow	LC	C	100	135	50	80	365	4.433
Argya striata	Jungle Babbler	LC	R	6	3	2	3	14	0.171
Sturnia pagodarum	Brahminy Starling	LC	R	4	8	0	0	12	0.145
Acridotheres tristis	Common Myna	LC	VC	180	153	86	93	512	6.218
Acridotheres fuscus	Jungle Myna	LC	C	120	105	50	60	335	4.068
Pastor roseus	Rosy Starling	LC	R	150	0	0	0	150	1.821
Copsychus saularis	Oriental Magpie Robin	LC	R	30	21	22	20	93	1.129
Saxicoloides fulicatus	Indian Robin	LC	R	28	24	20	23	95	1.153
Terpsiphone paradisi	Indian Paradise Flycatcher	LC	R	1	2	0	0	3	0.036
Cinnyris asiaticus	Purple Sunbird	LC	R	20	12	5	8	45	0.546
Nectarinia zeylonica	Purple-rumped Sunbird	LC	R	15	10	5	5	35	0.426
Passer domesticus	House Sparrow	LC	UC	55	42	30	35	162	1.967
Motacilla maderaspatensis	White-browed Wagtail	LC	UC	79	74	63	67	283	3.437
Anthus rufulus	Paddy Field Pipit	LC	R	20	33	15	18	86	1.044

Rdi: 0–1.75% as rare (R), 1.76–3.5% as uncommon (UC), 3.6–5.25% as common(C), 5.26–7% as very common (VC)
IUCN Red List: Least Concern (LC), Near Threatened (NT).

Table 2. Avian diversity in different seasons.

Biodiversity indices	Winter season	Summer season	Monsoon season	Retreating monsoon Season
Shannon Wiener index (Species diversity)	3.434	3.379	3.408	3.4
Margalef's index (Species richness)	6.506	6.052	5.112	5.228
Pielou evenness index (Species evenness)	0.869	0.873	0.93	0.922
Simpson's index (Species dominance)	0.04	0.043	0.038	0.038
Number of encounters	2446	2359	1691	1737
Number of species	52	48	39	40

climatic conditions (Aynalem & Bekele 2008). Invasive exotic species such as Common Lantana *Lantana camara,* Alligator Weed *Alternanthera phyloxiroides,* Parthenium Weed *Parthenium hysterophorus,* Water Hyacinth *Eichhornia crassipes, and* Water Lettuce *Pistia stratiotes* was also observed. Biological invasion in water bodies can cause significant damage to the abundance of aquatic communities such as fish, zooplankton, and aquatic invertebrates (Schirmel et al. 2016). The biological oxygen demand of water bodies may, in turn, affect the bird population (Klemetsen et al. 2013; Mallin et al. 2016).

CONCLUSION

The present research provides information on the status of the bird population in the Bengaluru district. The conversion of green spaces into concrete structures due to urbanization has influenced bird diversity. Urbanization has varying control over the avian population. The study identified a reduction in the wetland bird population. A biodiversity shift was observed in the avian population of species such as *Columba livia*, *Corvus macrorhynchos*, and *Corvus splendens,* were seen in common wherein the density

Table 3. Representation of the number of species belonging to each family observed in the study area.

Orders	Family	No. of genera	No. of species	Abundance
Anseriformes	Anatidae	1	1	1.81
Pelecaniformes	Threskiornithidae	1	1	1.81
	Ardeidae	5	7	12.7
Suliformes	Phalacrocoracidae	1	1	1.81
	Anhingidae	1	1	1.81
Accipitriformes	Accipitridae	4	4	7.27
Gruiformes	Rallidae	3	3	5.45
	Recurvirostridae	1	1	1.81
Charadriiformes	Charadriidae	1	1	1.81
Columbiformes	Columbidae	2	2	3.63
Psittaciformes	Psittacidae	1	1	1.81
Cuculiformes	Cuculidae	2	2	3.63
Coraciiformes	Coraciidae	1	1	1.81
	Alcedinidae	2	2	3.63
	Meropidae	1	1	1.81
Bucerotiformes	Bucerotidae	1	1	1.81
	Upupidae	1	1	1.81
Piciformes	Picidae	1	1	1.81
	Megalaimidae	1	2	3.63
Passeriformes	Laniidae	1	1	1.81
	Oriolidae	1	1	1.81
	Dicruridae	1	1	1.81
	Corvidae	1	2	3.63
	Pycnonotidae	1	2	3.63
	Hirundinidae	1	1	1.81
	Sturnidae	3	4	7.27
	Muscicapidae	3	3	5.45
	Nectariniidae	2	2	3.63
	Leiothrichidae	1	1	1.81
	Passeridae	2	2	3.63
	Motacillidae	1	1	1.81
13	32	49	55	

of the Near Threatened *Threskiornis melanocephalus* and *Anhinga melanogaster* populations was lower. Factors such as the magnitude of human activity during lockdown, pollution indices such as agricultural runoff, air and noise quality parameters, and food availability also influenced the migration pattern of birds. Regular monitoring of the wetland's biodiversity is an important prerequisite to tracking the changes in avian population and diversity. The study also discussed the importance of confounding factors such as seasonal variations in

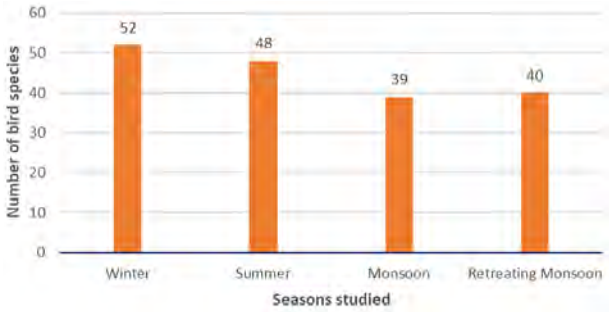

Figure 3. Effect of seasonal variations on the number of bird species.

the avian population. The involvement and support of residents are critical in conserving the vegetation, which can have a direct impact on the avian population and diversity.

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Image 1–16. Representation of bird species noted in the study area: 1—*Anas poecilorhyncha* | 2—*Threskiornis melanocephalus* | 3—*Egretta garzetta* | 4—*Ardea cinerea* | 5—*Ardea purpurea* | 6—*Mesophoyx intermedia* | 7—*Bubulcus ibis* | 8—*Ardeola grayii* | 9—*Ardea alba* | 10—*Phalacrocorax fuscicollis* | 11—*Anhinga melanogaster* | 12—*Elanus caeruleus* | 13—*Milvus migrans* | 14—*Haliastur indus* | 15—*Accipiter badius* | 16—*Amaurornis phoenicurus*. © H. Hemanth.

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Image 17–32. Representation of bird species noted in the study area (continued): 17—*Porphyrio poliocephalus* | 18—*Fulica atra* | 19—*Himantopus himantopus* | 20—*Vanellus indicus* | 21—*Columba livia* | 22—*Spilopelia chinensis* | 23—*Psittacula krameri* | 24—*Centropus sinensis* | 25—*Eudynamys scolopacea* | 26—*Coracias benghalensis* | 27—*Halcyon smyrnensis* | 28—*Ceryle rudies* | 29—*Merops philippinus* | 30—*Ocyceros birostris* | 31—*Upupa epops* | 32—*Dinopium benghalense*. © H. Hemanth.

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Image 33–48. Representation of bird species noted in the study area (continued): 33—*Psilopogon viridis* | 34—*Psilopogon haemacephalus* | 35—*Lanius cristatus* | 36—*Oriolus kundoo* | 37—*Dicrurus macrocercus* | 38—*Corvus splendens* | 39—*Corvus macrorhynchos* | 40—*Pycnonotus jocosus* | 41—*Pycnonotus cafer* | 42—*Petrochelidon luvicola* | 43—*Argya striata* | 44—*Sturnia pagodarum* | 45—*Acridotheres tristis* | 46—*Acridotheres fuscus* | 47—*Pastor roseus* | 48—*Copsychus saularis*. © H. Hemanth.

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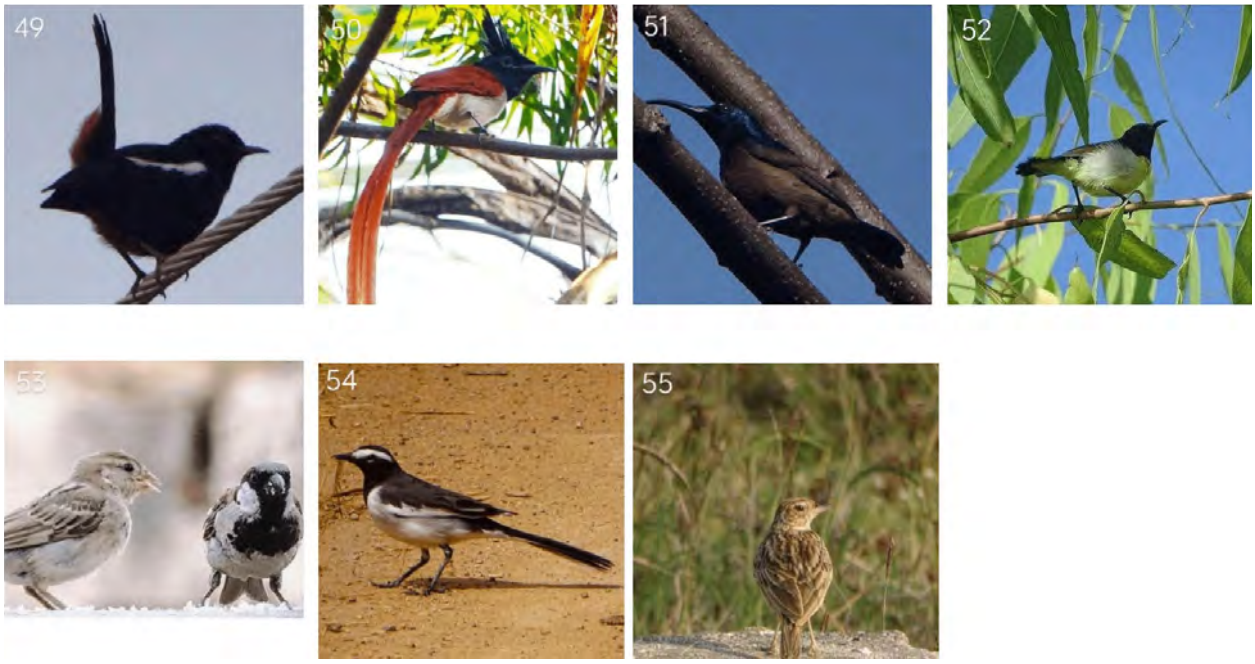

Image 49–55. Representation of bird species noted in the study area (continued): 49—*Saxicoloides fulicatus* | 50—*Terpsiphone paradisi* | 51—*Cinnyris asiaticus* | 52—*Nectarinia zeylonica* | 53—*Passer domesticus* | 54—*Motacilla maderaspatensis* | 55—*Anthus rufulus*. © H. Hemanth.

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Journal of Threatened Taxa | www.threatenedtaxa.org | 26 January 2024 | 16(1): 24568–24583
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.8638.16.1.24568-24583
#8638 | Received 18 July 2023 | Final received 28 November 2023 | Finally accepted 01 January 2024
OPEN ACCESS
COMMUNICATION

An annotated checklist of the birds in Loharghat Forest Range, Assam, India

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Abstract: Loharghat Forest Range, within the Indo-Burma biodiversity hotspot, features diverse habitats like wetlands, scrublands, grasslands, tropical and deciduous forests. Chandubi, a vital tectonic wetland in the landscape, is designated as Important Bird Area (2003) and Key Biodiversity Area (2005) but remains largely unexplored. This study aims to establish a baseline database of avifaunal assemblages from the Loharghat Forest Range in Kamrup District, Assam, which includes the Mayang Reserved Forest and Barduar Reserved Forest. The forest is protected and managed by the local community. The surveys were conducted between August 2021 to June 2023. The study revealed the occurrence of a total of 224 avian species belonging to 20 orders and 58 families. The birds are further categorised on the basis of their seasonal movements, diets, and rarity in the region. Our findings indicate that the community-managed forests have a rich and diverse avifauna.

Keywords: Avian diversity, biodiversity assessment, biodiversity hotspot, bird ecology, chandubi lake, community forest, ecological niches, forest ecology, species distribution, wildlife conservation.

Editor: Anil Kumar, Zoological Survey of India, Patna, India. **Date of publication:** 26 January 2024 (online & print)

Citation: Talwar, T., L.M. Abraham, B. Rabha & M. Rabha (2024). An annotated checklist of the birds in Loharghat Forest Range, Assam, India. *Journal of Threatened Taxa* 16(1): 24568-24583. https://doi.org/10.11609/jott.8638.16.1.24568-24583

Funding: None.

Competing interests: The authors declare no competing interests.

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Author contributions: TT—drafting manuscript, study design, data collection, cartography, data analysis, data pertaining; LMA—drafting manuscript, data collection, data analysis, data pertaining; MR—data collection, data pertaining; BR—data collection, data pertaining.

Acknowledgements: The research is an integral study of the 7WEAVES Research Foundation's Biodiversity Assessment project. Authors would express their gratitude to Nayanmoni Rabha, Deepmani Rabha and Nileshwar Rabha for assisting them in surveys as guides. We would like to thank Matiram Rabha for sharing his insight and picture of Orange-breasted Green-pigeon. Sincere thanks to Rituraj Dewan for constant support and supervision. We would like to thank Dhritimoni Goswami, Ecologist at 7WEAVES Research for sharing her observation on birds from the region.

INTRODUCTION

Birds play a significant part in the functioning and balancing of ecosystems, and are well-known bio-indicators. They serve as agents of the nitrogen cycle, pollination, seed dispersal, reduction of insects, and ecological cleaning through the consumption of carrion (Mariyappan et al. 2023). The evaluation of the avian community is a crucial step in conserving biodiversity and determining the best course of action for management.

Loharghat Forest Range, located inside the Kamrup Sal Forest, comprises various forest types, including tropical moist deciduous, tropical moist evergreen, and occasionally subtropical broadleaf hill forest. Pristine tectonic lakes namely Chandubi Beel, and Sakoli Beel are well-known wetlands that attract many birds and other wildlife (Nath et al. 2020). Birdlife International identified Chandubi Beel and the adjacent regions as an Important Bird Area (IBA) in 2003 (Birdlife International 2023).

The Loharghat Forest Range, in common with other Assam forests, presents an impressive array of avian diversity. This includes summer migrants like the Chestnut-winged Cuckoo *Clamator coromandus*, Emerald Cuckoo *Chrysococcyx xanthorhynchus*, and Ruddy Kingfisher *Halcyon coromanda*, as well as winter visitors like the Grey-bellied Tesia *Tesia cyaniventer* and Lesser Shortwing *Brachypteryx leucophrys*. Furthermore, the wetlands within this region are habitats for a diverse waterfowl community, including species like the Purple Heron *Ardea purpurea*, Eurasian Coot *Fulica atra*, and Whiskered Tern *Chlidonias hybrida*. In the grasslands, one can encounter various species, including the Striated Grassbird *Megalurus palustris*, Baya Weaver *Ploceus philippinus*, Scaly-breasted Munia *Lonchura punctulata*, and Zitting Cisticola *Cisticola juncidis*. Wintering warblers, crakes, bitterns, and herons are supported by the presence of perennial reed grasses such as Giant Reed *Arundo donax* and Tropical Reed *Phragmites karka* (Baruah & Sharma 1999).

Earlier studies in the area revealed a total of 99 bird species (Deka & Nath 2013). Pallas's Fish Eagle *Haliaeetus leucoryphus* (Birdlife International 2023) and Yellow-wattled Lapwing *Vanellus malabaricus* (Saikia & Saikia 2016) have been reported from Chandubi Lake. The local communities, primarily the Pati Rabha and Garo, who reside in the area, have a deep connection with nature and practise traditional ecological knowledge to actively protect the forests. These forests are crucial for maintaining biodiversity and supply of biomass needs for local domestic uses (Negi et al. 2012; Arya et al. 2021).

MATERIALS AND METHODS

Study Area

The study area falls in the geographical coordinates between 25.8409–25.8623 °N and 91.4510–91.4450 °E. It comprises of two reserved forests, namely, Barduar Reserved Forest and the Mayang Reserved Forest, extending south towards the Thaiñ-Mawdem Forest Range (Figure 1). These remote forest habitats are separated by Chandubi Lake, and subsequently, by roads and village settlements in the plains. The topographic variations within the area create a diverse landscape consisting of wetlands, scrublands, rivers, forests, and agricultural fields. Spanning over 63 km^2, the assessed area exhibits elevations ranging 55–280 m.

The climate of Chandubi exhibits summer temperatures reaching highs of 35–38 °C and winter lows ranging from 8–10 °C. The study area is also characterised by a temperate tropical monsoon climate, featuring abundant rainfall and high humidity (Imsong et al. 2018).

Data collection

Data collection for this study spanned from August 2021 to June 2023. The surveys were conducted on selected pre-existing trails at the study locations and opportunistic observations such as sightings of injured birds and detection of nocturnal birds calls were also considered to ascertain the occurrence of the species. Distance of the trail varied from 3–6 km walked at 600 m per hour (Bibbly et al. 1998; Tian et al. 2015). A total of 78 km^2 were covered across 22 transects for 368 hours. In Barduar, a 39.6 km^2 transect was walked in the Barduar Reserve Forest between 0630 h and 1300 h, and 38.4 km^2 in the Mayang Reserve Forest between 0530 h and 1200 h. Of all the transects, 15 were surveyed three times, and seven were surveyed twice. Each time, 2–3 observers were present, ensuring data reliability.

Equipment such as Olympus 8–16 x 40, Solognac 10 x 42 binoculars, Canon Powershot SX540 HS, and Nikon D7200 cameras with a 200–500 mm telelens, phone recorders for species call identification, and a Garmin Etrex 10 global positioning system (GPS) were used. The GPS data from fieldwork was meticulously integrated into QGIS to construct the map. The map portrays settlement patterns, agriculture, waterbodies, rivers, channels, and scrubland within the study area, providing valuable insights into its geographical features and land use (Figure 1). It also includes the 22 transect points where surveys were conducted. Data collection sheets and e-bird were used to record observations,

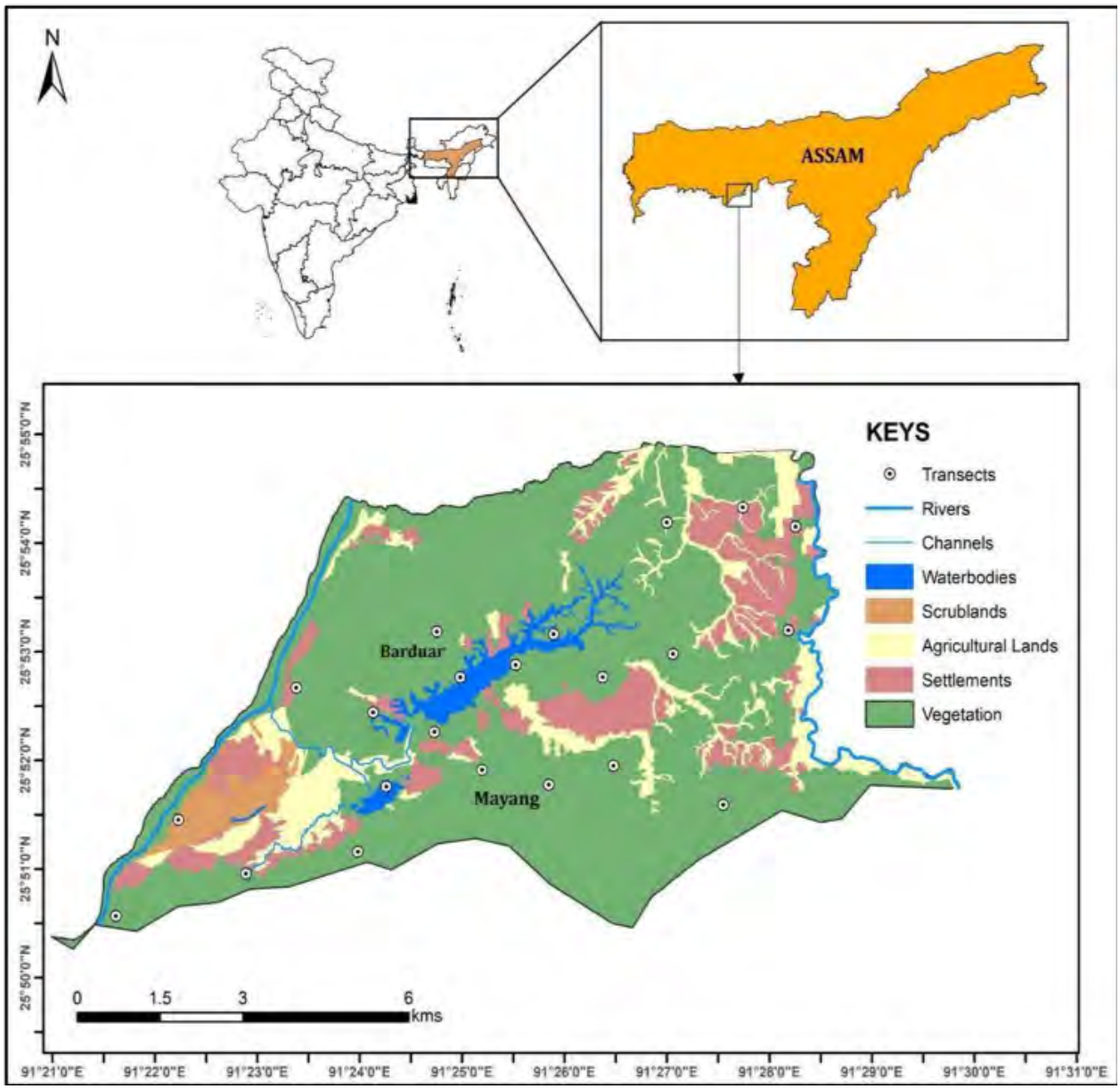

Figure 1. Loharghat Forest Range including Barduar Reserved Forest and Mayang Reserved Forest.

including date, time, weather conditions, species, flock size, coordinates, record type (vocalisations/sightings), and habitat type. The occurrence status of bird species is determined by the proportion of days with sightings from the research area throughout the length of the survey period: Very Common (VC) >50%, Common (C) = 25–50%, Uncommon (UC) = 5–25%, and Rare (R) = 1–5%.

RESULTS

The current study enlisted a comprehensive checklist of 224 avian species belonging to 20 orders and 58 families. Passeriformes exhibited the highest diversity, comprising a total of 106 species, followed by Piciformes (14 spp.), Coraciiformes (12 spp.), Anseriformes (12 spp.), Cuculiformes (11 spp.), Charadriiformes (11 spp.), Pelecaniformes (11 spp.), Columbiformes (10 spp.), Accipitriformes (8 spp.), Strigiformes (6 spp.), Gruiformes (5 spp.), Galliformes (3 spp.), Suliformes (3 spp.), Podicipediformes (2 spp.), Ciconiiformes (2 spp.), Bucerotiformes (2 spp.), Falconiformes (2 spp.), Caprimulgiformes (1 sp.), and Apodiformes (1 sp.).

Based on the IUCN Red List (2023), species were categorised according to their conservation status. Common Pochard *Aythya ferina* is designated as

'Vulnerable' while Ferruginous Pochard *Aythya nyroca*, Ashy-headed Green Pigeon *Treron phayrei*, River Lapwing *Vanellus duvaucelii*, Oriental Darter *Anhinga melanogaster*, Black-headed Ibis *Threskiornis melanocephalus*, Himalayan Griffon *Gyps himalayensis*, and Red-breasted Parakeet *Psittacula alexandri* were designated as 'Near Threatened'. Lesser Adjutant *Leptoptilos javanicus* IUCN status has been revised to 'Near Threatened', earlier it was classified as 'Vulnerable'. The remaining 215 species were classified as 'Least Concern'.

Table 1 provides insights into the rarity of bird species based on the frequency of sightings within the study area. Among the total number of species, 78 were categorised as very common (VC), 99 as common (C), 41 as uncommon (UC), and six as rare (RA) (Figure 2). Noteworthy rare sightings included raptors such as the Black Baza *Aviceda leuphotes*, Himalayan Griffon *Gyps himalayensis*, Black Kite *Milvus migrans*, and Eurasian Hobby *Falco subbuteo*, as well as summer migrants like the Brown-breasted Flycatcher *Muscicapa muttui* and Black Bittern *Ixobrychus flavicollis*.

In terms of migration patterns, 157 species were identified as resident, while 67 were classified as migratory (Grimmit et al. 2016). Non-migratory species were further categorised based on residency, altitudinal or local migrations. Migratory species were classified as summer, winter, or passage migrants. Figure 3 illustrates the distribution, indicating that 56.7% of the listed species were resident (R), 25.4% were winter migrants (WM), 8.4% were residents with winter influx (R-WI), 3.5% were summer migrants (SM), 2.6% were residents with summer influx (R-SI), 1.3% were residents with altitudinal movements (R-AM), 0.8% were residents with local migration (R-LM), and 0.4% were passage migrants (PM) (Figure 3). The Barn Swallow *Hirundo rustica* was categorised as both WM and R-WI since the majority of the population comprises winter migrants, but a small portion remains resident.

Table 1 also presents bird species categorised according to their dietary preferences. Dietary types included Carnivores (CR), Insectivores (I), Omnivores (O), Granivores (G), and herbivores. Herbivores are further categorised under Grainivore (H-G) and Frugivore (H-F). Figure 4 demonstrates that Insectivores accounted for 45.54% of the birds' principal diet, followed by 20.98% for CR, 14.29% for OM, 9.82% for H-F, 7.59% for H-G, and 1.79% for H.

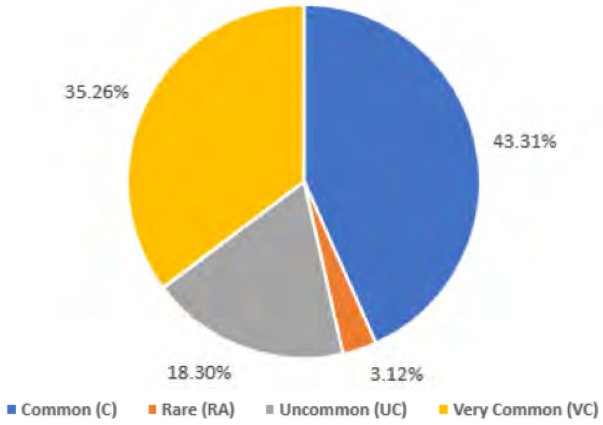

Figure 2. Rarity status of birds in Loharghat Forest Range.

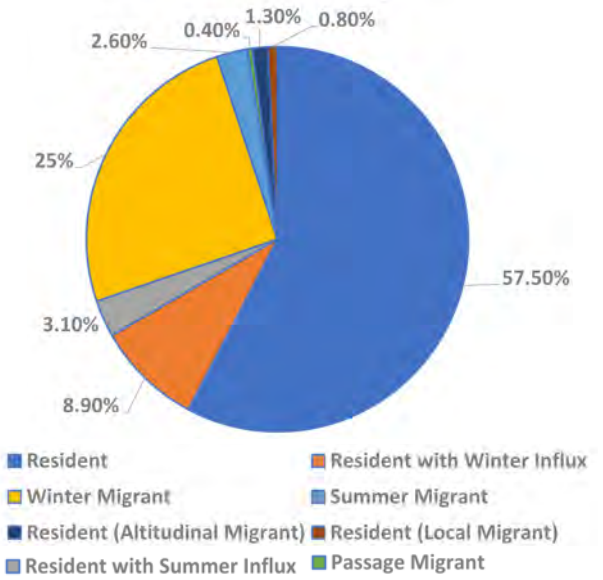

Figure 3. Migratory status of birds in Loharghat Forest Range.

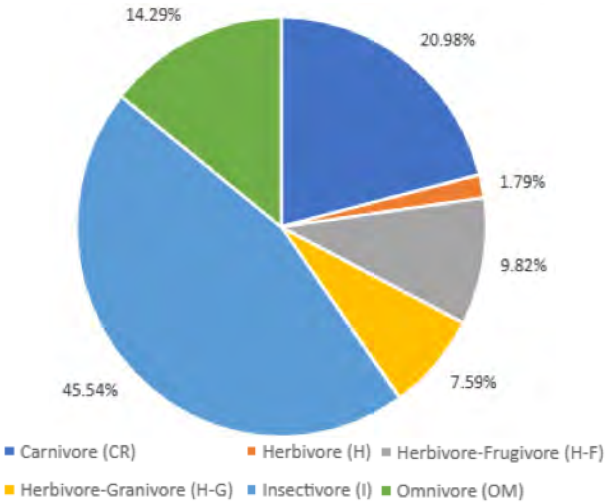

Figure 4. Feeding habit of birds in Loharghat Forest Range.

Notes on uncommon and/or interesting species of Loharghat Forest Range

1. Lesser Adjutant *Leptoptilos javanicus*

In September 2021, a solitary Lesser Adjutant was observed soaring in thermals by TT in the specified location during the forenoon hours at coordinates 25.9052°N, 91.4591°E. Although the Lesser Adjutant is not considered an uncommon species in the region, yet it is not frequently sighted in the study area. LMA has sighted 12 individuals together once in the nearby wetlands of Dora Beel and Deepor Beel.

2. Orange-breasted Green-Pigeon *Treron bicinctus*

The species was first identified based on a photograph taken by a local resident named Matiram Rabha, as reported by LMA and TT. On 18 October 2022, TT personally observed the species at coordinates 25.8761°N, 91.4194°E. Baruah et al. (1999) mention the species in their list, but Rahmani et al. (2023) reported that it is rather uncommon and has not been seen there in recent years.

3. Ashy-headed Green Pigeon *Treron phayrei*

In September 2021, TT had the opportunity to observe two Ashy-headed Green Pigeons at Mayang Reserved Forest at coordinates 25.8619°N, 91.4119°E. While this species is classified as 'Near Threatened'. It is not uncommon to encounter them along with other green pigeons during spring when there are many fruiting trees. LMA has sighted the species in both Garbhanga RF and Amchang WS.

4. Common Cuckoo *Cuculus canorus*

On 7 April 2023, an observation of a Common Cuckoo was made in a fringe village near the forest at coordinates 25.8819°N, 91.4330°E. This species is known to be a fairly common spring and autumn passage migrant in the Assam plains. The sighting contributes to our understanding of the seasonal movements and distribution patterns of this species in the region. LMA has seen them in Dorabeel and Garbhanga RF during autumn migration.

5. Oriental Darter *Anhinga melanogaster*

During a survey conducted by TT and Borojit Rabha (BR) in May 2022, a solitary individual was observed in Chandubi Lake (25.8791°N, 91.4169°E) on 20 May 2022. Oriental Darter has been recorded by LMA and TT in the nearby lakes namely Deepor Beel and Dora Beel.

6. Ruddy-breasted Crake *Zapornia fusca*

During a boat survey conducted in the late evening of 13 November 2021, multiple vocalisations of Ruddy-breasted Crakes were detected emanating from various sections of reedbeds and tall grasses within the beel by LMA. The area was teeming with activity as numerous insectivorous birds such as dollarbirds, hair-crested drongos, and large-tailed nightjars engaged in their foraging behaviours. Ruddy-breasted Crake has been recorded from Deepor Beel by LMA.

7. Spotted Bush Warbler *Locustella thoracica*

On November 14, 2021, while exiting the designated forest trail following a survey in Chandubi, a single vocalising Spotted Bush Warbler was detected by LMA, TT, and BR at coordinates 25.8802°N, 91.4169°E. The distinct calls of this bird originated from a reedbed situated in the stream that enters the forest patch on the north bund of Chandubi. It's worth noting that both the Spotted Bush Warbler and the Baikal Bush Warbler are documented in the surrounding forests and wetlands of Garbhanga during the winter season (Mahananda et al. 2023). The extent of white on the tail coverts can distinguish between these two species, and their calls also exhibit distinct differences (Kennerly & Pearson 2010).

8. Grey-lored Broadbill *Serilophus rubropygius*

During the survey of the Mayang hills, south to Chandubi Lake area on 17 April 2022, a vocalising solitary Silver-breasted Broadbill was detected by LMA at coordinates 25.8630°N, 91.4247°E. Subsequently, the bird was sighted by LMA, TT, and BR in the mid-story of the forest from a nearby patch. This species has been observed from the Garbhanga Reserve Forest by LMA.

9. Ruddy Kingfisher *Halcyon coromanda*

During the survey of the Mayang Hills on 17 April 2022, a Ruddy Kingfisher *Halcyon coromanda* was heard while surveying at coordinates 25.8641°N, 91.4213°E. It is a summer visitor to the region and is known to breed here (Grimmitt et al. 2016). However, we (TT, LMA, BR) were not able to see it. LMA has seen this species from various parts of Garbhanga during the summers. This species was also mentioned by Mahananda et al. (2023).

10. Red-breasted Parakeet *Psittacula alexandri*

The study area has witnessed the presence of a significantly large flocks comprising 400–500 birds on multiple occasions. These birds can be observed at close proximity in various locations within the study area such

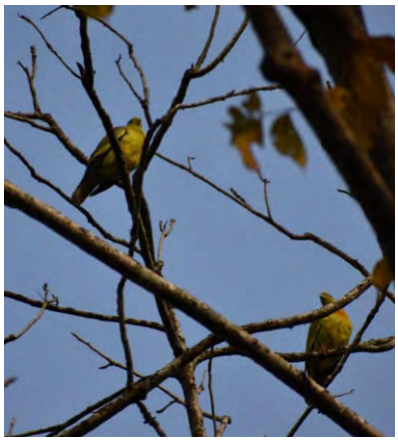

Image 1. Orange-breasted Green-pigeon *Treron bicinctus*. © Matiram Rabha

Image 2. Common Cuckoo *Cuculus canorus.* © Taniya Talwar

Image 3. Grey-lored Broadbill *Serilophus rubropygius*. © Leons Mathew Abraham

Image 4. Brown-breasted Flycatcher *Muscicapa muttui.* ©Taniya Talwar

Image 5. Great Crested Grebe *Podiceps cristatus*. © Nileshwar Rabha

Image 6. Black Bittern *Ixobrychus flavicollis*. © Nileshwar Rabha

Image 7. Juvenile of Changeable Hawk-eagle *Nisaetus cirrhatus.* ©Nileshwar Rabha

Image 8. Lesser Shortwing *Brachypteryx leucophris.* ©Taniya Talwar

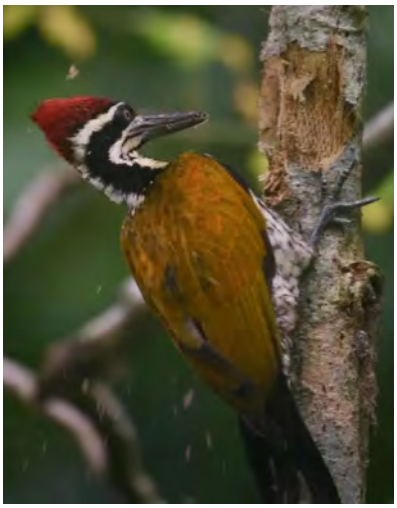

Image 9. Greater Flameback *Chrysocolaptes guttacristatus.* © Leons Mathew Abraham

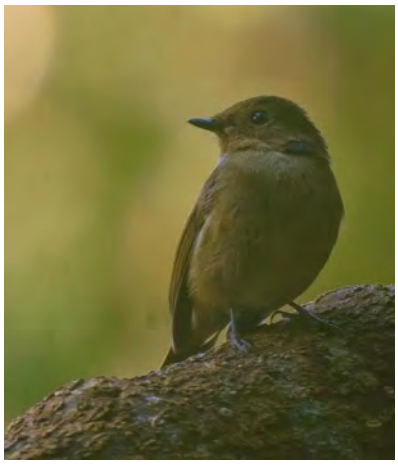

Image 10. Female of Small Niltava *Niltava macgrigoriae*. © Leons Mathew Abraham

Image 11. Pale-chinned Blue Flycatcher *Cyornis poliogenys*. © Leons Mathew Abraham

Image 12. Pin-striped Tit-Babbler *Mixornis gularis*. © Leons Mathew Abraham

Image 13. Blue-winged Leafbird *Chloropsis moluccensis*. © Leons Mathew Abraham

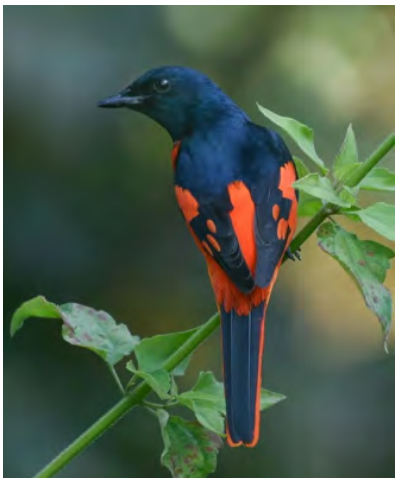

Image 14. Scarlet Minivet *Pericrocotus speciosus*. © Leons Mathew Abraham

Image 15. Large-tailed Nightjar *Caprimulgus macrurus*. © Leons Mathew Abraham

Image 16. Thick-billed Warbler *Arundinax aedon*. © Leons Mathew Abraham

Image 17. Short-billed Minivet *Pericrocotus brevirostris*. © Leons Mathew Abraham

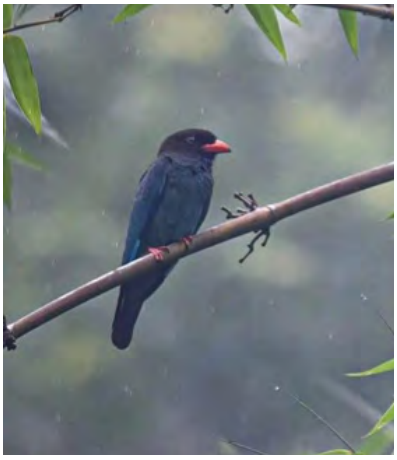

Image 18. Dollarbird *Eurystomus orientalis*. © Leons Mathew Abraham

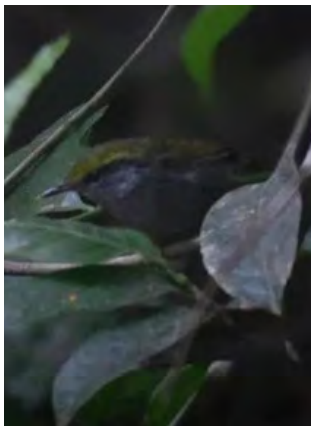

Image 19. Grey-bellied Tesia *Tesia cyaniventer*. © Leons Mathew Abraham

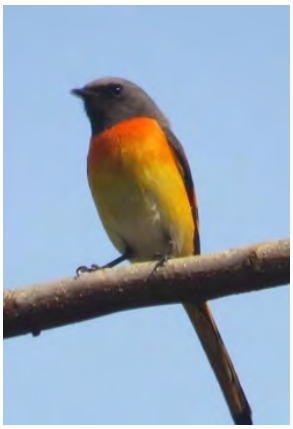

Image 20. Small Minivet *Pericrocotus cinnamomeus*. © Taniya Talwar

Image 21. Crested-serpent Eagle *Spilornis cheela*. © Taniya Talwar

Image 22. Thick-billed Green-Pigeon *Treron curvirostra*. ©Taniya Talwar

as Chandubi Lake during early mornings and at Batha River (25.9044°N, 91.4741°E) in the late evenings. The frequent sightings of such a substantial flock highlight the ecological significance and attractiveness of the area as a habitat and gathering site for this species.

11. Black Kite *Milvus migrans*

An individual Black Kite was observed soaring on thermals on 20 May 2022 by TT at coordinates 25.8794°N, 91.4713°E. This sighting was opportune and noteworthy, particularly considering that the species is uncommon in the study area. The species is very common in suburban and urban areas when compared to forests.

12. Brown-breasted Flycatcher *Muscicapa muttui*

On 26 May 2022, a solitary Brown-breasted Flycatcher was sighted by TT and BR at coordinates 25.8455°N, 91.3605°E and later identified by LMA. LMA has seen a juvenile once in Garbhanga RF. This avian species is relatively uncommon and primarily restricted to the lower Brahmaputra Valley area (Grimmett et al. 2016). They are known to breed during the summer months in this region. Given their infrequent encounters, further detailed studies are warranted to better understand their distribution and ecological preferences in the area.

13. Eurasian Hobby *Falco subbuteo*

On May 18, 2022, an Eurasian Hobby was observed effortlessly soaring at coordinates 25.7547°N, 91.4741°E by TT. Rahmani et al. (2023) describe the species as extremely rare in the Assam valley. Bikram et al. (2002) describe the bird as a sporadic visitor to the plains.

14. Great Crested Grebe *Podiceps cristatus*

On 21 April 2022, a solitary Great Crested Grebe was successfully rescued at coordinates 25.8830°N, 91.4225°E. These birds, although not rare, exhibit notable occurrences during the winter season, often congregating in significant numbers in water bodies

15. Black Bittern *Dupetor flavicollis*

On 18 June 2023, a Black Bittern was rescued from a Joramkhurai village north of Chandubi Lake at coordinates 25.8836°N, 91.4222°E. The individual had unfortunately become ensnared in a net but was fortunately liberated by the prompt action of local residents, ensuring its release and safety. There are no records of this species from nearby areas. The residential status of this species is perplexing, Grimmett et al. (2016) describe this species as a resident while Ali & Ripley (2001) describes it as a summer visitor.

16. Changeable Hawk Eagle *Nisaetus cirrhatus*

On 5 June 2023, a Changeable Hawk Eagle was successfully rescued at coordinates 25.8819°N, 91.4188°E. These raptors, while not as abundant as some other species such as Crested Serpent Eagles or Shikras, are fairly common in the forests of Assam. Rehmani et al. (2023) mentions this species as fairly common in Kaziranga National Park.

17. Black Baza *Aviceda leuphotes*

On 20 April 2023, a solitary Black Baza was observed soaring at coordinates 25.8819°N, 91.3561°E. This species, which is a summer visitor to the region, stands out significantly in terms of its distinctive appearance compared to all other species in the area.

Table 1. Checklist of the avian species of Loharghat Forest Range.

	Common name	Scientific name	Rarity (C, RA, UC, VC)	Movement (R, R-SI, R-WI, WM, SM, PM, R-AM,R-LM)	Food Habit (OM, CR, I, G, H-G, H-F)
	Anseriformes: Anatidae				
1	Fulvous Whistling-Duck	*Dendrocygna bicolor*	UC	WM	OM
2	Lesser Whistling-Duck	*Dendrocygna javanica*	VC	R-WI	OM
3	Greylag Goose	*Anser anser*	UC	WM	H
4	Ruddy Shelduck	*Tadorna ferruginea*	UC	WM	H
5	Cotton Pygmy-Goose	*Nettapus coromandelianus*	VC	R-WI	H
6	Garganey	*Spatula querquedula*	C	WM	OM
7	Northern Shoveler	*Spatula clypeata*	UC	WM	OM
8	Gadwall	*Mareca strepera*	C	WM	H
9	Green-winged Teal	*Anas crecca*	C	WM	OM
10	Common Pochard	*Aythya ferina*	UC	WM	OM
11	Ferruginous Duck	*Aythya nyroca*	C	WM	OM
12	Tufted Duck	*Aythya fuligula*	UC	WM	OM
	Galliformes: Phasianidae				
13	White-cheeked Partridge	*Arborophila atrogularis*	C	R	H-G
14	Kalij Pheasant	*Lophura leucomelanos*	C	R	H-G
15	Red Junglefowl	*Gallus gallus*	VC	R	H-G
	Phoenicopteriformes: Podicipedidae				
16	Little Grebe	*Tachybaptus ruficollis*	C	R-WI	CR
17	Great Crested Grebe	*Podiceps cristatus*	UC	WM	CR
	Columbiformes: Columbidae				
18	Rock Pigeon	*Columba livia*	VC	R	H-G
19	Oriental Turtle-Dove	*Streptopelia orientalis*	VC	R-WI	H-G
20	Eurasian Collared-Dove	*Streptopelia decaocto*	C	R	H-G
21	Red Collared-Dove	*Streptopelia tranquebarica*	VC	R-WI	H-G
22	Spotted Dove	*Spilopelia chinensis*	VC	R	H-G
23	Asian Emerald Dove	*Chalcophaps indica*	C	R	H-F
24	Orange-breasted Green-Pigeon	*Treron bicinctus*	UC	R	H-F
25	Ashy-headed Green-Pigeon	*Treron phayrei*	C	R	H-F
26	Thick-billed Green-Pigeon	*Treron curvirostra*	C	R	H-F
27	Yellow-footed Green-Pigeon	*Treron phoenicopterus*	VC	R	H-F
	Cuculiformes: Cuculidae				
28	Greater Coucal	*Centropus sinensis*	C	R	CR
29	Lesser Coucal	*Centropus bengalensis*	UC	R	I
30	Green-billed Malkoha	*Phaenicophaeus tristis*	C	R	I
31	Chestnut-winged Cuckoo	*Clamator coromandus*	UC	R	I
32	Asian Koel	*Eudynamys scolopaceus*	C	R	H-F
33	Asian Emerald Cuckoo	*Chrysococcyx maculatus*	UC	R	I
34	Banded Bay Cuckoo	*Cacomantis sonneratii*	C	R	I
35	Plaintive Cuckoo	*Cacomantis merulinus*	C	R	I
36	Common Hawk-Cuckoo	*Hierococcyx varius*	C	R	I
37	Indian Cuckoo	*Cuculus micropterus*	C	SM	I
38	Common Cuckoo	*Cuculus canorus*	UC	R-SI	I
	Caprimulgiformes: Caprimulgidae				
39	Large-tailed Nightjar	*Caprimulgus macrurus*	C	R	I
	Apodidae				
40	Asian Palm Swift	*Cypsiurus balasiensis*	VC	R	I

	Common name	Scientific name	Rarity (C, RA, UC, VC)	Movement (R, R-SI, R-WI, WM, SM, PM, R-AM,R-LM)	Food Habit (OM, CR, I, G, H-G, H-F)
	Gruiformes: Rallidae				
41	Eurasian Moorhen	*Gallinula chloropus*	C	R	OM
42	Grey-headed Swamphen	*Porphyrio poliocephalus*	VC	R	OM
43	Watercock	*Gallicrex cinerea*	C	R-SI	OM
44	White-breasted Waterhen	*Amaurornis phoenicurus*	VC	R	OM
45	Ruddy-breasted Crake	*Zapornia fusca*	C	R	OM
	Charadriiformes: Charadriidae				
46	Northern Lapwing	*Vanellus vanellus*	UC	WM	I
47	River Lapwing	*Vanellus duvaucelii*	C	R-WI	I
48	Grey-headed Lapwing	*Vanellus cinereus*	C	WM	I
49	Red-wattled Lapwing	*Vanellus indicus*	VC	R	I
50	Little Ringed Plover	*Charadrius dubius*	UC	R-WI	I
	Jacanidae				
51	Bronze-winged Jacana	*Metopidius indicus*	VC	R	OM
	Scolopacidae				
52	Common Sandpiper	*Actitis hypoleucos*	C	WM	CR
53	Green Sandpiper	*Tringa ochropus*	C	WM	CR
54	Common Greenshank	*Tringa nebularia*	C	WM	CR
55	Wood Sandpiper	*Tringa glareola*	C	WM	CR
	Laridae				
56	Whiskered Tern	*Chlidonias hybrida*	UC	SM	CR
	Pelecaniformes: Ciconiidae				
57	Asian Openbill	*Anastomus oscitans*	VC	R	CR
58	Lesser Adjutant	*Leptoptilos javanicus*	UC	R	CR
	Ardeidae				
59	Cinnamon Bittern	*Ixobrychus cinnamomeus*	C	R	CR
60	Black Bittern	*Ixobrychus flavicollis*	RA	R-SI	CR
61	Purple Heron	*Ardea purpurea*	VC	R	CR
62	Great Egret	*Ardea alba*	VC	WM	CR
63	Intermediate Egret	*Ardea intermedia*	VC	R-SI	CR
64	Little Egret	*Egretta garzetta*	C	R	CR
65	Eastern Cattle Egret	*Bubulcus coromandus*	VC	R	CR
66	Indian Pond-Heron	*Ardeola grayii*	VC	R	CR
67	Black-crowned Night-Heron	*Nycticorax nycticorax*	C	R	CR
	Threskiornithidae				
68	Glossy Ibis	*Plegadis falcinellus*	C	R-WI	CR
69	Black-headed Ibis	*Threskiornis melanocephalus*	UC	WM	CR
	Suliformes: Anhingidae				
70	Oriental Darter	*Anhinga melanogaster*	UC	R-WI	CR
	Phalacrocoracidae				
71	Little Cormorant	*Microcarbo niger*	VC	R	CR
72	Great Cormorant	*Phalacrocorax carbo*	UC	WM	CR
	Accipitriformes: Accipitridae				
73	Oriental Honey-buzzard	*Pernis ptilorhynchus*	C	R	I
74	Black Baza	*Aviceda leuphotes*	RA	R	I
75	Himalayan Griffon	*Gyps himalayensis*	RA	R	CR
76	Crested Serpent-Eagle	*Spilornis cheela*	VC	R-WI	CR
77	Changeable Hawk-Eagle	*Nisaetus cirrhatus*	RA	R	CR

	Common name	Scientific name	Rarity (C, RA, UC, VC)	Movement (R, R-SI, R-WI, WM, SM, PM, R-AM,R-LM)	Food Habit (OM, CR, I, G, H-G, H-F)
78	Pied Harrier	*Circus melanoleucos*	UC	R	CR
79	Shikra	*Accipiter badius*	VC	WM	CR
80	Black Kite	*Milvus migrans*	RA	R	CR
	Strigiformes: Tytonidae				
81	Barn Owl	*Tyto alba*	C	R	CR
	Strigidae				
82	Collared Scops-Owl	*Otus lettia*	C	R-WI	CR
83	Oriental Scops-Owl	*Otus sunia*	C	R	CR
84	Asian Barred Owlet	*Glaucidium cuculoides*	C	R	CR
85	Spotted Owlet	*Athene brama*	VC	R	CR
86	Brown Hawk-Owl	*Ninox scutulata*	C	R	CR
	Bucerotiformes: Upupidae				
87	Eurasian Hoopoe	*Upupa epops*	VC	WM	I
	Bucerotidae				
88	Oriental Pied-Hornbill	*Anthracoceros albirostris*	C	R	H-G
	Coraciiformes: Alcedinidae				
89	Common Kingfisher	*Alcedo atthis*	VC	R	CR
90	Blue-eared Kingfisher	*Alcedo meninting*	UC	R	CR
91	Stork-billed Kingfisher	*Pelargopsis capensis*	C	R	CR
92	Ruddy Kingfisher	*Halcyon coromanda*	UC	SM	CR
93	White-throated Kingfisher	*Halcyon smyrnensis*	VC	R	CR
94	Pied Kingfisher	*Ceryle rudis*	C	R	CR
	Meropidae				
95	Blue-bearded Bee-eater	*Nyctyornis athertoni*	C	R	I
96	Asian Green Bee-eater	*Merops orientalis*	VC	R	I
97	Blue-tailed Bee-eater	*Merops philippinus*	C	SM	I
98	Chestnut-headed Bee-eater	*Merops leschenaulti*	VC	R-SI	I
	Coraciidae				
99	Indochinese Roller	*Coracias affinis*	VC	R	I
100	Oriental Dollarbird	*Eurystomus orientalis*	VC	R	I
	Piciformes: Megalaimidae				
101	Coppersmith Barbet	*Psilopogon haemacephalus*	VC	R	OM
102	Blue-eared Barbet	*Psilopogon duvaucelii*	C	R	OM
103	Great Barbet	*Psilopogon virens*	UC	R-SI	OM
104	Lineated Barbet	*Psilopogon lineatus*	VC	R	OM
105	Blue-throated Barbet	*Psilopogon asiaticus*	VC	R	OM
	Picidae				
106	Speckled Piculet	*Picumnus innominatus*	C	R	I
107	White-browed Piculet	*Sasia ochracea*	C	R	I
108	Fulvous-breasted Woodpecker	*Dendrocopos macei*	C	R-SI	I
109	Greater Flameback	*Chrysocolaptes guttacristatus*	C	R	I
110	Rufous Woodpecker	*Micropternus brachyurus*	C	R	I
111	Black-rumped Flameback	*Dinopium benghalense*	VC	R	I
112	Lesser Yellownape	*Picus chlorolophus*	VC	R	I
113	Grey-headed Woodpecker	*Picus canus*	UC	R	I
114	Greater Yellownape	*Chrysophlegma flavinucha*	C	R	I
	Falconiformes: Falconidae				
115	Eurasian Kestrel	*Falco tinnunculus*	UC	WM	CR

	Common name	Scientific name	Rarity (C, RA, UC, VC)	Movement (R, R-SI, R-WI, WM, SM, PM, R-AM,R-LM)	Food Habit (OM, CR, I, G, H-G, H-F)
116	Eurasian Hobby	*Falco subbuteo*	RA	PM	I
	Psittaciformes: Psittaculidae				
117	Rose-ringed Parakeet	*Psittacula krameri*	C	R	H-F
118	Red-breasted Parakeet	*Psittacula alexandri*	VC	R	H-F
	Passeriformes: Eurylaimidae				
119	Grey-lored Broadbill	*Serilophus rubropygius*	UC	R	I
	Pittidae				
120	Western Hooded Pitta	*Pitta sordida*	UC	SM	I
	Campephagidae				
121	Small Minivet	*Pericrocotus cinnamomeus*	C	R	I
122	Short-billed Minivet	*Pericrocotus brevirostris*	UC	WM	I
123	Scarlet Minivet	*Pericrocotus speciosus*	C	R	I
124	Large Cuckooshrike	*Coracina macei*	C	R	I
125	Black-winged Cuckooshrike	*Lalage melaschistos*	UC	WM	I
	Oriolidae				
126	Black-hooded Oriole	*Oriolus xanthornus*	VC	R	H-F
	Artamidae				
127	Ashy Woodswallow	*Artamus fuscus*	VC	R	I
	Vangidae				
128	Large Woodshrike	*Tephrodornis virgatus*	C	R	I
129	Bar-winged Flycatcher-shrike	*Hemipus picatus*	UC	R-WI	I
	Aegithinidae				
130	Common Iora	*Aegithina tiphia*	VC	R	I
	Rhipiduridae				
131	White-throated Fantail	*Rhipidura albicollis*	C	R-WI	I
	Dicruridae				
132	Black Drongo	*Dicrurus macrocercus*	C	R	I
133	Ashy Drongo	*Dicrurus leucophaeus*	C	R	I
134	Bronzed Drongo	*Dicrurus aeneus*	C	R-WI	I
135	Lesser Racket-tailed Drongo	*Dicrurus remifer*	C	R-WI	I
136	Hair-crested Drongo	*Dicrurus hottentottus*	VC	R	I
137	Greater Racket-tailed Drongo	*Dicrurus paradiseus*	C	R	I
	Monarchidae				
138	Black-naped Monarch	*Hypothymis azurea*	C	R	I
	Laniidae				
139	Brown Shrike	*Lanius cristatus*	C	WM	CR
140	Long-tailed Shrike	*Lanius schach*	C	WM	CR
141	Grey-backed Shrike	*Lanius tephronotus*	C	WM	CR
	Corvidae				
142	Common Green-Magpie	*Cissa chinensis*	UC	R	OM
143	Rufous Treepie	*Dendrocitta vagabunda*	VC	R	OM
144	House Crow	*Corvus splendens*	C	R	OM
145	Large-billed Crow	*Corvus macrorhynchos*	VC	R	OM
	Stenostiridae				
146	Grey-headed Canary-Flycatcher	*Culicicapa ceylonensis*	VC	WM	I
	Paridae				
147	Cinereous Tit	*Parus cinereus*	VC	R	I

	Common name	Scientific name	Rarity (C, RA, UC, VC)	Movement (R, R-SI, R-WI, WM, SM, PM, R-AM,R-LM)	Food Habit (OM, CR, I, G, H-G, H-F)
	Alaudidae				
148	Bengal Bushlark	*Mirafra assamica*	C	R	H-G
	Cisticolidae				
149	Common Tailorbird	*Orthotomus sutorius*	VC	R	I
150	Dark-necked Tailorbird	*Orthotomus atrogularis*	C	R	I
151	Rufescent Prinia	*Prinia rufescens*	C	R	I
152	Grey-breasted Prinia	*Prinia hodgsonii*	C	R	I
153	Plain Prinia	*Prinia inornata*	C	R	I
154	Zitting Cisticola	*Cisticola juncidis*	VC	R	I
	Acrocephalidae				
155	Thick-billed Warbler	*Arundinax aedon*	C	WM	I
	Locustellidae				
156	Spotted Bush Warbler	*Locustella thoracica*	UC	WM	I
157	Striated Grassbird	*Cincloramphus palustris*	VC	R	I
	Hirundinidae				
158	Grey-throated Martin	*Riparia chinensis*	C	R-WI	I
159	Barn Swallow	*Hirundo rustica*	VC	R-WI/ WM	I
	Pycnonotidae				
160	Black-crested Bulbul	*Rubigula flaviventris*	VC	R	H-F
161	Red-vented Bulbul	*Pycnonotus cafer*	VC	R	H-F
162	Red-whiskered Bulbul	*Pycnonotus jocosus*	C	R	H-F
163	White-throated Bulbul	*Alophoixus flaveolus*	C	R	H-F
	Phylloscopidae				
164	Hume's Warbler	*Phylloscopus humei*	C	WM	I
165	Tickell's Leaf Warbler	*Phylloscopus affinis*	VC	WM	I
166	Dusky Warbler	*Phylloscopus fuscatus*	VC	WM	I
167	Whistler's Warbler	*Phylloscopus whistleri*	C	WM	I
168	Greenish Warbler	*Phylloscopus trochiloides*	VC	WM	I
169	Blyth's Leaf Warbler	*Phylloscopus reguloides*	VC	WM	I
	Scotocercidae				
170	Grey-bellied Tesia	*Tesia cyaniventer*	UC	WM	I
171	Yellow-bellied Warbler	*Abroscopus superciliaris*	C	R-WI	I
	Zosteropidae				
172	Indian White-eye	*Zosterops palpebrosus*	VC	R	OM
	Timaliidae				
173	Pin-striped Tit-Babbler	*Mixornis gularis*	VC	R	I
	Pellorneidae				
174	Puff-throated Babbler	*Pellorneum ruficeps*	C	R	I
175	Abbott's Babbler	*Malacocincla abbotti*	UC	R	I
	Leiothrichidae				
176	Jungle Babbler	*Argya striata*	C	R	I
177	Lesser Necklaced Laughingthrush	*Garrulax monileger*	C	R	OM
	Sturnidae				
178	Common Hill Myna	*Gracula religiosa*	VC	R	OM
179	Indian Pied Starling	*Gracupica contra*	VC	R	OM
180	Chestnut-tailed Starling	*Sturnia malabarica*	VC	R	OM
181	Common Myna	*Acridotheres tristis*	UC	R	OM
182	Bank Myna	*Acridotheres ginginianus*	VC	R-WI	OM

	Common name	Scientific name	Rarity (C, RA, UC, VC)	Movement (R, R-SI, R-WI, WM, SM, PM, R-AM,R-LM)	Food Habit (OM, CR, I, G, H-G, H-F)
183	Jungle Myna	*Acridotheres fuscus*	VC	R	OM
184	Great Myna	*Acridotheres grandis*	C	R	OM
	Muscicapidae				
185	Brown-breasted Flycatcher	*Muscicapa muttui*	RA	SM	I
186	Oriental Magpie-Robin	*Copsychus saularis*	VC	R	I
187	White-rumped Shama	*Copsychus malabaricus*	VC	R	I
188	Pale-chinned Blue Flycatcher	*Cyornis poliogenys*	VC	R-AM	I
189	Small Niltava	*Niltava macgrigoriae*	C	WM	I
190	Lesser Shortwing	*Brachypteryx leucophris*	UC	WM	I
191	Blue Whistling-Thrush	*Myophonus caeruleus*	C	WM	CR
192	Black-backed Forktail	*Enicurus immaculatus*	C	R	I
193	Snowy-browed Flycatcher	*Ficedula hyperythra*	C	WM	I
194	Little Pied Flycatcher	*Ficedula westermanni*	VC	WM	I
195	Taiga Flycatcher	*Ficedula albicilla*	VC	WM	I
196	Plumbeous Redstart	*Phoenicurus fuliginosus*	UC	WM	I
197	White-capped Redstart	*Phoenicurus leucocephalus*	UC	WM	I
198	Blue Rock-Thrush	*Monticola solitarius*	C	WM	I
199	Siberian Stonechat	*Saxicola maurus*	C	WM	I
	Dicaeidae				
200	Plain Flowerpecker	*Dicaeum minullum*	C	R	H-F
201	Scarlet-backed Flowerpecker	*Dicaeum cruentatum*	VC	R	H-F
	Nectariniidae				
202	Ruby-cheeked Sunbird	*Chalcoparia singalensis*	VC	R	H-F
203	Purple Sunbird	*Cinnyris asiaticus*	VC	R	H-F
204	Crimson Sunbird	*Aethopyga siparaja*	VC	R	H-F
205	Little Spiderhunter	*Arachnothera longirostra*	C	R-AM	H-F
	Irenidae				
206	Asian Fairy-bluebird	*Irena puella*	C	R	H-F
	Chloropseidae				
207	Blue-winged Leafbird	*Chloropsis cochinchinensis*	C	R	H-F
208	Golden-fronted Leafbird	*Chloropsis aurifrons*	VC	R-AM	H-F
	Ploceidae				
209	Baya Weaver	*Ploceus philippinus*	VC	R-LM	H-G
210	Black-breasted Weaver	*Ploceus benghalensis*	UC	R-WI	H-G
	Estrildidae				
211	Scaly-breasted Munia	*Lonchura punctulata*	VC	R	H-G
212	White-rumped Munia	*Lonchura striata*	C	R	H-G
213	Chestnut Munia	*Lonchura atricapilla*	UC	R-LM	H-G
	Passeridae				
214	House Sparrow	*Passer domesticus*	VC	R	H-G
215	Eurasian Tree Sparrow	*Passer montanus*	C	R	H-G
	Motacillidae				
216	Grey Wagtail	*Motacilla cinerea*	C	WM	I
217	Eastern Yellow Wagtail	*Motacilla tschutschensis*	UC	WM	I
218	Citrine Wagtail	*Motacilla citreola*	VC	WM	I
219	White Wagtail	*Motacilla alba*	VC	WM	I
220	Richard's Pipit	*Anthus richardi*	C	WM	I
221	Paddyfield Pipit	*Anthus rufulus*	VC	R	I

	Common name	Scientific name	Rarity (C, RA, UC, VC)	Movement (R, R-SI, R-WI, WM, SM, PM, R-AM,R-LM)	Food Habit (OM, CR, I, G, H-G, H-F)
222	Blyth's Pipit	*Anthus godlewskii*	C	WM	I
223	Rosy Pipit	*Anthus roseatus*	VC	WM	I
224	Olive-backed Pipit	*Anthus hodgsoni*	VC	WM	I

C—Common | RA—Rare | VC—Very common | UC—Uncommon | R—Residential | R-SI—Residential with summer influx | R-WI—Residential with winter influx | R-LM—Residential with local migration | R-AM—Resident with altitudinal migraton | WM—Winter migrant | SM—Summer migrant | PM—Passage migrant | CR—Carnivore | I—Insectivore | OM—Omnivore | H—Herbivore | H-G—Granivore | H-F—Frugivore.

DISCUSSION

The seasonal variability plays a significant role in the avifaunal composition of the study area. During the winter months, numerous species from the Himalaya, Europe, northern Asia, and northeastern Asia migrate to lower-elevation areas. Loharghat is connected to the Garbhanga-Rani Reserved Forest in the east and the Garo Hills in the north-west, which encompasses 307 species of birds (Mahananda et al. 2023). Therefore, due to the rich avian diversity in the neighbourhood, this region also becomes an important site for many avian species to visit or pass through. Deka & Nath (2013) conducted earlier investigations on the terrain, documenting a total of 99 bird species. The area recorded relatively low numbers of raptors, which were mostly Shikra *Accipiter badius* and Crested Serpent Eagle *Spilornis cheela*. Reports from Birdlife International (2023) and local sources mention the sightings of Pallas's Fish Eagle *Haliaeetus leucoryphus* in the past near Chandubi Lake around 12–15 years ago. Additionally, Saikia & Saikia (2015) documented sightings of Yellow-wattled Lapwing *Vanellus malabaricus* in the late winter months near Sakoli Lake.

The wide range of bird species found in the study area can be attributed to the diverse habitats present, including tea gardens, evergreen and deciduous forests, grasslands, marshes, scrublands, riverine, agricultural communities, and forest settlements. The occurrence of 106 passerines indicates the presence of varied and healthy habitats (Hilaluddin et al. 2008). Despite human activities in the landscape, this highlights the importance of maintaining niche requirements to support both migratory and resident bird species (Arya et al. 2021). However, further qualitative and quantitative investigations are required to strengthen the information on avifaunal community assemblages in this region, as there is a lack of comprehensive data.

CONCLUSION

Understanding the ecological richness and complexity of the Loharghat forest ecosystem, this study reveals Passeriformes as the predominant order, demonstrating significant representation, closely followed by Piciformes, Coraciiformes, and Anseriformes. The conservation status varied among species, with some species belonging to Vulnerable or Near Threatened categories of IUCN. Migration patterns showed both resident and migratory species, with winter migrants comprising a significant portion. The dietary preferences of birds varied, with insectivores being the most common group. The study emphasised the importance of further research, conservation efforts, and habitat preservation to safeguard the avian diversity in the area.

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Journal of Threatened Taxa | www.threatenedtaxa.org | 26 January 2024 | 16(1): 24584–24588
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.8701.16.1.24584-24588
#8701 | Received 21 August 2023 | Final received 03 December 2023 | Finally accepted 05 January 2024
OPEN ACCESS
COMMUNICATION

Trade of skulls as novelty and aquarium objects are an additional threat to porcupines

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Abstract: The commercial exploitation of wildlife affects many species, including porcupines that are traded for meat, as pets, and for medicinal purposes. Here we report on a novel trade in Sunda Porcupine *Hystrix javanica* skulls in Bali specifically for curios and as aquarium novelty objects. Since 2018, the species is protected within Indonesia and the sale of skulls is illegal. Between December 2022 and November 2023, we visited wildlife shops in seven towns, and conducted a survey of online sellers. We recorded 44 porcupine skulls in 11 shops and 10 skulls online. Skulls sold as curios were intricately carved and were priced at USD 61, whereas skulls sold as hiding caves for aquarium fish were not carved and priced at USD 22. Porcupine skulls were sourced from Bali and Java. Especially the carved skulls are marketed primarily for international tourists and may be inadvertently taken abroad. The novel trade in skulls adds to a multitude of threats faced by porcupines, and there is a need for improved regulations and enforcement against illegal trade. Appropriate mitigation measures need to be developed to protect porcupines from unsustainable and illegal exploitation and will require the full operation of the commercial sector, local and national governments, the tourism industry and the Indonesian public.

Keywords: Bali, CITES, conservation, Indonesia, natural resource management, wildlife trade.

Indonesian: Perdagangan tengkorak (hewan) sebagai hiasan akuarium merupakan ancaman tambahan bagi landak: Eksploitasi komersial satwa liar memengaruhi banyak spesies, termasuk landak yang diperdagangkan untuk memperoleh dagingnya, sebagai hewan peliharaan, dan untuk tujuan medis. Berikut laporan tentang perdagangan baru tengkorak landak Sunda (*Hystrix javanica*) di Bali, khususnya untuk barang-barang seni dan sebagai hiasan akuarium. Sejak tahun 2018, spesies ini dilindungi di Indonesia, dan penjualan tengkoraknya ilegal. Antara Desember 2022 dan November 2023, kami mengunjungi toko-toko satwa liar di tujuh kota dan melakukan survei terhadap penjual online. Kami menemukan 44 tengkorak landak di 11 toko fisik dan 10 lainnya di toko online. Tengkorak yang dijual sebagai barang seni diukir dengan sangat terperinci dan dijual seharga US$61 (sekitar Rp 900,000), sementara tengkorak yang dijual dalam bentuk gua persembunyian untuk ikan akuarium tidak diukir dan dijual seharga US$22 (sekitar Rp 300,000). Tengkorak landak diperoleh dari Bali dan Jawa. Tengkorak yang diukir khususnya dipasarkan untuk wisatawan asing dan mungkin tidak sengaja terbawa ke luar negeri. Perdagangan tengkorak landak ini menambah ancaman bagi landak, sehingga diperlukan peningkatan peraturan serta penegakan hukum terhadap perdagangan ilegal. Langkah mitigasi yang sesuai perlu dikembangkan untuk melindungi landak dari eksploitasi yang tidak berkelanjutan dan ilegal, dan memerlukan partisipasi penuh dari sektor komersial, pemerintah lokal dan nasional, industri pariwisata, dan masyarakat Indonesia.

Editor: Anonymity requested.

Date of publication: 26 January 2024 (online & print)

Citation: Chavez, J., Kuntayuni & V. Nijman (2024). Trade of skulls as novelty and aquarium objects are an additional threat to porcupines. *Journal of Threatened Taxa* 16(1): 24584–24588. https://doi.org/10.11609/jott.8701.16.1.24584–24588

Funding: We acknowledge financial support from Oxford Brookes University Research Excellence Award (awarded to VN) and the Royal Geographical Society (awarded to JC).

Competing interests: The funders had no role in study design, data collection, interpretation of results and manuscript writing. The authors declare no competing interests.

Author details & Author contributions: See end of this article.

Acknowledgements: The research took place as part of a Memorandum of Understanding between Universitas Warmadewa and Oxford Brookes University. We appreciate the support of Indonesia's National Research and Innovation Agency. The discussions with vendors followed the ethical guidelines proposed by the Association of Social Anthropologists of the UK and Commonwealth and the research was approved by Oxford Brookes University. We thank an anonymous reviewer and the associate editor for helpful suggestions for improvement.

INTRODUCTION

The commercial exploitation of wildlife, and the lack of evidence that this can be considered sustainable, is increasingly recognized as a major impediment to the conservation of wildlife (Hughes et al. 2023). This includes southeastern Asia (Nijman 2010). In recent years a series of initiatives have been taken to explore the trade in some lesser-known and somewhat overlooked species within this region that (potentially) are negatively impacted by the global wildlife trade. One of these groups are the porcupines, seven species of which occur in Asia (Van Weers 2005), and for which now a body of evidence reveals that hunting and trade are resulting in population declines (Brooks et al. 2010; Rao et al. 2011; Loke et al. 2020). Thus far, all research that has been conducted on the hunting and the trade in porcupines in Asia, focused on them being used for meat, for pets, or for medicinal purposes and in particular bezoar stones and quills (e.g., Brookes et al. 2010; Nijman & Nekaris 2014; Heinrich et al. 2020; Gomez 2021; Mardiastuti et al. 2021; Hasan & Csányi 2022). Here we focus on a novel trade in the Sunda Porcupine *Hystrix javanica* skulls in Bali (the only species of porcupine that lives in Bali and adjacent islands) specifically for curios (targeting domestic and international tourists) and as aquarium novelty objects.

Prior to 2018 the only species of porcupine that received legal protection in Indonesia was the Malayan Porcupine *H. brachyura* found on Sumatra and Borneo. In the new 2018 list (legally covered as UU Nomor P.20/MENLHK/SETJEN/KUM.1/6/2018) this was replaced by the Sunda Porcupine (Nuswantoro 2023). One cannot catch, transport, keep, sell, or buy a protected species nor any of its parts. It is irrelevant if the specimen itself was collected before or after it became listed as it is not just the catching or killing of a protected species that is illegal under Indonesian law, so is the act of selling and buying. Violations are punishable by up to five years imprisonment and/or a fine of USD 6,631 (using July 2023 exchange rates). In the years before 2018, there was no harvest quota for Sunda Porcupines and hence any commercial trade in the species would not have been allowed at the time either.

Inspired by the work of Gomez (2021) our aim was to: (a) assess the trade in Sunda Porcupines in Bali, specifically the trade in porcupine skulls, both in physical shops as online; (b) to establish the main purposes of this trade; (c) its legality and its monetary value; and (d) way to mitigate the negative effects of this trade on wild populations of Sunda Porcupines.

METHODS

From 25 December 2022 to 6 January 2023 (VN) and from 31 May to 19 June 2023 (JC and VN) we surveyed the towns of Sanur, Ubud, Legian, Jimbaran, Tampaksiring and parts of Beringkit, and Denpasar (Figure 1). Sanur, Jimbaran and Legian are known for its beaches and coastal tourism, Ubud is famous for its monkey forest and arts, and Tampaksiring is a centre for traditional Balinese culture and handicrafts. Beringkit and Denpasar are largely urbanized. All are within an hour car drive from each other. In general, the shops selling wildlife are situated along the main streets and prominently display their wares; it is no challenge locating them (Chavez et al. 2023). For shops that were visited during both periods we compared the items for sale and report only a minimum number, avoiding double counting (Chavez et al. 2024). In June, July, and November 2023 we searched the internet for porcupine skulls offered for sale by traders that were based in Bali (keywords for searching: landak, tengkorak, jual, porcupine skull, sale).

RESULTS AND DISCUSSION

With their large yellow-orange upper and lower incisors prominently on display, the porcupine skulls really do stand out amongst the other animal skulls that curio traders have on offer (Image 1). We recorded 44 porcupine skulls in 11 shops in southern Bali, i.e., five in two shops in Sanur, 21 in five shops in Tampaksiring, and 18 in four shops in Ubud. None were recorded in Legian, Beringkit, Denpasar or Jimbaran. Thirty-three of the skulls were carved and most of these were stained yellow, grey or brown to make them appear older (this is common practice in the Bali animal curio trade: Chavez et al. 2024). We obtained two independent quotes for carved porcupine skulls of USD 66 and USD 56 (vendors indicated that the price would go down after bartering something we did not do). In the online search we recorded 10 porcupine skulls for sale by five traders based in Denpasar and Gianyar; three of them specified that one of the purposes is as a decoration in an aquarium or more specifically as a hiding cave for aquarium fish. None of them were carved or stained. Prices ranged from USD 6 (two adverts) to USD 20 and USD 38 (weighted mean USD 22).

Three traders informed us that the porcupine skulls were sourced from Java (twice) and Bali (once), and all skulls were consistent with them being of Sunda Porcupine. As this is indeed most parsimonious, we

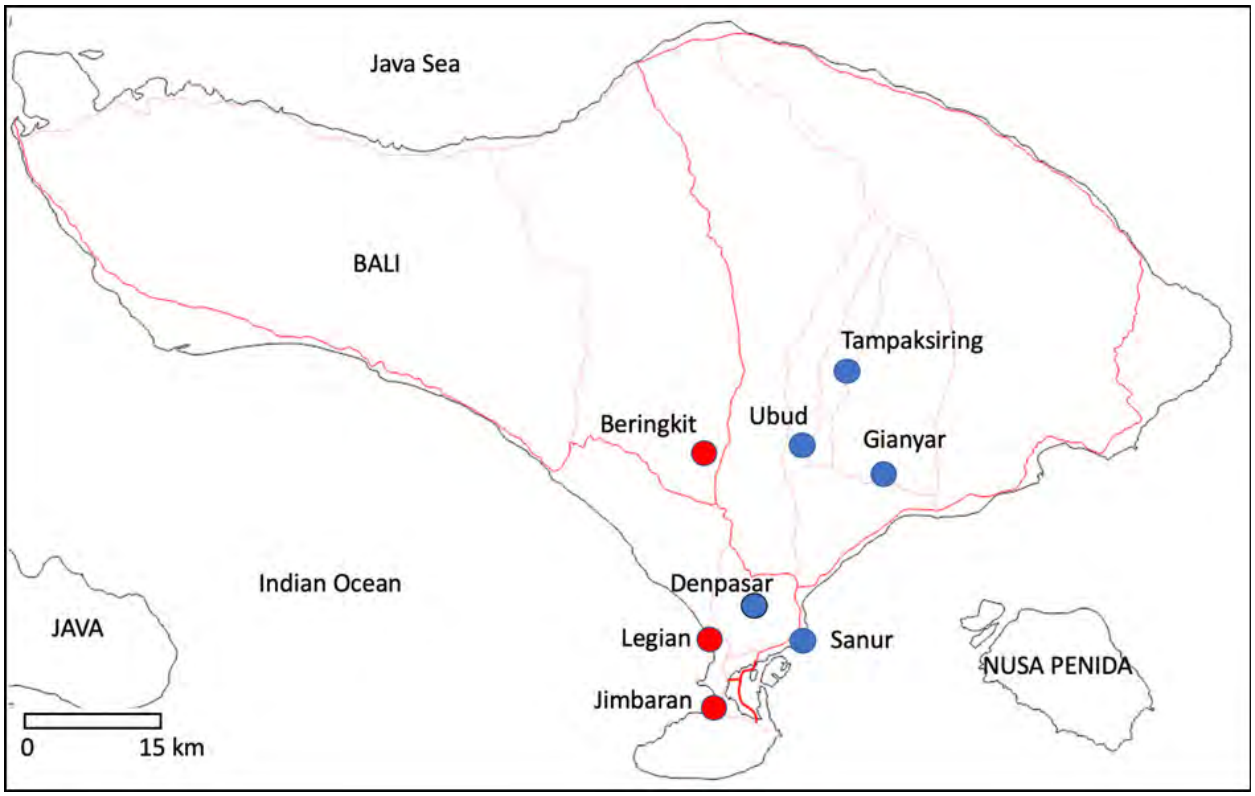

Figure 1. Map of Bali, Indonesia, with Ubud, Tampaksiring, Denpasar, Gianyar, and Sanur as locations where we did observe the trade of porcupines and Legian, Jimbaran, and Beringkit where we did not observe it.

expect most, if not all, of the skulls we did observe in Bali to belong to this species (sourcing porcupines from Sumatra or Borneo involves lengthy overland journeys and one or more sea crossings). This then confirms all the trade we observed was illegal under Indonesian law.

Our records of over 50 legally protected Sunda Porcupines in commerce recorded during a relatively short and no way near intense trade survey underscores the importance of putting more emphasis on monitoring threats to the so-called less important species. The purpose of this trade—to offer domestic and/or international tourists a unique souvenir to remind them of their time in Bali or to provide Indonesian aquarium enthusiasts with something different to their pet fish—is in no way a justification to allow this illegal trade to continue. We expect that some of the porcupines were found openly for sale in the Balinese tourist shops are intended for international tourists despite Indonesian law precluding their sale. We expect that many of these tourists will be unpleasantly surprised if their new purchases are confiscated either at Bali International Airport upon departure or when arriving at their final destination (in many countries the import of skulls or other body parts of wild rodents would require health certificates or veterinary inspections and clearance to reduce the risk of the introduction of zoonotic diseases).

As argued by Gomez (2021), porcupines in Asia face a multitude of threats, habitat loss, retaliatory killings, targeted hunting for commercial trade (see also Brooks et al. 2010; Heinrich et al. 2020; Hasan & Csányi 2022), and while it is crucial that all species of porcupine are to be listed as protected species under Indonesian wildlife laws to improve regulation and enforcement against illegal trade, it is also imperative that these laws and regulations are properly and fairly enforced. We were unable to pinpoint where exactly the Sunda Porcupines we observed in trade were sourced, with traders pointing both to Bali and the neighbouring island of Java. Sunda Porcupines live in forested areas as well as in more human-dominated landscapes, including agroforests (Mustikasari et al. 2019), and gaining insight in how, where, and when these animals are trapped would greatly increase our understanding of the risk that the trade in body parts poses to the species.

Creating awareness among decision makers, traders and tourists of the lack of sustainability in large parts of legal wildlife trade, let alone the illegal wildlife trade, is urgently needed. For the Sunda Porcupine, unsustainable

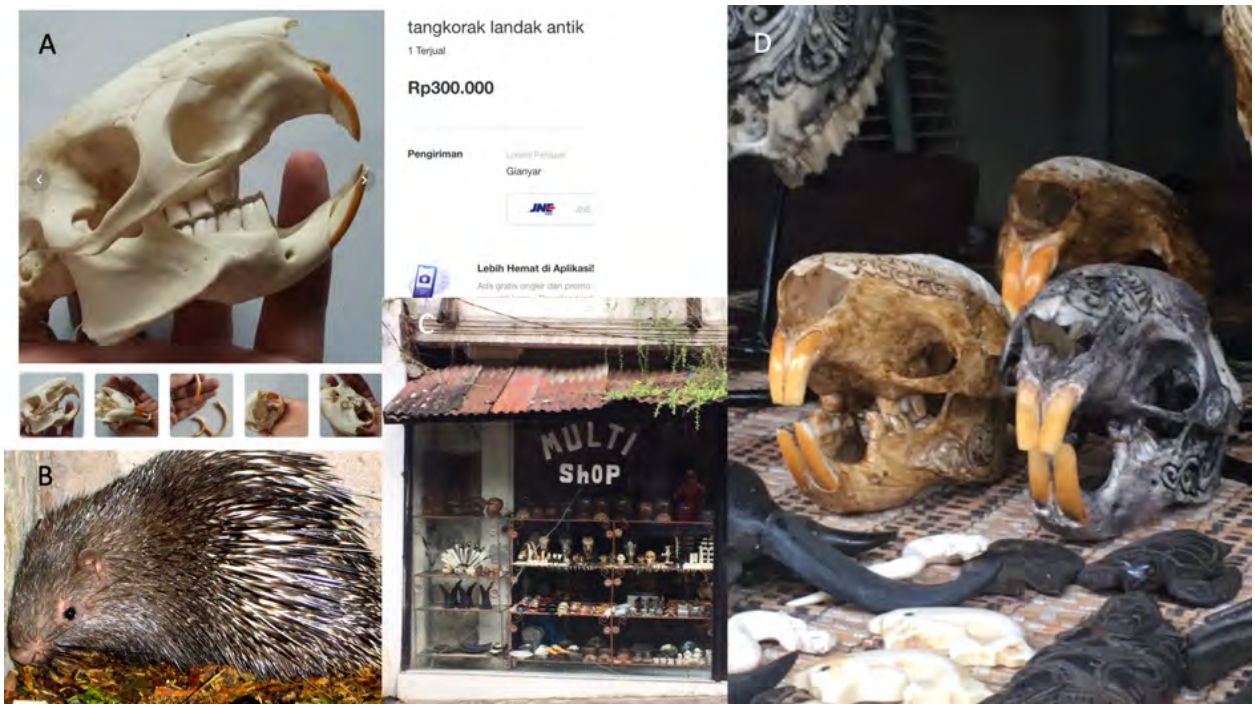

Image 1. Sunda Porcupine *Hystrix javanica* in Bali: A—a skull offered for sale on the e-commerce platform Bupalapak and while the caption suggests it is an antique, its appearance suggests otherwise; the trader is based in Gianyar (Right) | B—a juvenile Sunda Porcupine | C—a shop in selling porcupine skulls in Ubud | D—three skulls offered for sale in a shop in Ubud, all stained and intricately carved. Photos A, C and D, by Jessica Chavez and Vincent Nijman; Photo B, Linda van 't Hoff, CC-BY-NC 2.0 license

and illegal trade depletes wild populations and by doing so, undermines Indonesia's commitment to reaching biodiversity conservation goals. The online platforms that allow Sunda Porcupine skulls to be offered for sale need to enact their own terms and conditions as most preclude the sale of protected species. A more thorough examination of the commercial trade of porcupines is warranted so that appropriate mitigation measures can be developed to protect porcupines from unsustainable and illegal exploitation. If the trade indeed has a significant international component, as our research suggests it does, the Indonesian authorities may consider putting forward a Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) appendix III proposal as this would allow Indonesia to better regulate the international trade of this nationally protected species. The last two steps (mitigation measures and CITES listing) will require the full operation of both the commercial sector, local and national governments, the tourism industry and the Indonesian public.

CONCLUSION

We found the skulls of Sunda Porcupine, a legally protected species under Indonesian law, openly for sale in shops throughout Bali and by Balinese based sellers on online platforms. The impact of this trade on wild populations is unclear. Porcupine skulls are easily identifiable, and it is imperative that decisive action is taken to curb this illegal trade; for this the various stakeholders (government agencies, tourism bodies and the commercial sector) need to collaborate.

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Author contributions: JC and VN collected the data, performed the analysis and drafted the initial manuscript. K liaised with government bodies, oversaw administration, provided local context, and played a critical role in reviewing and providing constructive feedback on the initial draft. All authors contributed to the revision.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 January 2024 | 16(1): 24589–24596
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.8506.16.1.24589-24596
#8506 | Received 04 May 2023 | Finally accepted 27 December 2023
OPEN ACCESS
REVIEW

Fishes of Cocibolca, the great Central American lake

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Abstract: The diversity of freshwater fish species from Lake Cocibolca (Nicaragua) is presented, describing the history of biological explorations in the lake from the first record in 1519, to the 52 species that are listed today. Information on current and future threats is also included.

Keywords: Conservation, fishes, fisheries, history, Nicaragua, threats.

Resumen: Se describe la diversidad de peces del lago Cocibolca (Nicaragua), describiendo la historia de las exploraciones biológicas en el sitio desde el primer registro en 1519, hasta las 52 especies conocidas en la actualidad. Se incluye además información sobre las amenazas presentes y futuras.

Editor: Anonymity requested.

Date of publication: 26 January 2024 (online & print)

Citation: Contreras-MacBeath, T., B.J.R. Pérez, H. Mejia-Mojica & J.M. Rivas-González (2024). Fishes of Cocibolca, the great Central American lake. *Journal of Threatened Taxa* 16(1): 24589–24596. https://doi.org/10.11609/jott.8506.16.1.24589–24596

Funding: None.

Competing interests: The authors declare no competing interests.

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Author contributions: Topiltzin Contreras-MacBeath lead and coordinated the publication; Humberto Mejia Mojica and Juan Manuel Rivas-González helped integrate the species list. While Byron Josue Rodríguez Pérez contributed by gathering and reviewing local information from Nicaraguan sources.

Acknowledgements: We wish to thank Dr. Arturo Angulo from the Museo de Zoología, Centro de Investigación en Biodiversidad y Ecología Tropical (CIBET), Universidad de Costa Rica, for reviewing the species list.

FCC Freshwater Conservation Committee

Universidad Autónoma del Estado de Morelos

A view of Central America from the International Space Station reveals the majesty of Lake Nicaragua (Image 1), known regionally as Cocibolca and recognized as the 19th largest lake in the world in terms of surface area (Routley 2019). Cocibolca is considered the most important freshwater ecosystem of the Central American Isthmus and is in the San Juan River Basin, which covers an area of 38,569 km^2, 64% of the land area of the basin is in southern Nicaragua and 36% in northern Costa Rica. The lake has a maximum length of 165 km, a maximum width of 70 km and has a water volume of approximately 104,000 Hm^3. It is located at an altitude of 31 m and has an area of 8,264 km^2, an average depth of 13 m and a maximum depth of 40 m. In it there are numerous islands, the main ones being: Ometepe, with an area of 275 km^2 and a perimeter of 89 km; Zapatera, with an area of 53 km^2 and a perimeter of 38 km; and the Solentiname Archipelago with an area of 14 km^2 and a perimeter of 44 km. Fifty-one rivers flow into Lake Nicaragua: 15 on the western coast, 17 on the eastern coast, and 19 on the southern coast. The main tributaries are the Malacatoya River and the Tipitapa River on the northwestern coast; the Oyate River on the east coast and the Frio, El Niño and Sapoá rivers on the southern coast. Its only tributary is the San Juan River, which has a length of 198 km and a discharge of approximately 250,000 liters per second. The main ports of the lake are Granada, San Jorge, San Carlos, San Miguelito and Moyogalpa (Ometepe Island) (Incer 1976; INFONAC 1976; Orellana 1983).

At the dawn of the Spanish colony, one of the first historians in the region, Captain Don Gonzalo Fernández de Oviedo y Valdés (1478–1557) narrates aspects of fishing in the lake and cites the presence of marine species, including sharks and in a passage of his book XII, chapter III, describes how one day in 1529 he finds a dead sawfish on the shore of the lake (Villa 1976), in what represents the first ichthyological record for Cocibolca. The first described species of the lake was carried out by Albert Günther of the British Museum of Natural History, and it was *Heros labiatus*, which we now know is *Amphilophus labiatus* (Günther 1864a). In a second publication, the same author (Günther 1864b) describes four new species (now recognized as *Amphilophus citrinellus*, *Hypsophrys nicaraguensis*, *Parachromis dovii* and *Gobiomorus dormitor*) and mentions nine fish species for the Lake. In their synopsis of Lake Nicaragua, Gill & Bransford (1878) list 21 species, while Meek (1907) brings the number of species present in the Lake to 35. For the second part of the last century, there are outstanding contributions by Astorqui (1972) who describes the presence of 45 species and a few years later, Villa (1976) recognizes 41 species.

Based on the afore mentioned studies, as well as some more recent ones in which the ichthyofauna of Lake Cocibolca is mentioned (INFONAC 1976; Orellana 1983; McKaye et al. 1995; Hernández 2007; Bussing 2008; Hernández & Corea 2013) and through the review of fish records for the lake contained in the Global Biodiversity Information Facility using the GeoCat® geospatial tool, we obtained a list containing 52 species, placed in 16 families and 34 genera. Four of these species are invasive (Table 1). In terms of richness, the families Cichlidae stand out with 15 species, as well as Characidae and Poeciliidae with nine species each, which represents 63% of the total (Image 2). The only species endemic to the lake is *Axtyanax cocibolca*, described by Bussing (2007), with specimens collected by Jaime Villa & Montserrat Llobert near Granada. The ichthyofauna of Lake Cocibolca reflects what occurs in the Central American region, being represented by primary, secondary and peripheral species. Despite the distance of the lake to the coast (198 km) it is important to highlight the presence of three species of elasmobranchs: the Bull Shark *Carcharhinus leucas*, and two species of sawfish—*Pristis pristis and P. pectinata*.

From the point of view of conservation status, based on Red List data (IUCN 2023), there are seven species at risk, two of them Critically Endangered (*Pristis pristis* and *P. pectinata*), and the remaining five are Vulnerable (*Megalops atlanticus*, *Carlana eigenmanni*, *Atherinella sardina*, *Phallichthys tico*, and *Xenophallus umbratilis*). Five species were listed as 'Near Threatened' and 28 in the 'Least Concern' category. It was not possible to assign a risk category to five species due to lack of data, including the only endemic species (*Astyanax cocibolca*) and finally, three species were Not Evaluated (Table 1).

Although originally the sharks of the Lake were described as an endemic species (*Eulamia nicaraguensis*), later studies with sharks tagged in the Nicaraguan and Costa Rican coasts, showed that it was the Zambesi Shark *Carcharhinus Leucas*, which makes migrations between the sea and the lake and vice versa (Thorson 1971). In this study it was also found that it took the sharks 2–25 days to go up the 198 km of the river, as well as 7–11 days to go downstream, back to the ocean and a specimen was found that made the trip back to the sea in just one day.

Lacustrine way of life was very important in pre-Columbian Mesoamerican culture (Williams 2014), since, in many lakes, as in the case of Lake Cocibolca, the capture of fish and any other aquatic species, including birds and reptiles, as well as the use of alluvial lands

Image 1. Central America from space, black circle highlights Lake Cocibolca (Source: NASA/JPL/NIMA 2002).

Image 2. Cichlid species dominate Lake Cocibolca, including the Moga *Hypsophrys nicaraguensis*. © iStock.com/Tetiana Garkusha.

for agriculture was fundamental for food (Image 3). Currently, the Lake Cocibolca Basin has an approximate population of 750,000 inhabitants and represents an important agricultural production area and is home to one of the main tourist attractions of the country, the colonial city of Granada and the Island of Ometepe (Banco Mundial 2013). Given its size as well as its location in Nicaragua, the lake continues to be a strategic resource for the country because economic activities such as fishing, and tourism are developed in it and its waters are used for human consumption, agriculture, and navigation (Salvatierra 2016).

Due to the multiplicity of uses that have been given to the lake and its biodiversity, as well as the large number of people living in its territory, or in areas close to it, there are a series of environmental impacts that have been identified and that were described in detail in a study carried out by the World Bank in 2013. These are briefly described below: Diffuse pollution, evidenced by a high sedimentation rate, which has a value of 13.3 tons per ha and is the result of deforestation of the catchment basin for the development of agricultural activities, which could cause eutrophication of the lake by the increase in the load of nutrients, mainly nitrogen and phosphorus contained in the sediments. They also find that a water imbalance (increased precipitation) caused by climate change could increase the severity of this threat. Point pollution in the form of discharge of urban and industrial wastewater with poor treatment or untreated. They found that spot bacteriological contamination near the beaches of Grenada and other lake populations limits recreational opportunities and is likely harmful to health. Pollution from tilapia farming, which has different and perhaps more damaging effects on the Lake than nutrient runoff caused by agricultural activities and soil erosion, is also mentioned, although precise data on the impact of this activity are not given.

As mentioned above, fishing has always been an important activity for the communities settled on the shores of Lake Cocibolca, one of the first records in the literature of this activity is that of Ephraim George Squire, who in 1852 cites that in lakes Managua and Nicaragua there is a great variety of fish that are caught by the communities of the banks (Villa 1976). In one of the sections of his publication, this same author narrates how the women of the community fish sardines with spoon nets and then cook them in the form of omelet. In a study on the fishery resources of Lake Nicaragua carried out in the 70s, it was found that the fishing production of artisanal origin in the lake amounted to 680,388 kg and the most caught species were the Gaspar

Image 3. Young fisherman with his catch on the shores of Lake Cocibolca. © Topiltzin Contreras.

Atractosteus tropicus, the Mojarra and Guapote Cichlids, as well as the Sawfish, of which an average of 90 kg per fisherman per week was fished (INFONAC 1976). For his part, Davies (1976) includes in the list of species of fishing importance the Sabalo *Megalops atlanticus*.

In an evaluation of the fishery resources of Lake Cocibolca carried out by the Fisheries Research Center of the Nicaraguan Fisheries Institute between October 1982 and May 1983, 31 fish species were identified, six of which are dominant in terms of biomass, with 82.7% of the catch (Orellana 1983). In this study, the Moga *Hypsophrys nicaraguensis* dominated with 19.8% of the catch, followed by the Red-breasted Mojarra *Cribroheros longimanus*) with 16.5%, the Mojarra *Amphilophus citrinellus* with 16%, the Machaca *Brycon guatemalensis* with 13.7%, the Sabalete *Dorosoma chavesi* with 10.5%, and the Gaspar *Atractosteus tropicus* with 6.2%.

An example of the negative impact of fishing activity relates to the three elasmobranch species of Lake Cocibolca, the Bull Shark *Carcharhinus leucas*, and the

Image 4. The Sawfish *Pristis pristis* species Critically Threatened globally, was very abundant in Lake Cocibolca, to the extent that in the 70s a commercial fishery was established that made it practically disappear. © Peter Kyne, Charles Darwin University, CC BY 3.0 <https://creativecommons.org/licenses/by/3.0>, via Wikimedia Commons) of Threatened Philippine Fauna and their Categories) status and endemicity.

sawfishes *Pristis pristis* and *P. pectinata*, which were traditionally fished in the lake in an artisanal way, but that as a result of the establishment in Granada in the early 70s of an industrial fishery that included a processing plant for shark meat and fins, as well as two boats and the hiring of 50 fishermen (Image 4). The installed storage capacity of both vessels was 8,409 kg, however, the number of fish (mainly sawfish fillets) delivered weekly to the processing plant did not exceed 2,275 kg and the plant focused on the processing of Gaspar, Mojarras, and Guapotes (Davies 1976). According to Thorson (1982), sawfish populations decreased considerably in the lake because of industrial fishing, and despite efforts by the Nicaraguan fishing authority, due to of poaching, this situation could not be controlled and some authors assume that these species have disappeared from the lake (McCrary et al. 2007; Poulakis & Grubbs 2019), which is unfortunate since both sawfish species are Critically Endangered globally and because they bred in the Lake (Thorson 1982), Cocibolca represented a true sanctuary for them. To conserve these species in Cocibolca, the Government of Nicaragua included a total ban of these species in the Fisheries and Aquaculture Law (489), article 75, published on 27 December 2004, however, it seems that this regulation has not had a significant benefit on elasmobranch.

Despite the diversity of native fish species as well as the fishing use that has traditionally been given to these fish species, Lake Cocibolca was not spared from the introduction of invasive fish. Since the 16th century and with total ignorance, Oviedo suggested to the original inhabitants of the lake the need to introduce fish, since in his way of seeing things, “there is no fish of any kind in it, but some fishmongers as small as cabo de agujetas, which cannot be eaten because they are so often better than in egg tortillas” (Villa 1976). In the early 80s three species of tilapias—*Oreochromis niloticus*, O. *mossambicus*, and *O. aureus*—were introduced in Cocibolca with the idea of developing aquaculture and improving fishing (McKaye et al. 1995). In 2003, the Nicaraguan Government granted an authorization to the company NICANOR, for the production of tilapia in floating cages in 86.87 ha of the lake, in the community of San Ramón, Ometepe Island, however, as a non-native species of the lake, the intrusion of tilapia represents a threat to biodiversity and ecosystem health (Banco Mundial 2013). In this sense, when evaluating the status of tilapia in Nicaragua, McCrary et al. (2007) found that they have been successfully established in the Lake and that their presence corresponds to a reduction in

Table 1. Updated list of fish species present in Lake Cocibolca, showing its Red List Category.

Family	Species	Common name	Category
Carcharinidae	*Carcharhinus leucas* (Muller & Henle, 1839)	Bull Shark, Tiburon Toro	NT
Pristidae	*Pristis pectinata* Latham, 1794	Smalltooth Sawfish, Pez Sierra	CR
	Pristis pristis (Linnaeus, 1758)	Largetooth Sawfish, Pez Sierra	CR
Lepisosteidae	*Atractosteus tropicus* Gill, 1863	Gaspar, Gar	LC
Megalopidae	*Megalops atlanticus* Valenciennes, 1847	Tarpon, Sabalo Real	VU
Clupeidae	*Dorosoma chavesi* Meek, 1907	Nicaragua Gizzard Shad, Sabalete, Sandillero	NT
Characidae	*Astyanax aeneus* (Günther, 1860)	Banded Tetra	LC
	Astyanax bransfordii (Gill, 1877)	Sabalito	NT
	Astyanax cocibolca Bussing, 2008	Sardina	DD
	Astyanax nasutus Meek, 1907	Sardina Lagunera	DD
	Brycon guatemalensis Regan, 1908	Machaca, Sabalete, Macabi	LC
	Carlana eigenmanni (Meek, 1912)	Sardinita	VU
	Hyphessobrycon tortuguerae Böhlke, 1958	Sardinita	LC
	Roeboides bouchellei Fowler, 1923	Crystal Tetra	LC
	Roeboides guatemalensis (Günther, 1864)	Guatemalan Headstander	NT
Pimelodidae	*Rhamdia quelen* (Quoy & Gaimard, 1824)	Catfish, Chulin Barbudo	LC
	Rhamdia nicaraguensis (Günther, 1864)	Bagre	LC
Gobiidae	*Gobiomorus dormitor* Lacèpede, 1800	Bigmouth Sleeper, Guavina	LC
	Gobiomorus maculatus (Günther, 1859)	Pacific Sleeper	LC
Synbrinchidae	*Synbranchus marmoratus* Bloch, 1795	Marbled Swamp Eel, Anguila	LC
Centropomidae	*Centropomus parallelus* Poey, 1860	Fat Snook, Robalo	LC
Cichlidae	*Amatitlania nigrofasciata* (Günther, 1867)	Convict Cichlid, Mojarra	DD
	Amatitlania septemfasciata (Regan, 1908)	Mojarra	LC
	Amphilophus citrinellus (Günther, 1864)	Midas Cichlid, Mojarra	LC
	Amphilophus labiatus (Günther, 1864)	Red Devil, Labiata	NE
	Archocentrus centrarchus (Gill, 1877)	Flier Cichlid, Mojarrita Rayada	LC
	Cribroheros longimanus (Günther, 1867)	Red-breasted Cichlid, Mojarra pechito rojo	LC
	Cribroheros rostratus (Gill, 1877)	Carate, Masamiche	LC
	Cryptoheros spilurus (Günther, 1862)	Blue-eye Cichlid	DD
	Herotilapia multispinosa (Günther, 1867)	Rainbow Cichlid, Mojarrita	LC
	Hypsophrys nematopus (Günther, 1867)	Poor Man's Tropheus, Picaculo	NE
	Hypsophrys nicaraguensis (Günther, 1864)	Butterfly Cichlid, Moga	LC
	Parachromis dovii (Günther, 1864)	Guapote	LC
	Parachromis friedrichsthalii (Heckel, 1840)	Monarch Cichlid	LC
	Parachromis managuensis (Günther, 1867)	Jaguar Guapote, Guapote Tigre	LC
	Vieja maculicauda (Regan, 1905)	Blackbelt Cichlid, Vieja	LC
Atherinidae	*Atherinella sardina* (Meek, 1907)	Sardina Plateada	VU
Cyprinodontidae	*Cynodonichthys isthmensis* (Garman, 1895)	Rivulinos	LC
Poeciliidae	*Alfaro cultratus* (Regan, 1908)	Pepesca	LC
	Belonesox belizanus Kner, 1860	Top Minnow	LC
	Brachyrhaphis holdridgei Bussing, 1967	Olomina	NT
	Gambusia nicaraguensis Gunther, 1866	Nicaraguan Mosquitofish	LC
	Phallichthys amates (Miller, 1907)	Merry Widow Livebearer, Olomina	LC
	Phallichthys tico Bussing, 1963	Olomina	VU

Family	Species	Common name	Category
	Poecilia gillii (Kner, 1863)	Gill's Molly, Pepesca	DD
	Poeciliopsis turrubarensis (Meek, 1912)	Barred Livebearer	LC
	Xenophallus umbratilis (Meek, 1912)	Olomina	VU
Haemulidae	*Pomadasys croco* (Cuvier, 1830)	Burro Grunt, Roncador	NE
INVASIVES			
Loricaridae	*Hypostomus* sp.	Pleco	
Cichlidae	*Oreochromis niloticus*	Tilapia	
	Oreochromis mossambicus	Tilapia	
	Oreochromis aureus	Tilapia	

Image 5. Isletas de Granada, one of the most important tourist areas in Nicaragua. © Topiltzin Contreras.

the presence of native species in local markets. From 2003, the fishermen of the lake began to find Plecos of the Loricaridae family (INPESCA 2008) that according to Hernández & Corea (2012) are increasingly abundant in catches.

One of the most pressing threats to Lake Cocibolca is perhaps the interest in building a transoceanic canal like that of Panama, which could irreversibly impact the ichthyofauna of the lake, a situation that has been discussed by several authors (Huete-Pérez et al. 2013, 2015, 2016; Härer et al. 2017). Within the country this issue has also been much discussed, Salvatierra (2016) describes how the public interest, indigenous and local communities, NGOs and organizations such as the Association of Municipalities of the Great Lake Basin (AMUGRAN), have promoted policies for the integrated and sustainable management of Cocibolca, which have led to legislative reforms such as the General Law of National Waters (620), published in 2007, article 96 of which provides that, "It is in the social interest to ensure the quality of national bodies of water, through the promotion and implementation of the measures and actions necessary for their due and permanent protection and conservation"; Article 97 "prohibits the introduction and cultivation of exotic and invasive species in Lake Cocibolca" and that "Lake Cocibolca should be considered as a natural reserve of drinking water, being of the highest national interest and priority for national security". On the other hand, Law 699 approved in 2009, which creates the "Commission for Sustainable Development of the Water Basin of Lakes Apanás, Xolotlán and Cocibolca and the San Juan River", whose

axis is the formulation of the Integral Management Plan of the Basin of the Great Lakes of Nicaragua, under the model of Integrated Water Resources Management (IWRM). Salvatierra (2016) comments that in contradiction with these legal commandments in 2012 Law 800 "Law of the Legal Regime of the Grand Interoceanic Canal of Nicaragua and the Creation of the Authority of the Grand Interoceanic Canal of Nicaragua" is published, without incorporating any reference to the provisions contained in laws 620 and 699.

Although many of the concerns on the part of environmentalists have not been resolved, with a cost of more than 50 billion dollars, the construction of the canal by the Chinese company HK Nicaragua Development Investment (HKND) officially began in 2014, however, the stock market crisis that hit China between 2015 and 2016 made it lose 85% of his patrimony to Wang Jing, communications tycoon and main investor of HKND, with which the project has been suspended, but the State of Nicaragua maintains its willingness to continue it (Sputnik 2020).

We do not know what the fate of Lake Cocibolca and its impressive ichthyofaunal diversity will be, either with or without the transoceanic canal. What is clear is that the future of Nicaragua and its people, but especially of that with a lacustrine way of life, is linked to the future of its great lake (Image 5).

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Journal of Threatened Taxa | www.threatenedtaxa.org | 26 January 2024 | 16(1): 24597–24600

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

https://doi.org/10.11609/jott.8804.16.1.24597-24600

#8804 | Received 28 October 2023 | Final received 01 December 2023 | Finally accepted 25 December 2023

OPEN ACCESS

SHORT COMMUNICATION

Twice blooming flowers of *Antigonon leptopus* Hook. & Arn. (Magnoliopsida: Caryophyllales: Polygonaceae), a key forage source for insects during wet season in habitats disturbed by humans

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Abstract: *Antigonon leptopus* is an elegant weedy species that thrives well during wet season in habitats disturbed by humans; it shows vegetative and reproductive events in this season. Its flowers bloom twice with pollen and nectar presentation on day 1 and nectar presentation on day 2 for use by insects that act as pollinators. The flowers are unspecialized with exposed sex organs and presenting pollen and nectar which are easily accessible by the probing insects while collecting the floral rewards and effect pollination. The field study indicates that it acts as a key forage source for insects.

Keywords: Bees, butterflies, elegant weed, nectar, pollen, unspecialized flowers.

Flowering plants commonly depend on insects for pollination (Ollerton et al. 2011). A wide variety or a few taxonomically distinct insects may visit a single plant species for forage collection (Zych et al. 2013). However, all visiting insect species do not act as pollinators since some insects use floral sources without providing pollination service to the plant species they visit for forage collection (Irwin et al. 2010; Castro et al. 2013). Further, the insect species that effect pollination are not equally efficient in providing the pollination service (Schemske & Horvitz 1984; Rosas-Guerrero et al. 2014) and their efficiency in forage collection is often attributed to the size, morphology, hairiness of mouthparts, and legs (Armbruster et al. 2014). Baker & Baker (1982, 1983) described two categories of flowers, 'bee and butterfly flowers' and 'true butterfly flowers'; in the former category, the flowers are characterized by short-tubed corolla with hexose-rich nectar while in the latter category, the flowers are characterized by deep, narrow corolla tubes with relatively copious sucrose-rich nectar. With this backdrop, the present study was contemplated to investigate the flowers of *Antigonon leptopus* with reference to their role as key forage source for insects, especially bees and butterflies during wet season in habitats disturbed by humans.

Materials and Methods

Antigonon leptopus growing in vacant spaces surrounded by residential areas of Andhra University campus and along roadways in Visakhapatnam, Andhra Pradesh, India, was selected for the present study during June–December 2022. The field study was conducted on the flowering season, floral structural and functional aspects, anthesis, floral rewards produced, and flower visitors, their foraging time and foraging activities on

Editor: K.R. Sasidharan, Institute of Forest Genetics and Tree Breeding, Coimbatore, India. **Date of publication:** 26 January 2024 (online & print)

Citation: Raju, P.S., P. Srikanth & A.J.S. Raju (2024). Twice blooming flowers of *Antigonon leptopus* Hook. & Arn. (Magnoliopsida: Caryophyllales: Polygonaceae), a key forage source for insects during wet season in habitats disturbed by humans. *Journal of Threatened Taxa* 16(1): 24597–24600. https://doi.org/10.11609/jott.8804.16.1.24597–24600

Funding: Self-funded.

Competing interests: The authors declare no competing interests.

Acknowledgements: We thank Dr. K. Venkata Ramana, Department of Botany, Andhra University, Visakhapatnam, for field assistance.

this plant. The data collected on these aspects were examined to know the value of this plant as a forage source for visiting insect species during wet season in areas of human disturbance.

Observations and Discussion

Antigonon leptopus is an elegant creeper which grows and flowers vigorously during rainy season from June to October (Image 1a). The inflorescence is a compound umbellate cyme which produces several flowers daily during 0630–0830h (Image 1b). The flowers are hermaphroditic, small, showy, pink in color and cup-like. They close back by 1500 h on the first day and re-bloom on the next day along with the new flowers but close back again by 1500 h and remain so until they fall off. They are staminate on the first day with the downward curling of stigmas and pistillate on the second day with complete pollen shedding from the anthers. The flowers produce nectar in day 1 flowers only indicating that day 1 flowers provide both pollen and nectar while day 2 flowers provide left over nectar to insect foragers.

A variety of taxonomically different insects consisting of bees, a wasp and butterflies foraged on the flowers of *A. leptopus* daily during daylight hours from morning to evening. The bees were *Apis dorsata* (Image 1c), *A. cerana* (Image 1d), *A. florea* (Image 1e), *Trigona iridipennis* (Image 1f), *Xylocopa latipes* (Image 2a), and *X. pubescens*. The wasp included only one species of the genus *Rhynchium* (Image 2b). The butterflies were *Pachliopta aristolochiae, P. hector, Graphium agamemnon, Catopsilia pomona* (Image 2c), *C. pyranthe, Eurema hecabe, Acraea violae, Euthalia aconthea, Precis iphita, Danaus chrysippus, Euploea core, Hypolimnas bolina* (Image 2d), *Junonia lemonias* (Image 2e), *Jamides celeno* (Image 2f), and *Euchrysops cnejus* (Image 2g) (Table 1). The insects visited day 1 and day 2 flowers indiscriminately to collect pollen and/or nectar. Bees obtained both pollen and nectar from day 1 flowers and only left over nectar from day 2 flowers; the nectar availability in day 2 flowers depended on the utilization level of nectar by insects in day 1 flowers. The wasp and butterflies collected only nectar and use day 1 and day 2 flowers as nectar sources. Since flowers are small and cup-like with sex organs well exposed characterizing unspecialized floral syndrome, all foraging insects reached pollen and/or nectar easily and while collecting the forage they contacted the sex organs and pollinated the stigmas automatically (Burkill 1916; van der Pijl 1937). Raju et al. (2001) reported that since the flowers display temporal dioecy with

Image 1. *Antigonon leptopus*: a—Habit | b—*Umbellate cyme* with mature buds and flowers | c—*Apis dorsata* | d—*Apis cerana* | e—*Apis florea* | f—*Trigona iridipennis*. © A.J. Solomon Raju.

Table 1. List of flower visitors feeding on pollen/nectar of *Antigonon leptopus*.

Order/ Family	Scientific name	Common name	Forage collected	Foraging time
Hymenoptera				
Apidae	*Apis dorsata* F.	Rock Honey Bee	Pollen and Nectar	0730–1700
	Apis cerana F.	Asian Honey Bee	Pollen and Nectar	0730–1700
	Apis florea F.	Dwarf Honey Bee	Pollen and Nectar	0730–1700
	Trigona iridipennis Smith	Stingless honey bee	Pollen and Nectar	0800–1630
	Xylocopa latipes Drury	Carpenter bee	Nectar	0800–1700
	Xylocopa pubescens Spinola	Carpenter bee	Nectar	0800–1700
Vespidae	*Rhynchium* sp.	Potter wasp	Nectar	0830–1630
Lepidoptera				
Papilionidae	*Pachliopta aristolochiae* F.	Common Rose	Nectar	0830–1530
	P. hector L.	Crimson Rose	Nectar	0830–1530
	G. agamemnon L.	Tailed Jay	Nectar	0830–1530
Pieridae	*Catopsilia pomona* F.	Common Emigrant	Nectar	0830–1530
	C. pyranthe L.	Mottled Emigrant	Nectar	0830–1530
	Eurema hecabe L.	Common Grass Yellow	Nectar	0830–1530
Nymphalidae	*Acraea violae* F.	Tawny Coster	Nectar	0830–1530
	Euthalia aconthea Cr.	Common Baron	Nectar	0830–1530
	A. merione Cr.	Common Castor	Nectar	0830–1530
	Junonia lemonias L.	Lemon Pansy	Nectar	0830–1530
	Precis iphita Cr.	Chocolate Pansy	Nectar	0830–1530
	Danaus chrysippus L.	Plain Tiger	Nectar	0830–1530
	Euploea core Cr.	Common Indian Crow	Nectar	0830–1530
	Hypolimnas bolina L.	Blue Moon	Nectar	0830–1530
Lycaenidae	*Jamides celeno* Cr.	Common Cerulean	Nectar	0900–1500
	Euchrysops cnejus F.	Gram Blue	Nectar	0900–1500

Image 2. *Antigonon leptopus*: a—Carpenter Bee *Xylocopa latipes* | b—Wasp *Rhynchium* sp. | c—*Catopsilia pomona* (Pieridae) | d—*Hypolimnas bolina* (Nymphalidae) | e—*Junonia lemonias* (Nymphalidae) | f—*Jamides celeno* (Lycaenidae) | g—*Euchrysops cnejus* (Lycaenidae). © A.J. Solomon Raju.

either male or female phase at any given day, there is no possibility for self-pollination within the flower but facilitate self-pollination (geitonogamy) within the plant. The plant with intense flowering during wet season and unspecialized flowers is a key source of pollen and nectar for bees and of nectar for wasps and butterflies in habitats disturbed by humans.

Conclusion

The study indicates that *A. leptopus* with flowers opening twice is a key forage source for insects during wet season in areas where human disturbance results in decimation of plant cover and reduced species diversity.

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Journal of Threatened Taxa | www.threatenedtaxa.org | 26 January 2024 | 16(1): 24601–24606

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

https://doi.org/10.11609/jott.8629.16.1.24601-24606

#8629 | Received 11 July 2023 | Final received 20 November 2023 | Finally accepted 20 December 2023

OPEN ACCESS

SHORT COMMUNICATION

Two new weevil species of the genus *Myllocerus* Schoenherr, 1823 (Coleoptera: Curculionidae: Entiminae) from India

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Abstract: Two new species, *Myllocerus vathalmalaensis* sp. nov. and *M. depressus* sp. nov., are described from India. *M. vathalmalaensis* differs from *M. lineaticollis* (Boheman, 1842) in possessing a fine central carina on the impressed rostrum, the second funicle segment longer than the first one and tegmen without parameres. *M. depressus* differs from *M. cardoni* Marshall, 1916 by the dorsally depressed rostrum, which is longer than the head, a prothorax depressed and constricted near the posterior margin, the antennae and legs black in colour, the hind femora with a single spine and a spermatheca with curved nodulus.

Keywords: Broad nose weevil, Curculionoidea, Cyphicerini, oriental region, rostrum, snout beetles, weevil.

The Curculionidae (weevils) is one of the largest animal families comprising of 5,800 genera and 62,000 described species (Oberprieler 2007) in 16 subfamilies globally, and are widely distributed. Some of them are serious pest of many crops, including agricultural, horticultural, and forest crops. They feed on leaves, flowers, fruits, seeds, stems, roots and are also recorded in storage houses. They are documented as potential weed control agents, pollinators of crops, and playing an important role in maintaining the natural ecosystem. The genus *Myllocerus* Schoenherr, 1823 is one of the economically important genera, causing severe defoliation during the adult stage, while the grubs feed on the rootlets of many plants (O'Brien et al. 2006).

The genus *Myllocerus* was first described by Schoenherr (1823), with the type species *Curculio curvicornis* Fabricius. Three-hundred-and-fifty-four species have been described in this genus worldwide, of which 86 species have been recorded from India (Ramamurthy & Ghai 1988; Ramamurthy et al. 1992). This genus can be distinguished from other closely related genera by the following characters: the rostrum continuous with the head, its apex emarginated symmetrically, the epistome bounded by distinct carinae, the scrobes subdorsal or dorsal and broad, antennae with scape extending beyond the front margin

ZooBank: urn:lsid:zoobank.org:pub:7DC75BF3-005B-4CCC-98AF-F54F37EB8BCA

Editor: Andrei A. Legalov, Institute of Systematics and Ecology of Animals SB RAS, Novosibirsk, Russia. **Date of publication:** 26 January 2024 (online & print)

Citation: Mahendiran, G., M.M. Nagaraja & M. Sampathkumar (2024). Two new weevil species of the genus *Myllocerus* Schoenherr, 1823 (Coleoptera: Curculionidae: Entiminae) from India. *Journal of Threatened Taxa* 16(1): 24601–24606. https://doi.org/10.11609/jott.8629.16.1.24601-24606

Funding: This study is financially supported by the Science and Engineering Research Board (SERB), Department of Science and Technology, Government of India under Core Research Grant (CRG/2021/007862) with the project entitled "Biodiversity and Systematics studies on Weevils (Curculionidae: Coleoptera) with a special reference to Eastern Ghats of India".

Competing interests: The authors declare no competing interests.

Acknowledgements: The authors are highly thankful to the Director, ICAR-NBAIR, Bengaluru for providing the necessary facilities and to the Science and Engineering Research Board (SERB), Department of Science and Technology, Government of India (CRG/2021/007862) for financial assistance.

of the thorax, the procoxae almost in the middle of the prosternum and claws free (Ramamurthy & Ghai 1988). Currently, it is placed under the subtribe Myllocerina, tribe Cyphicerini, and subfamily Entiminae (Alonso-Zarazaga & Lyal 1999).

Marshall (1916) was the pioneering researcher who studied 71 species including 42 new species and provided a key to identifying the species from British India. Ramamurthy & Ghai (1988) redescribed the genus *Myllocerus*, examining 73 species, including 15 new species from India and adjacent countries. Ramamurthy et al. (1992) transferred six species to the genus *Myllocerus* and synonymised the name *Hyperstylus* Roelofs, 1873 with *Myllocerus*, and additionally described three new species under *Myllocerus*. Following Ramamurthy et al. (1992), there has been a scarcity of taxonomic studies on *Myllocerus* in India.

This paper focuses on describing of two new species of *Myllocerus* from Tamil Nadu, Karnataka, Telangana, and Andhra Pradesh.

Material and Methods

The studied specimens were collected during the survey conducted in different regions of India from 2016 to 2021. The morphological characters were studied using standard techniques for dried insect specimens (Marshall 1916; Ramamurthy & Ghai 1988). The diagnostic characters were photographed using Lecia M205A stereozoom microscope with AutoMontage facility utilizing Leica application suite V4.12 software.

The identification keys provided by Marshall (1916) and Ramamurthy & Ghai (1988) were used for identifying the species. Original descriptions and authentically identified specimens were compared. Standard terminologies were used for the species description following glossary of weevil characters by C.H.C. Lyal (2021) in International Weevil Community website. The type specimens are deposited in the National Insect Museum, ICAR-National Bureau of Agricultural Insect Resources (ICAR-NBAIR), Bengaluru.

Results

1. *Myllocerus vathalmalaiensis* Mahendiran, sp. nov.

(Image 1A–K)

urn:lsid:zoobank.org:act:F6E1EEA4-06E0-42B0-9A4D-24DCE482B305

Material examined: Holotype: Male, NIM/NBAIR/COL/MYLL/H-201223-A, 25.viii.2014, India: Tamil Nadu: Vathalmalai, Palsilambu, 12°02’50’’N 78°13’51’’E, 1,047 m, coll. G. Mahendiran, on C. leaves, National Insect Museum (NIM), ICAR-NBAIR, Bengaluru, India.

Paratypes: 10 specimens, NIM/NBAIR/COL/MYLL/P1-201223-A, NIM/NBAIR/COL/MYLL/P2-201223-A, NIM/NBAIR/COL/MYLL/P3-201223-A, NIM/NBAIR/COL/MYLL/P4-201223-A, NIM/NBAIR/COL/MYLL/P5-201223-A, NIM/NBAIR/COL/MYLL/P6-201223-A NIM/NBAIR/COL/MYLL/P7-201223-A, NIM/NBAIR/COL/MYLL/P8-201223-A, NIM/NBAIR/COL/MYLL/P9-201223-A, NIM/NBAIR/COL/MYLL/P10-201223-A, same data as holotype (NIM).

Diagnostic characters: This species can be distinguished from *M. lineoaticollis* (Boheman, 1842) in possessing a fine central carina on the impressed rostrum, the second funicle segment longer than the first one and a tegmen without parameres.

Description: Body length (without rostrum) 5.09–6.64 mm; width 1.80–2.51 mm; rostrum length 0.76–0.93 mm, width 0.91–1.08 mm. Body: colour black, covered uniformly with dense greenish scales laterally, brownish scales on dorsal side. Head: with prominent eyes, which is convex, oval and dorso-lateral in position, forehead broader than the space between the scrobes (Image 1A & B). Rostrum: as long as head, with apical emergination well defined forming an acute angle, impressed dorsally, with a fine central carina, which reaches middle of the head, sides narrowed gradually then dilated at apex. Antennae: reddish-brown or black, covered with fine whitish setae, scape slightly bent in middle, funicle segment second longer than first, other segments subequal (Image 1F). Pronotum: slightly broader than long, weakly rounded at sides, anterior margin slightly broader than posterior margin, broadest about middle and shallowly constricted before and behind the middle, depressed posteriorly, covered with rounded greenish scales with strips of brownish narrow scales on dorsal side (Image 1C). Legs: black or reddish brown, covered with green scales and white setaes, all femora with a single sharp spine at middle. Elytra: with distinct humeri, base subtruncate and slightly sinuate in middle, broadest behind the middle, punctato-striate, rounded green scale densely covered lateral parts, dorsally marked with irregular patches of brown scales, also covered with long, stout, erect setae (Image 1D & E). Male genitalia: aedeagus with penis membranous, apophyses longer than penis and moderately chitinised; tegmen without parameres, manubarium longer and slender; spiculum gastrale stouter, with strongly curved flattened apex (Image 1G–I). Female genitalia: spermatheca with nodulus stout, rounded; ramus distinct, perpendicular to proximal arm; cornu narrowing toward apex, apex curved and bluntly pointed (Image 1J). Spiculum ventrale

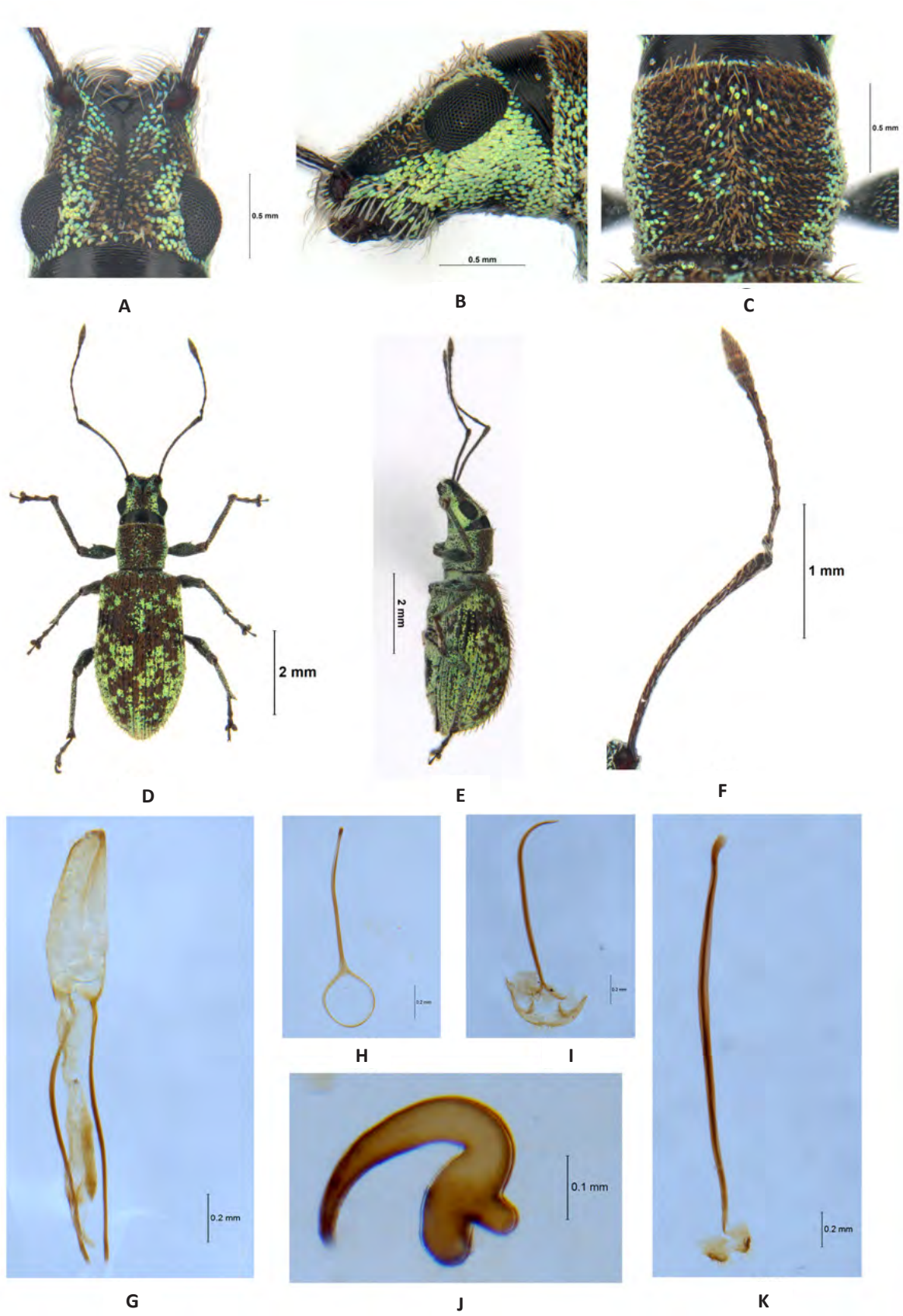

Image 1. *Myllocerus vathalmalaensis* sp. nov: A—head in dorsal view | B—head in lateral view | C—prothorax | D—dorsal habitus | E—lateral habitus | F—antenna | G—penis | H—tegmen | I—spiculium gastrale | J—spermatheca | K—spiculum ventrale. © A-K – G. Mahendiran.

with shaft elongate, thicker in the middle and narrowing towards both ends basal plate bilobed, its apex clubbed (Image 1K).

Etymology: The species name is the latinised form of its type locality, Vathalmalai.

Host plant: Curry Leaf *Murraya koenigii* (L.) Spreng.

Distribution: India: Tamil Nadu.

2. *Myllocerus depressus* Mahendiran, sp. nov.

(Image 2A–K)

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Material examined: Holotype: Male, NIM/NBAIR/COL/MYLL/H-201223-B, 6.ix.2018, India: Andhra Pradesh: Rajahmundry: Dowalaiwarum, 16°57'53.8"N 81°47'08.0"E, on *Pongamia pinnata* L., coll. G. Mahendiran, National Insect Museum (NIM), ICAR-NBAIR, Bengaluru, India.

Paratypes: 4 specimens, NIM/NBAIR/COL/MYLL/P1-201223-B, NIM/NBAIR/COL/MYLL/P2-201223-B, NIM/NBAIR/COL/MYLL/P3-201223-B, NIM/NBAIR/COL/MYLL/P4-201223-B, same as holotype, on Water Apple *Syzygium aqueum* Burm.; 2 specimens, NIM/NBAIR/COL/MYLL/P5-201223-B, NIM/NBAIR/COL/MYLL/P6-201223-B, same as holotype, on Cacao *Theobrama cacao* L.; 2 specimens, NIM/NBAIR/COL/MYLL/P7-201223-B, NIM/NBAIR/COL/MYLL/P8-201223-B, 13.x.2018, Telangana, Hyderabad, Rajendranagar, 17°19'23.2"N 78°23'57.3"E, on Water Apple, coll. M.M. Nagaraja; 2 specimens, NIM/NBAIR/COL/MYLL/P9-201223-B, NIM/NBAIR/COL/MYLL/P10-201223-B, 13.x.2018, Telangana, Hyderabad, Rajendranagar, 17°19'23.2"N 78°23'57.3"E, on *Acacia* sp., coll. M.M. Nagaraja; 2 specimens, NIM/NBAIR/COL/MYLL/P11-201223-B, NIM/NBAIR/COL/MYLL/P12-201223-B, 15.x.2018, Telangana, Hyderabad, Rajendranagar, 17°19'23.2"N 78°23'57.3"E, on Jamoon *Syzygium cumini* L., coll. M.M. Nagaraja; 1 specimen, NIM/NBAIR/COL/MYLL/P13-201223-B, 15.x.2018, Telangana, Hyderabad, Rajendranagar, 17°19'23.2"N 78°23'57.3"E, Mango *Mangifera indica* L., coll. M.M. Nagaraja; 1 specimen, NIM/NBAIR/COL/MYLL/P14-201223-B, Telangana, Hyderabad, Rajendranagar, 17°19'23.2"N 78°23'57.3"E, 21.x.2018, Sapota, coll. M.M. Nagaraja; 2 specimens, NIM/NBAIR/COL/MYLL/P15-201223-B, NIM/NBAIR/COL/MYLL/P16-201223-B, Telangana, Hyderabad, Rajendranagar, 17°19'23.2"N 78°23'57.3"E, 14.x.2018, Raintree *Samanea saman* Jacq., coll. M.M. Nagaraja; 1 specimen, NIM/NBAIR/COL/MYLL/P17-201223-B, Telangana, Hyderabad, Rajendranagar, 17°19'23.2"N 78°23'57.3"E, 14.x.2018, Tulip Tree *Liriodendron tulipifera* L., coll. M.M. Nagaraja; 2 specimens, NIM/NBAIR/COL/ MYLL/ P18-201223-B, NIM/NBAIR/COL/MYLL/P19-201223-B, Telangana, Hyderabad, Rajendranagar, 17°19'23.2"N 78°23'57.3"E, 14.x.2018, *Pongamia pinnata*, coll. M.M. Nagaraja; 2 specimens, NIM/NBAIR/COL/MYLL/P20-201223-B, NIM/NBAIR/COL/MYLL/P21-201223-B, Telangana, Hyderabad, Rajendranagar, 17°19'23.2"N 78°23'57.3"E, 14.x.2018, ornamental plant, coll. M.M. Nagaraja; 2 specimens, NIM/NBAIR/COL/MYLL/P22-201223-B, NIM/NBAIR/COL/MYLL/P23-201223-B, Telangana, Hyderabad, Rajendranagar, 17°19'23.2"N 78°23'57.3"E, 15.x.2018, ornamental plant, coll. M.M. Nagaraja; 1 specimen, NIM/NBAIR/COL/MYLL/P24-201223-B, Telangana, Hyderabad, Rajendranagar, 17°19'23.2"N 78°23'57.3"E, 15.x.2018, Lemon, coll. M.M. Nagaraja; 3 specimens, NIM/NBAIR/COL/MYLL/P25-201223-B, NIM/NBAIR/COL/MYLL/P26-201223-B, NIM/NBAIR/COL/MYLL/P27-201223-B, Tamil Nadu, TNAU, Coimbatore, 11°14'00.0"N 77°18'00.0"E, 21.ix.2018, Sapota *Manilkara zapota* Mill., coll. M.M. Nagaraja; 1 specimen, NIM/NBAIR/COL/MYLL/P28-201223-B, Tamil Nadu, TNAU, Coimbatore, 11°14'00.0"N 77°18'00.0"E, 21.ix.2018, Jamoon *Syzygium cumini* L., coll. M.M. Nagaraja; 2 specimens, NIM/NBAIR/COL/MYLL/P29-201223-B, NIM/NBAIR/COL/MYLL/P30-201223-B, Tamil Nadu, TNAU, Coimbatore, 11°14'00.0"N 77°18'00.0"E, 22.ix.2018, ornamental plant, coll. M.M. Nagaraja; 1 specimen, NIM/NBAIR/COL/MYLL/P31-201223-B, Tamil Nadu, TNAU, Coimbatore, 11°14'00.0"N 77°18'00.0"E, 22.ix.2018, Lucern, coll. M.M. Nagaraja; 1 specimen, NIM/NBAIR/COL/MYLL/P32-201223-B, Tamil Nadu, TNAU, Coimbatore, 11°14'00.0"N 77°18'00.0"E, 20.ix.2018, Sunflower *Helianthus annuus* L., coll. M.M. Nagaraja. The types are deposited in the National Insect Museum (NIM), ICAR-NBAIR, Bengaluru, India.

Diagnostic characters: This species can be distinguished from *M. cardoni* Marshall, 1916 by having the dorsally depressed rostrum, which is longer than the head, a prothorax depressed and constricted near the posterior margin, the antennae and legs black in colour, the hind femora with a single spine and a spermatheca with curved nodulus.

Description: Body length (without rostrum) 6.50–8.60 mm; width 2.52–3.79 mm; rostrum length 0.94–1.31 mm, width 1.21–1.58 mm. Body: colour black, covered with dense dull whitish, which prominent laterally, elytra variegated with irregular patches of brown scales. Head: with eyes subdorsal, forehead little broader than space between the scrobes. Rostrum: longer than head, broader than long, sides subparallel, dilated at apex, the apical emergination deep and acute in angle, distinctly depressed dorsally, with a fine central carinae,

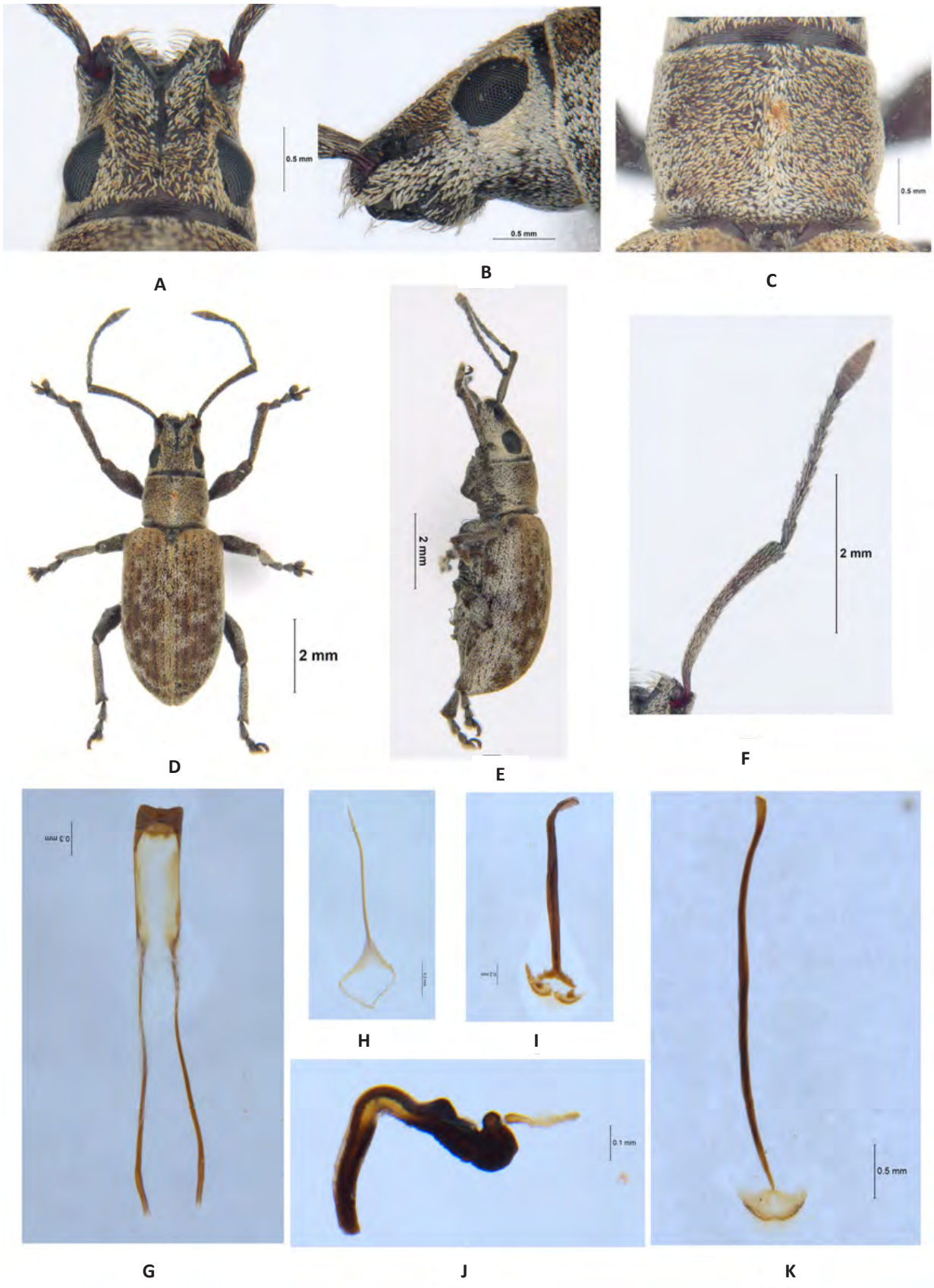

Image 2. ***Myllocerus depressus*** **sp. nov.: A—head in dorsal view | B—head in lateral view | C—prothorax | D—dorsal habitus | E—lateral habitus | F—antenna | G—penis | H—tegmen | I—spiculium gastrale | J—spermatheca | K—spiculum ventrale. © A-K – G. Mahendiran.**

lateral carina subparallel, sides narrowed gradually then dilated at apex (Image 2A & B). Antennae: black, covered with fine whitish setae, scape stout, gradually widening base to apex, curved at base, funicle segment second longer than first, other segments subequal (Image 2F). Pronotum: much broader than long, sides slightly rounded before middle, broadest about middle, constricted and depressed near posterior margin, anterior margin truncate, posterior margin slightly bisinuate, shallowly punctate dorsally (Image 2C). Legs: black, covered with whitish scales and setaes, all femors with a single sharp spine. Elytra: with distinct shoulders, base separately rounded, broadest behind the middle, punctato-striate, scales depressed, less prominent, dorsally marked with irregular patches of brown scales, without erect setae (Image 2D & E). Male genitalia: aedeagus with penis broader with distinct apical processes, apex sinuate and chtinised; apophyses longer than penis; tegmen without parameres, manubarium longer and slender; spiculum gastrale stout, much thicker than apophyses, apex flattened, strongly covered (Image 2G–I). Female genitalia: spermatheca with nodulus prominent, curved backward; ramus distinct, rounded, cornu slightly curved, apex bluntly pointed (Image 2J). Spiculum ventrale with shaft very long, thicker, basal plate broadly rounded, its apex slightly flattened (Image 2K).

Etymology: The species name '*depressus*' derived from the verb 'depress' (press down) + "-us" (adjective-derivational suffix) denoting its depressed rostrum dorsally.

Distribution: India: Tamil Nadu, Karnataka, Telangana and Andhra Pradesh

Host plant: *Pongamia pinnata* L., Water Apple *Syzygium aqueum* Burm., Cacao *Theobroma cacao* L., *Acacia* sp., Jamoon *Syzygium cumini* L., Mango *Mangifera indica* L., Sapota *Manilkara zapota* Mill., Raintree *Samanea saman* Jacq., Tulip Tree *Liriodendron tulipifera* L., Lemon *Citrus limon* L., Lucerne *Medicago sativa* L., Sunflower *Helianthus annuus* L. and ornamental plants.

Discussion

Myllocerus vathalmalaensis sp. nov. was collected from the Vathalmalai hills, which lies in the Eastern Ghats of India. This species heavily defoliates Curry Leaf *Murraya koenigii* during August to October. *Myllocerus depressus* sp. nov. was collected from southern states namely, Tamil Nadu, Karnataka, Telangana, and Andhra Pradesh. This species is found polyphagous in natures, feeding on different plants such as Pongamia, Water Apple, Cacao, *Acacia* sp., Jamoon, Mango, Sapota *Manilkara zapota*, Indian Raintree *Albizia lebeck*, Tulip Tree *Liriodendron tulipifera*, Lemon *Citrus limon*, Lucerne *Medicago sativa*, Sunflower *Helianthus annuus*, and ornamental plants. The number of *Myllocerus* species in India rises to 88 with the description of these two new species. There are many more weevil species waiting to be discovered, particularly under the genus *Myllocerus*, as they feed on a wide variety of plant species.

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Journal of Threatened Taxa | www.threatenedtaxa.org | 26 January 2024 | 16(1): 24607–24610

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

https://doi.org/10.11609/jott.8637.16.1.24607-24610

#8637 | Received 18 July 2023 | Final received 02 November 2023 | Finally accepted 11 December 2023

OPEN ACCESS

NOTE

Additional record of the Black Turmeric *Curcuma caesia* Roxb. (Zingiberales: Zingiberaceae) in Bhutan

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Curcuma L, is a genus of rhizomatous herbs distributed in tropical and subtropical regions especially in India, Thailand, Indochina, northern Australia, Malaysia, and Bangladesh (Jantan et al. 1999). The genus contains more than 200 species and subspecies, which belong to the family of Zingiberaceae. The majority of *Curcuma* species grow in mountainous areas around the world (Singh et al. 2002). Many species of *Curcuma* are cultivated and used as ingredient of traditional medicine (Jantan et al. 1999). In Bhutan, there are records of four species of *Curcuma* under Zingiberaceae family including *C. caesia* (i.e., *Curcuma longa* L., *Curcuma aromatica* salisb, *Curcuma zedoaria* (Christm.) Roscoe). The plants were found thriving in warm broadleaved forests near settlements against grazing and anthropogenic activities.

Specimen of *C. caesia* was collected during field exploration from Orong Gewog under Samdrup Jongkhar district (26.933117° N, 91.493064° E), Bhutan on 10 July 2021 at an elevation of 1,227 m. The geo-coordinates were recorded with Garmin GPS. Herbarium specimens was prepared following Smith (1971) and the morphological characteristics were examined for confirmation of the identity of specimen following Noltie (1994) and Mitra & Mukherjee (2013).

Taxonomy

***Curcuma caesia* Roxb.**

in Asiat. Res. (Calcutta) 11: 335. 1810 – Lectotype "*Curcuma caesia*" in Icones Roxburghianae Ineditae No. 1923 (Leong-Škorničková et al. 2010; Mitra & Mukherjee 2013).

Type: India, Calcutta 11: 335. 1810 W. Roxburgh (1923) (Lectotype-BM, Photo!)

Description: *Curcuma caesia* Roxb. satnds erect as a rhizomatous herb, reaching a height of 70–100 cm. Pseudo stem, approximately 30–35 cm tall, sheaths green. The rhizome large, 5–6 × 9–10 cm, blue-blackish, verging towards grey, the blue colour is highly variable, depending upon the nature of the soil and age of the rhizome, strongly aromatic; sessile tubers branched, condensed; roots fleshy; root tubers many, ovate oblong, pale, watery pearl colour. Leaves distichous, 79–100 cm; petiole as long as lamina; lamina 30–40 × 10–15 cm, oblong lanceolate, tip acute, base acuminate, glabrous, purple or reddish-brown patch along the sides on the distal half of the mid rib on upper side only, fading at maturity, groove of the midrib green. Inflorescence lateral, 25–30 cm long, peduncle 12–18 cm; spike 12–15 × 5 cm; coma bracts large, pink to violet, lower ones streaked green.

Editor: M. Sabu, University of Calicut, Kerala, India.

Date of publication: 26 January 2024 (online & print)

Citation: Orong, K., N. Shacha, K. Tobgay & R. Namgay (2024). Additional record of the Black Turmeric *Curcuma caesia* Roxb. (Zingiberales: Zingiberaceae) in Bhutan. *Journal of Threatened Taxa* 16(1): 24607–24610. https://doi.org/10.11609/jott.8637.16.1.24607-24610

Funding: None.

Competing interests: The authors declare no competing interests.

Acknowledgements: We would like to thank the management of Ugyen Wangchuck Institute for Forest Research and Training, (UWIFoRT) DoFPS, Royal Government of Bhutan for the continued support and guidance. We also would like to thank Mr. Cheten Dorji (CNR), Mr. Tashi Tobgay (CNR), and Mr. Ikaitkupar Lyngdoh (India) for their help in publishing this paper.

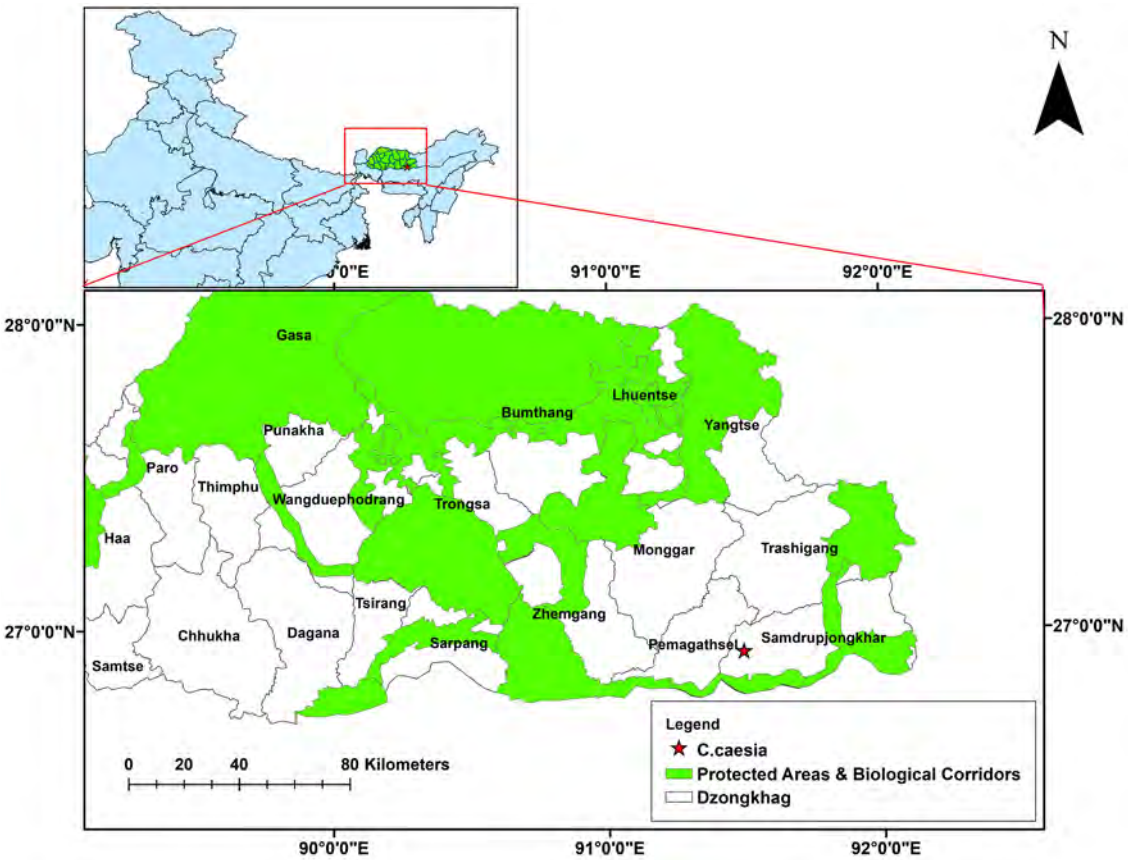

Figure 1. Distribution record of *Curcuma caesia* in Bhutan.

Fertile bracts 18–20, 6.5–7 × 4.4–5 cm, lower half fused, tip rounded, green with pink tip, each bract subtends a cincinnus of 8–10 flowers. Bracteoles large, 2.5–3.5 cm, white with medium light green patch. Flowers 4–6 cm equal to slightly shorter than bracts. Calyx 0.8–1 cm, truncate, 3-lobed at apex, split on one side. Corolla tube 3–3.3 cm long, lobes unequal; dorsal lobes 1.5 × 1.2 cm, concave, hooded; lateral lobes 1.5 × 1 cm, tip rounded, pink. Labellum 1.5–1.7 × 1.8 cm, tip emarginated, yellow with deep yellow median band. Lateral staminodes 1.5 × 1 cm, yellow. Anther 7 mm long, without crest, spurred at base, spurs 3 mm long, divergent. Epigynous gland two, 5 cm long, linear, yellowish green. Ovary 5 mm, trilocular, with many ovules. Style long, filiform; stigma bilipped, slightly exserted above the anther lobes (Leong-Škorničkováet al. 2010).

Distribution: The geographic distribution of the species ranges from northeastern India to Thailand, Indochina, Malaysia, Indonesia, and northern Australia (Apavatjrut et al. 1999).

Specimen examined: Bhutan: 17161 (THIM), Orong, Samdrup Jongkhar District, (26.933117° N, 91.493064° E; 1,227 m), 10.vii.2021, K. Orong & N. Shacha, 2023. 011 (Lectotype BM, Photo!).

Flowering: Flowers appear during the initiation of the monsoon and fruits mature at the end of the monsoon (May–July).

Habitat: *C. caesia* was found in warm broadleaved forest (dominated by species like *Castanopsis indica* Robx. Ex. Lindl, *C. hystrix* DC, *Callicarpa arborea* Roxb. & *Schima wallichii* (DC.) Korth growing near settlement at Orong Gewog under Samdrup Jongkhar District, Bhutan at an elevation of 1,227 m. Other associative species growing along with *C. Caesia* were *Phlogacanthus pubinervius* T. Anderson, *Artemisia* spp., *Biden pilosa* L., *Chromolaena odorata* (L.) R.M.King & H.Rob. and *Ageratina adenophora* (Spreng.) R.M.King & H.Rob.

Conservation Status: The species is widely cultivated because of its medicinal values and economic benefit (Apavatjrut et al. 1999). In the current exploration, the species was surviving near settlement with threats from grazing and developmental activities. It is imperative that the relevant authorities (e.g., Department of Forest and Park Services) and other conservation agencies take the necessary management strategies to conserve the species.

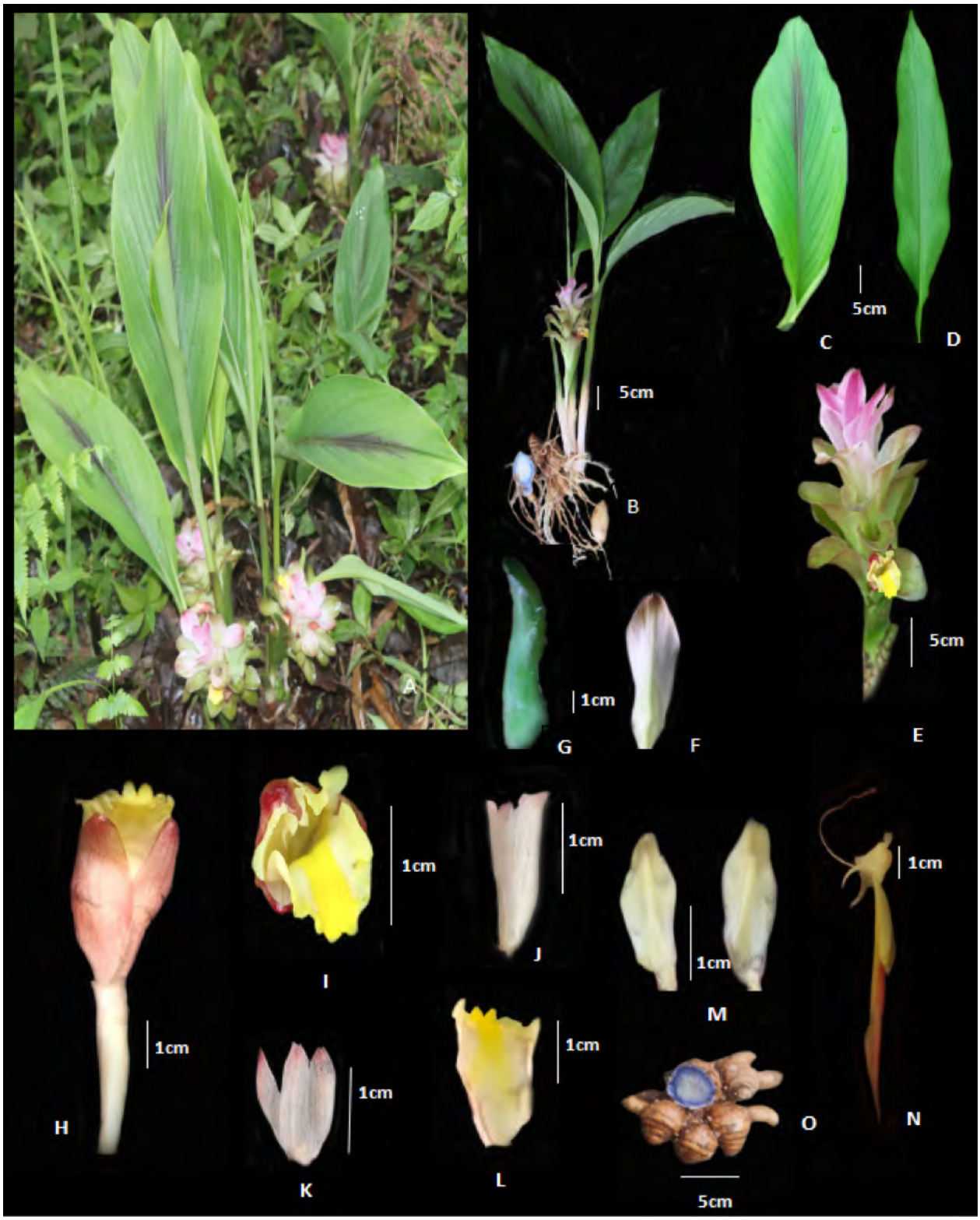

Image 1. *Curcuma caesia*: A—habitat | B—whole plant | C & D—front and back view of leaves | E—inflorescence | F—sterile bract | G—fertile bract | H—flower | I—front view of flower | J—Corolla lobes | K—Calyx | L—labellum | M—staminodes | N—anther | O–rhizomes. © K. Orong & N. Shacha.

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Journal of Threatened Taxa | www.threatenedtaxa.org | 26 January 2024 | 16(1): 24611–24614
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.8689.16.1.24611-24614
#8689 | Received 12 August 2023 | Final received 24 September 2023 | Finally accepted 22 December 2023
OPEN ACCESS
NOTE

A record of Chestnut-and-Black Royal *Tajuria yajna istrodea* De Nicéville, 1887 (Lepidoptera: Lycaenidae) from Arunachal Pradesh, India

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Tajuria yajna (Doherty, 1886) is an Indo-Malayan butterfly species commonly known as Chestnut-and-Black Royal, belonging to the family Lycaenidae. The genus *Tajuria* Moore, (1881) consists of nearly 50 species globally, of which only 15 species are known from India. *T. yajna* comprises five subspecies, of which two are reported from India, *viz., yajna* and *istroidea* (Schröder 2006; Varshney & Smetacek 2015). According to the Indian Wildlife (Protection) Amendment Act 2022, *Tajuria yajna* has been categorized under both Schedule I and II, reflecting its status as a critically endangered species necessitating rigorous conservation measures. Moreover, the subspecies *T. y. yajna* is listed as Critically Endangered under the Red Book Data of the Indian Butterflies (Gupta & Mondal 2005). *T. y. yajna* has been reported from Mussoorie-Kumaon, Uttarakhand, (Evans 1925; Varshney & Smetacek 2015) and Yunnan (Huang & Xue 2005). Whereas, according to Evans (1925), the status of subspecies *T. y. istroidea* is rare and distributed from Sikkim-Assam, Manipur & Meghalaya (Van Gasse 2021; Varshney & Smetacek 2015), West Bengal (Darjeeling) (Kehimkar 2008), Nepal (Van der Poel & Smetacek 2022), Bhutan (Van Gasse 2021), Vietnam, and Laos (https://yutaka.it-n.jp/lyc4h/8h030010.html). However, Varshney & Smetacek (2015) and Kehimkar (2008) state its distribution from Sikkim-Arunachal Pradesh. Although, there are no verifiable scientific reports or photographic evidence confirming the presence of this species in Arunachal Pradesh. The other three subspecies of *T. yajna*, viz., *selangorana* is reported from Thailand (Pendlebury & Corbet 1933) and ssp. *ellisi* is from Burma and Thailand (Evans 1925; Ek-Amnuay 2012) whereas *cato* is confined to Malaysia (Druce 1895).

During our opportunistic field survey, a single individual of *T. yajna istroidea* was encountered in an ecotone region where the human habitat area and the forest edges are separated by a flowing stream. The individual was photographed (Image 1–4) on 22 January 2021 at 11:47 h in the village of Buddha Mandir (27.21178 ºN; 96.99120 ºE), Vijaynagar Circle, District Changlang, Arunachal Pradesh (Figure 1). The individual was encountered sun-basking on a tree about 3–4 m above the ground level near the stream. After 5–6 min it

Editor: Anonymity requested.

Date of publication: 26 January 2024 (online & print)

Citation: Limbu, R., R. Achint, R. Gogoi, R. Upadhaya & J. Gaur (2024). A record of Chestnut-and-Black Royal *Tajuria yajna istrodea* De Nicéville, 1887 (Lepidoptera: Lycaenidae) from Arunachal Pradesh, India. *Journal of Threatened Taxa* 16(1): 24611–24614. https://doi.org/10.11609/jott.8689.16.1.24611-24614

Funding: None.

Competing interests: The authors declare no competing interests.

Acknowledgements: The authors are thankful to the Villagers of Buddhamandir and special thanks to Mrs. Saranga Limbu, Mr. Mohan Kumar Limbu, Mr. Nikil Rai and Mr. Bal Bahadur Pradhan, for helping unconditionally during the course of the field survey and for logistic support.

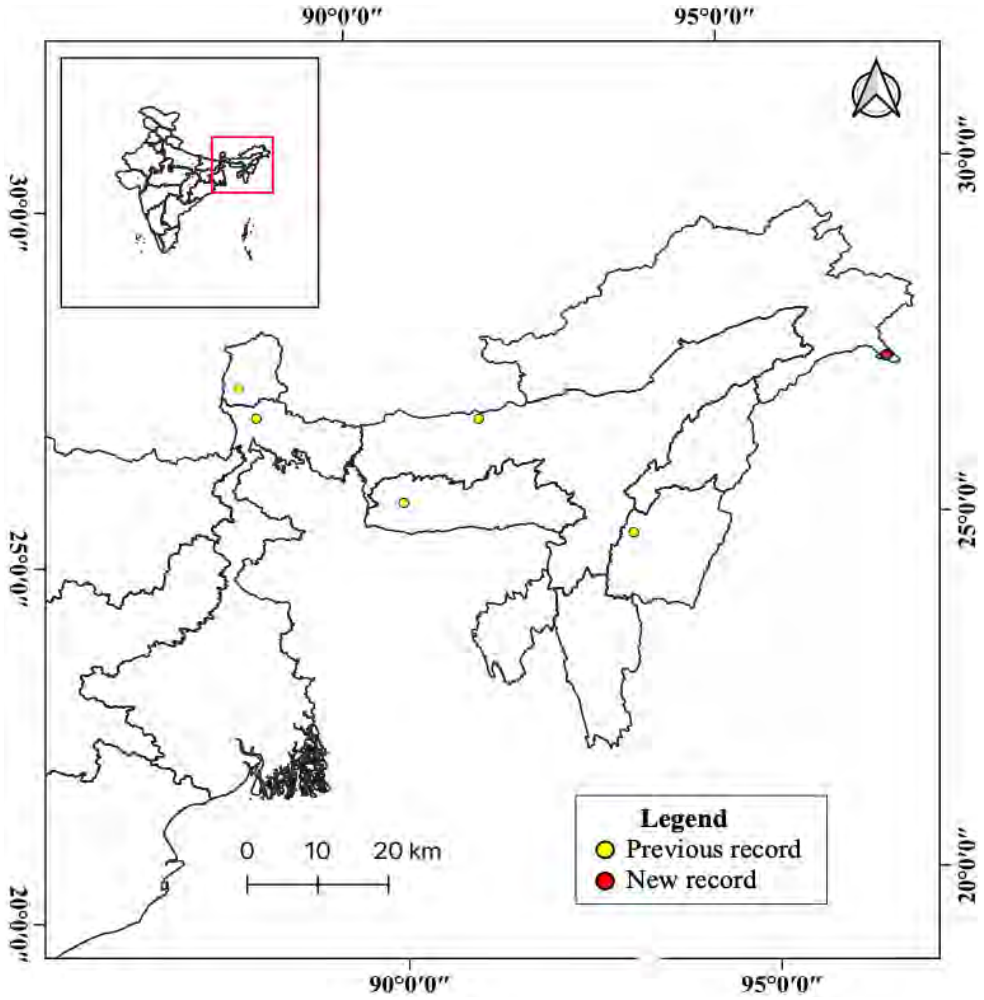

Figure 1. Records of *Tajuria yajna istroidea* de Nicéville, 1887 from India.

settled on the ground for about 1–2 min and flew away to the jungle. It looked like a predator had attacked this butterfly because its hindwing was half broken and its flight was slow and trembling still its discal band was clearly recognised. Consecutive surveys were done thrice a week around the same location for two subsequent years but no new observation has been made, which may indicate it is rare in the region. The species is known to fly at 1,430–1,740 m from May to October (Kehimkar 2008), but we encountered this species at 1,239 m in January during the peak season of winter in Vijaynagar. It is possible that to escape from the cold temperature at higher elevations this species flies to the lower elevations to find the more favourable temperature for its survival. The species was identified using de Nicéville (1889), Evans (1925), and Kehimkar (2008).

T. y. istroidea can be morphologically distinguished from *T. y. yajna* by its broader wings and the distinctly curving discal band on the underside of the forewing. The band on the wings of *t. y. yajna* is more fragmented, with a shorter area between the vein and a zigzag pattern on the hindwing that is considerably shorter compared to *T. y. istroidea* (Evans 1925).

Das et al. (2018) documented that regarding species biodiversity, Arunachal Pradesh is the most diverse state among the Indian Himalayan states. Moreover, Arunachal Pradesh is renowned for being a significant part of the Indo-Burma hotspot, known for its rich biodiversity of flora and fauna. Despite being rich in biodiversity at the global level the region has been poorly studied. However, in recent years, many biologists have conducted extensive research and made numerous discoveries of new species from the state. The earlier detailed review of literature on the taxonomy of butterflies from Arunachal Pradesh (Evans 1912; Betts 1950; Arora & Mondal 1981; Bhattacharya 1985; Gupta & Shukla 1988; Borang et al. 2008; Gogoi 2012; Srinivasan et al. 2012–2013; Sondhi & Kunte 2014, 2016; Sethy

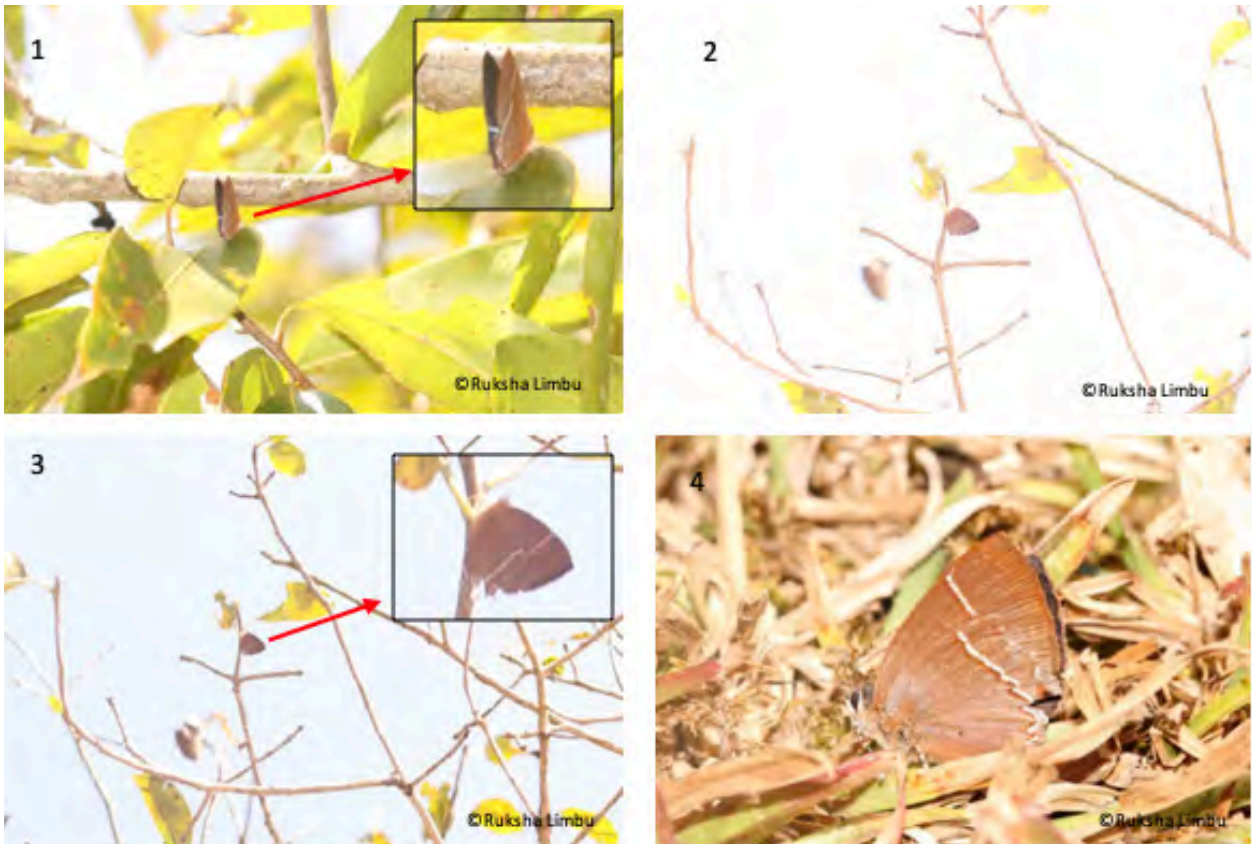

Image 1–4. Photograph of *Tajuria yajna istroidea* de Nicéville, 1887 from the village Buddha Mandir of Vijaynagar District Changlang, Arunachal Pradesh, India on 22 January 2021.

et al. 2014; Singh 2015, 2017; Durairaj & Sinha 2015; Kehimkar 2016; Singh & Das 2016; Sharma & Goswami 2021) revealed no published report of *T. y. istroidea* from Arunachal Pradesh till date. Therefore, the current study reports the first sighting with photographic evidence of *Tajuria yajna istroidea* from Arunachal Pradesh.

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NAAS rating (India) 5.64

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Journal of Threatened Taxa

www.threatenedtaxa.org

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

January 2024 | Vol. 16 | No. 1 | Pages: 24451–24614
Date of Publication: 26 January 2024 (Online & Print)
DOI: 10.11609/jott.2024.16.1.24451-24614

Publisher & Host

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